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Freshwater Ecosystem Assessment of Shasha Forest Reserve Streams Through the Lens of Odonata Assemblage Patterns and Abundance

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Abstract

Background

Odonata nymphs are recognized bioindicators of freshwater ecosystem health, yet their diversity and ecological relationships with physico-chemical parameters remain poorly documented in Nigerian tropical forest reserves.

Methods

This study assessed the water quality, distribution, and abundance of Odonata nymphs across six sampling stations (SFR A–F) in the Shasha Forest Reserve, Osun State, Nigeria, over a 24-month bimonthly sampling period. Water quality parameters including temperature, pH, dissolved oxygen, biochemical oxygen demand (BOD_5), total dissolved solids, conductivity, alkalinity, acidity, and depth were measured using instrumental and titrimetric methods. Odonata nymphs were collected using a 500 µm mesh dipnet along 5 m reaches and identified to species level using established keys.

Results

A total of 306 individuals representing 25 species, 14 genera, and 4 families were recorded. Libellulidae was the dominant family (212 individuals; 69.28%), while Gomphidae was the least abundant (20 individuals; 6.5%). Station C recorded the highest species richness (25 species; 87 individuals) and Shannon-Wiener diversity index (H = 3.28). Station E recorded the highest BOD_5 values (3.20–8.40 mg/L), indicative of organic enrichment from anthropogenic pressures. Correlation analyses revealed significant relationships between pH, temperature, turbidity, and family-level Odonata abundance.

Conclusions

The low overall abundance suggests progressive habitat degradation within the reserve driven by agricultural encroachment and human disturbance.

Background

Odonata is one of the most studied aquatic insects which predominantly inhabit freshwater environments, though some species have also been recorded in brackish water habitats (Watanabe et al., 2007). It is also used as a bioindicator because both the adult and the nymph are sensitive and responsive to environmental conditions (Balzan, 2012). The order also demonstrates changes to environmental disturbances, especially those from the effects of land degradation such as erosion as well as deforestation. They have been remarkably used as tools for assessing habitat connectivity (Clausnitzer, 2003; Dijkstra and Lempert, 2003). They offer several ecological advantages used to monitor their environments.

The two major suborders (Dragonflies and damselflies) are being studied and evaluated as potential modelling frameworks (Bried and Samways, 2015). Kadoya et al (2004) reported that some of their species have variation in the distribution, with some geographically restricted while some are widespread. Similarly, certain families are confined to cool flowing waters such as streams and rivers, others are associated with lentic water bodies like ponds, and still others are characteristic of marshy areas and wetland environments (Bybee et al., 2008). It is noteworthy that the occurrence of odonata diversity has been regarded as an indicator of healthy and well-functioning ecosystems (Dutra and De Marco, 2015). Adu et al (2015), reported that species richness is dominant in a site with varied microhabitat conditions, though dragonflies generally show greater sensitivity to pollutants than damselflies.

In Nigeria, using aquatic insects as bioindicators to assess the health of water bodies is uncommon, unlike physico-chemical monitoring, which is more widely adopted (Arimoro and Ikomi, 2008). Nevertheless, assessing the ecological condition of lotic water systems using physico-chemical parameters along with aquatic insects as a monitoring tool has been demonstrated to be a highly effective approach for evaluating water quality (Arimoro and Muller, 2010; Efe *et al*,. 2012).

Researchers within and outside the country have consistently agreed that aquatic insect communities accurately reflect the prevailing ecological conditions of the water bodies they occupy (Buss et al., 2004; Arimoro and Ikomi, 2008; Payakka and Prommi, 2014; Prommi and Payakka, 2015). This information underscores the need for other researchers to extend their biomonitoring knowledge to additional waterbodies in Nigeria.

Shasha Forest Reserve (SFR) is situated in Osun State, a tropical rainforest which is abundantly rich with different species of flora and fauna. It is located within the Nigero-Cameroonian-Gabon zone, a tropical forest region known for its diverse Odonata fauna (Dijkstra and Clausnitzer, 2006), the reserve presents conditions conducive to the occurrence of diverse aquatic insect communities, including Odonata nymphs. Although several studies have been conducted within the Shasha Forest Reserve, knowledge of water quality dynamics and Odonata nymph diversity in this area remains sparse. The present study therefore seeks to address this gap and contribute significantly to understanding the Odonata fauna of tropical forest ecosystems in relation to the freshwater habitats of the Shasha Forest Reserve, Nigeria.

Methods

Ehikhamele and Ogbogu (2026) identified six sampling stations (SFR A through F) within the forest reserve, selecting them based on vegetation structure and the proximity of water bodies. These locations were determined by the behavioural nature of the odonata, responsiveness to human-induced activities as well as their variability to climatic conditions such as the type of waterbodies, temperature, and degree of shadiness.

The nymph sampling was conducted according to Ehikhamele and Ogbogu (2017). Water samples were collected bimonthly from all six stations over the 24-month study period for physicochemical analysis. Instrumental methods were applied to measure air and water temperature, depth, pH, TDS, and conductivity, while acidity, alkalinity, dissolved oxygen (DO), and biochemical oxygen demand (BOD_5) were determined through titrimetric procedures. Pearson Correlation Coefficient was employed to assess relationships among physicochemical parameters, Analysis of Variance (ANOVA) to evaluate how water quality variables interacted with Odonata nymph abundance, and Shannon-Wiener, Simpson, and Evenness diversity indices were used to calculate the abundance, diversity, and spatial distribution of the nymphs.

Figure 1: **Map of Shasha Forest Reserve Showing the Study Sites in Ife South Local Government Area, Osun State, Nigeria (**Ehikhamele and Ogbogu (2026**).**

Results

The physico-chemical parameters of the six sampling stations are shown in Table 1. Mean air temperature was uniform across all six sampling stations ($P > 0.05$). Water temperature followed a similar pattern, with no significant variation among stations A, C, D, and F ($P > 0.05$); however, stations B and E deviated significantly from the remaining stations ($P < 0.05$). Dissolved oxygen (DO) levels were comparable among stations A, C, and F ($P > 0.05$), whereas stations D and E differed significantly from each other ($P < 0.05$), though neither differed significantly from station B. Total dissolved solids (TDS) were homogenous among stations B, D, and E ($P > 0.05$), while stations A, C, and F showed significant inter-station variation ($P < 0.05$). Biochemical oxygen demand (BOD_5) was comparable across stations A, B, C, D, and F ($P > 0.05$); station E, however, recorded a mean value that was significantly elevated relative to all other stations ($P < 0.05$). The BOD_5 amongst Stations A, B, C, D and F. However, the mean value of station E was significantly different ($P < 0.05$) from all the Stations.

