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DEFOLIATION IMPACT OF *APOCHEIMA CINERARIUS* (GEOMETRIDAE) ON DESERT POPLAR (*POPULUS EUPHRATICA*) POPULATIONS IN THE ZARAFSHAN NATIONAL PARK

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SUMMARY

Desert poplar (*Populus euphratica*) is a key tree species in riparian ecosystems, significantly contributing to ecological stability, biodiversity conservation, and the protection of desert landscapes in Central Asia. However, natural populations and vegetation, including those in the Zarafshan National Park, Samarkand, Uzbekistan, have gained increasing effects from defoliating insect pests, especially *Apocheima cinerarius*, which belongs to the family Geometridae and order Lepidoptera. The larvae feed actively on poplar leaves, causing severe defoliation during outbreak periods. Defoliation reduces photosynthetic capacity, weakens tree vitality, and increases vulnerability to environmental stress conditions. Recurring foliage damage may result in reduced growth, crown thinning, and limited natural regeneration, ultimately disrupting the ecological balance of arid riparian forests. Field surveys conducted from 2021 to 2025 across riparian lowlands, river terraces, and semi-arid zones, revealed clear spatial and seasonal variations in larval density and foliage damage. Larval abundance peaked in late spring and early summer, with the highest defoliation observed in lowland forests, while semi-arid zones experienced less damage. A significant ($p < 0.05$) correlation between larval density and defoliation ($r = 0.62$) highlighted the important role of population size in leaf loss. This study provides field-based insights into population dynamics and supports the strategies in sustainable pest management.

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Keywords: Desert poplar (*Populus euphratica*), *Apocheima cinerarius*, defoliation, forest pests, riparian ecosystems, ecological monitoring, integrated pest management

Key findings: Defoliation by *Apocheima cinerarius* in *Populus euphratica* populations revealed an irregular distribution across the Zarafshan National Park. The intensity of foliage damage varied with ecological conditions and season. The highest defoliation occurred in lowland riparian areas during late spring and early summer, when larval feeding activity peaked.

INTRODUCTION

Riparian forests play a crucial ecological role in arid and semi-arid regions by stabilizing riverbanks and supporting biodiversity. Biodiversity is a key concern for the sustainable management of insect pests in such delicate ecosystems (Gurr *et al.*, 2017). Desert poplar (*Populus euphratica*) is one of the most important tree species forming these habitats in Central Asia. However, the sustainability of these forests has reached progressive endangerment by biotic stress conditions. Recent studies reported that forest loss considerably enhanced the foliar insect and pathogen damage on poplar trees in natural riparian zones (Wang *et al.*, 2025a).

Apocheima cinerarius is one of the most significant defoliators of forest trees. The impact of such pests is not merely aesthetic; findings by Wang *et al.* (2022a) revealed that leaf trait-mediated effects in riparian ecosystems directly influence the insect herbivory patterns. Furthermore, Omonov *et al.* (2025a) have provided a comprehensive faunistic analysis of related Lepidoptera in Uzbekistan, highlighting how these defoliators specifically disrupt photosynthesis and plant vitality. Sobirova *et al.* (2024) also explored how similar biological stress factors alter overall plant productivity and health.

Pest management, ecological dynamics, and effective conservation require a transition from traditional methods of insect pest control to integrated pest management (IPM). Kogan and Jepson (2020) define the principles of IPM and find it necessary for modern agriculture and forestry. It is a sentiment echoed by Pimentel (2022) in his analysis of the environmental and economic impacts of pest control. In the context of

Central Asia, Wang *et al.* (2025b) reported that climate conditions and cropping patterns in Asia considerably shift the biology and ecology of major pests.

Defoliation caused by *A. cinerarius* reduces photosynthetic capacity, deteriorates tree vitality, and enhances susceptibility to environmental stress conditions (Wang *et al.*, 2025a). Constant foliage damage may lead to reduced growth, crown thinning, and limited natural regeneration (Wang *et al.*, 2022a), which can disturb the ecological balance of arid riparian forests. A comprehensive understanding of *A. cinerarius* population dynamics and its effects on *P. euphratica* is still insufficient.

Unlike previous studies conducted in China (Hou *et al.*, 2021a; Wang *et al.*, 2022a; Wang *et al.*, 2025a), this study provides the first field-based assessment of *A. cinerarius* population dynamics, infestation intensity, and spatial distribution on *P. euphratica* within the riparian forests of Uzbekistan. Zarafshan National Park represents a unique Central Asian riverine ecosystem characterized by isolated desert poplar stands, arid climatic conditions, and high conservation value, making it an important model for evaluating pest-host interactions under natural riparian forest conditions.

