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EXPLORING THE DIVERSITY, ECOLOGICAL ROLES AND CONSERVATION OF BUTTERFLIES

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Abstract

Butterflies are one of the well-studied groups of insects and play an important role in maintaining ecological stability. Belonging to the order Lepidoptera, they represent a significant portion of global insect diversity and are commonly found in both tropical and temperate environments. Pakistan supports a wide range of butterfly species because of its varied geography, including mountains, plains, forests, and agricultural landscapes. Apart from their visual appeal, butterflies perform several ecological functions, such as assisting in pollination, recycling nutrients, and acting as a food source for other organisms in ecological food chains. Their life cycle includes four distinct stages egg, larva, pupa, and adult demonstrating complete metamorphosis that depends greatly on host plants and suitable environmental conditions. Due to their high sensitivity to environmental changes, butterflies are often used as biological indicators to evaluate ecosystem health and the impacts of climate change. In recent years, however, their populations have been increasingly affected by human-related activities. Urban expansion, excessive pesticide use, habitat destruction, intensive agriculture, and shifting climate patterns are placing considerable pressure on butterfly communities. Reports from different regions of Pakistan indicate a noticeable decline in butterfly abundance and species diversity in both natural and urban environments. Variations in temperature and rainfall also influence their distribution, seasonal movements, and reproductive cycles. Conservation efforts such as restoring natural habitats, minimizing pesticide application, and promoting butterfly gardens can help protect these important insects. Furthermore, stronger environmental regulations and continued scientific research are essential for their long-term conservation. Safeguarding butterfly populations ultimately supports ecosystem resilience and environmental sustainability.

INTRODUCTION

Most people agree that one of the best taxonomically studied insect groups is the butterfly. Over 53% of the 1.4 million species that exist on Earth are insects. 80% of the more than 28,000 butterfly species recorded worldwide are found in tropical regions (Khan et al. 2015). Butterflies are members of the order Lepidoptera, which is currently the second largest class of insects with about 150,000 species. There are approximately 17,820 butterflies in the order of Lepidoptera, which also includes moths. Butterflies stand out from other members of the order Lepidoptera because they are among the most beautiful and appealing insects. Their vivid coloring makes us delighted. (Bibi et al., 2022). The butterfly's life cycle consists of four stages. The adult butterfly deposits the eggs, which hatch into larvae that go

through a pupal inactive stage before emerging as adults. Therefore, it is claimed that a butterfly undergoes complete transformation during its existence. (Mary et al, 2010) Every butterfly species in the family, even those found in tropical and temperate regions, migrates. With 275 species, the Nymphalidae family has more migratory species than any other family, although the Pieridae family has the highest percentage of migratory species (13%; 133 species). (Chowdhury et al, 2021)

Biodiversity in Pakistan

There are 5,000 insect species in Pakistan, 400 of which are moths and butterflies. *Freyeria trochilus putli*, also known as the Grass Jewel, is the smallest butterfly species in India, with a wingspan of 15 mm, while *Troides helena*, also known as the Common Birdwing, is the largest, with a wingspan of 90 mm. In addition to being crucial pollinators, butterflies serve as ecosystem indicators. With the exception of Antarctica, butterflies are present on every continent and have substantial aesthetic and commercial significance. Pakistan has a very high richness of butterflies, which are adapted to the arid steppe climate and can withstand the harsh winters. (Ullah et al, 2025) A study was conducted from March to September 2021 to investigate the biodiversity of butterflies in District Battagram, Khyber Pakhtunkhwa, Pakistan. A line transect method was used to gather 572 specimens of butterflies from 12 places in two of the district's tehsils. Three families and seven genera of butterflies were identified: *Cynthia cardui, Danaus chrysippus, Junonia orithya, Papilio demoleus, Papilio polytes, Colias croceus, Pieris ajaka, Pontia daplidice*, and *Pieris napi*. (Bibi et al, 2022) Twelve different species of butterflies were identified in this research article. These species are divided into three families, four subfamilies, and eight genera. The Pieridae family was the most represented among these species, accounting for 78.44%, followed by the Nymphalidae (8.18%) and Danaidae (13.36%). Six species of the Pieridae family have been discovered. *Anaphaes aurota, Pieris canidia, Pieris brassicae, Catopsilia florella, Catopsilia pyranthe*, and *Eurema hecabe* are some of these species. There were four species of the Nymphalidae family: *Ergolis merione,Vanessa cardui, Junonia orithya*,and *Junonia almana.Danaus chrysippus* and *Danaus* genutia were the two species that belonged to the Danaidae family. (Iqbal et al., 2016) Some common species of butterflies and their associated Host plants are summarized in table 01.