Table 1
Analysis of variance (ANOVA) showing the relationship among the physico-chemical parameters in Stations A-F at Shasha Forest reserve

Parameter	Station A		Station B		Station C		Station D		Station E		Station F	
	Min - Max	Mean ± S.D	Min – Max	Mean ± S.D	Min - Max	Mean ± S.D	Min - Max	Mean ± S.D	Min – Max	Mean ± S.D	Min - Max	Mean ± S.D
Air temp (°C)	24.00–29.00	27.13 ± 1.69^{a}	26.50–31.50	28.92 ± 1.35^{a}	26.00–31	28.75 ± 1.48^{a}	26.00-31.50	28.58 ± 1.74^{a}	25.00-29.50	27.58 ± 1.44^{a}	25.00-30.50	28.49 ± 1.68^{a}
Water temp (°C)	25.00-28.50	26.87 ± 1.09^{a,b}	27.00-31.50	28.54 ± 1.32^{b}	25.00-29.50	26.83 ± 1.37^{a,b}	25.00–30.00	27.33 ± 1.60^{a,b}	25.00-27.50	26.42 ± 0.79^{a}	24.50–30.00	27.46 ± 1.66^{a,b}
D.O (mg/L)	3.80–5.40	4.58 ± 0.57^{b,c}	2.40–5.20	3.78 ± 084^{a,b}	3.60–6.80	4.79 ± 0.92^{b,c}	4.20–6.80	5.39 ± 0.83^{c}	1.80–5.12	3.24 ± 1.24^{a}	3.80–6.80	4.99 ± 0.84^{b,c}
B.O.D$_5$(mg/L)	1.20–2.60	1.77 ± 0.40^{a}	0.80–1.42	1.03 ± 0.22^{a}	0.70–1.50	1.10 ± 0.27^{a}	0.90–2.20	1.37 ± 0.40^{a}	3.20–8.40	6.53 ± 1.52^{b}	1.00-2.60	1.76 ± 0.50^{a}
T.D.S(mg/L)	72.00-92.50	83.08 ± 6.53^{a}	98.00-126.00	114.17 ± 8.60^{b,c}	99.00-128.00	116.50 ± 8.99^{c}	88.00-125.00	106.42 ± 11.33^{b,c}	79.20–121.00	103.81 ± 15.35^{b,c}	74.00-115.00	99.17 ± 12.53^{b}
Acidity(mg/L)	4.00.-12.00	8.12 ± 2.48^{a,b}	5.00–14.00	9.00 ± 2.82^{a,b}	4.00–9.00	6.50 ± 1.45^{a}	9.00–19.00	13.50 ± 3.75^{c}	8.00–18.00	13.25 ± 2.96^{c}	8.00–16.00	11.58 ± 2.43^{b,c}
Alkalinity(mg/L)	28.00–54.00	40.83 ± 8.59^{a}	64.00–87.00	74.17 ± 8.21^{b}	62.00–85.00	72.83 ± 8.63^{b}	65.00–92.00	75.92 ± 9.31^{b}	46.00–87.00	66.17 ± 14.31^{b}	57.00–82.00	68.92 ± 8.26^{b}
Conduc. (µS/cm)	112.80–133.00	123.04 ± 7.58^{a,b}	114.20-142.70	127.80 ± 9.38^{b}	108.20-132.10	121.13 ± 8.51^{a,b}	98.00-126.00	113.25 ± 9.05^{a}	106.40-126.40	116.48 ± 6.00^{a}	110.50-130.40	121.14 ± 6.44^{a,b}
pH	6.70–7.90	7.18 ± 0.39^{a}	6.80–7.90	7.36 ± 0.33^{a}	6.70–7.80	7.24 ± 0.31^{a}	5.72–7.80	7.21 ± 0.56^{a}	6.80–7.80	7.40 ± 0.31^{a}	6.80–7.80	7.32 ± 0.35^{a}
Depth (m)	2.40–3.40	2.82 ± 0.32^{a}	1.30–2.90	2.02 ± 0.55^{b}	0.70–1.90	1.25 ± 0.36^{a}	1.50–3.50	2.26 ± 0.66^{b,c}	1.60–2.80	2.09 ± 0.45^{b}	0.70–3.50	2.48 ± 0.57^{b,c}

Mean subscript (X ± SD) of the same alphabet are not significantly different at 5% probability level, as determined with Duncan's protected least significant difference (LSD) test for means separation.

Table 1: **Analysis of variance (ANOVA) showing the relationship among the physico-chemical parameters in Stations A-F at Shasha Forest reserve**

Acidity was statistically similar between stations A and B, and between stations D and E ($P > 0.05$); however, stations C and F differed significantly from each other and from all other stations ($P < 0.05$). Alkalinity was largely uniform across stations B, C, D, E, and F ($P > 0.05$), with station A being the only outlier, differing significantly from all remaining stations ($P < 0.05$). Conductivity showed no significant variation among stations A, C, and F, nor between stations D and E ($P > 0.05$); station B was the exception, recording a value that diverged significantly from the rest ($P < 0.05$). pH remained consistently stable across all six stations, with no significant differences detected ($P > 0.05$). Stream depth showed no significant variation between stations A and B, between A and C, or between B and C ($P > 0.05$). Stations D and F similarly recorded comparable depth values ($P > 0.05$).

In station A, Acidity showed a positive correlation (0.815) with T.D.S., and pH is positively correlated with depth (0.716) (Table 2), while pH is negatively correlated with the distribution of Libellulidae (-0.652). T.D.S showed positive interaction with alkalinity (0.713), and T.D.S is positively correlated with depth (0.760) in sampling station B (Table 3). In sampling station C, D.O is positively correlated with B.O.D (0.893), TDS showed positive correlation with alkalinity (0.745), conductivity (0.775), pH (0.617), and depth (0.802). Alkalinity is positively correlated with conductivity (0.814), pH (0.633), and depth (0.815), while temperature is positively correlated with the abundance of libellulidae (0.670), and B.O.D is negatively correlated with the distribution of chlorocyphidae (-0.601) (Table 4). D.O showed positive correlation with B.O.D (0.629), and alkalinity showed positive correlation (0.769) with conductivity in sampling station D (Table 5).

