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Insects as Bioindicators: Using Entomofauna to Monitor Ecosystem Health

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Abstract: Insects play an important role in many ecosystem processes, including pollination, decomposition, nutrient cycling, and predation within food webs. They make up more than 80% of animal species. Their variety, short life spans, and sensitivity to environmental disturbances make them useful bioindicators for assessing ecosystem health. This research assessed insect diversity in three habitats of Bhopal Van Vihar National Park, agricultural areas, and Upper Lake, to determine ecosystem conditions. A total of 87 species were detected and classified into sensitive and tolerant categories. The findings indicated that Van Vihar National Park demonstrated the most variety and richness, agricultural lands presented intermediate diversity, while Upper Lake revealed the least, suggesting considerable ecological stress. Statistical investigations validated robust connections between insect diversity and environmental variables, including plant cover and pH levels. These results highlight the significance of entomofauna as bioindicators for ecological assessment and conservation strategy development.

Keywords: Monitoring, Bioindicators, Insects, Ecosystem, Entomofauna

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INTRODUCTION

Insects are one of the most varied and important categories of living things on Earth. They make up more than 80% of all known animal species. They provide important jobs in ecosystems, such pollination, decomposition, nutrient cycling, and becoming food for higher trophic levels [1]. Insects are well recognized as bioindicators because they are very diverse, have short life cycles, and are sensitive to changes in their environment. Their presence, abundance, or activity may provide us quantitative information about the health and integrity of ecosystems [2][3]. If we want to know how human activities like pollution, habitat loss, climate change, and intensified farming are affecting a certain area, we may look to insects as bioindicators.

Ephemeroptera mayflies and Plecoptera stoneflies are good indicators of the health of freshwater ecosystems because of their extreme sensitivity to changes in water quality. In a similar vein, insects that live on land, such as beetles, butterflies, and bees, may provide light on the fragility of terrestrial ecosystems via their reactions to factors including pesticide exposure, habitat loss, and climatic variability [4] [5].

Ecosystem management and conservation rely on bioindicators, which help shed light on the interconnected web of environmental variables and ecosystem health. Organizations such as the International Union for Conservation of Nature are actively advocating for the incorporation of bioindicators into biomonitoring systems, showcasing their ability to guide management and conservation efforts. There is a useful framework for understanding the histories and uses of bioindicators by classifying them into three separate groups: environmental, ecological, and biodiversity indicators. Since bioindicators from plants, animals, and microbes react differently to environmental stresses (Fig. 1), it is crucial to classify them according to their taxonomic responsibilities in order to comprehend their ecological roles and environmental importance [6].

