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Assessment of the water quality and Odonata assemblages in three waterbodies in Ilara-Mokin, south-western Nigeria

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This study investigated the biological water quality and Odonata assemblages in three waterbodies in Ilara-Mokin, with the aim of determining the ecological integrity of the ecosystems. Sampling of Odonata specimens was carried out over April–August, 2017 between 9.00am and 4.00pm under favourable conditions. Some physico-chemical parameters of the water such as dissolved oxygen, electrical conductivity, temperature, flow rate, pH, and water depth were also investigated. A total of 41 odonate species were recorded in this study and this was represented by 29 dragonfly and 12 damselfly species. These species are contained in seven families (Macromiidae, Gomphidae, Libellulidae, Calopterygidae, Coenagrionidae, Chlorocyphidae and Platycnemididae). The seven families were recorded at Aponmu River while Omifunfun River and Isokun River accounted for six and four families respectively. However, the highest number of individuals was collected at Isokun River. Libellulidae was the dominant family. Diversity indices revealed that Aponmu river was the richest in terms of species richness, diversity and taxa distribution (Shannon: 3.18, Simpson D: 0.95, Margalef: 7.38, evenness: 7.38, equitability: 0.93). Dragonfly Biotic Index (DBI) analysis indicated that Omifunfun River represented the best habitat condition in the study area while Isokun River was considered the most perturbed sampled site in the study area. Conservative efforts should be intensified to protect Omifunfun River in order to preserve all extant aquatic biota and other available resources therein.

Keywords: Odonata; community structure; Dragonfly Biotic Index; Ilara-Mokin

Introduction

The freshwater ecosystem has been identified as one of the major sources of livelihood for humans, especially in developing countries. As a result, information on the ecological status of waterbodies in these areas is of great concern to the general public. Freshwater habitats provide long-term potable water for domestic consumption, recreation and also serve as sources of raw materials for some industries (Damn, Dijkstra, & Hadrys, 2010). These socio-economic benefits derived from freshwater ecosystems are important factors contributing to the proliferation of human populations around waterbodies, with concomitant increase in water pollution. For instance, in the riverine areas in the south-western part of Nigeria, it has been observed that rivers are used as major means of refuse and human sewage disposal (Fagade, Adebisi, & Ugwumba, 1993). These activities have a cascading impact on the quality and quantity

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of water available for man's use. Deterioration in the water quality also affects the composition and diversity of aquatic organisms in such waterbodies. Furthermore, studies have shown that anthropogenic activities, such as throwing of refuse (e.g. plastic materials, organic and chemical wastes) into water, canalizations, and construction of bridges and dams within the water basin catchment, significantly alter macro-invertebrate community structures (Damn et al., 2010). This has resulted in organisms shifting from more specialist feeders in undisturbed areas to an increased number of generalists in less diverse disturbed areas (Garie & McIntosh, 1986).

The importance and abundance of resources in freshwater ecosystems have made the monitoring of freshwater bodies a global issue (Taiwo, Beddows, Shi, & Harrison, 2014). Consequently, international organizations including the World Health Organization (WHO), United Nation Environmental Programme (UNEP), United Nation Educational Scientific and Cultural Organization (UNESCO) and World Meteorological Organization (WMO) launched water monitoring programmes with the aim of collecting detailed information on the quality of ground water and surface water globally (Taiwo et al., 2014). In Nigeria, such information is available from the River Basins Development Authorities which were established in Nigeria in 1979 (WHO/UNEP 1997) and Benin-Owena River Basin Development Authority (BORBDA) is one of them.