Table 2
Correlation values (r) showing the interaction between water quality parameters as well as Odonata nymphs in Station A

Air_Temp	**Air_Temp**	**Water_Temp.**	**D.O**	**B.O.D**	**T.D.S**	**Acidity**	**Alkali**	**Condc.**	**Ph**	**Depth**	**Coenagrionidae**	**Chloro**
	0.000											
Water_Temp.	0.502	0.000										
D.O	-0.399	-0.555	0.000									
B.O.D	-0.295	0.156	-0.373	0.000								
T.D.S	-0.151	0.263	-0.210	0.017	0.000							
Acidity	-0.070	0.277	-0.227	0.006	0.815*	0.000						
Alkali	0.305	0.109	0.172	-0.276	-0.064	-0.075	0.000					
Condc.	0.446	0.255	-0.136	-0.220	0.019	-0.021	0.416	0.000				
Ph	-0.557	-0.038	-0.246	0.470	0.066	0.098	-0.792	-0.679*	0.000			
Depth	-0.585*	-0.098	0.012	0.097	0.455	0.548	-0.431	-0.734	0.716*	0.000		
Coenagrionidae	-0.093	-0.329	0.023	0.124	-0.450	-0.146	0.082	0.204	-0.025	-0.258	0.000	
Chlorocyphidae	0.256	0.036	0.119	-0.210	-0.052	-0.021	0.043	0.389	-0.311	-0.214	-0.232	0.000
Libellulidae	0.378	-0.048	0.523	-0.572	0.031	-0.197	0.399	0.325	-0.652*	-0.417	-0.256	0.315
Values asterisked are significant (P < 0.05)												

Table 3
Correlation values (r) showing the interaction between water quality parameters as well as odonata nymphs in station B

Air_Temp	**Air_Temp**	**Water_Temp.**	**D.O**	**B.O.D**	**T.D.S**	**Acidity**	**Alkali**	**Condc.**	**Ph**	**Depth**	**Coenag**	**Chlorocy**	**Lil**
	0.000												
Water_Temp.	-0.215	0.000											
D.O	0.214	-0.390	0.000										
B.O.D	-0.323	-0.436	0.426	0.000									
T.D.S	-0.674*	-0.097	-0.182	0.396	0.000								
Acidity	-0.334	0.583*	-0.293	0.050	0.034	0.000							
Alkali	-0.694*	0.091	-0.233	0.128	0.713*	0.102	0.000						
Condc.	-0.609*	0.535	-0.316	0.068	0.093	0.579*	0.470	0.000					
Ph	-0.257	0.068	-0.118	0.037	0.259	-0.197	0.638*	0.377	0.000				
Depth	-0.711*	0.103	-0.328	0.138	0.760*	0.509	0.672*	0.273	0.038	0.000			
Coenagrionidae	0.275	0.412	-0.295	-0.412	-0.018	-0.248	-0.062	-0.290	0.155	-0.265	0.000		
Chlorocyphidae	0.449	-0.493	0.089	0.017	-0.222	-0.296	-0.300	-0.356	-0.400	-0.247	-0.299	0.000	
Libellulidae	0.321	0.004	0.327	-0.065	-0.307	-0.455	0.019	-0.148	0.609*	-0.544	0.342	-0.204	0.(
Values asterisked are significant (P < 0.05)													

Table 4
Correlation values (r) showing the interaction between water quality parameters as well as odonata nymphs in station C

Air_Temp	Air_Temp	Water Temp.	D.O	B.O.D	T.D.S	Acidity	Alkali	Condc.	Ph	Depth	Coenagrio	Chlorocyp	Lib
	0.000												
Water_Temp.	0.916*	0.000											
D.O	0.110	0.265	0.000										
B.O.D	-0.069	0.162	0.893*	0.000									
T.D.S	-0.375	-0.369	-0.422	-0.167	0.000								
Acidity	-0.106	0.115	-0.314	-0.307	-0.063	0.000							
Alkali	-0.514	-0.629*	-0.263	-0.190	0.745*	-0.262	0.000						
Condc.	-0.497	-0.501	-0.212	-0.104	0.775*	-0.148	0.814*	0.000					
Ph	-0.005	-0.080	0.016	0.033	0.617*	-0.401	0.633*	0.788*	0.000				
Depth	-0.253	-0.292	-0.304	-0.179	0.802*	-0.121	0.815*	0.859*	0.864*	0.000			
Coenagrionidae	0.000	-0.049	-0.072	0.000	0.255	-0.373	0.297	0.121	0.066	0.074	0.000		
Chlorocyphidae	-0.083	-0.314	-0.391	-0.601*	-0.342	0.085	0.071	-0.068	-0.282	-0.203	-0.183	0.000	
Libellulidae	0.579*	0.670*	0.365	0.327	-0.048	0.014	-0.230	-0.315	0.015	-0.154	0.215	-0.393	0.0
Gomphidae_	-0.043	0.108	0.219	0.476	-0.028	-0.088	-0.210	-0.318	-0.214	-0.174	0.376	-0.515	0.4
Values asterisked are significant (P < 0.05)													

Table 5
Correlation values (r) showing the interaction between water quality parameters as well as Odonata nymphs in station D

Air Temp()	Air Temp(_)	Water Temp._(_)	D.O	B.O.D	T.D.S	Acidity	Alkali	Condc.	Ph	Depth_(M)	Coenagrionidae	Chloroc
	0.000											
Water Temp.()	0.951*	0.000										
D.O	-0.211	-0.307	0.000									
B.O.D	-0.180	-0.232	0.629*	0.000								
T.D.S	-0.656*	-0.523	-0.084	-0.230	0.000							
Acidity	-0.361	-0.416	0.238	-0.061	0.484	0.000						
Alkali	-0.456	-0.526	0.027	-0.055	0.367	0.556	0.000					
Condc.	-0.316	-0.342	0.021	0.038	0.242	0.355	0.769*	0.000				
Ph	-0.492	-0.459	0.181	0.145	0.418	0.452	0.447	0.544	0.000			
Depth_(M)	-0.858*	-0.791*	0.398	0.286	0.681	0.508	0.343	0.271	0.458	0.000		
Coenagrionidae	0.163	0.028	-0.310	-0.080	-0.577	-0.308	-0.169	-0.154	-0.186	-0.266	0.000	
Chlorocyphidae	0.271	0.295	0.187	-0.068	0.185	0.359	-0.123	0.037	0.243	-0.092	-0.504	0.000
Libellulidae	-0.161	-0.065	0.004	-0.053	0.569	0.260	-0.083	-0.123	0.494	0.194	-0.516	0.289
Values asterisked are significant (P < 0.05)												

In sampling station E, pH is negatively correlated with the abundance of Gomphidae (-.603) (Table 6).

