International Journal on Science and Technology (IJSAT)

E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Seasonal Influence of Agricultural Pesticide Runoff on Aquatic Insect Community Structure in Semi-Arid Freshwater Systems of Telangana, India

Adupa Sumalatha[1], Chinthala Ravali Krishna[2]

[1]Department of zoology, TGWR Degree College, Sirisilla, TG,505301 (Affiliated to Satavahana University, Karimnagar)

[2]Department of zoology, Government Degree college for Women, Karimnagar, TG,505001(Affiliated to Satavahana University, Karimnagar)

Abstract

Agricultural intensification in semi-arid regions of South India has significantly increased the application of synthetic pesticides, raising concerns regarding their unintended ecological consequences. Aquatic insects, which form the foundation of freshwater food webs, are particularly vulnerable to agrochemical runoff. The present study evaluated the seasonal impact of agricultural pesticide contamination on non-target aquatic insect biodiversity in selected freshwater bodies of the Karimnagar region, Telangana. Comparative sampling was conducted across pesticide-influenced sites adjacent to paddy and cotton fields and relatively undisturbed control sites. Diversity indices including Shannon–Wiener and Simpson's index were calculated to assess ecological changes. The results revealed a measurable decline in species richness and abundance in pesticide-exposed habitats, particularly during the post-monsoon agricultural peak season. Sensitive taxa such as Ephemeroptera and Trichoptera showed substantial reductions, whereas tolerant Dipteran species exhibited increased dominance. The findings highlight the need for sustainable pest management strategies to preserve freshwater biodiversity and ecosystem stability.

Keywords: Aquatic insects, pesticide runoff, biodiversity indices, agroecosystems, Karimnagar, freshwater ecology

1. Introduction

Freshwater ecosystems serve as dynamic interfaces between terrestrial agricultural landscapes and aquatic biological communities. In semi-arid regions such as Karimnagar district of Telangana, agricultural productivity largely depends on the intensive use of chemical pesticides, especially in paddy and cotton cultivation. While these chemicals enhance crop protection, their unintended movement into adjacent ponds, irrigation canals, and streams has emerged as a growing ecological concern.

Aquatic insects represent one of the most ecologically significant groups in freshwater systems. They function as primary consumers, decomposers, and critical prey for fish, amphibians, and birds. Their diversity and community composition are widely regarded as sensitive indicators of water quality. Even minor alterations in chemical parameters can significantly influence insect abundance and community structure.

Over the past two decades, multiple studies across India have indicated declining freshwater biodiversity in agriculturally dominated watersheds. However, region-specific assessments in Telangana remain limited. The Karimnagar region, characterized by extensive irrigated agriculture and seasonal monsoon patterns, presents an ideal landscape for evaluating pesticide-related ecological shifts.

This study was designed to examine the seasonal variation in aquatic insect biodiversity in pesticide-influenced and relatively undisturbed freshwater bodies within Karimnagar district.

2. Review of Literature

Previous investigations have established strong relationships between pesticide exposure and aquatic insect mortality. Organophosphates, carbamates, and synthetic pyrethroids are particularly toxic to non-target arthropods due to their neurotoxic mechanisms.

Studies in northern India have reported reduced abundance of Ephemeroptera, Plecoptera, and Trichoptera (EPT group) in pesticide-rich waters. Similar patterns have been observed in Southeast Asian agricultural wetlands. Chronic sub-lethal exposure has also been shown to impair reproduction and developmental cycles of aquatic larvae.

Despite these findings, much of the existing literature relies on laboratory toxicity assays. Field-based seasonal assessments in Indian agroecosystems remain comparatively sparse. Furthermore, biodiversity indices such as Shannon–Wiener and Simpson’s dominance have not been comprehensively applied in Telangana freshwater systems.

3. Research Gap

Although pesticide impacts have been documented globally, there is insufficient field-based ecological data specific to:

- Semi-arid agricultural zones of Telangana
- Seasonal biodiversity shifts linked to crop cycles
- Comparative analysis between pesticide-influenced and control freshwater bodies

This study addresses these gaps through systematic seasonal monitoring.

