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The Impact of Anthropogenic Activities in Different Areas on the Population of Butterfly Species in the Atewa Forest Reserve Enclave, Ghana

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Abstract
The persistent decline in biodiversity due to human activities is a major concern for ecosystems and society. The Atewa Forest Reserve (ATFR) in Ghana is a critical biodiversity hotspot, housing numerous butterfly species, including endemics and rare types, facing threats from human activities. This study assessed the different stress levels of anthropogenic activities on the population of butterflies in the ATFR. The three study areas considered were: Primary Forest, Secondary Forest, and Depleted Agricultural zones. Methods like transect counts, sweep nets, and bait traps were employed for species assessment. ANOVA analysis revealed significant population differences ($p= 0.003$, $\alpha = 0.05$) between the areas. The Shannon-Wiener index indicates the highest diversity in Primary Forests (2.196), moderate in Secondary Forests (2.230), and least in Depleted Agricultural areas (2.273). Despite degradation in Secondary and Depleted Agricultural areas due to human influence, the ATFR maintained rich butterfly diversity. The study highlights the richness of butterfly diversity in ATFR, emphasizing the need for conservation efforts to mitigate anthropogenic effects. Recommendations include reclamation of encroached farming zones, sustainable practices, legal frameworks for biodiversity conservation, halting damaging activities within the reserve, and offering alternative livelihoods for local communities dependent on the forest.

Keywords: Biodiversity, Hotspot, Anthropogenic Activities, Transect Counts, Bait Traps Sustainable Practices

1. Introduction

Butterflies are insects found in the order Lepidoptera that include Moths (from the Greek *lepis* meaning scale *pteron* meaning wing). There are about 17,500 species of butterflies (10% of lepidopterans) as compared to 160,000 species of moths (90% of lepidopterans). One of the most striking differences between butterflies and moths is their resting wing position. Butterflies, like to rest with their wings, closed, while moths prefer to rest with their wings open. There are about 28,000 species of butterflies with 80 per cent in the tropical region. They play vital ecological roles in promoting the healthy growth and development of other species in the ecosystem (Ghazafar, Malik, Hussain, Igbhal & Yunus, 2016) [6]. Their behavioural and anatomical features are adapted to serve as the central pollinators to many angiosperms including agricultural crops such as cocoa, citrus, mango, garden eggs and oil palm. Additionally, they are also a food source for predators like snakes, birds, lizards and other animals to maintain ecological balance (Duara, 2014) [5].

The population of the butterfly species in the Atewa Forest Reserve is roughly 200,000 – 400, 000, with 860 species. The Ghana butterfly fauna is the richest in western West Africa (Larsen, 2005) [9]. According to a survey conducted by Larsen (1994), butterfly species have been described (probably more than 95 % of the total in West Africa),

while only a fraction of other insects have (estimates range from being from 15 to 45 % of the total – he tended to support the lower levels). It is therefore not unreasonable to believe that the 860 butterfly species in Ghana serve as a rough proxy for more than 200,000 - 400,000 other insects.

According to Larsen (2005) [9], there are 100 species endemics to Africa west of the Dahomey Gap, 33 are strictly limited to the Ghana Subregion, including the special fauna of the Volta Region. Of these 17 (52%) are known from within the protected areas system and 16 (48%) are not. This is again partly because the Atewa Range has two narrowly endemic species and several rare endemics that may not be found elsewhere in Ghana. Ten of the 60 species known only from the Atewa Mountains are indigenous to West Africa. Due to their adaptation to the unique ecology of Atewa, perhaps half of the species are absent from the system of protected areas. Many of these are uncommon in Africa. A higher percentage of uncommon species may be anticipated in the total given that there are only 572 species known (697 are estimated). The total coverage would increase to 88% of the total for Ghana if the Atewa data were included in the list from protected areas. This is a justification for the Atewa Range GSBA receiving the greatest level of conservation protection.