Table 6
Correlation values (r) showing the interaction between water quality parameters as well as odonata nymph in station E

Air_Temp(°C)	Air Temp(°C)	Water Temp._(°C)	D.O	B.O.D	T.D.S	Acidity	Alkali	Condc.	Ph	Depth	Chlorocyphidae	Libel
	0.000											
Water_Temp._(°C)	0.007	0.000										
D.O	-0.260	-0.242	0.000									
B.O.D	0.512	0.116	0.213	0.000								
T.D.S	0.635*	-0.336	-0.097	0.474	0.000							
Acidity	-0.208	-0.029	0.448	-0.065	-0.656*	0.000						
Alkali	0.219	-0.423	0.017	-0.047	0.437	-0.381	0.000					
Condc.	-0.176	-0.577	-0.155	-0.380	0.215	-0.215	0.446	0.000				
Ph	-0.191	-0.695*	0.252	-0.281	0.015	0.039	0.655*	0.507	0.000			
Depth_(M)	-0.408	-0.078	-0.269	-0.542	-0.398	-0.012	0.421	0.383	0.492	0.000		
Chlorocyphidae	0.270	-0.196	0.523	0.280	0.257	0.276	0.193	-0.305	0.037	-0.471	0.000	
Libellulidae	0.493	-0.005	-0.095	0.253	0.633	-0.649*	0.515	0.055	-0.045	-0.125	-0.081	0.000
Gomphidae_	-0.018	0.033	-0.212	0.138	0.254	-0.133	-0.224	0.085	-0.603*	-0.272	0.135	0.014
Values asterisked are significant (P < 0.05)												

Table 2: **Correlation values (r) showing the interaction between water quality parameters as well as Odonata nymphs in Station A**

Table 3: **Correlation values (r) showing the interaction between water quality parameters as well as odonata nymphs in station**

Table 4: **Correlation values (r) showing the interaction between water quality parameters as well as odonata nymphs in station C**

Table 5: **Correlation values (r) showing the interaction between water quality parameters as well as Odonata nymphs in station D**

Table 6: **Correlation values (r) showing the interaction between water quality parameters as well as odonata nymph in station**

A total of 306 individuals belonging to 25 species, 14 genera, and 4 families of Odonata were collected across the Shasha Forest Reserve (Table 7). The families represented were Chlorocyphidae, Coenagrionidae, Gomphidae, and Libellulidae. Libellulidae was the dominant family, contributing 212 individuals (69.28%) across 14 species, while Gomphidae was the least abundant, with just 20 individuals (6.5%) across 3 species (Fig. 2). Station-level composition varied considerably. Station A yielded 19 individuals from 10 species across 3 families, with Libellulidae accounting for 11 individuals (55%) and Chlorocyphidae the fewest, with only 1 individual (5%). Station B recorded 51 individuals from 19 species across all 4 families; Libellulidae again dominated with 33 individuals (64.7%), while Chlorocyphidae had the lowest representation with 4 individuals (7.84%) (Table 7).

Table 7
Composition, Distribution, and Abundance of Odonate nymphs collected at Shasha Forest Reserve

Order	Suborder	Families	Species	Stations							
Odonata				**A**	**B**	**C**	**D**	**E**	**F**	**Total**	**%**
	Zygoptera	**Chlorocyphidae**	*Chlorocypha glauca (Selys, 1879)*	0	0	3	2	3	2	10	
			Chlorocypha radix (Longfield, 1951)	0	0	2	1	2	0	05	
			Chlorocypha sp	1	2	2	3	2	2	12	
			Chlorocypha cancellata (Selys, 1879)	0	0	2	3	0	0	05	
			Chlorocypha sp	0	2	3	0	1	1	07	
				1	**4**	**12**	**9**	**8**	**5**	**039**	**12.7%**
		Coenagrionidae	*Africallagma sp*	2	1	5	2	0	2	12	
			Pseudagrion sp	3	3	4	0	0	2	12	
			Ceriagrion glabrum (Burmeister, 1839)	2	3	2	3	0	1	11	
				7	**7**	**11**	**5**	**0**	**5**	**035**	**11.4%**
	Anisoptera	**Libellulidae**	*Acisoma sp (Selys, 1892)*	2	3	4	3	2	2	16	
			Brachythemis leucostita (Burmeister, 1839)	2	3	6	2	1	2	16	
			Crocotheymis erythrea (Brulle, 1832)	0	3	3	1	0	2	07	
			Orthetrum abbotti (Calvert, 1892)	0	3	5	2	2	2	14	
			Orthetrum sp	0	0	4	2	0	5	11	
			Orthetrum sp	0	0	3	1	1	4	09	
			Orthetrum icteromelas (Ris, 1910)	0	2	4	1	0	0	07	
			Orthetrum julia (Kirby, 1900)	2	2	2	3	8	12	29	
			Orthetrum stemmale (Burmeister, 1839)	1	3	5	3	8	1	21	
			Paplopleura lucia (Drury, 1773)	0	2	7	2	7	2	20	
			Trithemis sp	2	3	2	1	12	3	23	
			Trithemis imitata (Pinhey, 1961)	2	4	5	1	3	4	19	
			Urothemis sp	0	3	2	1	3	2	11	
			Urothemis edwarsii (Selys, 1849)	0	2	3	2	0	2	09	
				11	**33**	**55**	**25**	**47**	**41**	**212**	**69.28%**
		Gomphidae	*Lestinogomphus sp*	0	3	4	2	0	0	09	
			Ictonogomphus sp	0	0	3	0	0	0	03	
			Actinogomphus sp	0	4	2	0	1	1	08	
				0	**7**	**9**	**2**	**1**	**1**	**020**	**6.5%**

Station C recorded the highest overall species richness with 87 individuals from 25 species across all 4 families; Libellulidae contributed the majority with 55 individuals (63.2%), and Gomphidae the least with 9 (10.3%). At station D, 41 individuals from 21 species across 4 families were collected, with Libellulidae again dominant at 25 individuals (65.79%) and Gomphidae least represented with 2 individuals (5.26%) (Table 7).

Station E yielded 56 individuals from 15 species across 3 families, with Libellulidae comprising 47 individuals (83.93%) — the highest proportional dominance recorded across all stations — and Gomphidae contributing just 1 individual (1.79%) (Table 7).

Station F recorded 54 individuals from 20 species across 4 families. Libellulidae remained dominant with 43 individuals (79.63%), while Gomphidae was again the least abundant with a single individual (1.85%) (Table 7).

Table 7: **Composition, Distribution, and Abundance of Odonate nymphs collected at Shasha Forest Reserve**

Figure 2: **Percentage composition of the Families at Shasha Forest Reserve Stream**

Richness and Diversity of Shasha Forest Reserve streams

Diversity of Shasha Forest reserve is presented in Table 8. Station D recorded the highest value of Simpson (1-D = 0.9683) while the lowest value was recorded in station E (1-D = 0.8987). Station A recorded the lowest value of Shanon (H = 2.497) while station B had the highest value (H = 3.28).

