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Assessment of Riverbank Environmental Integrity Using Dragonfly Assemblage Patterns

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Abstract

The localized environmental status of riverbank areas in Butuan City and Las Nieves was assessed using dragonfly assemblage patterns as biological indicators. The study employed a quantitative methodology involving four sampling rounds, physicochemical measurements of soil and water, and the computation of the Dragonfly Biotic Index (DBI). Analysis of eight identified species revealed non-uniform environmental integrity. Notably, all species were classified as Least Concern (LC) under the IUCN Red List, indicating a dominance of resilient taxa. Water analysis across San Mateo Old (SMO), Dankias, and Lingayao showed safe TDS (145–195 ppm) and a constant SG of 1.000. However, areas exhibited Highly Alkaline conditions (pH 8.87–9.47) and temperatures between 29.5°C 30.7°C. Dankias showed a critical ORP of -5 mV, signaling low oxygen, while Lingayao remained healthy at 208 mV. Soil analysis confirmed a "Heavy, Very Fine Texture" across areas. Soil pH ranged from moderately acidic (6.57) in SMO to neutral (6.95) in Lingayao. Nitrogen and Potassium were adequate in SMO, slightly deficient in Dankias, and deficient in Lingayao. Phosphorus was adequate in SMO and Dankias but slightly deficient in Lingayao. The DBI classified Lingayao as Disturbed but Recovering (DBI: 1.25), while Dankias and SMO were Highly Disturbed (DBI: 1.00), with Dankias showing very low diversity (H′=0.6207). The study recommends immediate habitat rehabilitation and ongoing monitoring by agencies such as the DENR to stabilize these ecosystems.

Keywords: Bioindicator, Dragonfly Biotic Index, IUCN Red List, Physicochemical Parameters, Riverbank Integrity, Tungao, Butuan City, Philippines

Introduction

River ecosystems were crucial for maintaining ecological balance, providing essential services such as water purification, flood control, and nutrient cycling. They also supported a wide variety of plant and

animal life. The health of these systems, particularly in riparian zones along riverbanks and streambanks, is vital to sustaining biodiversity and environmental integrity (Rivers are Life Team, 2023).

Dragonflies were recognized as effective indicators of environmental health because of their sensitivity to changes in their surroundings. They offered valuable insights into the ecological condition of freshwater systems, both in aquatic and terrestrial habitats (Adu et al., 2022). Their presence, abundance, and diversity often reflected the quality and stability of their environment, making them a useful tool for ecological monitoring.

The conduct of this study was imperative due to the ecological significance of dragonflies in maintaining ecosystem stability. As both predators and prey, they regulated insect populations and contributed to the balance of aquatic and terrestrial food webs. Assessing their diversity through measures such as species richness, evenness, and dominance provided valuable insights into the integrity of riverbank ecosystems. A decline in dragonfly populations not only indicated deteriorating water quality and habitat conditions but also disrupted ecological interactions and diminished biodiversity. Such outcomes underscore the importance of monitoring dragonfly assemblages to inform conservation strategies and sustainably manage riverine environments.

Despite the recognized importance of dragonflies in ecosystem monitoring, there remained a significant gap in understanding their species accounts across different regions and habitat types, particularly in riverbank ecosystems where biodiversity interacts closely with human activities such as fishing, agriculture, and domestic water use. Although studies such as Gómez-Tolosa et al. (2022) have shown that dragonfly assemblages respond sensitively to both aquatic and terrestrial conditions, demonstrating their value as indicators of ecosystem integrity, comprehensive assessments of this kind remain limited in the Philippine context. This gap is especially evident in Agusan del Norte, particularly in the riverbank systems of Butuan City and Las Nieves, where freshwater habitats have not been thoroughly documented for Odonata diversity. Environmental pressures such as siltation, riparian vegetation loss, and fluctuating water quality are known to alter habitat conditions, yet their effects on local dragonfly communities remain insufficiently examined. Without localized baseline information, LGUs and environmental agencies lack the biological indicators necessary to detect early ecological changes and to support evidence-based conservation measures.

This study addresses this deficiency by generating baseline data on dragonfly assemblages in selected riverbank areas of Butuan City and Las Nieves. It documents the species present, their relative abundance, and the environmental characteristics of their habitats, providing an initial understanding of how dragonfly communities respond to local ecological conditions. The findings are expected to support future ecological assessments, strengthen biodiversity monitoring initiatives in Agusan del Norte, and reinforce the use of dragonflies as reliable bioindicators of riverbank ecosystem health.

Related Literature

Odonata are among the earliest winged insects and play a vital role in understanding evolutionary and ecological processes. Their biological characteristics provide insights into flight, metabolism, and life history strategies across environments. Oliveira-Junior et al. (2022) stated that these organisms bridge ecological and evolutionary research by providing valuable insights into biodiversity and adaptation. This makes them highly relevant in modern ecological studies.

Odonata are divided into two major suborders, Anisoptera and Zygoptera, which differ in morphology and behavior. These differences include wing structure, eye arrangement, and resting posture. In a study conducted on dragonfly diversity, Hastomo et al. (2022) emphasized that these distinctions are essential for ecological identification. Accurate classification supports biodiversity assessment and

conservation planning. Dragonflies are widely recognized as effective bioindicators of environmental change due to their sensitivity to habitat conditions. Their dual life cycle allows them to reflect ecological conditions in both aquatic and terrestrial ecosystems. This makes them reliable tools for environmental monitoring and assessment. Their ecological importance in detecting environmental change has been emphasized (Guerrero-Moreno et al., 2024).

The life cycle of dragonflies involves a prolonged aquatic larval stage followed by a relatively short adult phase. This transition highlights their ecological role in both freshwater and terrestrial systems. Chen et al. (2024) explained that this biphasic life cycle contributes to their effectiveness as indicators of ecosystem health. Their development also influences their role in food webs and energy transfer. Water quality is a major factor influencing dragonfly diversity and distribution. Key physicochemical parameters such as dissolved oxygen, temperature, and vegetation determine habitat suitability. In a study of oil palm waterways, Ishak et al. (2021) found that these factors significantly shape species richness and assemblage patterns. Maintaining suitable conditions is therefore critical for biodiversity.

Aquatic ecosystems rely on stable chemical conditions to sustain biodiversity and ecological balance. Variations in pH, nutrient levels, and dissolved oxygen can directly affect species survival. Dawood (2020) noted that disruptions in water chemistry alter predator–prey interactions and community composition. These changes highlight the importance of water quality management. Reliable assessment of water quality requires standardized measurement methods and consistent parameters. Indicators such as turbidity, conductivity, and dissolved oxygen provide baseline data for ecological evaluation. Another study investigated monitoring protocols, where Fitri et al. (2020) emphasized the importance of uniform assessment techniques. These methods improve the reliability of biodiversity studies.

Chemical processes in aquatic environments influence organism physiology and habitat stability. Changes in water chemistry can lead to stress or loss of sensitive species. Ali et al. (2021) demonstrated that balanced chemical conditions are necessary to support diverse aquatic communities. These findings reinforce the importance of chemical equilibrium in ecosystems. Physical properties such as water density and dissolved substances also affect aquatic organisms. These factors influence larval development, buoyancy, and habitat preference. In a related study, Harris (2020) explained that such variables can indicate pollution or nutrient imbalance. Monitoring these parameters enhances ecological understanding.