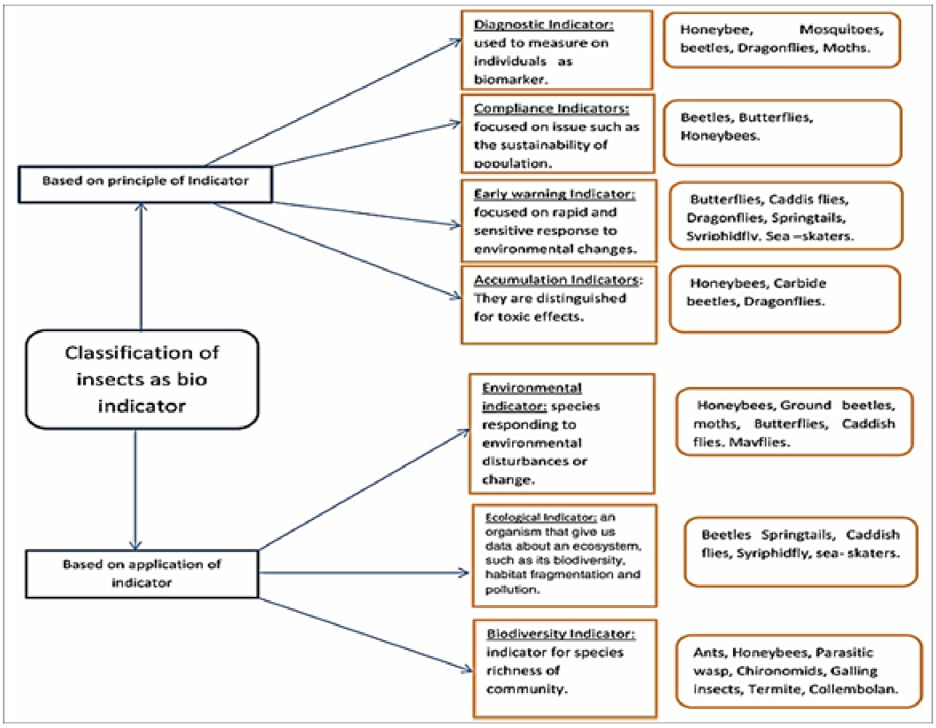

Figure 1: Insect classification as a bioindicator

Insects are widely used as bioindicators to evaluate pollution levels in the environment. Studies have shown that the presence of toxins such as heavy metals, insecticides, and other chemical contaminants can significantly affect their populations and behaviors [7][8]. Because of their high reproduction rates and short life cycles, insects are able to detect changes in ecosystems at an early stage because of their sensitivity to environmental stresses.

The use of insects for environmental monitoring has been greatly improved by technological improvements. Insect diversity and abundance may now be more accurately assessed and monitored in real-time with the use of tools like DNA identification, remote sensing, and species recognition based on machine learning. These advancements pave the way for widespread biomonitoring programs, which in turn aid scientists and politicians in making educated choices about the preservation and management of ecosystems.

OBJECTIVES

1. To assess the role of insects (entomofauna) as bioindicators in evaluating the health of different ecosystems.
2. To analyze the relationship between insect diversity, abundance, and environmental parameters across varying habitats.

REVIEW OF LITERATURE

Manpreet Singh et al. (2024) [9] discovered via their study that caddisflies (Trichoptera) provide several ecological services in watery settings. They brought attention to the fact that the variety and habitats of Trichoptera are greatly impacted by climate change. Caddisflies are great bioindicators for measuring the health of aquatic ecosystems due to their sensitivity to changes in water quality and environmental factors, making this research very significant.

Anshuman Pati et al. (2023) [10] discovered a great deal of species diversity among the macroinvertebrates studied in West Bengal's suburban and rural bodies of water. Their research sheds light on how insect diversity changes in response to various human-induced changes in habitat type. Insect heterogeneity monitoring may help with ecosystem health assessments, vector control, and environmental management, according to this research.

Marina Vilenica (2022) [11] performed research on the richness of aquatic insects and found that these creatures account for more than 60% of the species variety in freshwater ecosystems, with over 130,000 species documented worldwide. This work expands our knowledge of aquatic insects' ecological value and lends credence to their use in ecosystem monitoring.

Abdul Salam et al. (2022) [12] Researchers in the Euphrates River discovered that the larvae of the Chironomidae family were the most numerous, but the nymphs of the Zygoptera species were the most numerous at the first site. One important aspect of employing insects as bioindicators of water quality and ecosystem health is their ability to show variations in sensitive and tolerant bug species. Their results provide important evidence for this.

K. Elango et al. (2021) [13] Although nymphs of the Zygoptera species were more common in the first location, researchers in the Euphrates River found that the Chironomidae family larvae were the most numerous overall. Using insects as bioindicators of ecosystem health and water quality is significant because different kinds of bugs might display different levels of sensitivity or tolerance. Important proof for this is provided by their outcomes.

RESEARCH METHODOLOGY

Study area

I performed the research in three separate habitats in the Bhopal area of Madhya Pradesh to evaluate insect diversity and ecosystem health. The first location was Van Vihar National Park, a safeguarded forest region in central Bhopal, exemplifying a mostly unspoiled ecology with a variety of flora and wildlife. The second site included agricultural areas in the Kolar Road region, with wheat, soybean, and vegetable growth, indicative of managed agroecosystems with modest human intervention. The third location was the Upper Lake (Bhojtal) coastline, a freshwater environment affected by urban runoff and recreational activities, exemplifying a compromised aquatic habitat. These three sites were chosen to represent distinct degrees of ecological disturbance and provide a comparative investigation of insect diversity across various environmental circumstances.