The presence of butterflies is an indicator of ecosystem well-being. As a key indicator of the health and diversity of the environment, butterflies provide us with practically all the information we require. According to Ghazafar et al. (2016), a rise in butterfly populations may be a sign of greater plant and animal diversity in an environment. Chung (2017) [4] investigated the other ecological importance of butterflies and found that the intrinsic importance of butterflies is immense and worthy of conservation. Butterflies are part of the rich biodiversity in the tropical ecosystem, they are sensitive towards changes in the environment, thus, they are often used as bioindicators of the status and health of the environment. They have been extensively used in insect diversity studies because most of the species can easily be identified. Also, butterfly species aid in the reduction of pollution by supporting the growth of their host plants which absorb carbon dioxide in the atmosphere (Landers, Verner & Thomas, 1998, as cited in Ghanzafar et al., 2016). Butterflies' sanctuaries are sites for eco- tourism because they are rich in interesting biodiversity which generates economic value for the local communities.

The ecosystem is now constantly changing due to the human population increase. The increase in human populations has led to the release of anthropogenic materials that are harmful to the environment. This act of man is changing the structure and the complexity of the ecosystem and as a result, affecting the population of butterflies (Warren, Maes, Swagy & Ellis, 2021) [16]. The anthropogenic activities that are thriving in the forest reserve are illegal mining, logging, felling trees for firewood, hunting and coppicing. These activities release pollutants such as pesticides, carbon dioxide, weedicides, fungicides, bactericides, gases, fertilizer residue, heavy metals and wastewater. These pollutants from man-made activities impact the soil, water bodies and biodiversity in the ATFR.

According to a study conducted by Natalia, Margarita and Olga (2023) [12], on the impact of anthropogenic activities on the ecosystem and the challenges associated with effective and sustainable conservation of the ecosystem. Anthropogenic activities are essential to the modern world since they consume resources such as food, energy, and other necessities for humankind. However, concurrently, the environmental impact has come into focus, carrying grave implications for the planet's biological diversity and ecological system. Anthropogenic activities of various kinds, including transportation, building, agriculture, and industrialization, may adversely affect the environment. This may include changes in biological diversity, the degradation of ecosystems, the alteration of water and other natural resources, and climate change (Ullah et al., 2020)

Anthropogenic impact on the environment is the impact that human activity has on natural ecosystems, leading to their change and degradation. The history of such an impact has been conducted since the appearance of man on Earth, but in the modern world the level of anthropogenic impact on the environment has increased significantly, which has become a global problem (Hefty & Kaprowski, 2021) [7]. The study was a quantitative study, which employed a correlational approach based on the positivist paradigm. The purpose of this was to investigate the different stress levels of anthropogenic activities on the population of butterfly species in the ATFR, specifically at Sagyimase and Asikam near Kibi in the Eastern Region of Ghana. The data collection period in the field spans from February to May 2023 to cover the dry and wet seasons, which could influence the anatomical features of the butterflies.

The objective of the study was to investigate the impact of anthropogenic activities in different areas on the population of butterfly species in the enclave. There were three (3) study sites: Primary Forest Area (PFA) which is free from anthropogenic activities at mild stress levels, Secondary Forest Area (SFA) within the reserve with exposure to moderate stress levels of anthropogenic activities and Depleted Agricultural Area (DAA) which was an open cultivated area degraded by farming activities, logging, bush burning and hunting with severe stress levels. The hypothesis for this study was the levels of anthropogenic activities in different areas of ATFR impact the population of butterflies.

The findings of the study were obtained from the collected data and analyzed using the appropriate statistical tools such as ANOVA and Shannon-Weiner Index. The ANOVA was performed for the population means based on the frequencies of butterflies in the three (3) study areas. Thus, PFA (Primary Forest Area), SFA (Secondary Forest Area), and DAA (Degraded Agricultural Area) Statistically, there was a significant difference between the means of the population; consequently, the H_0 was rejected while the H_A was accepted. After the hypothesis testing, the accepted H_A states that the levels of anthropogenic activities in the different areas of the ATFR impact the population of butterfly species. Additionally, the Shannon-Weiner Diversity Index showed that PFA was highly diverse, SFA moderate, and DAA the least diverse species. Researchers would use the findings from this study to develop top-notch and convincing proposals to attract international organizations to conduct periodic surveys and further studies on the population and conservation of butterfly species in the ATFR.

Table 1 shows the types of anthropogenic activities identified in the preliminary stages of the study in the ATFR. The features of the various study areas in terms of the impact of human activities resulting in detrimental effects on the forest ecosystem. This provides a template for the repeatability of the study.