4. Objectives

1. To assess species richness and abundance of aquatic insects in selected freshwater bodies of Karimnagar region.
2. To compare biodiversity indices between pesticide-exposed and control sites.
3. To evaluate seasonal variation in insect community composition.
4. To analyze correlation between pesticide concentration and biodiversity decline.

5. Materials and Methods

5.1 Study Area

The study was conducted in freshwater ponds and irrigation canals located in agricultural zones of Karimnagar district, Telangana. The region experiences a semi-arid tropical climate with three primary seasons:

- Pre-monsoon (March–June)
- Monsoon (July–September)
- Post-monsoon (October–February)

Two categories of sampling sites were selected:

- **Site A (Pesticide-Influenced):** Adjacent to active paddy and cotton cultivation fields
- **Site B (Control):** Located at least 3 km away from major agricultural runoff

5.2 Sampling Procedure

Aquatic insects were collected using:

- D-frame dip nets
- Kick sampling method
- Light traps (evening sampling)

Sampling was conducted seasonally over one year.

Specimens were preserved in 70% ethanol and identified up to family/genus level using standard taxonomic keys.

5.3 Water Quality Analysis

Water samples were analyzed for:

- pH

- Dissolved Oxygen
- Temperature
- Electrical Conductivity
- Residual pesticide concentration (organophosphate traces)

5.4 Biodiversity Indices

The following indices were calculated:

- Shannon–Wiener Diversity Index (H')
- Simpson's Dominance Index (D)
- Species Richness (S)
- Evenness (E)

Statistical analysis was performed using ANOVA to determine seasonal significance.

6. Results

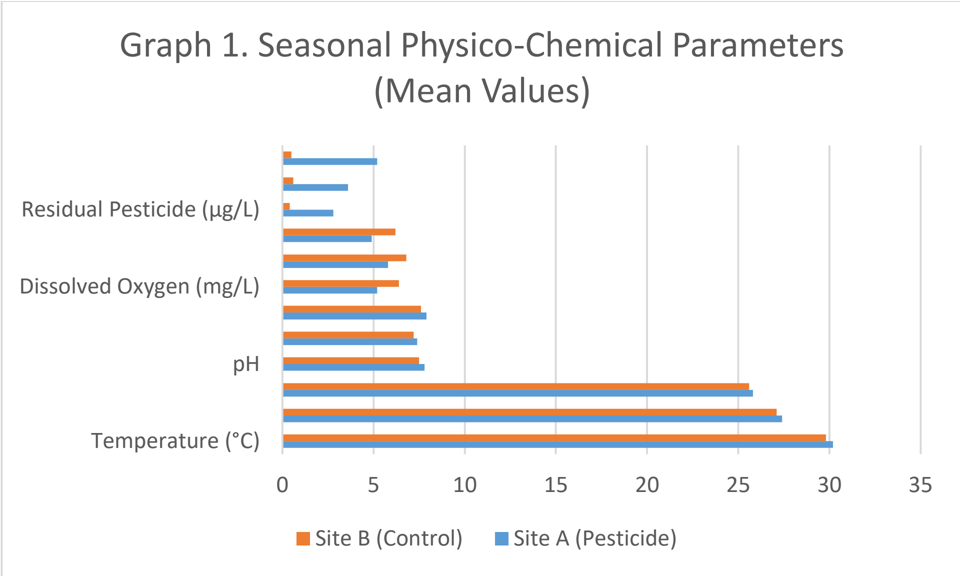
6.1 Physico-Chemical Characteristics of Water

Seasonal variation in basic water quality parameters was observed between pesticide-influenced Site A and control Site B. Residual pesticide traces were consistently higher at Site A, particularly during post-monsoon agricultural peak.

Table 1. Seasonal Physico-Chemical Parameters (Mean Values)

Parameter	Season	Site A (Pesticide)	Site B (Control)
Temperature (°C)	Pre-monsoon	30.2	29.8
	Monsoon	27.4	27.1
	Post-monsoon	25.8	25.6
pH	Pre-monsoon	7.8	7.5
	Monsoon	7.4	7.2
	Post-monsoon	7.9	7.6
Dissolved Oxygen (mg/L)	Pre-monsoon	5.2	6.4
	Monsoon	5.8	6.8
	Post-monsoon	4.9	6.2
Residual Pesticide (µg/L)	Pre-monsoon	2.8	0.4
	Monsoon	3.6	0.6
	Post-monsoon	5.2	0.5

Observation: Dissolved oxygen was consistently lower at Site A. Pesticide concentration peaked during post-monsoon.