Table 8
Diversity of odonote nymphs at Shasha Forest Reserves

Taxa_S	Station A	Station B	Station C	Station D	Station E	Station F
	10	**19**	**25**	**21**	**15**	**20**
Individuals	19	51	87	41	56	54
Simpson_1-D	0.9415	0.9624	0.9647	0.9683	0.8987	0.9287
Shannon_H	2.497	3.082	3.28	3.205	2.505	2.915

Table 8: **Diversity of odonote nymphs at Shasha Forest Reserves**

Discussion

The low abundance and distribution of Odonata larvae species collected at the study sites have demonstrated that Shasha Forest Reserve is losing its status as a climax tropical rain forest due to deteriorating stream conditions, significantly impacted by anthropogenic activities and habitat fragmentation. Due to the degree of the streams' impairment and the fact that the majority of Odonata species are species that are tolerant of pollution and habitat destruction, the abundance of Odonata was low (Schmidt-Kloiber and Hering, 2015). The abundance and distribution of Odonata in lotic ecosystems are largely governed by their sensitivity to pollution and habitat disturbance (Vinson and Hawkins, 1998; Che Salmah et al., 2005; Subramaniam and Sivaramakrishnan, 2005; Milesi et al., 2009), particularly alterations in pH, dissolved oxygen, water temperature, and turbidity (Connolly et al., 2004; Smith and Lamp, 2008; Walters et al., 2009). Consistent with this, several study sites in the present investigation were found to be unfavourable for nymph development, owing to deteriorating water conditions, habitat homogenization (including a deficit of suitable aquatic vegetation), and marked fluctuations in water level and discharge (Dasilva-Montero et al., 2013; Vilenica et al., 2020; Pereira-Moura et al., 2021).

All the parameters observed in this study have been previously used for the assessment of water quality in Nigeria (Adefemi *et al*,. 2007; Adu et al., 2016; Auta et al., 2016). The physico-chemical characteristics of the stream at all six study sites were observed and they are not significantly different from each other except BOD_5 in station E. Biochemical oxygen demand (BOD5) reflects the amount of oxygen consumed by bacteria and protozoa during the oxidation of organic compounds in water (Revelle and Revelle, 1988), and is known to be influenced by temperature, nutrient concentration, and organic load (Haque et al., 2019). All stations except E recorded BOD_5 values within WHO permissible limits; station E yielded values ranging from 3.20 to 8.40 mg/L. While BOD_5 levels below 6 mg/L suggest moderate organic enrichment that still permits aquatic life (Oluyemi et al., 2010), higher values are indicative of elevated organic pollution likely to impair sensitive taxa such as Odonata nymphs.

Odonata larvae are sensitive to changes in their environment because they depend on the characteristics of their aquatic environment. As a result, they are commonly utilized as bioindicators of the integrity and health of the ecosystem. Environmental quality plays a significant role in constructing the aquatic communities of insects, especially Odonata, in aquatic habitats (Souza et al., 2015). Yet, many aquatic insects, such as Odonata, adapt physiologically and morphologically to deal with the decline in habitat quality (Al-Shami et al., 2014b).

The distribution and abundance of Libellulidae in stations A and B were inversely correlated with pH. There is strong evidence that the species/taxa richness of Odonata in acidification-sensitive waters is inversely associated with pH (Harvey and McArdle 1986, Schell and Kerekes 1989, Carbone et al., 1998). Nonetheless, decreasing pH has less impact on dragonflies (Schell and Kerekes, 1989; Pollard and Berrill, 1992; Buczyski, 2001). This was attributed to both having a high tolerance for challenging environmental circumstances and altered predator-prey dynamics as a result of the lack of predatory fish in acidic waters (Bendell and McNicol 1987, Johansson and Brodin 2003, Schilling et al., 2009).

The relationship between freshwater acidification and aquatic biota has been extensively documented, driven in part by the growing prevalence of acid precipitation (Hargreaves et al., 1975; Stokes, 1986; Gerhardt, 1993; Carbone et al., 1987; Schilling et al., 2009). It is well established that dragonflies exhibit considerable tolerance to low pH (Bell, 1971; Gorham and Vodopich, 1989), potentially benefiting from reduced predation pressure by fish in highly acidic environments (pH 4.0). At station C, air and water temperatures correlated positively with Libellulidae abundance, while BOD_5 showed a significant negative correlation with Chlorocyphidae distribution. Additionally, TDS was positively associated with Libellulidae abundance, whereas acidity exerted a negative influence on their distribution.

In station E, pH and Gomphidae abundance had a negative relationship. The functioning and alteration of communities as a result of the acidification of natural water bodies, as reported by Berezina (2001), demonstrated a connection between water pH and zoobenthos structural traits. The species composition is decreased and macroinvertebrate abundance and biomass decline when pH falls from 8 to 4.

For instance, Station B stream was close to the village where all kinds of human disturbances like washing clothes, bathing, and even cleansing were taking place as a result of their traditional belief that the source of the stream is unknown to them and that no one should dare touch the fish in the stream. According to Souza et al. (2015), changes in the habitat structure typically have an impact on the diversity and distribution of Odonata nymph. Their ability to be used as markers for environmental pollution in aquatic ecosystems is thus increased (Berquier et al., 2016).

The majority of the streams are also used by farmers for cultivation activities. The distribution of the species that have been collected may suffer as a result of these operations. This assertion is in accordance with Mason's (1981) research, which found that the use of chemicals (pesticides and fertilizers) on

agricultural land may have an impact on the water quality of nearby water bodies. Following the use of herbicides, plant decomposition and death alter the composition and oxygen levels in the water, resulting in the loss of habitats, breeding grounds, and food sources (Al-Shami et al., 2010).

One of the possible explanations for station C stream having more species than other streams is that it is surrounded by a variety of half-shaded plants, which could serve as a factor for higher diversity and distribution of Odonata. This aligns with Hornung and Rice (2003) and Wazhizatul-Afzan et al. (2006) that such microhabitats are found with varieties of flora. Moreover, Dijkstra and Lempert (2003) observed that choosing a forest environment for odonates appears to be largely influenced by the amount of shade. Furthermore, the majority of the Odonata larvae assemblage collected at these stations were generalists like Orthetrum species and Paplopleura species, which are relatively tolerant of the environmental conditions in their habitats. Research showed that Odonata species that can tolerate disturbed water are successful in the water body (Schmidt-Kloiber and Hering 2015; Doln *et al*. 2012; Dijkstra and Lewington 2006). The fact that the water quality parameters were below the species' tolerance levels for those parameters for the study's species could also account for this observation.

Different diversity indices were used to measure diversity and species richness in the waterbodies in order to address the problems or limitations of a single index (Purvis and Hector, 2000). The statistical study using the diversity indices clearly demonstrated that station C had a higher Shannon-Wiener index (3.28), indicating greater diversity and abundance of species collected. This corroborates Adepoju and Amusan (2026) that such a situation could be attributed to the ecological status of a balanced stream.