Odonata (dragonflies and damselflies) are conspicuous and quintessential of freshwater habitats, with over 6500 identified and described species worldwide (Clausnitzer & Dijkstra, 2005). Their high diversity, ease of identification and their conspicuousness have made them widely useful in biodiversity studies (Adu, Akindele, & Obadofin, 2015; Vick, 2003) and as bioindicators of ecological integrity of ecosystems (Corbet, 2004). The presence or absence of species of Odonata in a freshwater environment could also be an indication of the condition of the water body (Chovanec & Raab, 1997). However, most studies on Nigerian Odonata were done many years ago (Gambles, 1975; Hassan, 1976, 1981; Pinhey, 1961, 1962). Recent information on this group of insects is scarce; therefore filling the knowledge gap on the country's odonate fauna is warranted. This study aims to provide information on the faunistic composition of Odonata and the water quality of the waterbodies in the study area. This is with a view to assessing the ecological integrity of these habitats using the community assemblage of Odonata as bio indicators. We hypothesized that there will be no difference in the diversity of species of Odonata occurring at the three water bodies.

Methods

Study area

The study was carried out on three waterbodies in Ilara-Mokin (7. 204150°N, 5.06700°E). This town is located within the jurisdiction of the Benin-Owena River Basin Authority. The waterbodies sampled include Rivers Isokun (ISO), Aponmu (APO) and Omifunfun stream (OMI). Ilara-Mokin (Figure 1) is a fast-growing university town which is about 12 km from Akure, the capital of Ondo State, Nigeria. The population of the town is about 45,000 people. South-western Nigeria is characterized by two seasons, the wet and dry seasons. The wet season covers March–October with an average rainfall of 1900mm, while the dry season covers November–February (Ashaolu & Adebayo, 2014). The mean monthly temperature ranges between 27°C and 30°C while the mean monthly relative humidity is below 70%. Ilara-Mokin used to be an agrarian community with a serene environment; however, the establishment of Elizade University and its Golf Club (which are of international standard) has suddenly turned the town to a lively fast-growing town.

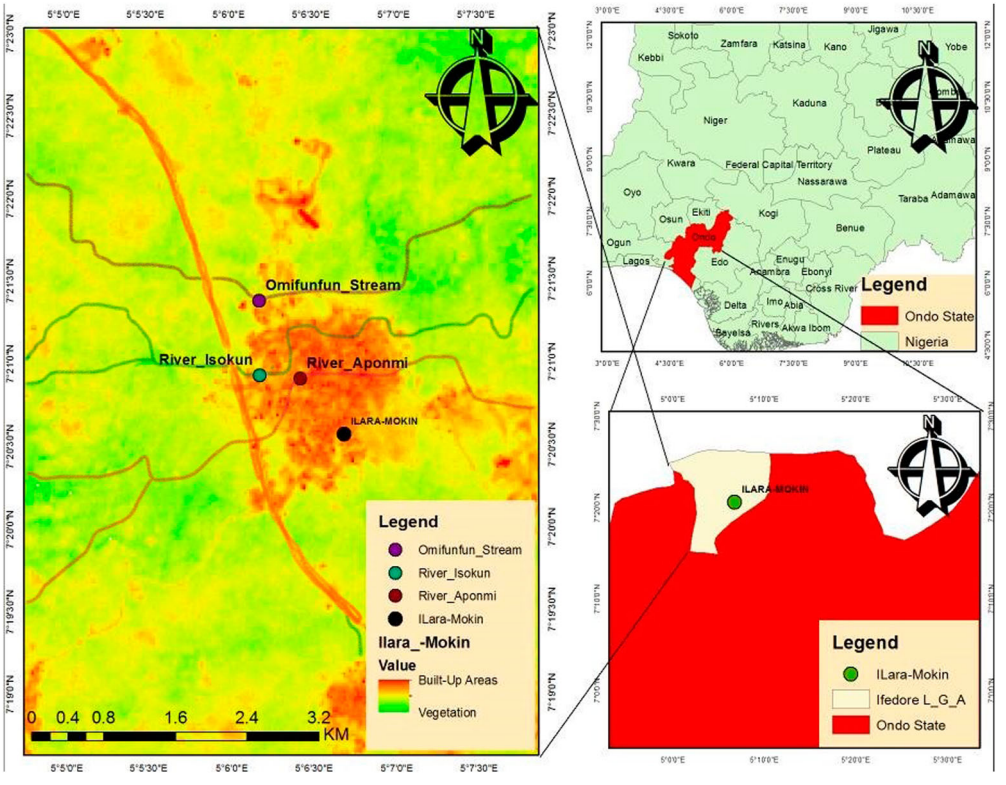

Figure 1. Map of Ilara-Mokin showing the three water bodies (inset: map of Ondo state in Nigeria showing the Ilara-Mokin in Ifedore local government area).