Soil processes indirectly influence aquatic ecosystems by affecting vegetation and nutrient availability. Riparian vegetation plays a key role in providing habitat and regulating environmental conditions. Arora et al. (2022) highlighted that soil nutrients support plant growth and ecosystem stability. These interactions shape dragonfly habitats and behavior. Microbial activity in soils regulates nutrient cycling and supports ecosystem stability. These processes help maintain water clarity and reduce sedimentation in aquatic systems. Another study revealed that soil biochemical activity enhances habitat conditions (Xiong et al., 2021). Healthy soil systems, therefore, support aquatic biodiversity.

Plant–soil interactions influence vegetation structure and microclimate conditions such as shading and humidity. These factors are essential for maintaining suitable habitats for dragonflies. Govindasamy et al. (2023) emphasized that plant–soil relationships regulate ecosystem productivity and habitat quality. These interactions link terrestrial and aquatic ecosystems. Species richness in dragonflies varies across regions due to climate, geography, and habitat conditions. Tropical ecosystems generally support higher biodiversity compared to temperate regions. In a study on global distribution, Liao et al. (2023) found that climate change is shifting species' ranges. These shifts affect ecological balance and biodiversity patterns.

Environmental gradients and habitat availability influence regional diversity patterns. Factors such as temperature, water flow, and geography determine species distribution. Kalkman et al. (2022) explained that these gradients shape biodiversity across large spatial scales. Understanding these patterns is important for conservation planning. Species diversity includes both richness and evenness within ecological

communities. These components are measured using indices such as Shannon and Simpson. Another study revealed that these metrics provide insights into ecological stability (Roswell et al., 2021). They are widely used in biodiversity assessments.

Functional diversity reflects the range of ecological roles species within a community play. It often responds more strongly to environmental change than to taxonomic diversity. Mousseau (2021) showed that functional traits provide deeper insights into ecosystem resilience. This makes it a valuable tool in ecological studies. Integrated biodiversity approaches combine taxonomic, phylogenetic, and functional data. These frameworks provide a more comprehensive understanding of ecological systems. In a recent study, Chao et al. (2021) introduced unified methods for measuring biodiversity. These approaches improve ecological monitoring and conservation strategies.

Habitat structure significantly influences dragonfly assemblages and ecological roles. Variations in vegetation and waterbody types determine species distribution. Deacon et al. (2024) found that complex habitats support higher functional diversity. These findings highlight the importance of habitat preservation. Environmental changes can disrupt natural habitat selection and species behavior. Altered environmental cues may lead to maladaptive decisions. Another study investigated ecological traps, in which Daly et al. (2021) explained their effects on species survival. Maintaining habitat integrity is therefore crucial.

Habitat complexity influences predator–prey interactions within ecosystems. Diverse habitats provide refuge and support balanced ecological relationships. Ara et al. (2021) demonstrated that simplified environments increase predation risk. Structural diversity is essential for ecological stability. Environmental conditions and species traits shape community assembly. Factors such as temperature, habitat size, and physiology influence species distribution. In a study on tropical streams, Bastos et al. (2020) found that these variables determine coexistence patterns. These processes structure ecological communities.

Environmental filtering plays a major role in shaping community composition. Water chemistry and habitat quality determine which species can survive. Minot et al. (2021) reported that these factors strongly influence biodiversity patterns. They act as key drivers of ecological structure. Species interactions, such as competition and predation, influence community dynamics. These interactions affect resource use and species coexistence. Another study revealed that these processes shape assemblages (Pons et al., 2023). They are essential components of ecological systems.

Large-scale biodiversity patterns are influenced by habitat connectivity and landscape structure. These factors affect species movement and gene flow. Lynch et al. (2023) showed that connectivity supports biodiversity maintenance. Fragmentation can reduce ecological resilience. Human activities significantly impact ecosystem health and biodiversity. Pollution and habitat degradation reduce species richness and alter communities. In a study on nutrient enrichment, Kolar et al. (2023) found that these pressures negatively affect aquatic ecosystems. Environmental management is therefore essential.

Climate change affects species distribution and ecological balance across regions. Warm-adapted species tend to expand while cold-adapted species decline. Olsen et al. (2022) explained that these shifts alter biodiversity patterns. This highlights the impact of global warming on ecosystems. Restoration efforts can improve ecosystem conditions and support biodiversity recovery. Effective conservation strategies enhance habitat quality and resilience. Another study found that restoration promotes ecological stability (Samways et al., 2020). These efforts are vital for long-term sustainability.

Biotic interactions such as competition and predation shape ecological dynamics. These processes influence species traits and population structures. Iversen et al. (2025) stated that both abiotic and biotic factors determine community composition. These interactions maintain ecosystem complexity. Dragonflies adapt to environmental changes through morphological and behavioral responses. These adaptations enhance survival in changing conditions. In a related study, Lehká et al. (2025) highlighted adaptive traits in response to predation. These responses improve ecological resilience.

Parasitic interactions also affect dragonfly populations and the balance of ecosystems. These relationships influence fitness and survival. Xu et al. (2022) found that parasitism shapes population dynamics over time. Understanding these interactions is important in ecology. Dragonflies serve as indicators of environmental quality because they are sensitive to habitat conditions. Their presence reflects ecosystem health and stability. Another study revealed their importance in monitoring ecosystems (Datto-Liberato et al., 2024). They are widely used in ecological assessments.

Dragonflies play key roles as predators in ecological systems. Their feeding behavior influences insect populations and food webs. Zebsa et al. (2022) explained that these interactions support ecological balance. Their role contributes to ecosystem stability. The Dragonfly Biotic Index is used to assess ecosystem health and environmental integrity. It integrates species sensitivity, distribution, and conservation status. In a study of freshwater systems, Samways and Simaika (2016) highlighted its effectiveness. It is widely used in ecological monitoring.

Habitat integrity strongly influences dragonfly community composition. Healthy ecosystems support specialized and sensitive species. Silva Rocha et al. (2023) found that generalist species dominate degraded habitats. This reflects environmental quality. Dragonfly communities reflect both aquatic and terrestrial environmental conditions. Their distribution provides insights into habitat quality and ecological change. Another study confirmed their effectiveness as indicators (Juen et al., 2024). This reinforces their ecological importance.

Local studies show that undisturbed habitats support higher biodiversity. Disturbed environments often show reduced diversity and altered community structure. Sanguila and Mohagan (2022) reported that these patterns are consistent across regions. Conservation efforts are therefore necessary. Dragonflies are essential for understanding biodiversity and ecosystem processes. Their responses to environmental changes provide valuable insights for conservation. In a synthesis of recent studies, Oliveira-Junior et al. (2022) emphasized their role in ecological monitoring. These findings support their use in environmental management.

Theoretical/Conceptual Framework

The present study utilizes the sensitivity of dragonfly assemblages to assess riverbank ecological integrity, an approach supported by established ecological theories. It is anchored on the Ecological Indicators Theory and the framework recognizing dragonflies as comprehensive biological indicators. These frameworks provide the scientific basis for using Odonata as reliable bio-assessors in freshwater ecosystems.

The study is grounded in the Ecological Indicators Theory, which explains that biological assemblages can reflect environmental conditions and ecological changes. Ferris and Humphrey (1999) stated that dragonflies are effective indicators due to their sensitivity to environmental stressors and their ability to integrate both aquatic and terrestrial influences. This makes them suitable for monitoring dynamic riverbank ecosystems exposed to natural and anthropogenic disturbances.