Ecological Importance of Butterflies

Butterflies as Pollinators

Pollination is the process by which pollen grains are transferred from the male anther of the stamen to the female stigma of the same or a different plant, fertilizing the plant and producing seeds for the plant's reproduction. An outside force, such as the wind, water, or animals, typically makes this possible (Frankie and Thorp, 2009). Because of their lengthy probosci, most butterfly species primarily ingest nectar, while some, like the Heliconius, also eat pollen. Butterflies mostly use flower colors to locate flowers. They gather pollen grains while searching for nectar. Evidence suggests that some of the butterflies that visit flowers could not actually be pollinators. For example, Viola and Lathyrus flowers are not pollinated by *Leptidea synapis*. The length of the proboscis varies significantly among species (Reddi and Bai, 1984). Long-tongued butterflies have the ability to visit long, narrow flowers like Pimelea (Thymelaeaceae) and Calytrix (Myrtaceae), where nectar is found deep inside the flower tube.

However, some members of the Hesperiidae, such as the small skippers, are diurnal (Ghazanfar et al., 2016). Figure 01: The figure illustrates the four stages of complete metamorphosis in the butterfly life cycle egg, larva, pupa, and adult highlighting the cyclical developmental process. Long-tongued bees are the most effective pollinators of *Angadenia berteroi*, a tropical perennial subshrub with big yellow flowers that yield few fruits. Numerous other species also visit the blooms, but because of their tiny proboscis, which is unable to transport much pollen, they are not effective pollinators of the plant. In this instance, the diameter of the pollinators' proboscis is correlated with their efficiency (Barrios et al., 2016).

Table 01: Selected butterfly species in Pakistan and their Host

Butterfly Species	Common Name	Host Plant(s) for Caterpillars	Habitat in Pakistan	Ecological Importance	Reference
Papilio demoleus	Lime Butterfly	Citrus plants such as Citrus limon, Citrus sinensis	Farmland, gardens	An essential component of agricultural ecosystems and a pollinator	(Roberts, 2001)
Danaus chrysippus	Plain Tiger	Calotropis procera, Asclepias species	Dry open grasslands	Pollination and the coevolution of insects and plants	(Ehrlich & Raven, 1964)
Pieris brassicae	Large White	Cabbage, mustard and other Brassica crops	Cultivated farmland	affects the dynamics of the food web and plant population	(Scudder, 2017)
Junonia lemonias	Lemon Pansy	Barleria and Ruellia plants	Natural grassland areas	Serving as a crucial bioindicator of biodiversity and ecological health.	(Thomas, 2005)
Catopsilia pomona	Lemon Emigrant	Cassia plants	Tropical forests and gardens	Assistance for reproduction of plants and blooming	(Bonebrake et al., 2010)
Papilio polytes	Common Mormon	Citrus plants	Forest margins and urban gardens	Retains pollination networks intact.	(Kevan & Baker, 1983)
Delias eucharis	Common Jezebel	Loranthus plants such as mistletoe	Forested habitat	Encourages the natural connections between insects and plants.	(New, 1997)
Vanessa cardui	Painted Lady	Thistle plants (Cirsium species)	Meadows and natural habitats	Pollination across regions is assisted by migratory species.	(Bonebrake et al., 2010)

Butterflies in the food web

Butterflies feed other animals that end up becoming their prey, while their caterpillars sometimes feed ants and scorpions. Some fly and wasp species also lay their eggs within the caterpillars. A decline in butterfly populations will affect birds, mice, and other species that consume them, upsetting the entire food chain (Ghazanfar et al., 2016) Butterflies don't have any organs designed to capture pollen. Rather, they use the sections of their bodies that come into contact with the anthers while feeding to passively gather pollen. These consist of the head, thorax, proboscis, and occasionally the wings. Since butterflies don't actively seek out pollen, the quantity of pollen generated by plants they visit for reproduction is small and insufficient to supply extra food for other visitors, such as bees (Anýž, 2019).