Study sites

River Isokun

Two study sites were located around this waterbody, namely ISO 1: 7.34715°N, 5.104468°E and ISO 2: 7.34919°N, 5.102150°E. ISO 1 was located adjacent to an abandoned farmland very close to a cocoa plantation. ISO 2 was located in an area characterized by the presence of grasses and short trees. The river has almost lost its riparian vegetation, which is an indication of environmental degradation. River Isokun is clear, shallow, slow-flowing, and with a fine sand bed.

Anthropogenic activities witnessed at this site include clearance of the aquatic vegetation, washing and fetching of water for irrigation and other domestic purposes.

River Aponmu

The two study sites located around this river are: APO 1: 7. 348422°N, 5. 107004°E and APO 2: 7.35047°N, 5.108322°E. The riparian vegetation was characterized by the presence of grasses, shrubs, and food crops such as oranges and plantains. APO 2 was fairly shaded, with an abundance of suspended organic matter. River Aponmu is a shallow and slow-flowing waterbody. The observed anthropogenic activities around the river include bathing, automobiles navigating the shallow portion and grazing by cattle at the bank of the river.

Omifunfun River

The two study sites located around Omifunfun are OMI 1: 7.356290°N, 5.102880°E and OMI 2: 7.35100°N, 5.093497°E. Omifunfun is shallow, slow-flowing moderately clean water. The bottom is silty mud and some part of the river has rocky banks and the observed anthropogenic activities here include farming and domestic washing.

Sampling methods

Sampling of Odonata specimens (adults and larvae) was carried out twice in a month for a period of five months covering April–August 2017. Sampling exercise was usually done between 9:00 am and 4:00 pm under favourable conditions. All the species of Odonata encountered within the study sites were sampled using sweep nets (for adults), kick sampling and D-frame dip net (for larvae). The adult specimens were kept in small triangular envelopes with the wings placed together at the back to prevent them from being rumpled and the envelopes were appropriately labelled. The male and female species of adult Odonata caught in tandem were placed together inside an envelope.

The final instars of Odonata larvae were sampled at the littoral section of the water bodies using standard aquatic D-frame dip net (with a 600-µm Nitex bag). The final instars collected were reared to adults so as to ensure that adults that could not be sampled with the sweep net have the chance of being recorded. A small metal kitchen sieve and white tray were used to ease the sorting out of the larvae from other macroinvertebrates collected from the rivers. The specimens were kept in a perforated container for onward transportation to the laboratory.

All physico-chemical parameters were measured *in situ*, except the dissolved oxygen (DO) which was done in the laboratory using Winkler's method. Water and air temperature were measured using hand-held mercury thermometers while the electrical conductivity (EC) was measured using a conductivity meter (EC-3EC/TEMP). Water current velocity was determined using the flotation method descried by Jones and Reynolds (1996). The pH was determined using a pH digital tester.

Preservation of adults and larvae

All adult specimens collected were soaked in acetone for a minimum of 12 h so as to ensure absorption of sufficient acetone to guarantee proper preservation. The soaked specimens were removed and air-dried on tissue paper. The air-dried specimens were thereafter kept in well-labelled triangular envelopes and then placed in an insect box for further processing.

Emerged teneral adults from the rearing cages were placed in an insectarium for a few hours to allow the soft cuticle to harden up and be preserved for identification. Penultimate and ultimate larvae that died before emergence were preserved in 70% ethanol.

Identification of specimens

All the specimens were morphologically examined and documented using a digital microscope (10 × –200 ×) (model VP EYE 6.6 Aeromax 090828, Maplin Electronics, London, UK). Specimens were identified to lowest possible taxonomic level using appropriate standard identification manual and guides, including Dijkstra and Clausnitzer (2014), Samways (2008) and Suhling, Muller, and Martens (2014). The Odonata database (African Dragonflies and Damselflies Online: ADDO) on the Internet was also consulted for illustrations and guides during the identification processes (Dijkstra, 2018).