The scientific innovation of this study lies in its field-based evaluation of *A. cinerarius* population dynamics and defoliation intensity under the specific ecological conditions of Zarafshan National Park, Uzbekistan (Hou *et al.*, 2021b; Wang *et al.*, 2025b). The practical implication relates to enhancing ecological monitoring and developing environmentally sustainable forest protection strategies (Wang *et al.*, 2022b).

MATERIALS AND METHODS

This pioneering research commenced in the *P. euphratica* forests of the Zarafshan National Park, Samarkand, Uzbekistan (Figure 1). Field surveys conducted transpired during 2021–2025 across riparian lowlands, river terraces, and semi-arid zones to evaluate the spatial and seasonal variations in larval density of *A. cinerarius* and foliage damage of *P. euphratica* (Hou *et al.*, 2021a; Wang *et al.*, 2022a, 2022b).

A total of five study plots succeeded in their establishment in habitats differing in soil moisture, vegetation density, and microclimatic conditions. Each plot measured 100 m × 100 m. Within each plot, 20 randomly selected *P. euphratica* trees received permanent markings and monitoring throughout the study period, resulting in a total sample of 100 trees. Sampling continued weekly, from May to July during 2021–2025, corresponding to the period of peak larval activity. A total of 3,600 field observations entailed recordings during the study period.

Field observations focused on larval abundance and defoliation intensity. Larvae collection used sweep nets and direct branch sampling. Collected specimens underwent identification using standard entomological identification keys, with representative voucher

specimens preserved for future reference. Defoliation intensity estimates occurred visually as the percentage of damaged leaf area. The standardization of field assessments had defoliation severity classified into a five-grade scale: 0 = no visible damage; 1 = 1%–25% leaf area damaged; 2 = 26%–50%; 3 = 51%–75%; and 4 = more than 75% leaf area damaged.

Laboratory analyses determined larval developmental stages, feeding intensity, and damage potential. Feeding intensity assessment ensued under controlled laboratory conditions by providing fresh *P. euphratica* leaves to collected larvae and recording the amount of leaf tissue consumed over a 24-hour period. Damage levels attained quantification by comparing the initial and remaining leaf area using digital image measurements.

Meteorological data analysis sought to evaluate the influence of environmental conditions on pest population dynamics. Data obtained came from the nearest meteorological station to the study area and included the mean air temperature, minimum and maximum temperatures, relative humidity, and precipitation. Records collected during 2021–2025 aided the analysis. Historical pest occurrence records and forestry reports also underwent review to support interpretation of field data (Omonov *et al.*, 2025b).

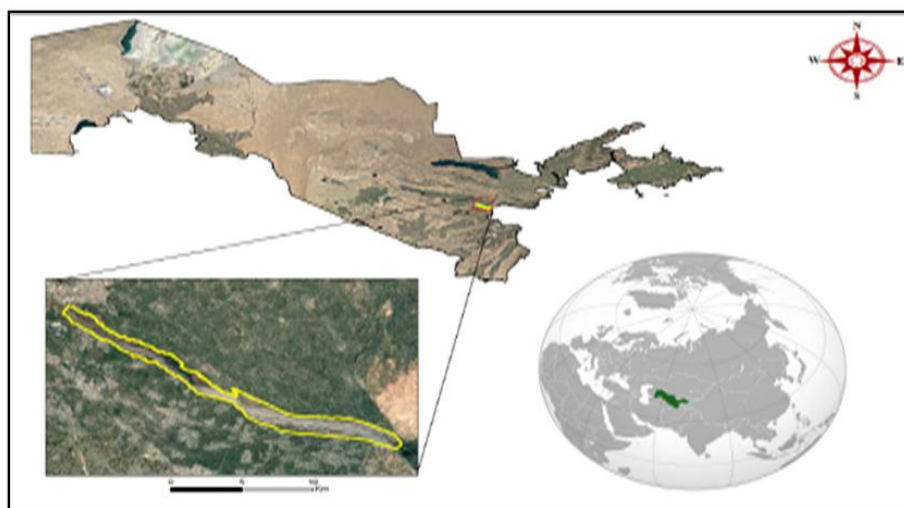


Figure 1. Study area (Zarafshan National Park).