Conclusions

The study site is expected to be rich in species abundance, distribution, and composition due to its reserve nature, but unfortunately the study clearly demonstrated the environmental degradation due to human encroachment and the anthropogenic effect as a result of farming activities, logging, and cultural belief on the streams within the reserve. The predominant odonata nymphs collected were known to be resilient and tolerant of pollution and any form of contaminating medium, which further corroborated the compromised ecological condition of the study area.

Abbreviations

BOD_5
Biochemical Oxygen Demand (5-day)
DO
Dissolved Oxygen
TDS
Total Dissolved Solids
SFR
Shasha Forest Reserve
ANOVA
Analysis of Variance
WHO
World Health Organization
H
Shannon-Wiener diversity index
D
Simpson's diversity index.

Declarations

Ethics approval and consent to participate

The study complied with institutional and national guidelines for the collection and handling of aquatic invertebrates.

Consent for publication

Not applicable

Availability of data and materials

The data used for this study are available at the laboratory of the Department of Zoology at Obafemi Awolowo University, Ile Ife, Osun State.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

EI and SO developed the scope of the work. EI and BA collected the samples; AA helped in the identification of the samples, while SO helped review the manuscript. All authors read and approved the final manuscript.

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References

1. Adefemi OS, Asaolu SS, Olaofe O. Assessment of the physico-chemical status of water samples from major dams in Ekiti State, Nigeria. Pakistan J Nutr. 2007;6:657–9.
2. Adekunle VAJ, Olagoke AO, Akindele SO. Tree species diversity and structure of a Nigerian strict nature reserve. Trop Ecol. 2013;54:275–89.
3. Adepoju O, Amusan B. Assessment of macroinvertebrate communities and physico-chemical characteristics of a tropical stream. Res Square Preprint. 2026. https://doi.org/10.21203/rs.3.rs-8570101/v1.
4. Adu BW, Ogbogu SS, Akinwale AE. Composition and distribution of dragonfly nymphs (Odonata: Anisoptera) from lotic water ecosystems of Ile-Ife, Osun State, Nigeria. Int J Sci Res Environ Sci. 2015;3:180–8.
5. Adu BW, Ogbogu SS, Akinwale AE. Physico-chemical parameters and odonate nymph assemblage of streams in Ile-Ife, Osun State, Nigeria. J Biology Agric Healthc. 2016;6:64–77.
6. Akinyemi AF, Kayode JF, Olatunde SO. Mapping and assessment of land use land cover changes in Shasha Forest Reserve. Global J Environ Sci Manage. 2018;4:121–32.
7. Al-Shami SA, Che Salmah MR, Siti-Azizah MN, Hassan A, Abu-Hassan A. Temporal distribution of Chironomidae in polluted and unpolluted streams in Pinang River Basin, Malaysia. J Environ Sci. 2010;22:1409–17.
8. Al-Shami SA, Heino J, Che Salmah MR, Hassan AA, Suhaila AH, Madrus MR. Drivers of beta diversity of macroinvertebrate communities in tropical forest streams. Freshw Biol. 2014;58:1126–37.
9. Arimoro FO, Ikomi RB. Ecological integrity of upper Warri River, Niger Delta using aquatic insects as bioindicators. Ecol Ind. 2008;8:840–8.
10. Arimoro FO, Muller WJ. Mayfly community structure as an indicator of the ecological status of a stream in the Niger Delta area of Nigeria. Environ Monit Assess. 2010;166:581–94.
11. Auta YI, Bichi AH, Kela SL. Assessment of physico-chemical water quality of Jakara Dam, Kano, Nigeria. J Fish Aquat Sci. 2016;11:321–8.
12. Balzan MV. Associations of Odonata communities with riparian vegetation and land- use in a semi-arid Mediterranean region. Acta Oecol. 2012;39:77–86.
13. Bell HL. Effect of pH on the life cycle of the mayfly *Ephemerella funeralis*. Can Entomol. 1971;103:1022–30.
14. Bendell BE, McNicol DK. Fish predation, lake acidity and the composition of aquatic insect assemblages. Hydrobiologia. 1987;150:193–202.
15. Berezina NA. Tolerance of freshwater invertebrates to changes in water salinity. Russian J Ecol. 2001;32:337–44.
16. Berquier C, Andrei-Ruiz MC, Brustel H. Odonata as bioindicators of the ecological status of aquatic environments. Ecol Ind. 2016;62:81–7.
17. Bried JT, Samways MJ. A review of odonatology in freshwater applied ecology and conservation science. Freshw Sci. 2015;34:1023–31.
18. Buczynski P. Dragonflies (Odonata) of peatlands with various degrees of damage in eastern Poland. Pol J Environ Stud. 2001;10:9–14.
19. Buss DF, Baptista DF, Nessimian JL, Egler M. Substrate specificity, environmental degradation and disturbance structuring macroinvertebrate assemblages. Hydrobiologia. 2004;518:179–88.
20. Bybee SM, Ogden TH, Branham MA, Whiting MF. Molecules, morphology and fossils: A comprehensive approach to odonate phylogeny. Cladistics. 2008;24:477–514.
21. Carbone J, Wetzel RG, Brisbin IL. Odonata of acidic lakes. Oecologia. 1987;71:300–5.
22. Carbone J, Wetzel RG, Brisbin IL. Odonata populations in relation to lake acidification. Hydrobiologia. 1998;85:56–64.
23. Che Salmah MR, Al-Shami SA, Hassan A, Abu-Hassan A. Odonata as bioindicators of water quality in streams of Pinang. Malaysia Serangga. 2005;10:63–73.
24. Clausnitzer V. Dragonfly communities in coastal habitats of Kenya. Biodivers Conserv. 2003;12:333–56.
25. Connolly NM, Crossland MR, Pearson RG. Effect of low dissolved oxygen on tropical stream macroinvertebrates. J North Am Benthological Soc. 2004;23:251–70.
26. Dasilva-Montero A, Mendez-Camacho R, Palacino-Rodriguez F. Dragonfly assemblages along an altitudinal gradient in the Colombian Andes. Odonatologica. 2013;42:25–36.
27. de Moor IJ, Day JA, de Moor FC. Guides to the Freshwater Invertebrates of Southern Africa. Volume 7. Pretoria: Water Research Commission; 2003.
28. de Moor IJ, Day JA, de Moor FC. Guides to the Freshwater Invertebrates of Southern Africa. Volume 8. Pretoria: Water Research Commission; 2009.