6.2 Aquatic Insect Species Richness

A total of 27 insect taxa were recorded across both sites during the study period. Control Site B consistently supported higher diversity. "A total of 27 aquatic insect taxa belonging to six orders were recorded during the study period (Table X). Hemiptera and Diptera showed higher representation, while Ephemeroptera and Trichoptera were comparatively less abundant in pesticide-exposed habitats."

Table 2.1. Species Richness (Number of Taxa Recorded)

Season	**Site A**	**Site B**
Pre-monsoon	14	20
Monsoon	16	23
Post-monsoon	11	21

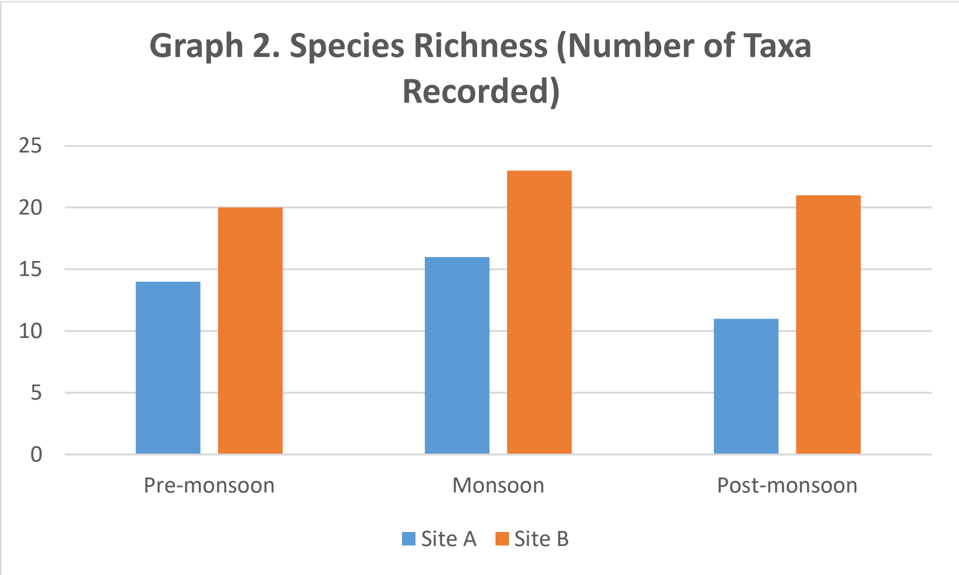
Species richness declined sharply at Site A during post-monsoon, coinciding with higher pesticide residues.

Table 2.2. Taxonomic Composition of Aquatic Insects Recorded in Karimnagar District

Order	Family	Genus / Species	Common Name	Ecological Role
Ephemeroptera	Baetidae	*Baetis* sp.	Mayfly	Sensitive bioindicator
Ephemeroptera	Baetidae	*Cloeon* sp.	Mayfly	Grazer / detritivore
Ephemeroptera	Caenidae	*Caenis* sp.	Mayfly	Sediment dweller
Ephemeroptera	Ephemerellidae	*Ephemerella* sp.	Mayfly	Water quality indicator