This theoretical foundation is further supported by the framework describing dragonflies as comprehensive biological indicators. Kietzka (2019) emphasized that dragonflies respond to variations in water quality, vegetation structure, and habitat integrity due to their dual life stages. Their ecological role extends to functioning as biodiversity surrogates, where their presence reflects the condition of other sensitive aquatic taxa. This strengthens their value in ecological assessment and conservation studies.

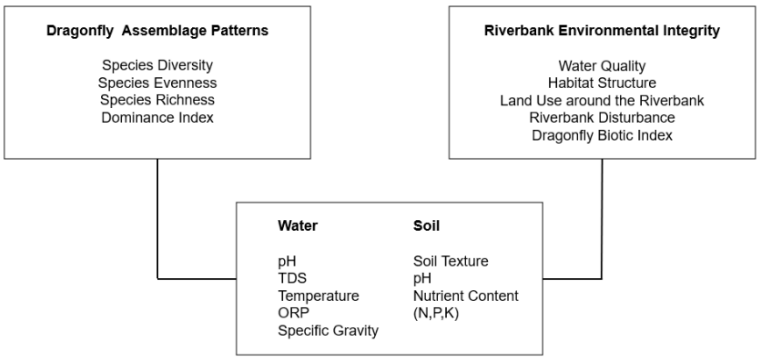
The integration of these frameworks provides a strong scientific basis for this research. By combining ecological sensitivity and multi-indicator capacity, dragonflies serve as effective tools for evaluating ecosystem health. Their diversity, abundance, and assemblage patterns are used to infer environmental

conditions and detect ecological changes. This supports their application in assessing riverbank degradation and recovery.

The study also examined key physicochemical parameters of the riverbank environment to support ecological assessment. Water parameters included pH, total dissolved solids, temperature, oxidation-reduction potential, and specific gravity, while soil parameters included texture, pH, and nutrient content. These variables provided baseline data on environmental quality and were correlated with dragonfly assemblages. This approach enabled the study to establish relationships between environmental conditions and biodiversity patterns.

Figure 1

Dragonfly assemblage patterns as indicators of riverbank environmental integrity, showing the influence of various environmental parameters.



Research Objectives

This study assessed the the following objectives: (1) the common dragonfly species that can be found in the areas; (2) assess the physicochemical parameter of the tributaries in terms of pH, total Dissolved Solids (TDS), temperature, oxidation-Reduction Potential (ORP), and specific gravity; (3) evaluate the physicochemical parameter of the soil in terms of soil texture, pH, and nutrient content (N, P, K); (4) determine the level of dragonflies in Barangay Dankias, Barangay Lingayao and Barangay San Mateo in terms of species Diversity, evenness, species richness, and dominance index; (5) determine the conservation status of the identified dragonflies; and (6) determine the condition and integrity of the riverbank.

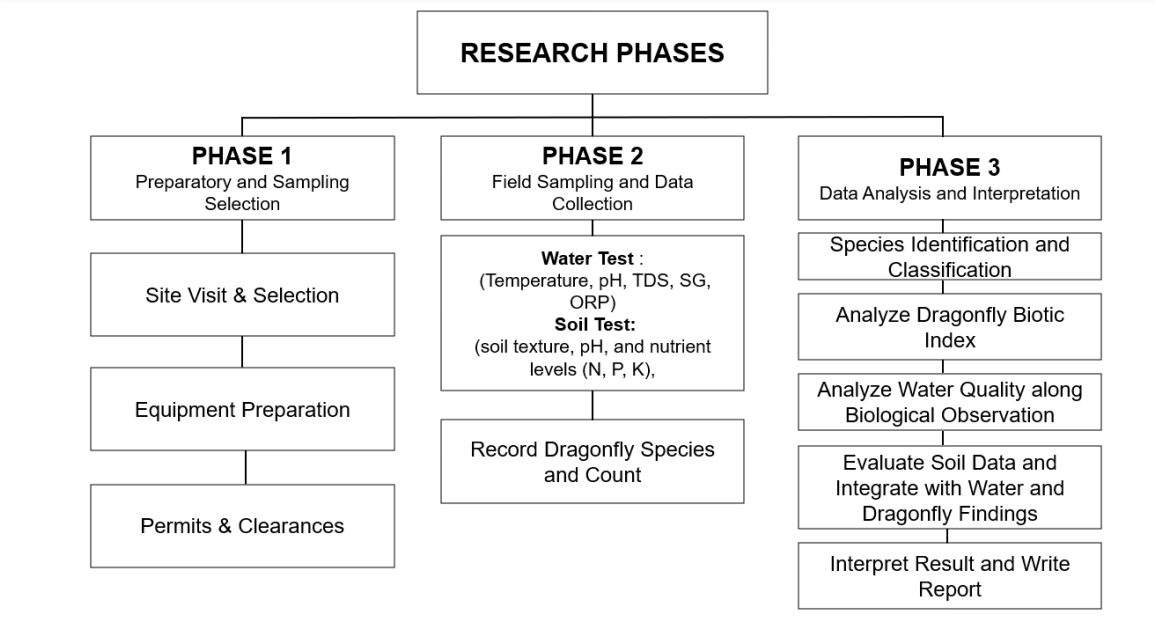
Methodology

This study employed a quantitative design to assess riverbank environmental integrity by analyzing species richness, abundance, and diversity. The research was carried out at three riverbank areas in Agusan del Norte—Barangay Dankias (8.755903° N, 125.584554° E), Barangay San Mateo in Butuan City (8.792709° N, 125.579703° E), and Barangay Lingayao in Las Nieves (8.742516° N, 125.582865° E). This study on dragonfly assemblage patterns required a specific set of materials and equipment to ensure accurate data collection and safe handling of the specimens. This study followed a structured quantitative approach in three phases to examine dragonfly assemblage patterns as indicators of riverbank environmental integrity.

Table 1. *Materials and Procedure Used for Data Collection*

Materials and Equipment	Purpose
Calibrated multi-parameter Quality Checker	Monitors the water quality of the habitat where the dragonfly lives.
Acetone	Preserves the color and prevents decay of the dragonfly specimen.
Forceps	Allows for the delicate handling of a dragonfly without causing damage.
Wax Paper	Keeps moisture away to ensure the dragonfly remains dry.
Liquid Eraser	Applied as a visible mark to track an individual dragonfly.
Insect Net	Designed to safely capture and secure dragonflies for study.
Container	Holds the chemical solution used for soaking the dragonfly.

Figure 2. *Research Phases for the Study Dragonfly Assemblage Patterns as Indicators of Riverbank Environmental Integrity*



Results and Discussion

Problem 1. What are the common dragonfly species that can be found in the areas?