Sampling Methods

I used several sample methods based on the kind of habitat:

- **Van Vihar Forestused:** pitfall traps and sweep nets to gather terrestrial insects.
- **Agricultural Fields:** used sweep nets during the day and light traps for nocturnal insects.
- **Upper Lake:** used a D-frame net to collect samples of aquatic insects, paying particular attention to the water's surface and submerged plants.

After being stored in 70% ethanol, every specimen that was gathered was brought to the lab for identification.

Identification of Insects

I used field guides and conventional entomological keys to identify insects in the lab, identifying them at the family level and, if feasible, the genus and species level. I was able to classify them into sensitive and tolerant groups by taking pictures of typical specimens and noting biological characteristics like habitat choice and pollution tolerance.

Data Recording and Analysis

Along with environmental factors like temperature, humidity, plant cover, soil pH, and water quality, I documented the variety, number, and composition of insects at each location. I computed the diversity indices of Simpson and Shannon-Wiener to measure evenness and species richness. In order to evaluate the health of the ecosystem, I examined the diversity and abundance of insects in the three habitats. I also used correlation analysis to look at the connections between environmental parameters and insect diversity.

RESULTS

Table 1: Total Insect Species and Abundance in Each Habitat

Habitat	Total Species	Sensitive Species	Tolerant Species	Total Individuals Collected
Van Vihar National Park	45	30	15	420
Agricultural Fields	28	12	16	310
Upper Lake	14	5	9	180

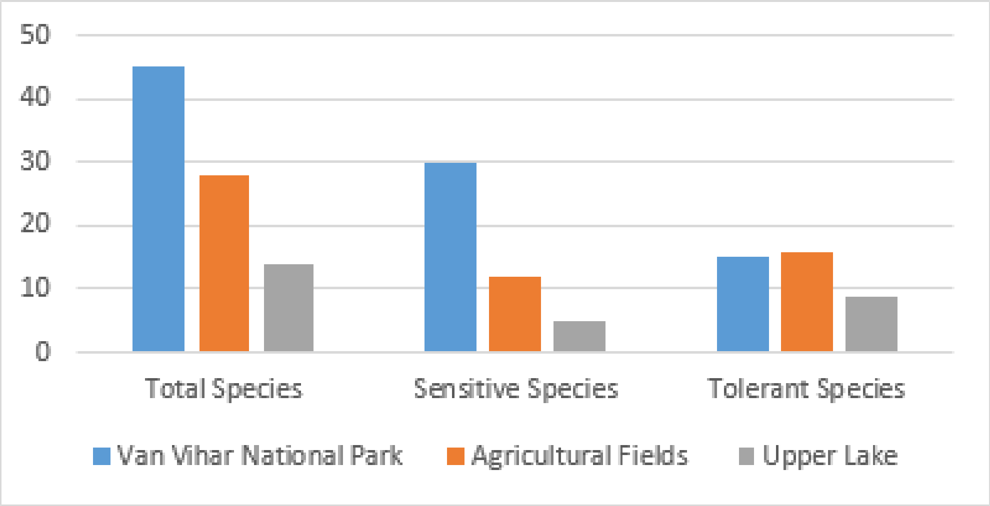

Figure 2: Total Insect Species and Abundance in Each Habitat

The above table and figure indicate that Van Vihar National Park has the largest quantity of species (45) and individuals (420), including 30 sensitive and 15 tolerant species. This signifies a rather robust and unperturbed ecology. Conversely, the agricultural lands harbored 28 species, exhibiting a more even distribution of sensitive (12) and tolerant (16) species, indicative of mild anthropogenic impact. The Upper Lake had the lowest species richness (14) and total individual count (180), with just 5 sensitive species, indicating environmental stress and contamination. The distribution of sensitive and tolerant species suggests that insect populations decrease in disturbed ecosystems.