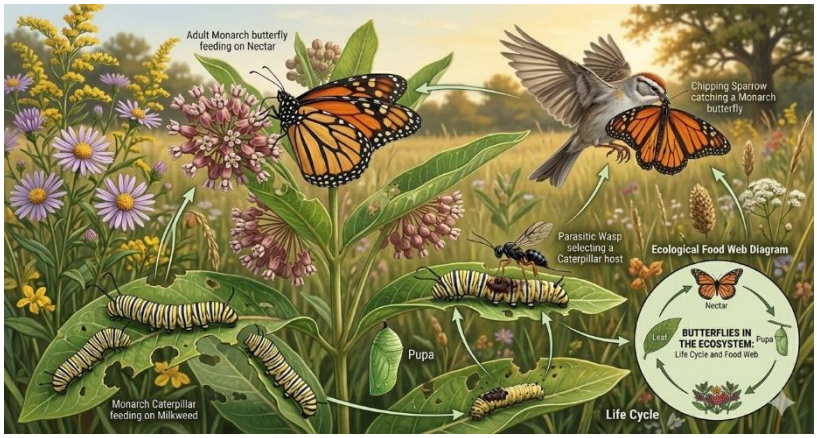

Figure 01: Butterfly Life Cycle (Complete Metamorphosis)

Butterflies as Bioindicators of Environmental Change

In fact, butterflies have also been praised for their remarkable capability as bioindicators to monitor environmental changes around us (Williams and Hughes, 1999). Due to their short-life cycle and ease of reliance on specific host plants, these insects' sensitivity to ecological disturbances is high (Thomas, 2005). While many biological factors such as temperature, moisture or leaf structure can determine their survival, even minute stressors in these environmental parameters can potentially alter their population dynamics (Parmesan et al., 1999). Consequently, by just closely tracking butterfly communities, we can gain an early warning signal about broader ecological shifts that might occur within an ecosystem (Fleishman et al., 2005).

Numerous extensive researches from Europe and North America within the past several decades have demonstrated unequivocal association between distributional patterns of butterfly populations and climate change. Several species are witnessing shifts in their geographical range in response to rising temperatures towards higher latitudes (Parmesan et al., 1999). Furthermore, some species are observed shifting towards higher elevations in mountainous regions in order to find cooler climates (Devictor et al., 2012). Since butterflies are ectothermic animals, their physiological processes are driven by external heat sources, meaning they respond rapidly and directly to temperature oscillations (Forister et al., 2010). For this reason, butterflies are considered to be natural thermometers of the climate change phenomenon (Parmesan, 2006).

Apart from climate change effects, niche fragmentation also greatly impacts the butterfly diversity Of particular significance are those species which depend on particular host plants as habitat or breeding sites; they tend to be particularly vulnerable as geographies become disjoined or demoralized (Thomas, 2000). Continued intensification of agriculture has also played its part by increasingly reducing the number of nectar sources and breeding sites available for larvae, leading to a visible decline of butterfly populations (Pe'er and Settele, 2008). Connectedness of habitat patches has also been shown through studies to be pivotal in stabilizing butterfly populations (Öckinger et al., 2010). Moreover, experimental research on isolated ecosystems has confirmed that biodiversity losses tend to be amplified over time in ecosystems affected by habitat fragmentation (Haddad et al., 2015)

On other hand, butterflies are sensitive towards chemical adulterants and fungicide exposure (Williams and Hughes, 1999). Studies have confirmed that chemical contamination occurring in butterflies can accumulate within their appendages and impact their reproductive capacity and reproductive survival negatively (Zvereva & Kozlov, 2010). Increased use of neonicotinoid pesticides has been associated with reductions in numbers of adult butterfly populations, especially those in agricultural zones (Forister et al., 2016). Field-based studies have further suggested that fungicide exposure may be indirectly associated with the decline of common species (Gilburn et al., 2015). Broader assessments of nonentity population decline traits further validate indeed emphasis the role of butterflies as informative environmental indicators (Wagner et al., 2021).