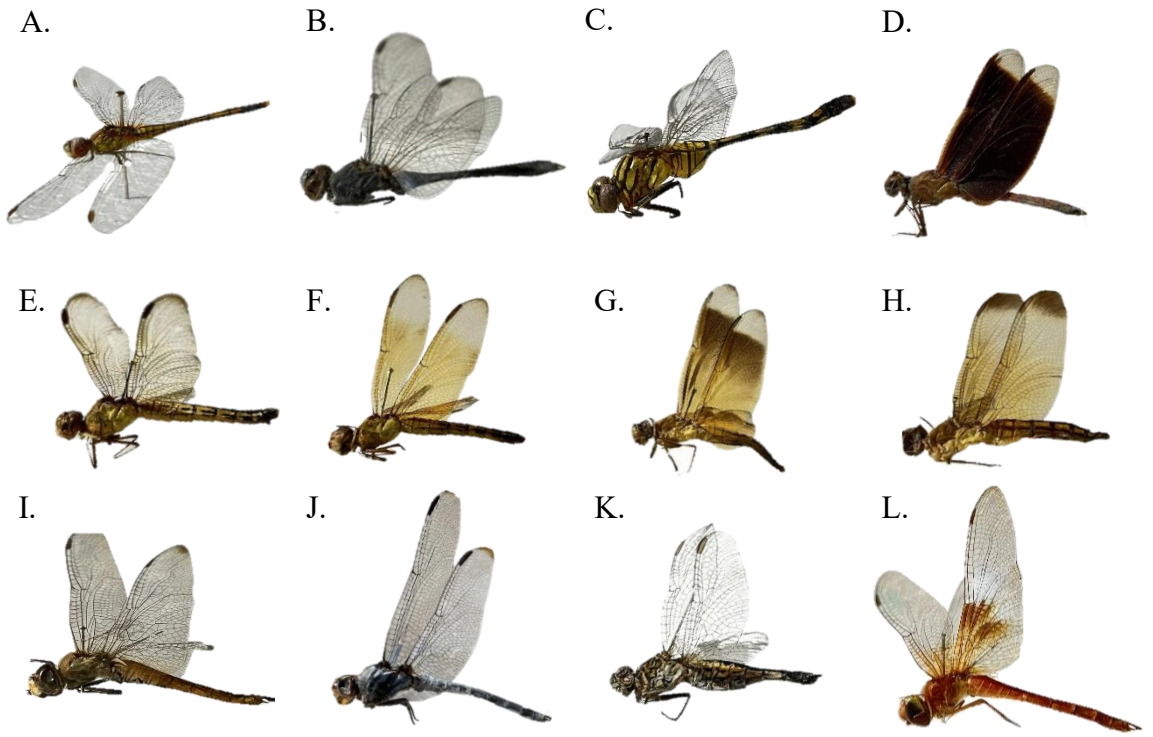
Dragonfly individuals were predominantly recorded in Barangay San Mateo (260 individuals) and Lingayao (258 individuals), which together account for 518 of the total population. The similarly high counts in these areas suggest that they provide more favorable habitat conditions, such as better water quality and sufficient vegetation that support dragonfly populations. In contrast, Barangay Dankias recorded only 139 individuals, indicating a comparatively lower abundance.

Table 3. *Dragonfly species recorded in the area.*

Scientific Name	Common Name	Number of dragonflies caught			Total	% of total
		San Mateo Old	Dankias	Lingayao		
Diplacodes trivialis	Chalky Percher	186	117	184	487	74.0%
Orthetrum sabina	Slender Skimmer	14	8	36	58	8.8%
Neurothemis ramburii	Red Percher	24	2	21	47	7.2%
Neurothemis terminata	Red-winged Dragonfly	19	2	12	33	5.0%
Pantala flavescens	Wandering Glider/	11	10	2	23	3.5%
Potamarcha congener	Yellow-tailed Ashy Skimmer	6	0	1	7	1.1%
Acisoma panorpoides	Trumpet Tail	0	0	1	1	0.2%
Trithemis aurora	Crimson Marsh Glider	0	0	1	1	0.2%
	Total	260	139	258	657	**100%**

The data presented in Table 3 show that a total of 657 individual dragonflies were recorded across eight species belonging to the family Libellulidae. These species include *Diplacodes trivialis*, *Orthetrum sabina*, *Neurothemis ramburii*, *Neurothemis terminata*, *Pantala flavescens*, *Potamarcha congener*, *Acisoma panorpoides*, and *Trithemis aurora*. The distribution of these species across the three sampling areas indicates a pattern of homogenization, characterized by the dominance of eurytopic generalist species.

Figure 3. *Visual Documentation of Dragonfly Species Collected*



*(Legend: **A** – Diplacodes trivialis (female), **B** – Diplacodes trivialis (male), **C** – Orthetrum sabina, **D** – Neurothemis ramburii (male), **E** – Neurothemis ramburii (female), **F** – Neurothemis terminata (male), **G** – Neurothemis terminata (female), **H** – Neurothemis terminata (female), **I** – Pantala flavescens, **J** – Potamarcha congener, **K** – Acisoma panorpoides, **L** – Trithemis aurora)*

Diplacodes trivialis (Chalky Percher) (Figure 4A & 4B) exhibited clear dominance, comprising 487 individuals of the total population. This species was highly abundant across all sampling sites, particularly in San Mateo Old and Lingayao, indicating strong adaptability to varying environmental conditions. As a heliophilic species that prefers open habitats, its high abundance may reflect reduced canopy cover or altered environments (Oliveira-Junior et al., 2021). Its ability to utilize temporary and stagnant water sources and forage in exposed areas further supports its success in such conditions (Zunnikah et al., 2025).

Orthetrum sabina (Slender Skimmer) (Figure 4C) was the second most abundant species, with 58 individuals recorded across all sites. It was most prevalent in Lingayao, followed by San Mateo Old and Dankias, indicating a wide distribution. This consistent presence suggests that the species can tolerate a range of environmental conditions and habitat types. Its adaptability to human-influenced environments and rapid recolonization ability further explain its occurrence across all sites (Guerzon et al., 2023).

The genus *Neurothemis* was represented by *Neurothemis ramburii* (47 individuals) and *Neurothemis terminata* (33 individuals) (Figure 4D–H). These species were observed across all sampling sites but at lower abundance than the dominant taxa. Their presence in areas with grasses and open vegetation suggests association with transitional or edge habitats. Additionally, environmental stress in such habitats may influence developmental stability, as reflected in morphological variations reported in similar species (Fernando & Tabugo, 2016).

Pantala flavescens (Wandering Glider) (Figure 4I) was recorded with 23 individuals across the three sites. Its occurrence in San Mateo Old, Dankias, and Lingayao indicates its ability to utilize a variety of habitat conditions. As a migratory species that breeds in temporary water bodies, its presence indicates the availability of such habitats. However, its relatively low abundance compared to dominant species may indicate that these habitats are not well-suited for sustained population growth (Guerzon et al., 2023).

San Mateo Old and Lingayao exhibited similarly high abundance levels, with 260 and 258 individuals, respectively, along with greater species representation. In contrast, Dankias recorded fewer individuals and lacked rare species such as *Acisoma panorpoides* and *Trithemis aurora*. This difference suggests variation in habitat conditions among the sampling sites. The dominance of widespread species in these areas may indicate environments influenced by disturbance or human activities (Potapov et al., 2020).

The simplified community structure observed in Dankias suggests the presence of environmental stressors. Such conditions may result from habitat loss or homogenization, which can reduce species diversity while favoring adaptable taxa. Previous studies have shown that anthropogenic disturbances can act as environmental filters, limiting sensitive species and promoting tolerant ones (Villalobos-Jiménez et al., 2016). Additionally, ecological interactions such as predation may further influence species composition in altered habitats (McPeek, 1990; Suhonen et al., 2010).