Table 1. The physico-chemical parameters (mean ± standard error) of water samples from the three water bodies from April 2017 to August 2017.

Month	Location	AT (°C)	WT (°C)	FR (m s^{-1})	EC (µS cm^{-1})	pH	DO (mg l^{-1})	WD (m)
April 2017	Aponmu	29.17 ± 0.17^{b}	27.00 ± 0.00^{b}	0.030 ± 0.0003^{a}	157.33 ± 0.67^{a}	6.70 ± 0.00^{b}	20.00 ± 0.00^{b}	0.65 ± 0.00^{a}
	Isokun	29.10 ± 0.21^{b}	27.17 ± 0.17^{b}	0.030 ± 0.0003^{a}	250.33 ± 0.33^{c}	6.60 ± 0.00^{a}	18.17 ± 0.17^{a}	0.60 ± 0.00^{a}
	Omifunfun	27.17 ± 0.17^{a}	26.33 ± 0.17^{a}	0.032 ± 0.0003^{b}	200.33 ± 0.33^{b}	6.83 ± 0.03^{c}	22.50 ± 0.00^{c}	0.45 ± 0.00^{a}
May 2017	Aponmu	31.33 ± 0.17^{c}	28.20 ± 0.10^{b}	0.030 ± 0.000^{a}	160.33 ± 0.33^{a}	6.80 ± 0.00^{a}	20.67 ± 0.17^{b}	0.68 ± 0.00^{a}
	Isokun	29.93 ± 0.07^{b}	27.17 ± 0.17^{a}	0.030 ± 0.000^{a}	250.67 ± 0.33^{c}	6.60 ± 0.00^{a}	18.17 ± 0.17^{a}	0.65 ± 0.00^{a}
	Omifunfun	28.50 ± 0.00^{a}	27.17 ± 0.17^{a}	0.032 ± 0.0003^{b}	198.33 ± 0.333^{b}	6.70 ± 0.00^{a}	20.33 ± 0.17^{b}	0.50 ± 0.00^{a}
June 2017	Aponmu	29.17 ± 0.17^{c}	27.50 ± 0.00^{b}	0.03 ± 0.00^{a}	160.67 ± 0.33^{a}	6.80 ± 0.00^{a}	20.17 ± 0.17^{b}	0.70 ± 0.00^{a}
	Isokun	28.33 ± 0.17^{b}	27.17 ± 0.17^{b}	0.03 ± 0.00^{a}	248.33 ± 0.33^{c}	6.60 ± 0.00^{a}	20.17 ± 0.17^{b}	0.72 ± 0.00^{a}
	Omifunfun	27.17 ± 0.17^{a}	26.17 ± 0.17^{a}	0.03 ± 0.00^{a}	200.67 ± 0.33^{b}	6.70 ± 0.00^{a}	19.33 ± 0.17^{a}	0.55 ± 0.00^{a}
July 2017	Aponmu	29.00 ± 0.00^{c}	28.33 ± 0.17^{c}	0.035 ± 0.000^{b}	160.67 ± 0.33^{a}	6.80 ± 0.00^{a}	21.00 ± 0.00^{c}	0.72 ± 0.00^{a}
	Isokun	28.17 ± 0.17^{b}	27.17 ± 0.17^{b}	0.032 ± 0.000^{a}	250.33 ± 0.33^{c}	6.60 ± 0.00^{a}	19.40 ± 0.20^{a}	0.75 ± 0.00^{a}
	Omifunfun	26.67 ± 0.17^{a}	25.00 ± 0.00^{a}	0.033 ± 0.0003^{a}	200.00 ± 0.00^{b}	6.70 ± 0.00^{a}	20.00 ± 0.00^{b}	0.58 ± 0.00^{a}
August 2017	Aponmu	28.00 ± 0.00^{a}	27.33 ± 0.17^{b}	0.037 ± 0.00^{a}	172.67 ± 13.00^{a}	6.70 ± 0.00^{a}	20.00 ± 0.00^{b}	0.75 ± 0.00^{a}
	Isokun	28.00 ± 0.00^{a}	27.33 ± 1.67^{b}	0.034 ± 0.00^{a}	252.00 ± 0.00^{b}	6.70 ± 0.00^{a}	19.17 ± 0.17^{a}	0.78 ± 0.00^{a}
	Omifunfun	27.00 ± 0.00^{a}	26.00 ± 0.00^{a}	0.033 ± 0.00^{a}	200.00 ± 0.00^{a}	6.80 ± 0.00^{a}	20.00 ± 0.00^{b}	0.62 ± 0.00^{a}