As well as their role as informed pointers to environmental change, butterflies also hold an active ecological role (Boggs et al., 2003). Butterflies, in their larval stage, are units of prey and adults contribute to pollination. They also constitute essential links for other food webs, connecting primary producer communities to blood-feeders and small mammals (Thomas, 2005). Thus, a reduced butterfly populations could be an indicator of major dislocations within ecological web systems (Forister et al., 2010).

Life Cycle and Habitat Conditions of Butterflies

Butterflies are classified under the order Lepidoptera and go through complete metamorphosis, an intricate experimental sequence consisting of four stages: egg, naiad, nymph, and adult (Boggs et al., 2003). Every stage has its own unique ecological requirements, and the survival of a given species hinges on the proper execution of all four phases within suitable environmental conditions.

The cycle of life of butterflies contributes to the sustainment of the ecosystem through its

biological intricacy. Each stage of the life cycle interacts uniquely with the environment. The cycle of life of butterflies includes a full metamorphosis to become an adult. This happens in four parts of their life (egg, larva, pupal, adult). The female butterflies lay eggs on specific host plants. They make this decision based on the chemical signals of the potential food source of the emerging larvae. The plants are their long-term evolutionary hosts. This behavior fosters the stability of the ecosystem and goes to great lengths (Ehrlich & Raven, 1964). After the offspring, who are called larvae, hatch and they begin what is called the crawling stage. This stage is characterized by some very serious and intense feeding. At this stage, caterpillars are trying to generate as much energy as possible to transition into their next pupal stage where they develop into adults. This feeding is very important in regards to their own adult survival, the reproductive potential of the adult they will become as well as their influence on other animals (Boggs, 1997).Figure 2: The figure represents the butterfly's position in the food web, showing its role in energy transfer between plants and higher-level predators. The pupal stage is characterized by internal activity that is profound; the organism undergoes the most dramatic transformation of any stage by remodeling its anatomy to acquire the adult form. During the pupal stage, organisms provide nutrition to predators and parasitoids (Gilbert & Singer, 1975). In the adult stage, butterflies further assist in the reproduction of the angiosperm community by acting as pollinators and carrying out the genetic exchange of nectar (pollinator) plants and genes (Bonebrake et al., 2010). The rapid decline of a butterfly population in response to the loss of natural resources and changes in climate also makes them a good marker of ecosystem health (Thomas, 2005). The complete metamorphosis of a butterfly is a reflection of a number of interrelated factors influencing ecosystem health, the biodiversity of the community, vegetation, and the interrelatedness of the various levels of the food web.

Figure 02: Butterfly Role in the Terrestrial Food Web

Threats to butterfly populations

Approximately 3 million tons of insecticides are used worldwide. Because of the activities of cultivation, monoculture farming, ground burning, herbicides, insecticides, and the application of inorganic fertilizers within the agricultural ecosystem, butterflies are also impacted by the changing environment in cultivated habitats. Due to the lack of food and host plants throughout the growth stage, this has significantly changed the natural environment and put the butterfly species in grave danger (Antil et al., 2024) Pesticides and fertilizers are frequently used in modern agriculture, and the employment of contemporary technology has encouraged the removal of marginal zones. Because many uncultivated areas, such as ditches, hedgerows, and habitat islands, have been removed, the agricultural landscape's variability has decreased. The species richness of

the agricultural landscape may have decreased as a result of the removal of these regions and the application of agrochemicals (Weibull et al., 2000). Additionally, the loss of shade, humidity, and certain host species all essential for the survival of forest-dwelling butterflies causes significant disruption to the forest ecology, particularly in silvicultural environments. Additionally, it may result in isolated populations, increased wind exposure, elevated temperature stress, increased vulnerability to predators, and numerous other variables that are detrimental to butterfly survival. (Naeem-Ullah et al., 2025) Urbanization's impact on butterflies over the past few decades, biodiversity has been steadily declining due to the growth of urban areas and the construction of buildings, residential colonies, highways, flyovers, and bridges. This has led to an increase in the techno ecosystem and a decrease in natural habitats for the survival of other species, which has resulted in environmental pollution. (Choudhary & Chishty, 2020)