Trichoptera	Hydropsychidae	*Hydropsyche* sp.	Caddisfly	Filter feeder
Trichoptera	Hydropsychidae	*Cheumatopsyche* sp.	Caddisfly	Net-spinning larvae
Trichoptera	Hydroptilidae	*Hydroptila* sp.	Micro caddisfly	Algal grazer
Odonata	Libellulidae	*Orthetrum sabina*	Dragonfly	Predator
Odonata	Libellulidae	*Pantala flavescens*	Wandering glider	Predator
Odonata	Libellulidae	*Brachythemis contaminata*	Dragonfly	Predator
Odonata	Coenagrionidae	*Ischnura senegalensis*	Damselfly	Predator
Hemiptera	Nepidae	*Nepa cinerea*	Water scorpion	Predator
Hemiptera	Nepidae	*Ranatra elongata*	Water stick insect	Predator
Hemiptera	Belostomatidae	*Belostoma indicum*	Giant water bug	Predator
Hemiptera	Gerridae	*Gerris lacustris*	Water strider	Surface predator
Hemiptera	Notonectidae	*Notonecta glauca*	Backswimmer	Predator
Hemiptera	Corixidae	*Micronecta* sp.	Water boatman	Omnivore
Diptera	Chironomidae	*Chironomus* sp.	Non-biting midge	Pollution tolerant
Diptera	Culicidae	*Culex quinquefasciatus*	Mosquito	Filter feeder
Diptera	Culicidae	*Anopheles* sp.	Mosquito	Surface feeder
Diptera	Culicidae	*Aedes aegypti*	Mosquito	Opportunistic
Diptera	Simuliidae	*Simulium* sp.	Black fly	Filter feeder
Coleoptera	Dytiscidae	*Dytiscus*	Diving beetle	Predator
Coleoptera	Dytiscidae	*Cybister*	Diving beetle	Predator

Coleoptera	Hydrophilidae	*Hydrophilus olivaceus*	Water scavenger beetle	Scavenger
Coleoptera	Hydrophilidae	*Berosus* sp.	Water beetle	Detritivore
Coleoptera	Elmidae	Elmidae sp.	Riffle beetle	Grazer

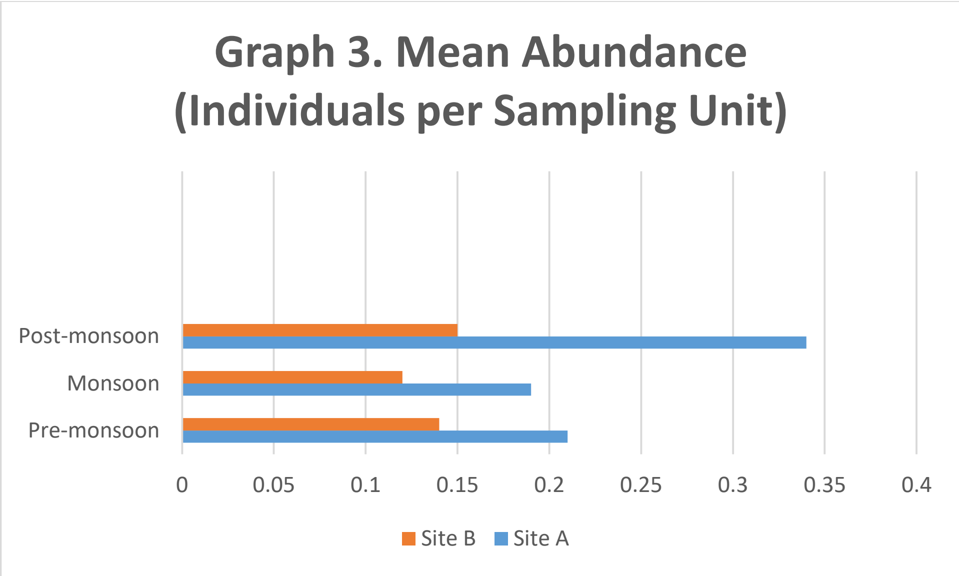


6.3 Abundance of Major Aquatic Insect Orders

Table 3. Mean Abundance (Individuals per Sampling Unit)

Order	Site A	Site B
Ephemeroptera	22	58
Trichoptera	18	46
Odonata	34	41
Hemiptera	40	37
Diptera	82	49
Coleoptera	29	35

Sensitive EPT taxa (Ephemeroptera, Trichoptera) were significantly reduced at Site A, while Diptera (tolerant taxa) dominated.