The absence of less common or sensitive species in Dankias may indicate reduced habitat quality. Changes in vegetation structure and environmental conditions can limit the availability of suitable niches for certain species. This pattern highlights the importance of maintaining habitat heterogeneity to support diverse dragonfly assemblages. Such ecological conditions are essential for sustaining biodiversity and ecosystem stability (Chovanec & Waringer, 2001).

Problem 2. What is the physicochemical parameter of the tributaries in terms of, pH, total Dissolved Solids (TDS), temperature, oxidation-Reduction Potential (ORP), and specific gravity?

Dragonflies are recognized as effective indicators of freshwater ecosystem health because they are sensitive to environmental conditions. Changes in water chemistry influence their diversity and distribution, making assemblage patterns useful for assessing ecological integrity. Key parameters such as pH, total dissolved solids (TDS), temperature, oxidation-reduction potential (ORP), and specific gravity play important roles in shaping species composition. Evaluating these variables is essential for understanding riverbank environmental conditions.

To examine these relationships, physicochemical data were collected in situ using a calibrated multi-parameter device following standard protocols. This ensured consistency and accuracy of measurements across all sampling sites. The collected data provided a basis for comparing environmental conditions among the tributaries. These measurements supported the interpretation of dragonfly assemblage patterns.

The pH values recorded across the sampling sites indicate varying levels of alkalinity. San Mateo Old (pH 8.61) falls within the upper limit of tolerable conditions, where freshwater diversity may still be maintained (Wilson et al., 2023). However, Dankias (9.47) and Lingayao (9.20) exceed the ecological threshold of pH 9.0, indicating more stressful conditions for aquatic organisms (U.S. EPA, 2020). These elevated values suggest potential impacts on species richness and community stability (Adu et al., 2022).

Extreme alkalinity may indicate underlying environmental disturbances or pollution sources. Such conditions are often associated with runoff, sedimentation, or chemical inputs from surrounding land use (Correia & Roseland, 2022). These factors contribute to long-term habitat degradation and ecological stress (Šigutová et al., 2025). Maintaining balanced pH levels is therefore critical for sustaining freshwater ecosystems (Water Quality Australia, 2020; U.S. Environmental Protection Agency [EPA], 2020).

Total Dissolved Solids (TDS) values ranged from 145 ppm in San Mateo Old to 195 ppm in Lingayao. These values fall within acceptable limits for freshwater systems and indicate generally low levels of dissolved substances. Such concentrations suggest minimal chemical stress and good baseline water quality. They also reflect the limited influence of pollutants from surrounding activities (Suhardono et al., 2025).

Low TDS levels indicate that the water systems remain within the oligosaline category and are considered of high quality. These conditions reduce physiological stress on aquatic organisms and support biodiversity (Karmakar et al., 2025). The absence of elevated TDS suggests minimal accumulation of dissolved pollutants. This creates a favorable environment for sensitive species to persist (Muhamad Ishak et al., 2021).

Maintaining low TDS levels is important for long-term ecosystem sustainability. Increased inputs from agricultural runoff or waste discharge may elevate TDS and degrade water quality. Conservation strategies should therefore focus on limiting pollutant inputs. Additionally, improving habitat structure will further enhance biodiversity under stable chemical conditions (Sheha Kumari Bharati et al., 2025).

Temperature measurements showed a gradient across the study sites, ranging from 28.5°C in Lingayao to 30.5°C in Dankias. This variation indicates differences in thermal conditions that may affect aquatic organisms. Elevated temperatures can impose physiological stress and influence metabolic processes. Such conditions may affect species survival and distribution (Haque et al., 2025; Baranov et al., 2025).

Increased temperature reduces dissolved oxygen levels while increasing metabolic demand. This creates stressful conditions for aquatic organisms, particularly sensitive species. As a result, energy is diverted from growth and reproduction to survival processes (Chapra et al., 2021; Lee & Matthews, 2024). These conditions may limit population development and resilience.

Thermal stress can also affect life-history traits, such as growth rate and emergence timing. Changes in these traits may result in smaller body sizes and reduced reproductive success. These effects can alter population dynamics and species interactions (Castillo-Pérez et al., 2024; Olsen et al., 2022). Over time, this may lead to shifts in community composition.

Oxidation-reduction potential (ORP) values varied across the study sites, indicating differences in sediment chemical conditions. Lingayao showed a highly oxidizing environment (208 mV), while San Mateo Old indicated moderate conditions (146 mV). In contrast, Dankias recorded a negative ORP (-5 mV), suggesting anaerobic conditions. These differences reflect varying levels of ecological stability.

Positive ORP values indicate oxygen-rich environments that support aerobic processes and nutrient stability. In such conditions, pollutants are often immobilized, reducing ecological risk (Wang et al., 2024). Conversely, negative ORP values indicate oxygen depletion and the formation of harmful substances. These conditions can negatively affect benthic organisms (Defeo et al., 2024).

The negative ORP recorded in Dankias suggests severe environmental stress. Low oxygen levels and toxic compounds may limit species survival and diversity. Such conditions are often associated with pollution and organic loading (Adu et al., 2022; Bowles & Kleinsasser, 2022). This may explain the reduced biodiversity observed in the area.

Anthropogenic activities such as vegetation clearing and agricultural practices may contribute to these conditions. Runoff and chemical inputs can alter sediment chemistry and promote oxygen depletion. These processes lead to long-term habitat degradation. Effective management is necessary to restore ecological balance (Zhang et al., 2023; Defeo et al., 2024).

Specific gravity remained constant at 1.000 across all sampling sites, indicating typical freshwater conditions. This suggests the absence of excessive dissolved salts or contaminants. As a result, this parameter is unlikely to contribute to environmental stress. Stable values support favorable conditions for freshwater organisms (Manonmani et al., 2024).

Table 4. *Physicochemical parameters of water of the three riverbeds.*

Sampling Areas	Parameters	Interpretation
	pH	
San Mateo Old	8.61	Alkaline
Dankias	9.47	Highly Alkaline
Lingayao	9.20	Highly Alkaline
	Total Dissolved Solids (TDS) ppm	
San Mateo Old	145	Safe for drinking, minimal taste/ odor
Dankias	170	Safe for drinking, minimal taste/ odor
Lingayao	195	Safe for drinking, minimal taste/ odor
	Temperature (ºc)	
San Mateo Old	29.7	Moderate condition
Dankias	30.5	Highest temperature, more thermal stress
Lingayao	28.5	Most suitable condition
	Oxidation Reduction Potential (mV)	
San Mateo Old	146	Reducing/ low oxygen
Dankias	-5	Reducing/ low oxygen
Lingayao	208	Healthy oxygenated
	Specific Gravity	
San Mateo Old	1.00	Freshwater
Dankias	1.00	Freshwater
Lingayao	1.00	Freshwater

Problem 3. What is the physicochemical parameter of the soil in terms of soil texture, pH, and nutrient content (N, P, K)?

The selected areas in this study were examined to determine the soil's physical and chemical characteristics, which play a crucial role in supporting plant growth and maintaining ecosystem stability. Soil provides essential nutrients, moisture, and a stable medium for root development, all of which influence vegetation density and structure. Since dragonflies rely on riparian vegetation for perching, breeding sites, shade regulation, and prey availability, soil quality indirectly affects their presence and diversity.