Pesticide Use

A major threat to the butterfly population is the widespread use of pesticides in our environment. These chemicals are used to kill harmful insects that damage our crops and environment. However, they fail to realize that they are killing not just the harmful insects, but all insects in general, including the butterflies that we want to preserve in our environment. In particular, young butterfly populations are at greater risk because they depend on foliage as their primary source of nutrition, which may contain harmful substances. A change in our perspective is necessary to minimize the use of pesticides in our environment. By improving our farming techniques, we can use alternative methods in maintaining our environment, such as organic pest management or crop rotation. Landscapers can avoid using pesticides unless absolutely necessary. By using this method, we can benefit our butterfly populations and our environment as a whole, including our resources such as our soil, water, and other flora and fauna that inhabit our environment. This approach will surely give us a desired outcome in the near future, as this method will surely bring balance to our environment, and our environment will work hand in hand with our farming techniques to produce more and better crops, rather than damaging our environment as we currently do. (Tilman ET al.2002)

Present Conservation Status of Butterflies in Pakistan

Pakistan's unequalled terrain supports rich butterfly diversity, from the towering Himalayas to the expansive plains and Littoral (Roberts, 2001). Over 400 species have been proved in accordance with major butterfly families like Nymphalidae, Papilionidae, Pieridae and Lycaenidae (Sheikh & Ashfaq, 2014). Contemporary researches and surveys have highlighted a rich richness of butterflies especially in the Punjab region and in the mountainous northern regions (Sial et al., 2023). Northern Pakistan has the significance of a biodiversity hotspot where pairs of species from Palearctic and Oriental regions coexist (Bibi et al 2021). Despite the high diversity of butterflies, systematic conservation assessments are still very limited (Waseem et al., 2025).When talking about the conservation of butterflies, it is very important to take into account their contribution to the maintenance of the ecological balance of our planet. The butterflies are sensitive creatures whose lives are greatly affected by the environmental conditions surrounding them. Due to the extended human activities like deforestation, urbanization, and excessive agricultural activities, it has become very difficult for these creatures to live. In order to sustain the lives of butterflies in our environment, it is very important for us to take very responsible actions.

Butterfly Gardens and Native Plants

One of the practical and effective measures for the protection and preservation of wildlife is the development of butterfly gardens. The gardens consist of plants with flowers that offer nectar for the adult butterflies and plants where the female will lay eggs. The eggs hatch into caterpillars, which will eat the plant leaves as they develop into adult butterflies. The native plants used for the butterfly gardens have been growing for many years in the same areas as the butterfly species. Therefore, the plants and the butterfly species have adapted to each other. The

native plants have the butterfly species' requirements, which include the provision of the necessary food and shelter for the butterfly to survive (Tallamy, 2007).

Policy-Level Protection for Insects

Individual contributions and initiatives have value, and for the future, it is essential to have robust environmental laws and regulations. The governments have the mandate to regulate the use of pesticides, protect the ecosystem from land degradation, and conserve biodiversity zones. The conservation areas offer safe havens for the butterfly species, which will have an uninterrupted living space without human interference. The incorporation of butterfly species and various insect species into the country-wide conservation strategy will acknowledge the importance of the species. The development of support for scientific research and educational activities regarding the importance of the environment will improve the effectiveness of the protection and preservation strategy for the butterfly species and the ecosystem as a whole. Butterflies, despite their fragile appearance, are influential members of ecological systems. Their contribution to facilitating the reproduction of plants by helping pollinators is a vital contribution to biodiversity conservation. The numerous agricultural produce and flora that thrive because of cross-pollination are a significant contribution to human nutrition networks and biodiversity reserves. (Potts et al., 2010)