The analysis proceeded using SPSS version 26 and R software, with larval abundance, defoliation rates, and seasonal fluctuations calculated. Pearson correlation and regression analysis, as applied by the study, assessed the relationship between the larval density and foliage damage.

The use of geographical information system (GIS) techniques helped map the spatial distribution of *A. cinerarius* infestations and identify high-risk areas. Spatial analyses performed used ArcGIS software. Larval density and defoliation data reached interpolation using the Inverse Distance Weighting (IDW) method to generate infestation risk maps. Defining high-risk infestation zones was successful as areas exhibiting the highest observed larval densities and defoliation levels. Mapping accuracy evaluation continued through cross-validation procedures and comparison with field observations (Gurr et al., 2017; Chen et al., 2021).

In the Zarafshan National Nature Park, the field surveys followed the comprehensive entomological frameworks established (Pedigo and Rice, 2015) and the management protocols of Dent and Binks (2020). Larvae collection and identification employed standard taxonomic keys to ensure scientific accuracy. The study integrated ground observations with advanced technology to assess the infestation scale. Following the approach of Hou et al. (2021a), time-series MODIS NDVI data and remote sensing were considered tools for

monitoring *A. cinerarius* outbreaks across the large areas of *P. euphratica*. Using statistical analyses and GIS mapping methods, the study identified areas with a high risk of pest spread.

RESULTS AND DISCUSSION

According to field observations, the defoliation intensity in *P. euphratica* caused by *A. cinerarius* significantly varied across the study sites located in the Zarafshan National Park. The most severe foliage damage occurred in riparian lowland areas where dense populations of *P. euphratica* existed. In these habitats, average defoliation reached 35%–40% of the total leaf surface, while in semi-arid transitional zones, the damage remained below 15%.

Population monitoring exhibited that larval activity considerably depends on the seasonal temperature and fluctuations. The highest larval density was evident during late spring and early summer (May–June), coinciding with the active leaf development stage of *P. euphratica* (Table 1). This period represents the most critical phase for forest protection measures (Chen et al., 2020).

Seasonal monitoring of *A. cinerarius* larval populations showed clear fluctuations in pest abundance throughout the vegetation period. Larval density increased from April and peaked in June, then gradually declined in July (Table 2). As noted previously, the larval density increased rapidly from April and

Table 1. Defoliation intensity of *Populus euphratica* by *Apocheima cinerarius* in different habitats.

Study site	Mean larval density (larvae/tree)	Defoliation level (%)
Riparian lowland forests	18.6	38.4
River terrace stands	12.3	24.7
Semi-arid transitional zones	7.8	15.2

Table 2. Seasonal dynamics of *Apocheima cinerarius* larvae and defoliation levels.

Month	Larval density (Mean ± SE [SD])	n (%)
April	8.4±0.7 (2.3)	100
May	14.2±1.1 (3.5)	100
June	18.6±1.4 (4.2)	100
July	10.3±0.8 (2.7)	100

reached its peak in June, followed by a gradual decline in July. This seasonal pattern corresponds to the active leaf development stage of *P. euphratica* when food resources were abundant and environmental conditions favored rapid larval growth (Figure 2).

In *P. euphratica*, the defoliation intensity also varied depending on habitat characteristics. The highest level of foliage damage occurred in riparian lowland forests, while river terrace stands and semi-arid zones experienced considerably lower levels of

defoliation (Figure 3). Between larval density and defoliation level, a significant positive relationship was notable during the study period. More larvae per tree showed an association with increased percentages of leaf damage. Analysis further revealed a significant ($P < 0.05$) correlation ($r = 0.62$) between these variables, indicating that larval abundance was a key determinant of defoliation severity in natural poplar stands (Figure 4) (Hou *et al.*, 2021a, 2021b).