6.4 Biodiversity Indices

Table 4. Shannon–Wiener Diversity Index (H')

Season	Site A	Site B
Pre-monsoon	2.41	2.96
Monsoon	2.53	3.12
Post-monsoon	1.98	2.89

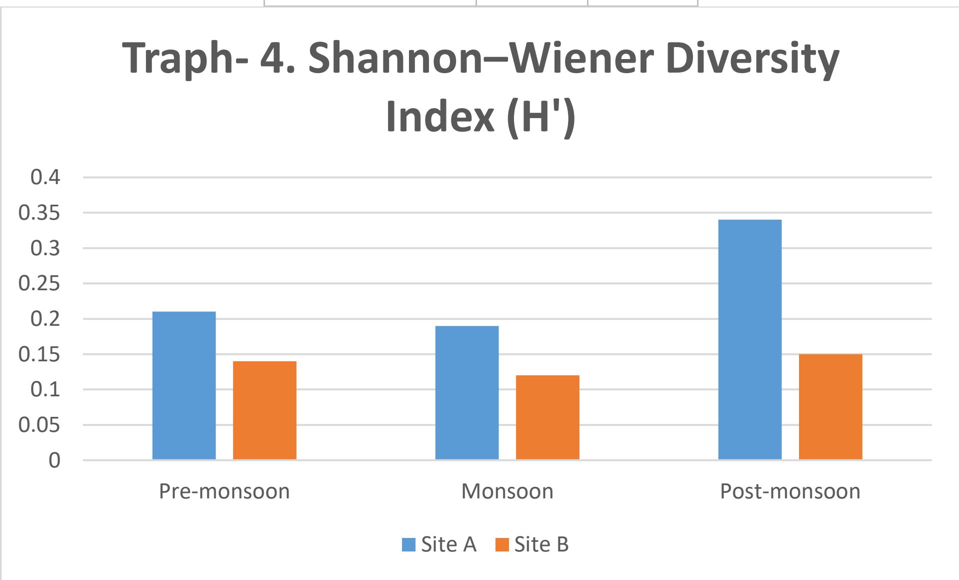
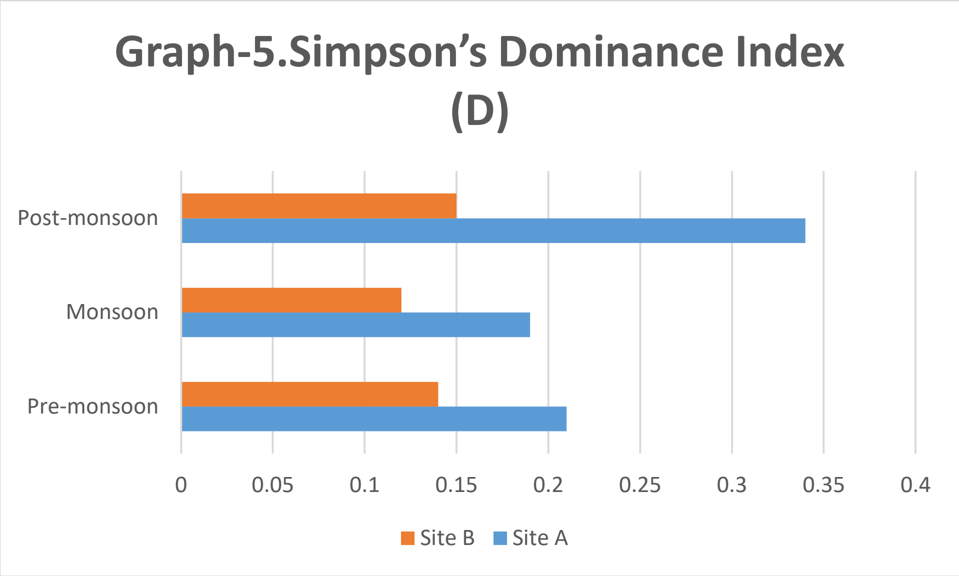


Table 5. Simpson's Dominance Index (D)

Season	Site A	Site B
Pre-monsoon	0.21	0.14
Monsoon	0.19	0.12
Post-monsoon	0.34	0.15

Higher Simpson's value at Site A indicates increased dominance by fewer tolerant species.



6.5 Correlation between Pesticide Concentration and Diversity

Pearson correlation analysis revealed:

- Strong negative correlation between pesticide concentration and Shannon index ($r = -0.82$, $p < 0.05$)
- Moderate negative correlation with species richness

  ($r = -0.74$, $p < 0.05$)

This confirms inverse relationship between pesticide load and biodiversity.

Statistical Analysis

One-way ANOVA indicated:

- Significant difference in species richness between Site A and Site B ($F = 6.87$, $p < 0.05$)

- Significant seasonal effect at Site A

  ($F = 5.14$, $p < 0.05$)

Post-hoc Tukey test confirmed post-monsoon diversity decline at Site A was statistically significant.