Urgent Need for Research and Conservation

Biodiversity loss of butterflies is a pressing concern that needs urgent attention. The changes in weather conditions affect when they mate and travel. The loss of habitats restricts these creatures' access to food and safety. The pollution also adds pressure on those that are already having difficulties surviving. Further research on the number of butterflies and their ecological impact will be required to address this issue appropriately. The focus of conservation should be on effective land management, reducing chemicals, and community involvement. Time is of the essence in addressing this issue appropriately and ensuring that the current species continue to enjoy these unique creatures in the coming years. (Thomas, 2005).The butterflies show a high level of sensitivity towards any change in their environment. Even minor changes in climatic conditions and living environment play a significant role in determining the scope for survival of these butterflies. These elements, considering the inherent nature of butterflies, can be considered genuine warning signals for any potential threats (New, 1997)

Evidence of Butterfly population Decline

Butterfly populations in Pakistan, as some other place, are showing clean symptoms and signs and symptoms of decline due to an aggregate of habitat loss, agricultural intensification, urbanization, climate trade, and pollution (Dirzo et al., 2014). Those sensitive bugs act as bioindicators, which means that that declines of their populations frequently mirror broader environmental degradation. Local research and observational surveys have documented decreased sightings throughout town centres, agricultural plains, and even some included wooded location areas. But, ongoing anthropogenic pressures have disrupted those habitats, ensuing in fragmentation, decreased nectar availability, and lower reproductive fulfilment. Several butterfly species, particularly habitat professionals and immoderate-altitude endemics, at the moment are going through increased vulnerability (IUCN, 2022). Proof from both nearby and worldwide research suggests that without on the spot conservation motion, many species may enjoy lengthy-time period population declines or neighbourhood extinctions (Sánchez-Bayo & Wyckhuys, 2019)

Decreased Sightings in urban and Agricultural regions

In city and peri-urban landscapes of Pakistan, butterfly populations have particularly declined at some stage in the previous few decades (McKinney, 2008). Towns consisting of Lahore, Karachi, and Islamabad have elevated hastily, converting inexperienced areas with houses, roads, and commercial enterprise areas. Butterflies rely closely on urban parks, gardens, and roadside plant life for nectar and breeding websites. research display that during closely constructed-up areas, the amount of butterfly

sightings has reduced thru forty–60% in assessment to comparable regions surveyed 20 years in the past (Khan et al., 2020; Dirzo et al., 2014). Agricultural intensification, in particular in Punjab and Sindh, moreover contributes to the decline. Monoculture farming, pesticide use, and loss of untamed host vegetation have made farmland inhospitable for all and sundry butterflies and larvae (FAO, 2018). In regions much like the cotton-growing belt of southern Punjab, big-spectrum pesticides remove non-goal insects, causing extensive mortality (Sánchez-Bayo & Wyckhuys, 2019).

Declines in commonplace metropolis Species

Even not unusual, previously ample species collectively with the not unusual Mormon (*Papilio polytes*) and the Lime Butterfly (*Papilio demoleus*) are now much less often decided in city areas (Khan et al., 2020). Their decline know-how that metropolis habitat degradation, lack of flowering plants, and pollution have cumulative influences even on generalist species. Surveys done in Lahore parks amongst 2015 and 2020 determined out a reduction of almost 35% in the type of individuals sighted at some point of fashionable transect walks (Hallmann et al., 2017).

Impact of Agricultural Practices

Extensive agriculture in Punjab and Sindh has fragmented herbal flora and eliminated host plants along discipline margins, leading to decreased butterfly populations (FAO, 2018). Repeated pesticide packages not first-class reduce larval survival know-how additionally disrupt adult feeding behavior, as nectar resources are inflamed or destroyed (IUCN, 2022). Longitudinal research mean that regions practicing integrated pest manipulate or retaining hedgerows and location margins have better butterfly abundance, demonstrating the hyperlink between agricultural practices and species persistence (Sánchez-Bayo & Wyckhuys, 2019).