The identified soil samples from the selected sites showed variations in texture, moisture content, pH, and organic matter. These differences are shaped by land use, vegetation cover, and surrounding environmental conditions. Areas with healthier vegetation, supported by richer, more stable soil, tend to offer more suitable microhabitats for dragonflies, such as shaded resting areas and abundant insect prey (Banaybanay et al., 2024). In contrast, soils disturbed by agriculture and residential development showed compaction and reduced fertility, resulting in sparser vegetation that may limit the availability of perching sites and negatively impact dragonfly assemblages (Silva & Lambers, 2023; Napoletano et al., 2025).

Table 5. *Recorded Physicochemical Parameters of the Soil*

Sampling Areas	Parameters Soil Texture	Interpretation
San Mateo Old	Heavy	Very Fine Texture
Dankias	Heavy	Very Fine Texture
Lingayao	Heavy	Very Fine Texture
	pH	
San Mateo Old	6.57	Moderately Acidic
Dankias	7.75	Slightly Alkaline
Lingayao	6.95	Neutral
	Nutrient Content	
	Nitrogen (N)	
San Mateo Old	0.18	Adequate
Dankias	0.09	Slightly Deficient
Lingayao	0.04	Deficient
	Phosphorus (P) *ppm*	
San Mateo Old	13	Adequate
Dankias	12	Adequate
Lingayao	5	Slightly Deficient
	Potassium (K) *ppm*	
San Mateo Old	247	Adequate
Dankias	115	Slightly Deficient
Lingayao	74	Deficient

The sediment across San Mateo, Old, Dankias, and Lingayao was consistently classified as heavy with very fine texture, indicating dominance of silt and clay fractions. Such soil characteristics promote low infiltration and high surface runoff, increasing the likelihood of sediment transport into adjacent aquatic systems (Agriculture and Agri-Food Canada, 2020; U.S. Department of Agriculture, Natural Resources Conservation Service, 2023). These conditions facilitate siltation and may contribute to benthic degradation by reducing oxygen availability and increasing turbidity (Vieira et al., 2025). As a result, the terrestrial properties of the soil are directly linked to aquatic habitat conditions and may influence dragonfly assemblages.

The dominance of fine-textured soils suggests a catchment system prone to sediment loading and associated pollutant transport. During precipitation events, reduced soil structure and drainage can accelerate runoff, carrying fine particles and nutrients into river systems (U.S. Department of Agriculture, Natural Resources Conservation Service, 2022). This process can lead to habitat embedding, reduced interstitial oxygen, and impaired foraging conditions for aquatic organisms. Consequently, such environmental conditions may favor tolerant species while limiting sensitive taxa, contributing to reduced biodiversity.

Soil pH varied across the sampling areas, with San Mateo Old (6.57) classified as moderately acidic, Lingayao (6.95) as neutral, and Dankias (7.75) as slightly alkaline (Pinheiro et al., 2021). These differences indicate variability in soil chemical conditions that may influence surrounding aquatic systems. Soil pH affects nutrient solubility and microbial activity, which are important for maintaining ecosystem productivity (Peeters et al., 2025). Neutral to moderately acidic conditions generally support balanced ecological processes,

while slight alkalinity may alter nutrient availability and habitat structure (Horiba, 2024; Duhamel, 2025).

The influence of soil pH on dragonfly assemblages is primarily indirect, acting through its effects on vegetation and nutrient dynamics. Variations in pH can alter plant growth and microhabitat availability, which are essential for larval development and survival (Daniel et al., 2021). These changes may affect the distribution and composition of Odonata communities. Environments with balanced pH conditions are more likely to support stable ecological interactions. In contrast, deviations from optimal ranges may contribute to shifts in community structure (Renner et al., 2022).

The soil nutrient profile showed relatively adequate nitrogen and potassium levels but limited phosphorus availability across the sampling sites. Soil nutrient content is a key determinant of ecosystem productivity and influences both terrestrial and aquatic processes (Zhang et al., 2025). High nitrogen availability, particularly in San Mateo Old (0.18%), indicates a strong potential for nutrient transport into adjacent water bodies. This condition may increase the risk of nutrient enrichment and associated ecological impacts.

Nitrogen is highly mobile in soil systems and can be transported into aquatic environments through runoff and leaching. Once introduced into water bodies, nitrogen compounds such as nitrate and ammonium can alter water chemistry and affect species composition (U.S. Environmental Protection Agency, 2025). Elevated nitrogen levels are commonly associated with eutrophication, which can disrupt food webs and reduce dissolved oxygen levels (Vilenica et al., 2022; Peeters et al., 2025). These conditions may negatively affect dragonfly larvae, which are sensitive to changes in oxygen availability.

Phosphorus levels were moderate in San Mateo Old and Dankias but low in Lingayao, indicating variability in nutrient availability. Although phosphorus may be limited in soils, it can still enter aquatic systems through sediment transport (U.S. Environmental Protection Agency, 2025). Even small increases in phosphorus can stimulate algal growth and contribute to eutrophication. This process may alter habitat conditions and affect aquatic biodiversity (Vilenica et al., 2022). Consequently, phosphorus dynamics remain important in understanding ecosystem health.

Potassium levels varied across the sites, with adequate levels in San Mateo Old and lower concentrations in Dankias and Lingayao. While potassium is not a primary driver of eutrophication, it contributes to overall dissolved ion concentrations in water systems (Azevedo et al., 2020). Increased ion concentrations may influence osmotic balance and physiological processes in aquatic organisms. These changes can contribute to cumulative environmental stress. As a result, potassium plays a supporting role in shaping aquatic conditions.

Overall, the soil physicochemical characteristics of the study area indicate a system with the potential to transport sediment and nutrients into aquatic habitats. High nitrogen availability, combined with fine-textured soils, increases the likelihood of runoff-driven pollution. These conditions can lead to eutrophication, reduced oxygen levels, and habitat degradation. Consequently, such environmental pressures may favor tolerant species while reducing the presence of sensitive Odonata taxa (Dolai, 2023; Karmakar et al., 2025).

The ecological response to these conditions is expected to involve shifts in community composition toward more adaptable species. Environmental stress during the aquatic larval stage can significantly influence survival and development (Iversen, 2025; Eagles-Smith et al., 2020). Over time, this may result in reduced specialization and increased dominance of generalist taxa. Although species richness may remain stable, overall ecological integrity may decline (Daniel et al., 2021; Jansen et al., 2024). These findings highlight the importance of managing both soil and water quality to sustain biodiversity.

Problem 4. What is the level of dragonflies in Barangay Dankias, Barangay Lingayao and Barangay San Mateo in terms of species Diversity, evenness, species Richness; and dominance index?

Table 6. *Computed Statistical Values on Diversity Indices of Dragonflies*

Sampling Areas	Parameters	Interpretation
	Shannon_*H*	
San Mateo Old	1.029	Very Low Diversity
Dankias	0.621	Very Low Diversity
Lingayao	0.965	Very Low Diversity
	Evenness_*e^H/S*	
San Mateo Old	0.466	Less Balanced
Dankias	0.372	Less Balanced
Lingayao	0.328	Less Balanced
	Margalefs	
San Mateo Old	0.899	Low Species Richness
Dankias	0.811	Low Species Richness
Lingayao	1.261	Low Species Richness
	Dominace_*D*	
San Mateo Old	0.531	Moderate Dominance
Dankias	0.717	Moderate Dominance
Lingayao	0.537	Moderate Dominance

Shannon–Wiener Diversity Index

Table 6 summarizes the computed diversity indices of dragonflies across San Mateo, Dankias, and Lingayao, revealing generally low and uneven community structures. The Shannon–Wiener index values are very low in all sites, with San Mateo Old (H = 1.029), Lingayao (H = 0.965), and Dankias (H = 0.621), indicating reduced ecological complexity. These results suggest that the dragonfly assemblages are composed of a limited number of species with uneven distribution. The particularly low value in Dankias reflects a more simplified community structure dominated by a few tolerant taxa (Renner et al., 2022).