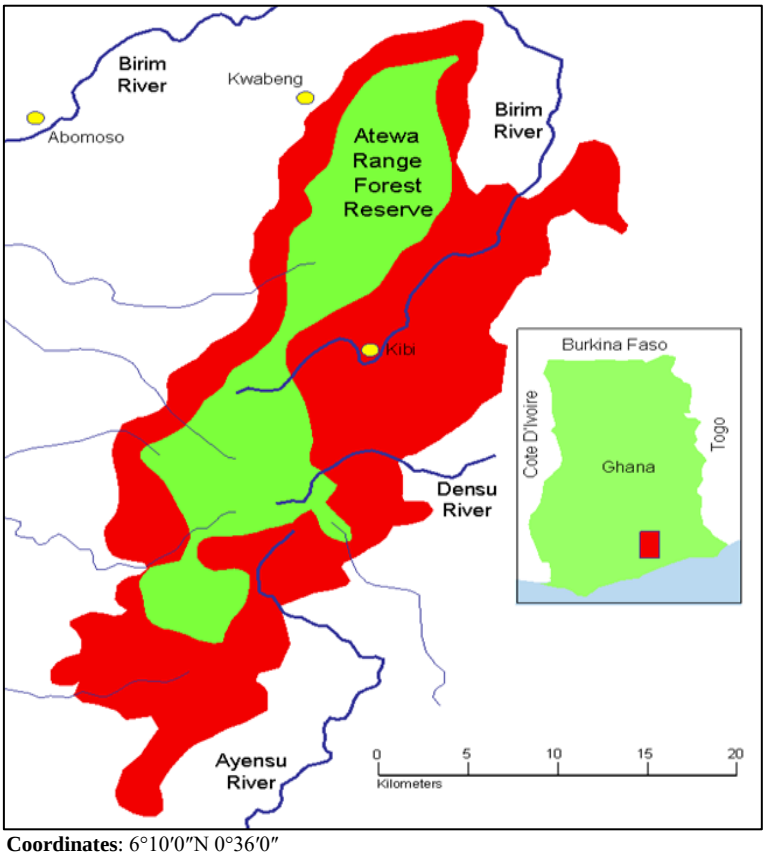
Table 1: Types of anthropogenic activities and their impact on the ATFR

Study Area	Type of anthropogenic Activity (ies)	Description	Scale
PFA	Hunting	Hunting for wild animals persist in the demarcated PFA. Virgin areas and free from human activities. Located in the protected forest reserve, biodiversity is conserved. (Pate 7).	Mild/Low stress levels human activities.
SFA	Hunting, farming, and logging	Located within the forest reserve and downhill the evergreen forest. Reclamation programs taking place in such areas, some biodiversity loss.	Moderate stress levels of human activities.
DAA	Hunting, farming, logging, bushfires, use of fertilizers, pesticides.	Depleted areas such as the fringes of the forest reserve, open farming areas, deforestation, logging, bushfires, use of pesticides and fertilizers, massive loss in vegetation and biodiversity.	Severe/High anthropogenic activities observed.

2. Materials and Methods

Study area and Sampling site

The study was carried out at The Atewa Forest Reserve (ATFR) (Fig.1) also called the Atiwa-Atwaredu Range located in the Akyem Abuakwa region of south-eastern Ghana, near the town of Kibi, and southwest of the Kwahu Plateau which forms the south-west boundary of Lake Volta. Atewa covers a total landmass of 232 Km2 at Coordinates: 6°10′0″N 0°36′0″. The range runs roughly north-south, consisting of steep-sided hills with a flat summit. More than 1,000 plant species, 230 bird species, 570 butterfly species, and at least 50 mammal species live in Ghana's Atewa Forest. On the IUCN (International Union for the Conservation of Nature) Red List of Threatened Species, four species are classified as Critically Endangered (CR), several more as Vulnerable, and five are potentially endemic. It is a Key Biodiversity Area, which means it is vital to world biodiversity and the planet's overall health, as well as meeting the requirements for Alliance for Zero Extinction status. It also listed on the Globally Significant Biodiversity Areas (GSBA). Moreover, the range is the site of a significant forest reserve and the source of three major rivers. A large area of the range has been declared a forest reserve, including about 17,400 hectares of upland evergreen forest. The reserve is managed by the Forestry Commission of Ghana in collaboration with other stakeholders, key of them is the Okyeman Environment Foundation, which has restricted people from farming in the area but rather is trying to encourage eco-tourism. (SOURCE: Eco-Fest. Biodiversity Reporting Award, 2001, retrieved)