Effect of climate trade on Butterflies in Pakistan

Weather alternate is rising as a major riding force affecting butterfly populations globally, and Pakistan is not any exception. Growing temperatures, changing precipitation patterns, and increasing frequency of extreme weather sports are changing butterfly distribution, abundance, and life cycles (Parmesan, 2006; Chen et al., 2011). Butterflies are exceptionally sensitive to temperature and humidity due to the fact their improvement, survival, and duplicate are intently tied to ambient conditions (Sánchez-Bayo & Wyckhuys, 2019). In Pakistan, several ecosystems—from the immoderate-altitude Himalayas and Karakoram degrees to the plains and barren region regions—are experiencing variable impacts, influencing each montage and lowland species. Those environmental adjustments can result in phenological mismatches, shifts in distribution, or maybe community extinctions if species are unable to conform rapid (Thomas et al., 2004; IUCN, 2022). The impacts are especially immoderate on professional species that depend on a narrow type of host flowers, as weather change alters plant flowering instances and availability (Parmesan et al., 1999).

Temperature growth directly impacts the frame shape, improvement, and existence cycle timing of butterflies. Higher temperatures can boost up larval improvement, leading to smaller person length and reduced durability that could affect reproductive achievement. This phenological mismatch reduces larval survival and reproductive output (Parmesan, 2006; Chen et al., 2011). Moreover, extended development can shorten the time for larvae to collect sufficient vitamins, affecting character fitness and lifespan. Repeated seasonal shifts can cause cumulative population declines through the years (Thomas et al., 2004).

Changes in Flowering and Host Plant Availability

Butterflies depend upon flowering flowers for nectar and particular host plant life for larval development. Climate change affects the timing of plant flowering and leaf production, causing mismatches with butterfly lifestyles levels (Parmesan et al., 1999; Chen et al., 2011). In regions like Gilgit-Baltistan, wherein montane species are quite specialized, early flowering of plant life together with Artemisia and Berberis can go away newly hatched larvae without food, decreasing survival prices (Khan et al., 2020).

Altered precipitation styles also impact host plant abundance. Decreased rainfall in southern Punjab and Sindh can purpose drought-careworn plant life, decreasing the quantity and high-quality of nectar to be had for adults and leaves for larvae (FAO, 2018). Conversely, excessive rainfall and floods can spoil larval habitats, wash away eggs, and reduce survival of early instars. The ones disruptions can lower population sizes and bring about fragmented, isolated populations over time (Sánchez-Bayo & Wyckhuys, 2019; Hallmann et al., 2017).

Shifts in Distribution and Altitude Migration

As temperatures upward push, butterflies normally have a tendency to move in the direction of higher altitudes or latitudes to discover appropriate microclimates. In Pakistan, montane species together with the Apollo (*Parnassius apollo*) and large Blue (*Phengaris arion*) had been positioned at more and more high elevations inside the Himalayas and Karakoram levels, decreasing to be had habitat and growing competition with resident species (IUCN, 2022; Khan et al., 2020).

Lowland species like the obvious Tiger (*Danaus chrysippus*) and Blue Tiger (*Tirumala limniace*) can also amplify their variety into higher altitudes, probably introducing new predator-prey interactions and opposition for resources. But, excessive-altitude endemics face mountaintop extinction, as they've nowhere to migrate if their required microclimate disappears (Parmesan, 2006; Thomas et al., 2004). Those shifts moreover affect ecological networks, as pollination and meals net interactions are disrupted by means of changes in species composition.

Intense weather activities and Mortality

Weather exchange increases the frequency and intensity of excessive weather activities, along with heatwaves, droughts, floods, and storms. These sports can straight away motive mortality of eggs, larvae, and adults, and in a roundabout way lessen survival by means of way of destroying host plants and nectar assets (Chen et al., 2011; Hallmann et al., 2017). For example, flash floods in Gilgit-Baltistan and KP can wash away larval tiers of montane butterflies, even as prolonged droughts in Sindh and southern Punjab lessen flowering, inflicting starvation in grownup populations.