The low diversity values indicate that environmental conditions may not be suitable for supporting a wide range of species. Habitat disturbance, vegetation structure, and water quality conditions likely influence these patterns. Observed anthropogenic activities, such as human movement and land-use pressures, may contribute to reduced diversity. These stressors limit the persistence of sensitive species, resulting in simplified assemblages.

Species Evenness

Species evenness values varied across the sampling sites, with San Mateo Old (0.466), Dankias (0.372), and Lingayao (0.328). These values indicate that individuals are not equally distributed among species in any of the areas. Lower evenness suggests that certain species dominate while fewer individuals represent others. This uneven distribution reflects differences in habitat conditions and ecological dynamics.

The relatively low evenness values suggest that a few dominant species account for a large proportion

of individuals. Such patterns are often associated with environmental conditions that favor generalist or tolerant species. In aquatic ecosystems, habitat quality and vegetation structure influence species distribution. Balanced conditions support more even assemblages, while disturbances lead to dominance by a few taxa (Gutiérrez-Fonseca et al., 2020).

In Dankias and Lingayao, lower evenness values indicate stronger dominance patterns within the assemblages. Environmental filtering and ecological interactions, such as competition, may influence species distribution. Generalist species like *Diplacodes trivialis* and *Orthetrum sabina* are more likely to dominate under variable conditions. This results in less balanced communities where only a few taxa reach high abundance (Renner et al., 2022).

Margalef's Index for Species Richness

Margalef's richness index values indicate low species richness across all sampling areas, with Lingayao (1.261), San Mateo Old (1.036), and Dankias (0.811). All values fall below the threshold of $R < 2.0$, confirming limited species diversity in the study sites. This suggests that the ecological conditions do not support a wide range of dragonfly species. Dankias, having the lowest value, reflects the most reduced species richness among the sites.

Low species richness may be associated with limited habitat heterogeneity and environmental disturbance. Anthropogenic activities such as vegetation clearing, chemical application, and construction can reduce habitat quality. These factors affect breeding sites, microhabitats, and resource availability for dragonflies. Habitat structure and vegetation cover are key determinants of species richness in aquatic ecosystems (Beaujour et al., 2024; Barbosa et al., 2025).

The consistently low richness values suggest broader landscape-level constraints affecting the study areas. Changes in land use and riparian conditions can limit colonization and persistence of sensitive species. Environmental stressors may reduce the regional species pool available for these habitats. As a result, assemblages become simplified and dominated by fewer, more adaptable taxa (Mooduto & Syahribulan, 2025; Renner et al., 2022).

Simpson's Dominance

Simpson's dominance values indicate moderate dominance across all sampling sites, with San Mateo Old ($D = 0.531$), Lingayao ($D = 0.537$), and Dankias ($D = 0.717$) showing the highest dominance. These values suggest that while multiple species are present, a few taxa contribute more significantly to overall abundance. The higher value in Dankias indicates stronger dominance compared to the other sites. This pattern reflects an uneven distribution of species within the assemblages.

Moderate dominance is often associated with environmental filtering that favors tolerant species. Water quality parameters such as pH, dissolved oxygen, and nutrient levels influence species survival and distribution. Under moderately stressed conditions, adaptable species are more likely to persist and become dominant. This results in assemblages where several species coexist but are unevenly represented (Gutiérrez-Fonseca et al., 2020; Renner et al., 2022).

Habitat structure and ecological interactions also influence dominance patterns. Reduced habitat complexity may increase predation pressure and limit resources for less competitive species. In such conditions, resilient taxa become more abundant while others decline. These dynamics contribute to the moderate dominance observed across the study sites (Beaujour et al., 2024; Barbosa et al., 2025).

Table 7. *Conservation Classification Status of the Identified Dragonflies*

Species Account	IUCN STATUS
Acisoma panorpoides	Least Concern (LC)
Diplacodes trivialis	Least Concern (LC)
Neurothemis terminata	Least Concern (LC)
Neurothems ramburii	Least Concern (LC)
Orthetrum sabina	Least Concern (LC)
Pantala flavescens	Least Concern (LC)
Potamarcha congener	Least Concern (LC)
Trithemis aurora	Least Concern (LC)

The conservation status of all Odonata species recorded across the sampling sites was determined using the globally recognized framework of the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, as presented in Table 7.

A total of eight dragonfly species were identified during the study. The conservation classifications for each species are presented in detail in Table 7. The results show that all eight species recorded—*Diplacodes trivialis*, *Orthetrum sabina*, *Neurothemis ramburii*, *Neurothemis terminata*, *Pantala flavescens*, *Potamarcha congener*, *Acisoma panorpoides*, and *Trithemis aurora* are uniformly categorized as Least Concern (LC). This classification indicates that, according to current global assessments, these species do not face an immediate threat of extinction.

The fact that all recorded species are classified as Least Concern (LC) is an important finding, as it indicates the presence of dragonflies that are generally widespread and tolerant of varying habitat conditions. De Oliveira-Junior et al. (2020) explained that species such as *Diplacodes trivialis* and *Orthetrum sabina* commonly occur in environments that remain suitable even with moderate levels of disturbance. This tolerance stems from their generalist life histories and high dispersal capacity, traits common among species that successfully colonize human-modified landscapes (Samways & Simaika, 2016). The presence of *Pantala flavescens*, a highly adaptable and mobile species, also reflects basic habitat conditions that support generalist dragonflies, consistent with the observations of Samways et al. (2016).

These species are often successful colonizers of ephemeral or disturbed waters, confirming that the study sites retain basic survival conditions but not necessarily the structural complexity required by more specialist Odonata (Carchini et al., 2018). Termaat et al. (2019) highlight that freshwater areas dominated by Least Concern species often remain ecologically stable but still require regular assessment. This necessity arises because the global LC status does not account for the vulnerability revealed by local diversity metrics, such as the less balanced and moderate dominance observed in sampling areas, which signal localized environmental filtering (Twardochleb & Kefford, 2019). As noted by Deacon et al. (2023), shifts in vegetation, water quality, or land use can eventually influence species composition. In tropical systems, this degradation can be rapid, leading to the loss of sensitive species before changes are reflected in regional conservation status (Dudgeon et al., 2020). Continuous monitoring is therefore essential to detect early signs of environmental change and to support long-term riverbank management.

Problem 5. What are the conservation status of the identified dragonflies?

Assessing the conservation status of identified species is essential for evaluating the ecological integrity of riverbanks. It provides baseline information on species vulnerability and habitat conditions. The IUCN Standards and Petitions Committee (2022) emphasized that conservation assessments are critical for

guiding biodiversity management. This approach supports informed decision-making in conservation planning.

Dragonflies (Order Odonata) are recognized as reliable bioindicators due to their sensitivity to environmental changes. Their distribution and abundance respond to variations in water quality, habitat condition, and disturbance. These characteristics make them effective tools for monitoring freshwater ecosystems. Their ecological responses provide insights into habitat integrity and environmental change (Simaika & Samways, 2016).