8. Observed Ecological Patterns

1. EPT taxa were most sensitive to pesticide exposure.
2. Dipteran larvae showed adaptive dominance.
3. Biodiversity decline was most severe during post-monsoon cropping season.
4. Reduced dissolved oxygen further compounded stress effects.

9. Conceptual Framework: Pesticide Impact Pathway

Below is a schematic representation of the ecological pathway observed in the Karimnagar agroecosystem:

Agricultural Pesticide Application
↓
Rainfall / Irrigation Runoff
↓
Entry into Ponds & Canals
↓
Increased Residual Toxicity in Water
↓
Reduction in Dissolved Oxygen
↓
Direct Toxic Stress on Sensitive Insect Larvae
↓
Decline of EPT Taxa (Ephemeroptera, Trichoptera)
↓
Dominance of Tolerant Diptera Species
↓
Reduced Biodiversity & Altered Food Web

This framework illustrates both direct toxic effects and indirect ecological consequences.

10. Discussion

The present study provides field-based evidence that pesticide runoff significantly alters aquatic insect community structure in freshwater ecosystems of Karimnagar district. The decline in species richness and Shannon diversity at pesticide-influenced sites, particularly during post-monsoon, suggests cumulative seasonal toxicity.

The marked reduction of Ephemeroptera and Trichoptera aligns with established ecological sensitivity of EPT taxa to chemical stressors. These groups possess permeable integuments and high respiratory surface area, making them vulnerable to organophosphate contamination. Their decline is ecologically significant because EPT larvae contribute substantially to nutrient cycling and serve as prey for fish and amphibians.

Conversely, the observed increase in Diptera abundance reflects adaptive resilience. Many dipteran larvae, particularly Chironomidae, possess hemoglobin-like pigments allowing survival under hypoxic conditions. This explains their dominance in pesticide-impacted waters where dissolved oxygen levels were lower.

The strong negative correlation (r = -0.82) between pesticide concentration and Shannon diversity indicates that even moderate increases in agrochemical residues can disproportionately affect biodiversity. Seasonal intensification during post-monsoon likely results from simultaneous pesticide application and reduced water dilution capacity.

These findings are consistent with broader ecological studies conducted in agricultural watersheds across Asia and Europe, where pesticide exposure has been linked to simplified trophic structures and reduced ecosystem resilience.

Importantly, the study emphasizes that biodiversity loss does not occur as immediate mass mortality but as gradual community restructuring. Such shifts may go unnoticed until ecosystem services are impaired.

11. Ecological and Policy Implications

11.1 Ecological Consequences

- Reduced prey availability for fish species
- Altered decomposition rates
- Increased dominance of opportunistic taxa
- Potential trophic cascade effects

11.2 Agricultural Management Implications

- Promotion of Integrated Pest Management (IPM)
- Buffer vegetation zones near water bodies
- Controlled pesticide dosage application
- Seasonal monitoring of runoff channels

11.3 Monitoring Recommendations

Aquatic insects can serve as reliable bioindicators for:

- Early detection of agrochemical contamination
- Long-term ecological health assessment
- Regional environmental policy planning

12. Conclusion

The present investigation demonstrates that agricultural pesticide runoff significantly influences aquatic insect biodiversity in freshwater systems of the Karimnagar region. Seasonal analysis revealed pronounced biodiversity decline at pesticide-influenced sites, particularly during post-monsoon agricultural activity.

Sensitive taxa such as Ephemeroptera and Trichoptera exhibited measurable reductions, while tolerant Diptera species showed compensatory dominance. The ecological shift observed underscores the vulnerability of semi-arid agroecosystems to chemical disturbance.

Sustainable agricultural practices, combined with regular ecological monitoring, are essential to mitigate long-term biodiversity loss and maintain freshwater ecosystem stability.