Table 2: Shannon-Wiener and Simpson's Diversity Indices

Habitat	Shannon-Wiener Index (H')	Simpson's Index (D)
Van Vihar National Park	3.21	0.91
Agricultural Fields	2.45	0.82
Upper Lake	1.67	0.71

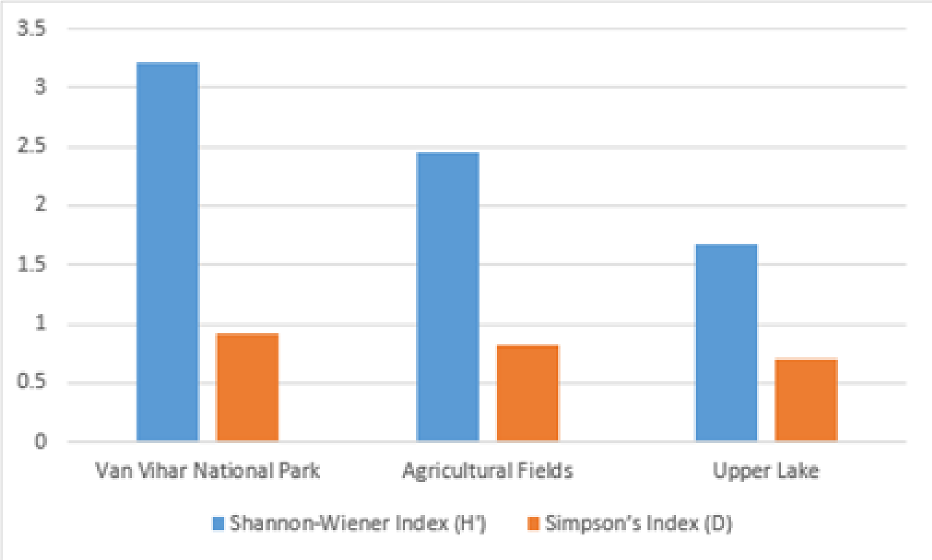

Figure 3: Shannon-Wiener and Simpson's Diversity Indices

The table and figure above provide diversity indices for the three environments. Van Vihar National Park had the greatest Shannon-Wiener index (3.21) and Simpson's index (0.91), indicating significant species richness and evenness. The agricultural lands exhibited moderate variety (H' = 2.45, D = 0.82), but Upper Lake had the lowest diversity (H' = 1.67, D = 0.71). The findings validate that insect diversity diminishes in environments impacted by human activities and ecological stress, hence endorsing the use of insects as bioindicators of ecosystem vitality.

Table 3: Dominant Insect Orders in Each Habitat

Habitat	Order	Number of Species	Number of Individuals
Van Vihar National Park	Odonata (Dragonflies)	8	95
	Coleoptera (Beetles)	12	130
	Lepidoptera (Butterflies)	10	85
Agricultural Fields	Coleoptera (Beetles)	6	70
	Hymenoptera (Bees & Wasps)	5	60
	Diptera (Flies)	4	50

Upper Lake	Diptera (Flies)	5	60
	Odonata (Dragonflies)	2	25
	Coleoptera (Beetles)	3	30