Problem 6. What is the condition and integrity of the riverbank?

The Dragonfly Biotic Index (DBI) was used to assess the ecological condition of the three study areas by scoring the species present and computing their final DBI values. This index provides a quick indication of whether the riverbanks are disturbed, recovering, or in better ecological health based on the sensitivity or tolerance of dragonfly species found.

Table 8. *Dragonfly Biotic Index (DBI) Results for the Three Study Areas*

Study Area	Species Present (Count)	Sum of Species Scores	Final Site	Interpretation
San Mateo Old	6	6	1.00	Highly Disturbed
Dankias	5	5	1.00	Highly Disturbed
Lingayao	8	10	1.25	Disturbed but Recovering

The computed DBI values show that both Dankias and San Mateo Old (DBI = 1.00) fall under the category "Highly Disturbed," indicating low ecological quality. In contrast, Lingayao (DBI = 1.25) shows a slightly higher score, classifying it as "Disturbed but Recovering," which means that while the area has experienced disturbance or degradation, there are observable signs of natural regeneration or ecological improvement. In other words, the ecosystem is beginning to regain stability, and conditions are gradually becoming more favorable for biodiversity and habitat recovery. Overall, the results indicate that all three areas are disturbed, with Lingayao showing early signs of ecological improvement.

The Dragonfly Biotic Index (DBI) results reveal notable differences in ecological condition among the three study areas. Both Dankias and San Mateo Old recorded DBI scores of 1.00, placing them in the "Highly Disturbed" category. San Mateo Old is characterized by extensive rice fields, grasses, and vegetation, with frequent motor traffic contributing to habitat disturbance. Dankias exhibits sparse vegetation along a dike adjacent to the road, with cultivated plants present. Lingayo displays abundant vegetation and grass cover, despite being near a bridge under construction. Such low scores suggest that communities are dominated by disturbance-tolerant, generalist species and are characterized by a scarcity or absence of sensitive taxa—a pattern commonly observed in degraded freshwater systems (Gunawan et al., 2024). Vorster et al. (2020) similarly indicate that DBI values near 1.00 reflect strong anthropogenic stressors, including pollution, habitat loss, and diminished riparian cover.

The dominance of tolerant species such as *Diplacodes trivialis*, *Orthetrum sabina*, and *Pantala flavescens* further underscores the ecological degradation in these areas. Šigutová et al. (2022) emphasized that Odonata species vary widely in their sensitivity to pollution and habitat alteration, making them reliable bioindicators of ecosystem quality (OUP Academic, 2022). Similarly, in a study of a polluted tropical river in

Malaysia, Che Salmah Md Rawi et al. (2017) found that tolerant dragonfly taxa dominated disturbed sites, mirroring the situation in Dankias and San Mateo Old.

In contrast, Lingayao, with a DBI of 1.25, falls into the "Disturbed but Recovering" category, suggesting early signs of ecological recovery. This assessment is supported not only by the numerical DBI difference but also by the species composition: moderately adaptable species such as *Acisoma panorpoides* and *Trithemis aurora* appear alongside highly tolerant species, indicating improved habitat conditions, including vegetation recovery and better water quality.

This pattern aligns with other regional studies. In the Lahat District rivers of Indonesia, researchers demonstrated that less disturbed river stretches supported a greater diversity of both tolerant and sensitive Odonata species, confirming that recovery stages are reflected in species assemblages (Suparman et al., 2023). Moreover, dragonflies serve as amphibiotic bioindicators, reflecting the health of both aquatic and terrestrial ecosystems. A recent Brazilian study demonstrated strong correlations between DBI and the degradation of both riparian soils and stream habitats (Bega et al., 2024), suggesting that improvements in Lingayao's DBI may signal broader ecosystem recovery beyond water quality alone.

Overall, the prevalence of disturbance-tolerant species in Dankias and San Mateo Old, together with the moderate presence of recovering taxa in Lingayao, supports the DBI-based classification of these areas. The additional literature confirms that these patterns are ecologically meaningful and consistent with global trends in freshwater biodiversity responses to disturbance.

Conclusions and Recommendations

Conclusions

Based on the data gathered in this study, the following conclusions are given:

1. The study identified Diplacodes trivialis as the most common dragonfly species across the three study areas, demonstrating its high adaptability and dominance in varying environmental conditions.
2. The physicochemical parameters of the tributaries, including pH, Total Dissolved Solids (TDS), temperature, Oxidation-Reduction Potential (ORP), and specific gravity, varied significantly among the sites, indicating differences in local water quality conditions.
3. Soil physicochemical characteristics, such as texture, pH, and nutrient content (N, P, K), also differed across the study areas, suggesting variability in habitat quality that may influence dragonfly distribution.
4. The level of dragonfly diversity across the three areas was generally low, with only eight species recorded. Barangay Lingayao exhibited very low diversity, while Barangay Dankias showed the lowest diversity and moderate dominance, indicating an uneven distribution of species and ecological stress in the area.
5. Most of the identified dragonfly species are classified as Least Concern (LC), indicating they are not currently threatened but still require ongoing monitoring to maintain population stability.
6. Based on the Dragonfly Biotic Index (DBI), Barangay Lingayao is classified as "Disturbed but Recovering," while Barangay Dankias and Barangay San Mateo (Old) are classified as "Highly Disturbed," reflecting varying levels of ecological degradation across the riverbank ecosystems.

Recommendations

Based on the study's results and conclusions, the following recommendations are forwarded.

Conservation organizations (DENR–Caraga, BFAR, and environmental NGOs). They may strengthen riverbank conservation by restoring riparian vegetation using native plant species and implementing habitat rehabilitation programs. Regular monitoring of dragonfly diversity is recommended to track ecological changes and guide evidence-based conservation efforts.

Local Government Units (LGUs) in Barangay San Mateo, Barangay Dankias, and Barangay Lingayao. They are advised to use the findings as a scientific basis for environmental planning and policy development. The LGUs should regulate waste disposal, manage land-use activities near riverbanks, and implement native vegetation planting to improve riverbank stability and ecosystem health. Establishing barangay-level guidelines for riverbank protection is also encouraged.

Ecologists in academic and environmental institutions. They may continue conducting dragonfly assemblage studies across seasons and additional areas to verify biodiversity patterns and detect long-term ecological shifts. These efforts help identify priority areas for conservation and support the development of more effective freshwater ecosystem management strategies.

Entomologists and insect researchers, particularly those specializing in Odonata. They are encouraged to use the species records and baseline data from this study to enhance research on dragonfly taxonomy, biodiversity documentation, and insect-based ecological assessment. Entomologists from Caraga State University (CSU), along with other institutions in the region, may further expand species surveys across nearby municipalities to strengthen the Odonata inventory of the Caraga Region.

Environmental scientists, including water-quality specialists and habitat analysts. They may utilize the findings as baseline information for assessing environmental integrity in Butuan City and Las Nieves. Further research on water and soil parameters, pollution sources, and vegetation structure is recommended to understand better the environmental factors influencing dragonfly diversity.

Future researchers in ecology, biodiversity, and environmental science. They are encouraged to build on this study by expanding spatial coverage, incorporating long-term ecological monitoring, and examining additional environmental variables. Community participation, such as citizen reporting, riverbank clean-ups, and native planting activities, may also be included to enhance conservation outcomes and promote sustainable riverbank management.

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