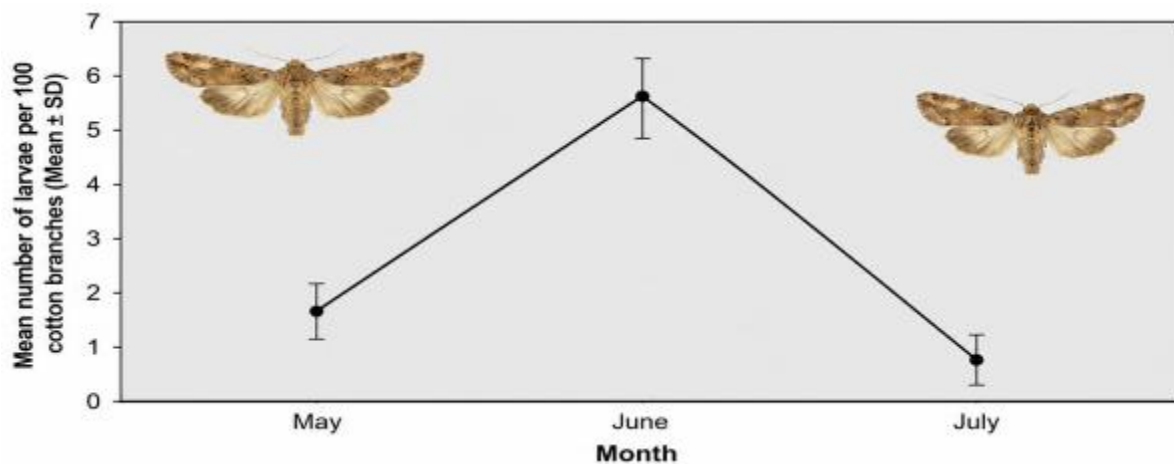


Figure 2. Seasonal dynamics of *Apocheima cinerarius* larval populations in *Populus euphratica* stands of the Zarafshan National Park during the study period.

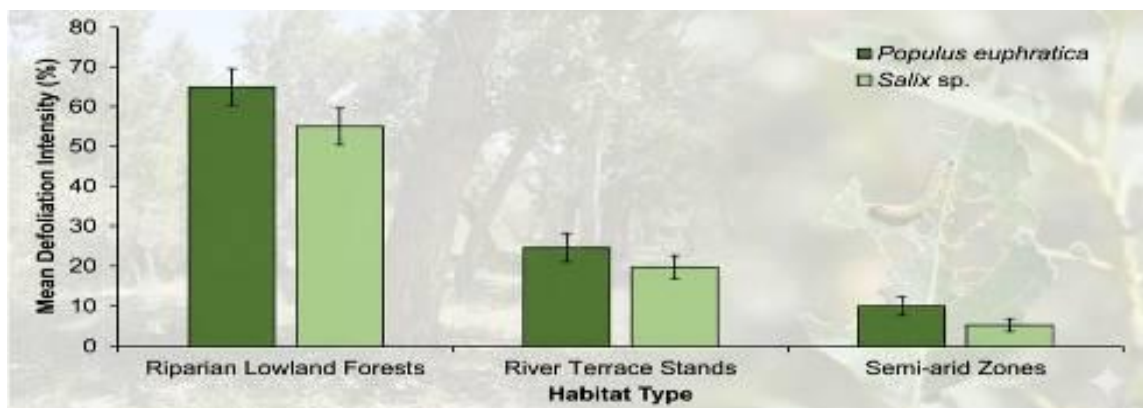


Figure 3. Defoliation intensity of *Apocheima cinerarius* larvae across the different habitats characteristics within the Zarafshan National Nature Park.