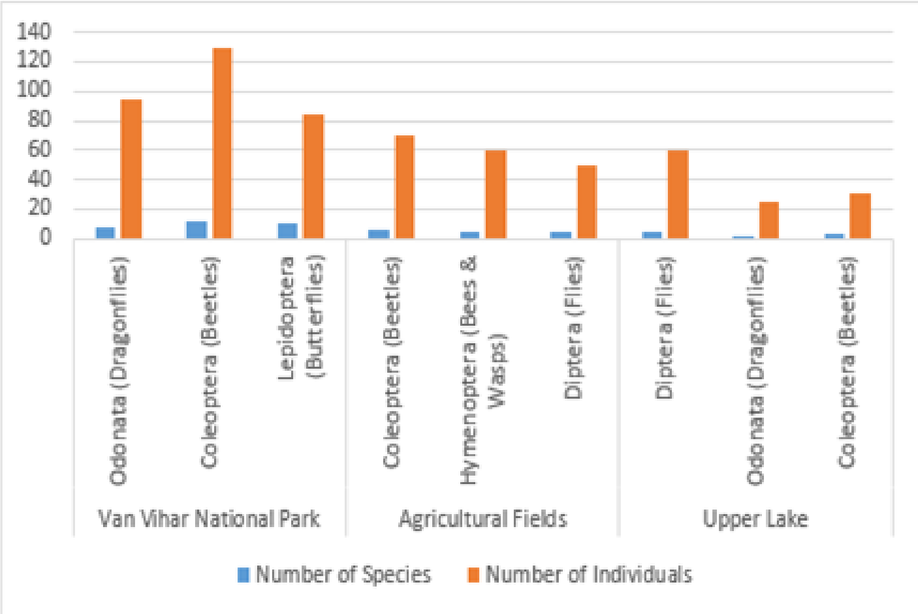

Figure 4: Dominant Insect Orders in Each Habitat

The table and picture above demonstrate that several insect orders predominated in each area. Van Vihar National Park was characterized by a predominance of Odonata (dragonflies), Coleoptera (beetles), and Lepidoptera (butterflies), indicative of a robust and intricate ecology. Coleoptera, Hymenoptera (bees and wasps), and Diptera (flies) were the most prevalent in agricultural areas, indicating moderate disturbance and the impact of crops. Upper Lake was mostly inhabited by Diptera, with a limited presence of tolerant Coleoptera and Odonata, indicating that sensitive orders diminish in contaminated aquatic environments. This pattern highlights that the mix of insect orders might signify habitat quality.

Table 4: Pollution-Sensitive vs. Pollution-Tolerant Species

Habitat	Sensitive Species	Tolerant Species	Sensitive: Tolerant Ratio
Van Vihar National Park	30	15	2:1

Agricultural Fields	12	16	0.75:1
Upper Lake	5	9	0.55:1

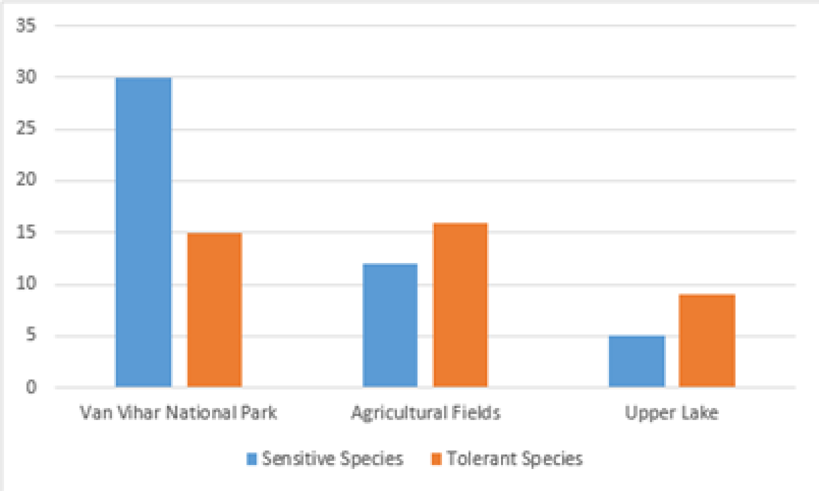

Figure 5: Pollution-Sensitive vs. Pollution-Tolerant Species

The table and picture above illustrate the ratio of sensitive to tolerant species in each environment. In Van Vihar National Park, sensitive species surpassed tolerant species in abundance, with a ratio of 2:1, indicating low disturbance. Agricultural fields had a ratio of 0.75:1, indicating modest anthropogenic influence. In Upper Lake, the ratio was just 0.55:1, indicating that tolerant species prevailed as a result of pollution and habitat destruction. This tendency illustrates that sensitive species diminish while tolerant species proliferate in disturbed ecosystems, validating their significance as bioindicators.

Table 5: Correlation of Insect Diversity with Environmental Parameters

Habitat	**Temperature (°C)**	**Relative Humidity (%)**	**Soil/Water pH**	**Vegetation Cover (%)**	**Correlation with Shannon Index (H')**
Van Vihar National Park	28	65	6.8	85	+0.82
Agricultural Fields	30	55	7.2	60	+0.68
Upper Lake	32	50	7.5	40	+0.45