Mean ± standard error represent three replicates. The mean having the same alphabet down the column are not significantly different from one another using Tukey's HSD (honest significant difference) at $p > 0.05$.

Table 2. Checklist of Anisoptera species of the study sites in Ilara-Mokin April–August 2017.

Family	Anisoptera species	ISO 1	ISO 2	APO 1	APO 2	OMI 1	OMI 2	Total
Macromiidae	*Phyllomacromia hervei* (Langrand, 1980)	0	0	2	1	0	0	3
Gomphidae	*Crenigomphus renei* Fraser, 1936	0	0	3	2	0	0	5
Libellulidae	*Acisoma panorpoides* Rambur, 1842	2	2	0	0	0	0	4
	Brachythemis leucosticta (Burmeister, 1839)	1	1	0	1	0	0	3
	Crocothemis erythrae (Brulle, 1832)	0	0	1	4	0	0	5
	Diplacodes pumila Dijkstra, 2006	1	1	0	0	3	6	11
	Hadrothemis infesta (Karsch, 1891)	0	0	2	1	2	0	5
	Hadrothemis vrijdaghi Schouteden, 1934	2	2	0	0	0	0	4
	Neodythemis klingi ((Karsch, 1890)	2	1	0	0	0	0	3
	Nesciothemis farinose (Forster, 1898)	1	1	0	0	1	1	4
	Orthetrum africanum (Selys, 1887)	1	1	4	2	0	5	13
	Orthetrum cancellumtun (Linnaeus,1758)	0	0	0	1	1	2	4
	Orthetrum Julia Kirby, 1900	4	2	1	1	2	2	12
	Orthetrum monardi Schmidt, 1951	0	1	2	1	0	0	4
	Orthetrum stemmale (Burmeister, 1839)	4	2	2	1	0	0	9
	Palpopleura lucia (Drury, 1773)	0	1	4	3	1	0	9
	Palpopleura Portia (Drury, 1773)	2	2	5	3	0	0	12
	Palpopleura albifrons Legrand, 1979	0	0	2	1	0	0	3
	Sympetrum fronscolombii (Selys,1840)	0	0	3	2	2	1	8
	Trithemis aconita Lieftinck, 1969	0	0	3	2	1	0	6
	Trithemis aenea Pinhey, 1961	1	1	0	0	1	0	3
	Trithemis annulata (Palisot de Beauvois, 1807)	1	1	1	1	1	2	7
	Trithemis arteriosa (Burmeister, 1839)	42	34	13	8	10	5	112
	Trithemis dejouxi Pinhey, 1978	1	0	0	0	0	1	2
	Trithemis dorsalis (Rambur, 1842)	6	2	3	2	3	1	17
	Trithemis grouti Pinhey, 1961	0	0	0	0	4	2	6
	Trithemis imitate Pinhey, 1961	3	1	2	1	0	0	7
	Trithemis kirbyi Selys,1891	3	1	3	2	0	0	9
	Trithemis tropicana Fraser, 1953	2	0	1	0	0	0	3
	Total number of individuals	79	57	57	40	32	28	293
	Total number of species	18	18	19	20	13	11	

Abbreviations: ISO 1, Isokun 1; ISO 2, Isokun 2; APO 1, Aponmu 1; APO 2, Aponmu 2; OMI 1, Omifunfun 1; OMI 2, Omifunfun 2