Coordinates: 6°10′0″N 0°36′0″

Fig 1: Map of Atewa Range in Ghana showing forest reserve boundaries

Description of study sites

1. The Primary Forest Area (PFA), which is virgin and free from anthropogenic activities, The (PFA) was in the protected forest reserve with mild stress levels of anthropogenic activities such as pesticides, bushfires, farming, logging.
2. The Secondary Forest Area (SFA), such as a cocoa or oil palm plantation, located in the forest and downhill evergreen of the forest reserve. The (SFA) was part of protected enclave with exposure to moderate stress levels of anthropogenic activities in the area of study.
3. The Depleted Agricultural Area (DAA) was an open

cultivated area degraded by farming activities and other human activities such as logging, bush burning, etc. The DAA was highly depleted at the lower fringes of the forest reserve with severe stress levels of anthropogenic activities due to prolonged.

3. Research Methods

About 1km long transect separated into segments that correspond to distinct habitat areas or different site components were set up. During the butterfly season, the transect walk was performed once a week, counting numbers seen within an imagined box 5m wide, 5m high, and 5m ahead of the observer. (Burt, Borchers, Jerkins & Marques, 2014) [3]. The density and abundance of wild populations were frequently estimated using line-transect distance sampling (DS) methods. Items on the transect line (referred to as the tracking) were also certain to be identified, and objects detected at their original location, according to two basic assumptions of DS (Buckland et al., 2001, as cited in Burt et al., 2014) [2,3]. When these assumptions are broken, traditional DS estimators produce biased density and abundance estimations. Because wild populations are typically ambiguous, or because the area of interest was too wide to conduct a census, sampling procedures were required.

An observer travelled along the lines, or stands at spots, collecting information about the target species, and lines or points are placed down at random or with some random component. We focused on online transects rather than points in this article, but the methods apply to both. A single observer (where the term observer refers to either a single observer or a team of observers performing the same duty) searches the track lines for the objects of interest using a traditional line transect DS search technique. The observer notes the perpendicular distance after detecting an object (Burt et al., 2014) [3].

In a nutshell, the transect established a defined route at a location where butterflies were documented weekly over some time while adhering to some fundamental guidelines. The transect walks, observations, and counting of butterfly species at the three (3) study sites were conducted from 9:00 am- 12:00 pm local time, under conditions of an average temperature of 30 °C, weather also sunny with cloud cover of 50 % and an average wind speed of 5 on the Beaufort scale. The 1 km transect at each site was divided into 100meter sections using a GPS machine. The PFA data was collected at the Asikam part of the ATFR. The SFA and DAA data were collected at the Sagyimase enclave near Kibi (Fig. 1).

The Primary Forest Area (PFA), which is virgin and free from anthropogenic activities, The (PFA) was in the protected forest reserve with mild stress levels of anthropogenic activities such as pesticides, bushfires, farming, and logging. The Secondary Forest Area (SFA), such as a cocoa or oil palm plantation, located within the forest and downhill evergreen of the forest reserve. The (SFA) was part protected enclave with exposure to moderate stress levels of anthropogenic activities in the area of study. The Depleted Agricultural Area (DAA) was an open cultivated area degraded by farming activities and other human activities such as logging and bush burning. The DAA was highly depleted site at the lower fringes of the forest reserve with severe stress levels of anthropogenic activities due to prolonged farming.

Data Analysis

Quantitative analysis of the data collected from the three (3) study sites was conducted using appropriate statistical tools. The descriptive statistics from the frequencies of the butterflies were computed to ascertain their shape and robustness and to identify outliers in the data (Acosta & Brooks, 2021) [1]. A one-way ANOVA was performed to determine the differences in butterfly frequencies between the three sites in the ATFR. The ANOVA showed that there was a significant difference in the means of the populations. Thus, the data collected was real and not obtained by chance ($p = 0.03$ at $\alpha = 0.05$). The hypothesis testing proved that the H_0 was rejected while the H_A was accepted, indicating that the levels of anthropogenic activities in the ATFR impact the population of butterfly species. The frequencies of butterflies sampled were again analyzed by computing the Shannon-Weiner indexes to determine species diversity (Shannon & Weaver, 1949) [14]. Also, species richness was calculated by employing the Calculator Academy.