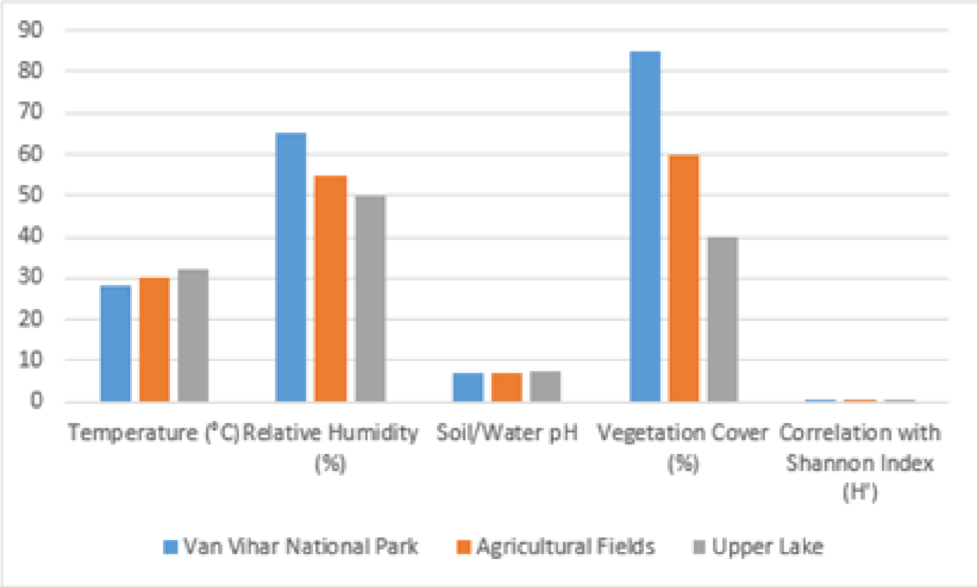

Figure 6: Correlation of Insect Diversity with Environmental Parameters

The table and picture illustrate the relationships between insect diversity, as measured by the Shannon index, and environmental parameters like temperature, humidity, soil/water pH, and plant cover. Van Vihar National Park, characterized by substantial plant cover (85%) and a moderate temperature (28°C), had the most robust positive connection (+0.82) with biodiversity. Agricultural lands had a modest correlation (+0.68), while Upper Lake demonstrated the lowest correlation (+0.45) attributed to less vegetation and increased disturbance. The data demonstrate that environmental factors, particularly vegetation and appropriate pH, significantly affect insect diversity and ecosystem health.

The research found 87 different insect species in three different Bhopal environments, with diversity and abundance changing significantly with different levels of ecological disturbance. With 45 species, including 30 vulnerable species, Van Vihar National Park had the greatest diversity, suggesting a mostly undisturbed and robust ecology. The presence of 28 species in agricultural fields is indicative of a moderate level of human impact; these areas supported both sensitive (12) and tolerant (16) species. Pollution and urban runoff had a greater effect on Lower Lake, which reported only 14 species, including just 5 delicate species. With a Shannon-Wiener score of 3.21 in Van Vihar and 1.67 in Upper Lake, diversity indexes corroborated this tendency. Insect diversity was shown to be significantly affected by plant cover and ideal pH, according to correlation analysis. In contrast, disturbed habitats were found to sustain a higher number of tolerant species. Insect diversity patterns are a good indicator of ecosystem health and a tool for tracking environmental change, as shown by these results.

DISCUSSION

The variety of insects is a trustworthy indication of the health of ecosystems since it demonstrates unambiguous reactions to environmental stress points. According to [14], aquatic insects are able to detect early indicators of pollution because of their sensitivity to changes in water quality. This makes them an ideal tool for monitoring pollutants. It was found in [15] that agricultural intensification causes decreases in insect richness as well as variations in community composition, which lends credence to the modest diversity that is seen in controlled settings. [16] highlighted the fact that the reduction of insects across the world is highly linked to the destruction of habitats and the fluctuation of climate, which explains why tolerant species are more prevalent in ecosystems that have experience disturbance. Another point that was emphasized in [17] was the significance of integrating insect monitoring into conservation plans. This is because insects are able to offer accurate and timely indications of ecological change.

CONCLUSION

The study confirms that insects serve as reliable bioindicators of ecosystem health, with diversity and abundance patterns reflecting the level of environmental disturbance. Protected habitats such as Van Vihar National Park maintained higher insect richness and a greater proportion of sensitive species, while disturbed habitats like Upper Lake showed dominance of pollution-tolerant species. The strong correlation between insect diversity and ecological parameters highlights their value for biomonitoring and conservation strategies. Incorporating insect-based indicators into environmental management can enhance early detection of ecological stress and support sustainable ecosystem conservation.

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