29. Dijkstra K-DB, Clausnitzer V. Thoughts from Africa: How can forest influence the evolution of dragonfly diversity? In: Cordero-Rivera A, editor. Forest and Dragonflies. Sofia: Pensoft; 2006. pp. 127–50.
30. Dijkstra K-DB, Lempert J. Odonate assemblages and habitat quality in forests of West Africa. Odonatologica. 2003;32:277–314.
31. Dijkstra K-DB, Lewington R. Field Guide to the Dragonflies of Britain and Europe. Dorset: British Wildlife Publishing; 2006.
32. Dolnik OV, Meineke JU, Meineke T. New records of dragonflies (Odonata) from the East European Plain. Odonatologica. 2012;41:331–42.
33. Dutra S, De Marco P. Bionomics of the Odonata fauna in the Cerrado and its use as bioindicators. Ecol Ind. 2015;48:674–81.
34. Efe K, Kokoette A, Alex A. Evaluation of water quality for drinking in Nigeria. J Environ Sci Technol. 2012;5:110–20.
35. Ehikhamele IE, Ogbogu SS. Assessment of the concentrations of some heavy metals and their effects on the macroinvertebrate composition in Igun southwestern Nigeria, using reference site approach. J Entomol Zool Stud. 2017;5(1):452–8.
36. Ehikhamele IE, Ogbogu SS. Checklist of Odonata of Shasha Forest Reserve, Southern Ife, Osun State, Nigeria. Int J Biol Ecol Eng. 2026;20(2):38–42.
37. Gerhardt A. Review of impact of heavy metals on stream invertebrates. Water Air Soil Pollut. 1993;66:289–314.
38. Gorham JN, Vodopich DS. Effect of acidic pH on predation rates and survivorship of calopterygid damselfly larvae. Can J Zool. 1989;67:783–8.
39. Haque MA, Hossain MA, Hossain MS. Seasonal variation of physico- chemical parameters of Halda River water, Bangladesh. Int J Fisheries Aquat Stud. 2019;7:1–6.
40. Hargreaves JW, Lloyd EJH, Whitton BA. Chemistry and vegetation of highly acidic streams. Freshw Biol. 1975;5:563–76.
41. Harvey HH, McArdle JM. Composition of the benthos in relation to pH in the La Cloche Mountain lakes. Water Air Soil Pollut. 1986;30:529–36.
42. Hornung JP, Rice CL. Odonata and wetland quality in southern Alberta. Can Odonatologica. 2003;32:119–29.
43. Johansson F, Brodin T. Effects of fish predators and abiotic factors on dragonfly community composition. J Freshw Ecol. 2003;18:415–23.
44. Kadoya T, Suda S-I, Washitani I. Dragonfly species richness on moorland: Landscape and local environmental factors. Ecol Res. 2004;19:489–97.
45. Mason CF. Biology of Freshwater Pollution. Essex: Longman; 1981.
46. Milesi SV, Biasi C, Restello RM, Hepp LU. Distribution of benthic macroinvertebrates in subtropical streams. Brazilian J Biology. 2009;69:167–75.
47. Oludare H, Clement O. Assessment of land use land cover changes of Omo– Oluwa–Shasha Forest Reserve. Int J Environ Stud. 2014;71:629–39.
48. Oluyemi EA, Adekunle AS, Adenuga AA, Makinde WO. Physico-chemical properties and heavy metal content of water sources in Ife North Local Government Area, Nigeria. Afr J Environ Sci Technol. 2010;4:691–7.
49. Payakka A, Prommi T. Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. Sains Malaysiana. 2014;43:1337–44.
50. Pereira-Moura MVL, Salino A, Stehmann JR. Plant diversity along riparian zones in the Atlantic Forest. Acta Bot Brasilica. 2021;35:245–55.
51. Pollard JB, Berrill M. The distribution of dragonfly nymphs across a pH gradient in Ontario lakes. Can J Zool. 1992;70:878–85.
52. Prommi T, Payakka A. Aquatic insect communities as bioindicators of stream water quality in Thailand. Sains Malaysiana. 2015;44:707–17.
53. Purvis A, Hector A. Getting the measure of biodiversity. Nature. 2000;405:212–9.
54. Revelle C, Revelle P. The Environment: Issues and Choices for Society. 3rd ed. Boston: Jones and Bartlett; 1988.
55. Schell JM, Kerekes J. Distribution and abundance of dragonfly larvae in relation to pH in Nova Scotian lakes. Hydrobiologia. 1989;175:3–9.
56. Schilling EG, Loftin CS, Huryn AD. Macroinvertebrates as indicators of fish absence in naturally fishless lakes. Freshw Biol. 2009;54:181–202.
57. Schmidt-Kloiber A, Hering D. *www.freshwaterecology.info*—an online tool for European freshwater organisms. Ecol Ind. 2015;53:271–82.
58. Smith RF, Lamp WO. Comparison of insect communities between adjacent headwater and main-stem streams. J North Am Benthological Soc. 2008;27:161–75.
59. Souza FL, Cunha AF, Oliveira DHS, Moreira NF, Rossa-Feres DC. Odonata assemblages in stretches of Atlantic Forest streams. Environ Monit Assess. 2015;187:1–12.
60. Stokes PM. Ecological effects of acidification on primary producers in aquatic systems. Water Air Soil Pollut. 1986;30:421–38.
61. Subramaniam KA, Sivaramakrishnan KG. Aquatic insects of a montane stream: Diversity and functional feeding groups. Curr Sci. 2005;89:976–87.
62. Vilenica M, Vajdić I, Gligora-Udović M, Franjević D, Plantak L, Mihaljević Z. Lotic dragonfly community structure and its relationship with environmental variables. Int J Odonatol. 2020;23:77–92.
63. Vinson MR, Hawkins CP. Biodiversity of stream insects: Variation at local, basin and regional scales. Ann Rev Entomol. 1998;43:271–93.
64. Walters DM, Leigh DS, Freeman MC, Freeman BJ, Pringle CM. Geomorphology and fish assemblages in a Piedmont river basin, USA. Freshw Biol. 2009;48:1950–70.
65. Watanabe M, Sawada H, Ito Y. Brackish water Odonata of Japan and neighbouring areas. Int J Odonatol. 2007;10:73–87.
66. Wazhizatul-Afzan A, Juliana J, Norhayati A. Diversity and distribution of odonates in Ulu Muda Forest Reserve, Kedah, Malaysia. J Biosci Bioeng. 2006;17:33–42.