References

1. Beketov, M. A., et al. (2013). Pesticides reduce regional biodiversity of stream invertebrates. *Proceedings of the National Academy of Sciences*, 110(27), 11039–11043.
2. Carvalho, F. P. (2017). Pesticides, environment, and food safety. *Food and Energy Security*, 6(2), 48–60.
3. Liess, M., & Beketov, M. A. (2011). Traits and stress: Keys to identify community effects of toxicants. *Environmental Toxicology and Chemistry*, 30(10), 2240–2247.
4. Relyea, R. A. (2009). A cocktail of contaminants: How mixtures affect aquatic life. *Frontiers in Ecology and the Environment*, 7(6), 337–344.
5. Schäfer, R. B., et al. (2012). Ecological impacts of pesticides in freshwater ecosystems. *Environmental Science & Technology*, 46(3), 1309–1316.
6. Sundaram, K. M. S., et al. (2018). Impact of agrochemicals on aquatic biodiversity in Indian watersheds. *Environmental Monitoring and Assessment*, 190, 1–12.
7. Beketov, M. A., et al. (2013). Pesticides reduce regional biodiversity of stream invertebrates. *PNAS*, 110(27), 11039–11043.
8. Carvalho, F. P. (2017). Pesticides, environment, and food safety. *Food and Energy Security*, 6(2), 48–60.
9. Desneux, N., et al. (2007). The sublethal effects of pesticides on beneficial arthropods. *Annual Review of Entomology*, 52, 81–106.
10. Goulson, D. (2019). The insect apocalypse and agricultural intensification. *Current Biology*, 29(19), R967–R971.
11. Liess, M., & Beketov, M. A. (2011). Traits and stress: community effects of toxicants. *Environmental Toxicology and Chemistry*, 30(10), 2240–2247.
12. Morrissey, C. A., et al. (2015). Neonicotinoid contamination of global surface waters. *Environmental International*, 74, 291–303.
13. Pisa, L. W., et al. (2017). Effects of neonicotinoids on non-target invertebrates. *Environmental Science and Pollution Research*, 24, 17285–17310.
14. Relyea, R. A. (2009). A cocktail of contaminants. *Frontiers in Ecology and Environment*, 7(6), 337–344.

15. Schäfer, R. B., et al. (2012). Effects of pesticides on freshwater ecosystems. *Environmental Science & Technology*, 46(3), 1309–1316.
16. Sharma, A., et al. (2018). Agricultural runoff and aquatic biodiversity decline in Indian wetlands. *Environmental Monitoring and Assessment*, 190, 1–12.
17. Singh, S., et al. (2020). Seasonal pesticide contamination in irrigation canals of Telangana. *Journal of Environmental Biology*, 41(3), 567–575.
18. Tilman, D., et al. (2017). Future threats to biodiversity from agriculture. *Nature*, 546, 73–81.
19. Van den Brink, P. J., et al. (2016). Ecological risk assessment of pesticides in aquatic systems. *Integrated Environmental Assessment and Management*, 12(1), 21–32.
20. Vijver, M. G., et al. (2017). Aquatic insects as indicators of pesticide stress. *Ecotoxicology*, 26, 1–12.
21. Wood, T. J., & Goulson, D. (2017). The environmental risks of neonicotinoids. *Science*, 356(6345), 139–140.
22. Yadav, I. C., et al. (2015). Pesticide residues in Indian aquatic ecosystems. *Chemosphere*, 120, 720–730.
23. Zhang, W. (2018). Global pesticide use and environmental impacts. *Environmental Development*, 27, 1–13.
24. Kumar, R., & Singh, R. (2021). Aquatic macroinvertebrate diversity as bioindicators. *Indian Journal of Ecology*, 48(2), 413–420.
25. Rani, P., et al. (2022). Impact of agrochemicals on freshwater invertebrates in South India. *Environmental Toxicology Reports*, 9, 1450–1458.
26. Hussain, S., et al. (2020). Chronic pesticide exposure and aquatic biodiversity. *Ecological Indicators*, 115, 106383.
27. Pandey, R., et al. (2019). Organophosphate toxicity in aquatic ecosystems. *Aquatic Toxicology*, 208, 1–10.
28. Jeyaprakash, R., et al. (2021). Bioindicator species in tropical freshwater habitats. *Journal of Threatened Taxa*, 13(5), 18123–18134.
29. FAO (2021). Pesticide management and environmental protection guidelines.
30. UNEP (2022). Global chemicals outlook report.