Species that rely upon seasonal cues for copy may also fail to synchronize with host plant availability, decreasing successful egg-laying and larval survival (Sánchez-Bayo & Wyckhuys, 2019; IUCN, 2022). Through the years, repeated excessive activities can fragment populations, lessen genetic diversity, and increase the threat of nearby extinctions.

Contributor to insect biodiversity decline (IUCN, 2022). International meta-analyses display robust correlations among pesticide intensity and discounts in butterfly abundance (Hallmann et al., 2017).

Herbicides additionally no longer without delay damage butterflies with the resource of getting rid of untamed flowers considered "weeds" but vital as larval host species. Elimination of these plants reduces breeding sites and restricts caterpillar improvement. The simplification of plant businesses due to chemical use considerably lowers environment resilience and biodiversity. Global evidence indicates that chemical-considerable agriculture is a dominant element in insect decline throughout multiple continents (Sánchez-Bayo & Wyckhuys, 2019).

Vegetation, nectar sources, and appropriate microclimatic situations. Whilst town areas make bigger, continuous habitats are divided into smaller, remote fragments that won't maintain feasible populations. Consistent with the worldwide Union for Conservation of Nature, habitat fragmentation appreciably increases extinction chance for specialized insect species (IUCN, 2022). Similar international sorts of insect population decline linked to metropolis boom have been highlighted through the world natural world Fund, emphasizing that land-use exchange stays a number one chance to biodiversity (WWF, 2021). In developing areas such as Pakistan, rapid and often unplanned city increase has intensified pressure on green areas and local ecosystems (Dirzo et al., 2014).

Extended Vulnerability to Environmental pressure

The global Union for Conservation of Nature emphasizes that sustainable urban making plans, mixed with habitat recuperation, is essential for mitigating biodiversity decline (IUCN,

2022).evidence of Butterfly population Decline. Butterfly populations in Pakistan, as some other place, are showing clean symptoms and signs and symptoms of decline due to an aggregate of habitat loss, agricultural intensification, urbanization, climate trade, and pollution (Dirzo et al., 2014). Those sensitive bugs act as bioindicators, which means that that declines of their populations frequently mirror broader environmental degradation. Local research and observational surveys have documented decreased sightings throughout town centres, agricultural plains, and even some included wooded location areas. Pakistan hosts several ecosystems from the mountainous areas of Gilgit-Baltistan to the deserts of Sindh and Balochistan that historically supported a wealthy butterfly fauna (Khan et al., 2020). But, ongoing anthropogenic pressures have disrupted those habitats, ensuing in fragmentation, decreased nectar availability, and lower reproductive fulfilment. Several butterfly species, particularly habitat professionals and immoderate-altitude endemics, at the moment are going through increased vulnerability (IUCN, 2022). Proof from both nearby and worldwide research suggests that without on the spot conservation motion, many species may enjoy lengthy-time period population declines or neighbourhood extinctions (Sánchez-Bayo & Wyckhuys, 2019; Hallmann et al., 2017).

Conclusion

In addition to being a vital part of terrestrial ecosystems, butterflies are important for pollination, biodiversity, and ecological food chains. They are useful indicators for identifying ecological disturbances and changes in habitat quality since their survival is strongly correlated with environmental circumstances. Pakistan's diverse landscapes and climatic zones are home to a wide variety of butterfly species. However, these insect populations are under a great deal of strain due to growing human activity. Many butterfly species are declining due to factors like habitat loss, pesticide use, fast urbanization, and climate change. A number of species may experience additional population declines or even local extinction if these issues are not properly managed. Butterfly populations can be maintained by implementing ecologically friendly land-use practices, reducing the use of chemical pesticides, restoring natural habitats, and promoting the establishment of native host plants. To further understand their distribution, ecological significance, and conservation needs, additional research and ongoing ecological monitoring are also required. In addition to preserving an amazing and aesthetically pleasing collection of insects, protecting butterflies also improves the ecological balance that sustains both human life and natural environments.

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