3. Results

The descriptive statistics from the data collected on the frequencies of butterflies from the study sites were adequately presented in Table 2. This is to ascertain the shape, robustness and any outliers in the data.

Table 2: Descriptive statistics of butterfly frequencies from PFA, SFA & DAA.

Study Site	Mean	Mode	Median	Min.	Max.	Range	SE	SD	Variance	Sum	Count
PFA	34.2	40	27	15	63	48	5.38	17.02	289.73	342	10
SFA	23.6	N/A	25	8	36	28	2.78	8.80	77.62	236	10
DAA	15.2	18	16.5	10	20	10	1.21	3.82	14.62	152	10

ANOVA was performed to determine if the differences in butterfly frequencies between the three areas are statistically significant. Additionally, each area's specific ecological and environmental factors could be considered to understand the reasons behind the observed patterns in butterfly populations.

Table 3: Single Factor ANOVA of the frequencies of butterfly populations in PFA, SFA and DAA.

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1813.0667	2	906.53333	7.1202001	0.0032851	3.35413083
Within Groups	3437.6	27	127.31852			
Total	5250.6667	29	F= 3.37	df =2,27	p = 0.03	p< 0.04

Table 3 shows the ANOVA test conducted for the population means from the frequencies of butterflies in the three (3) sites, PFA, SFA, and DAA, produced a p -value of 0.003 at $\alpha = 0.05$ level. Statistically, there is a significant difference in the means of the population. Thus, the data collected was real and not obtained by chance. The hypothesis test decision is that we reject the H_0 and accept the H_A that the levels of anthropogenic activities in the ATFR impact the population of butterfly species. The difference between the means for the three (3) areas was statistically significant ($F= 3.35$; $df = 2, 27$; $p < 0.05$).

This shows that there is a significant difference in the means of the population. Thus, the data was real and not obtained by chance. Since, p- value $\leq \alpha$ Reject the H_0.

The frequency of butterflies sampled was analyzed by computing the Shannon-Weiner Indexes to determine the species diversity in the three (3) study sites in PFA, SFA, and DAA. The results are shown in Table 4. The diversity of the species of butterfly observed in the study area is presented in Table 4.

Table 4: Diversity of butterfly species in sites PFA, SFA, & DAA

Study +Site	Shannon – Weiner Diversity Index (H')	Species Richness
PFA	2.196	3.42
SFA	2.230	2.36
DAA	2.273	1.52

4. Discussion of Results

Based on the mean values and standard deviations (Table 2), it appears that there are differences in butterfly frequencies among the three areas, with PFA having the highest abundance and variability. According to Shannon and Weaver (1949) [14], the Shannon-Wiener index assumes that individuals are drawn randomly from a large, independent population and that all species are represented in the sample. The Shannon-Weaver diversity index value typically falls between 1.5 and 3.5, and it rarely rises above 4.5. According to Omayio and Mzungu (2019) [13], the higher the diversity index, the more diverse the species are in the habitat. If the index equals 0, only one species exists in the community. From Table 3, the index value of PFA was 2.196, which showed moderate diversity in species; the SFA index value was 2.230, which indicated a moderately diverse community; and the DAA index value of 2.273 also indicated a moderately diverse community. However, the indexes on the three sites are almost the same; this is one of the flaws of the index.

Comparatively, the PFA is diverse, SFA is more diverse and DAA is more diverse in the community. It also implies more certainty in PFA, followed by SFA and DAA sites having the highest uncertainty. Butterflies are more numerous and exposed to the open environment along forest borders. This researcher agrees that depleted areas in the forest recorded the highest diversity of species (Vu et al., 2015). From Table 4, species richness in sites PFA, SFA, and DAA was also computed using a species richness calculator authored by the Calculator Academy. The species richness for PFA, SFA, and DAA was 3.42, 2.36, and 1.52, respectively. The inference from the values shows that site PFA had the highest species richness, site SFA had fewer species richness, and site DAA had the least species richness.