Figures

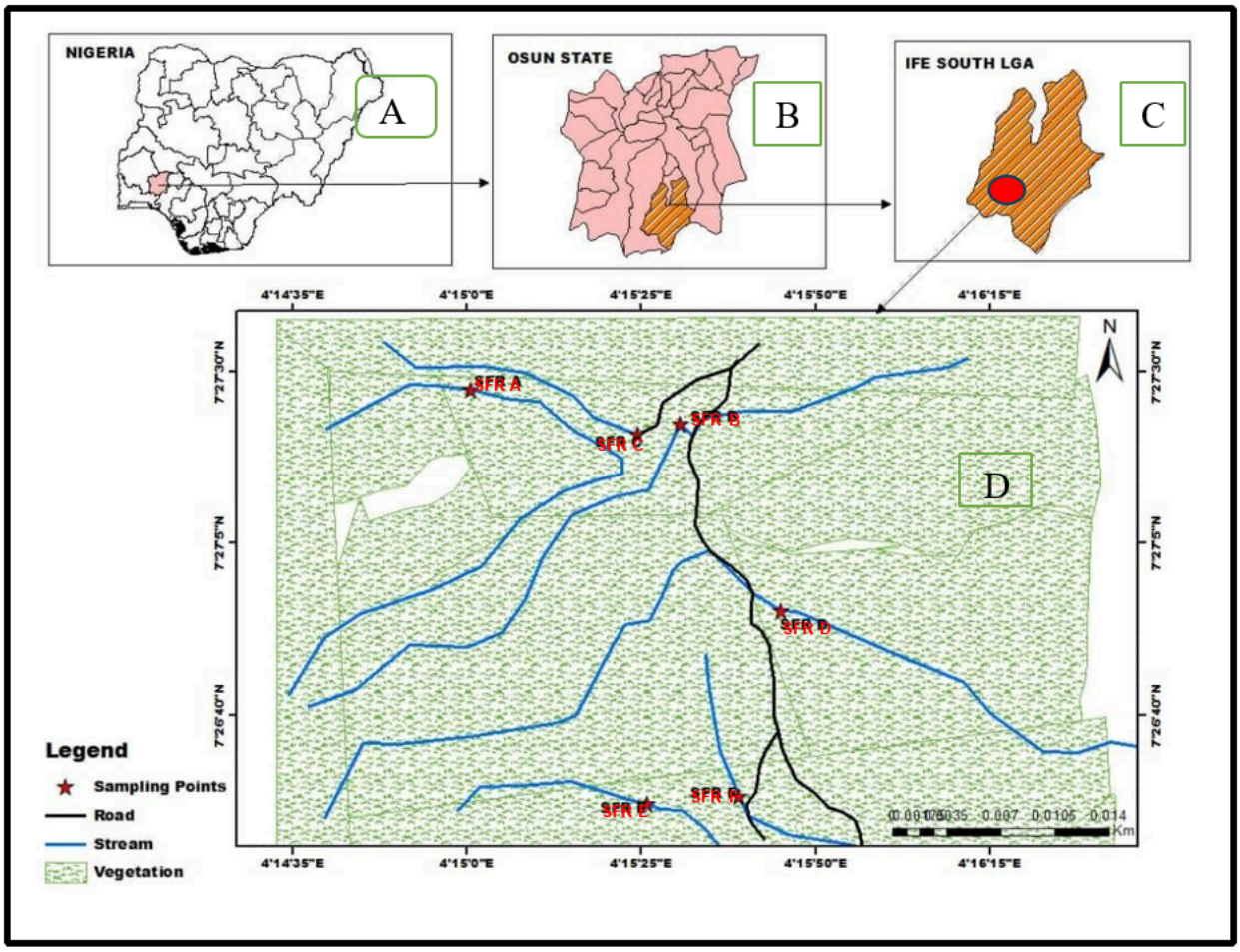


Figure 1

Map of Shasha Forest Reserve Showing the Study Sites in Ife South Local Government Area, Osun State, Nigeria

A: Map of Nigeria Showing Osun State

B: Map of Osun State showing Ife South Local Government

C: Map of Ife South Local Government

D: Map of Shasha Forest Reserve Showing the position of the Study Sites (SFR A-F)

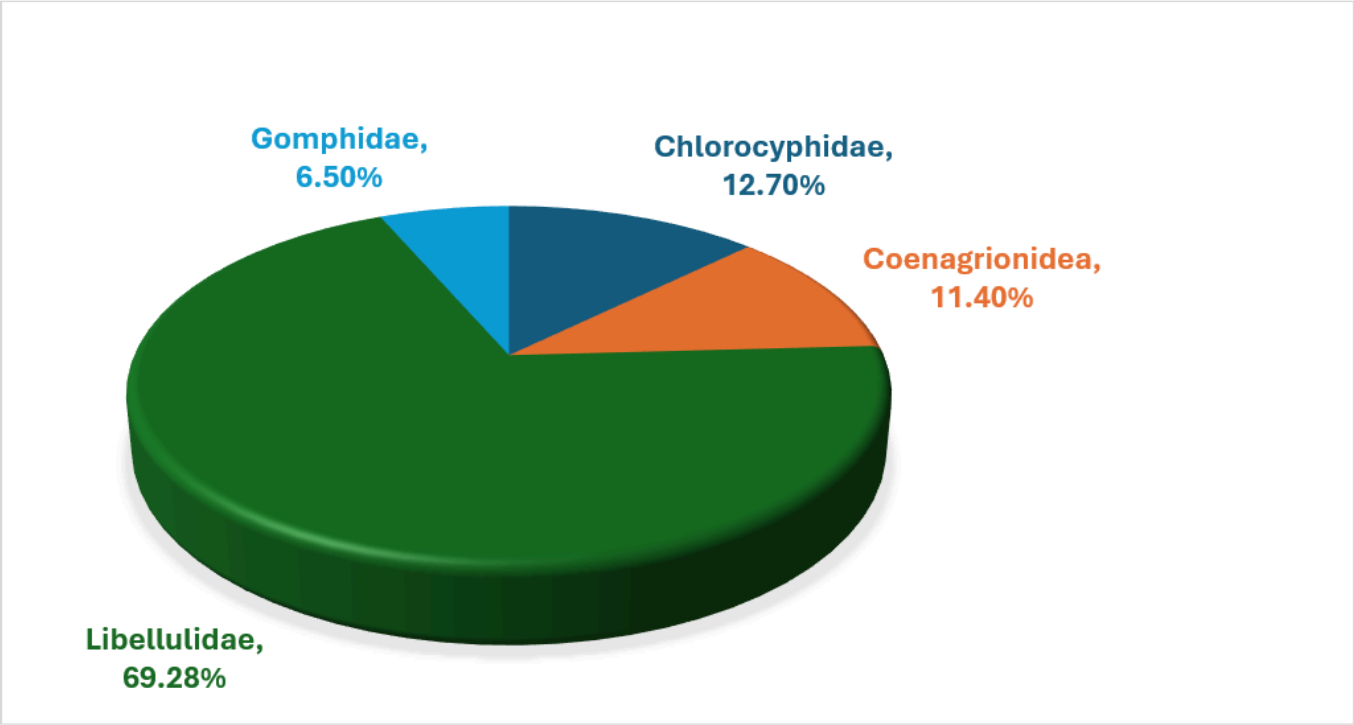


Figure 2

Percentage composition of the Families at Shasha Forest Reserve Stream