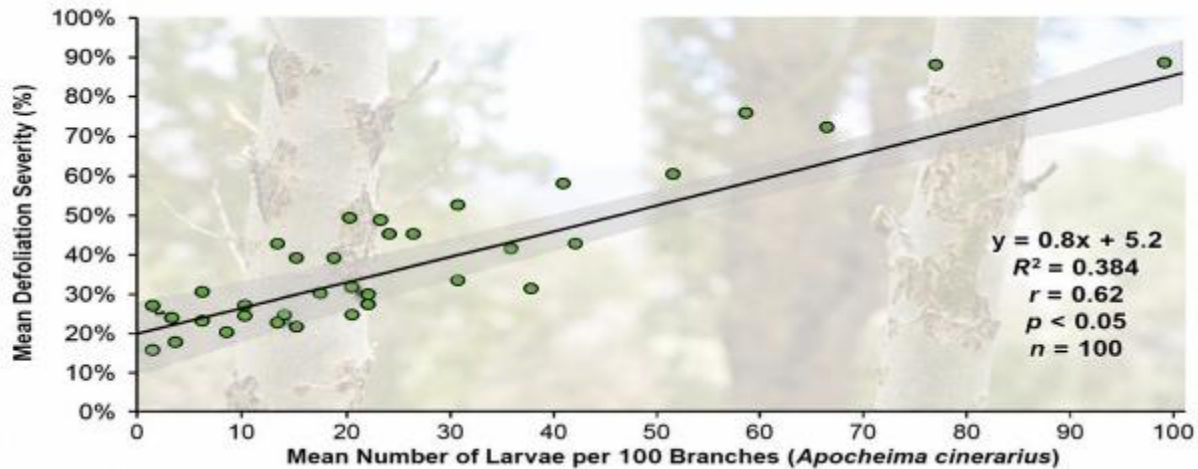


Figure 4. Relationship between *Apocheima cinerarius* larval density and defoliation severity of *Populus euphratica* in the Zarafshan National Park. The fitted linear regression model indicates a significant positive relationship between larval abundance and foliage damage ($y = 0.8x + 5.2$; $R^2 = 0.384$; $P < 0.05$; $n = 100$).

Repeated defoliation events may weaken the physiological condition of *P. euphratica* trees, reduce photosynthetic efficiency, and negatively affect natural regeneration processes. In arid ecosystems, such as the Zarafshan River valley, forest vegetation recovery was relatively slow, making these ecosystems particularly vulnerable to pest outbreaks. Therefore, early detection of population increases and continuous ecological monitoring proved essential for effective pest and forest management (Allen et al., 2015).

Overall, the results highlight the importance of integrating ecological monitoring with sustainable pest management approaches. Implementation of environmentally sound strategies, including biological control and habitat management, could help regulate pest populations and maintain the stability of riparian forest ecosystems in Uzbekistan (FAO, 2020).

Frequent defoliation events can weaken the physiological condition of *P. euphratica* trees, reduce photosynthetic efficiency, and negatively affect natural regeneration processes. In arid ecosystems, such as the Zarafshan River valley, forest vegetation recovers relatively slowly, proving that these ecosystems are found particularly

vulnerable to pest epidemics. Therefore, early detection of population increases and continuous ecological monitoring are recognized essential for effective forest management.

Prolonged and repeated defoliation can substantially reduce photosynthetic performance, compromise tree vigor, and hinder natural regeneration processes, thereby increasing ecosystem vulnerability under arid climatic conditions. The results underscore the ecological sensitivity of Central Asian riparian forests to defoliator outbreaks and highlight the necessity of integrating long-term ecological monitoring with predictive pest dynamics modeling. Implementing adaptive and environmentally sustainable management strategies, including habitat-based regulation and biological control measures, is essential for maintaining forest resilience and ensuring the long-term conservation of *P. euphratica*-dominated ecosystems.

The recurring defoliation of *A. cinerarius* could deter photosynthetic performance, weaken tree vigor, and impair the natural regeneration of *P. euphratica*. As riparian forests of the Zarafshan River occur under arid environmental conditions, their recovery from severe defoliation is relatively slow, increasing ecosystem vulnerability to

pest outbreaks. The observed relationship between larval density and foliage damage highlights the importance of early detection and long-term ecological monitoring. Sustainable management approaches, including biological control and habitat-based regulation, will contribute to maintaining the resilience and long-term conservation of *P. euphratica* ecosystems.

The results indicated that ecological conditions, such as moisture availability and vegetation density, play an important role in the development of pest populations (Hou *et al.*, 2021b; Wang *et al.*, 2022a). These patterns coincide with the active leaf development period of *P. euphratica*, revealing that pest impact was maximum during critical growth stages (Li *et al.*, 2019). Reports of similar seasonal dynamics have emerged in other riparian forest ecosystems of Central Asia, where temperature and humidity significantly influence the insect's life cycle (Zhang *et al.*, 2018). However, these differences can be due to microclimatic stability and greater host-plant availability in lowland habitats, which provided favorable conditions for larval survival and feeding activity (Wang *et al.*, 2022b).

CONCLUSIONS

This study provided a detailed assessment of the effect of *A. cinerarius* on *P. euphratica* populations within the Zarafshan National Park, Samarkand, Uzbekistan, revealing a pronounced spatial and seasonal variability in defoliation intensity. The results confirmed that riparian lowland forests were the most vulnerable habitats, where higher host plant density and favorable microclimatic conditions facilitated pest proliferation and feeding activities. Larval population dynamics showed an observable seasonal pattern, with maximum abundance occurring in late spring to early summer, closely aligned with the phenological development of *P. euphratica*. The significant positive correlation between larval density and defoliation intensity further emphasized the direct role of population pressure in regulating canopy loss and ecosystem stress.

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