Finally, studies that concur with these results suggest that insects which account for more than 50% of terrestrial biodiversity are one of the animal species groupings with diversified species richness. In contrast to most other insect species, butterflies are widely known, well-documented, and simple to identify. Butterflies are well adapted to their surroundings and respond swiftly to any change in their habitat brought on by human-induced activities like intensifying logging and farming (Mora et al., 2011). Climate change has an impact on species diversity and is predicted to worsen ecosystems (Scott & Lemieux, 2005) [13]. It is necessary to consider variations in temperature, rainfall patterns, and extreme weather events like heat waves, protracted droughts, or excessive rains.

5. Limitation

The mapping and demarcation of the anthropogenic areas for sampling of butterfly species was problematic.

6. Implication of the Study

Butterflies play a major role in the ecosystem. They aid in the pollination of flowers, which is one of the most important stages in the formation of fruits and seeds. Therefore, preserving the lives of the butterfly species is crucial. The study identified some activities of humans that impact butterfly population and areas of the forest impacted by these activities, thus curbing these known activities could stabilize the ecosystem to ensure continuity. The study further adds to the limited literature on butterfly species in the Atewa Forest reserve of Ghana.

7. Conclusions

The study suggests that butterflies are more abundant in the Primary Forest Areas (PFA) than in the other two areas. It also shows that PFA may have higher concentrations and frequency variability than the SFA and DAA. The butterfly species in PFA are diverse, SFA is more diverse and DAA more diverse. This implies that there are more species certainty in PFA, followed by SFA, and DAA habitats. PFA had the highest species richness, SFA had less species richness and DAA had the least. Moreover, the hypothesis test decision based on the ANOVA conducted showed a significant difference. Thus, we reject the null hypothesis (H_0) and accept the alternative hypothesis (H_A) that the levels of anthropogenic activities in the ATFR impact the population of butterfly species. It can be deduced from these findings that PFA which has mild stress levels of anthropogenic activities, had high frequency, abundance and dominant population of butterflies, followed by SFA with moderate stress levels and DAA with high levels of anthropogenic activities, had the least frequency and population.

Based on the results and findings from this study, it provides a deep understanding that the stress levels of anthropogenic activities impact the population of butterfly species in the ATFR.

7. Recommendations

The findings of this study form the basis for some practical recommendations. The ATFR is rich and abundant in butterfly species while degraded and open areas have a population decline. The ecological importance of butterflies is enormous; this necessitates the Forestry Commission of Ghana and stakeholders such as Environmental Non – Governmental Organizations and Traditional leaders in the enclave of forest reserve to enforce policies and regulations

to conserve and protect species including butterflies. Also, it restricts people from entering the reserve without a permit. Human activities that are thriving in the forest reserve are illegal mining, logging, felling trees for firewood, hunting, and farming practices that should be curbed by providing alternative sources of livelihood for the culprits.

Apart from this, the major cause of the decline in the population of butterflies in the ATFR is habitat loss in depleted or degraded areas. The District Forest Authorities should reclaim the farming areas encroached upon by the indigenes, pay compensation, and implement taungya farming. Laws regarding sustainable biodiversity protection practices should be enacted by policymakers to help them in the reduction of anthropogenic activities in the ATFR and other protected reserves in Ghana. Moreover, the ATFR has been listed among the Globally Significant Biodiversity Areas (GSBA) by the IUCN. For this reason, stakeholders such as the Forestry Commission of Ghana, District Assemblies bordering the forest reserve, and the Okyeman Environmental Foundation should collaborate to develop the forest reserve and encourage eco-tourism, which will provide employment and economic opportunities in the area.

Finally, environmental advocates and non-governmental organizations should liaise with the local authority and the GES to sensitize the inhabitants and schoolchildren around the forest reserve enclave on the ecological and economic importance of biodiversity in the ATFR. Researchers should develop top-notch and convincing proposals to attract and solicit grants from international organizations to conduct periodic surveys and further studies on the population and conservation of butterfly species in the ATFR. Erect signages with inscriptions such as “Never capture a butterfly except for research purposes” close to the ATFR. Persuade people to let butterflies fly unharmed. We must admire their beauty. We ought to educate the public about the importance of insects like butterflies. At the school level, there should be foundation courses on the preservation and conservation of insects and wildlife.

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