Data analyses

Data were analysed using various statistical methods such as descriptive and inferential statistics. Analysis of variance (ANOVA) was used for the comparison of the physico-chemical parameters of the three waterbodies. Species assemblages were estimated using the diversity indices such as Shannon–Wiener diversity index (H′), Pielou evenness (E) and Simpson's dominance index (c) and Margalef index (*d*). The species assemblages of the study sites was also compared using Shannon–Wiener diversity *t*-test. These analyses were done using Palaeontological Statistics Software (PAST) (Version 3.0 exe, https://folk.uio.no/ohammer/past Oslo Norway). Ecological integrity of the study sites was assessed and compared using the Dragonfly Biotic Index (DBI) (Samways & Simaika, 2016). The assessment was based on three metrics: geographical distribution, conservation status, and sensitivity of the species to human disturbances. Each of the metrics was scored 0–3, making the minimum total score of 0 and the maximum 9. A common and widely distributed species that is tolerant to human disturbance was scored 0. A range-restricted species, that is threatened and sensitive to disturbances is scored 9. The IUCN assessment of each of the species (Samways & Simaika, 2016) and previous studies on dragonflies of West Africa and Central Africa (Dijkstra, Tchibozo, & Ogbogu, 2009; Dijkstra & Vick, 2004) were considered for accurate scoring of the species. To arrive at the DBI value per site, the total DBI (tDBI) was divided by the total number of species found at each of the sites (Samways & Simaika, 2009). This method thus standardized the DBI score to give the DBI site

Table 3. Checklist of Zygoptera species of the study sites in Ilara-Mokin April–August 2017.

Family	Zygoptera species	ISO 1	ISO 2	APO 1	APO 2	OMI 1	OMI 2	Total
Calopterygidae	*Phaon iridipennis* (Burmeister, 1839)	0	0	2	1	0	0	3
	Umma cincta (Hagen in Selys, 1853)	1	0	1	1	0	0	3
Ceonagrionidae	*Ceriagrion glabrum* (Burmeister, 1839)	1	1	2	1	2	0	7
	Pseudagrion kersteni (Gerstacker	0	0	2	2	1	1	6
	Pseudagrion serrlatum Karsch, 1894	0	0	1	1	0	0	2
	Pseudagrion sjestedti Forster, 1906	0	0	1	1	0	0	2
	Pseudagrion sublacteum (Karsch, 1893)	0	0	1	1	1	1	4
Chlorocyphidae	*Chlorocypha cancellata* (Selys, 1879)	0	0	2	1	2	1	6
	Chlorocypha curta (Hagen in Selys, 1853)	0	0	2	1	2	1	6
	Chlorocypha glauca (Selys, 1879)	0	0	0	0	1	2	3
	Chlorocypha victoriae (Forster, 1914)	0	0	0	0	1	1	2
Platycnemididae	*Mesocnemis singularis* Karsch, 1891	5	2	1	1	1	1	11
	Total number of individuals	7	3	15	11	11	8	55
	Total number of species	3	2	10	10	8	7	

Abbreviations: ISO 1, Isokun 1; ISO 2, Isokun 2; APO 1, Aponmu 1; APO 2, Aponmu 2; OMI 1, Omifunfun 1; OMI 2, Omifunfun 2.

Table 4. Diversity of Odonata species in the study sites.

	ISO 1	ISO 2	APO 1	APO 2	OMI 1	OMI 2
Taxa_S	21	20	29	30	21	18
Individuals	86	60	72	51	43	36
Simpson_1-D	0.7426	0.6678	0.9375	0.9443	0.9086	0.9105
Shannon_H	2.124	1.934	3.107	3.177	2.75	2.645
Evenness_eˆH/S	0.3984	0.346	0.7709	0.7995	0.7449	0.7826
Margalef	4.49	4.641	6.547	7.376	5.317	4.744
Equitability_J	0.6977	0.6457	0.9227	0.9342	0.9033	0.9152

Abbreviations: ISO 1, Isokun 1; ISO 2, Isokun 2; APO 1, Aponmu 1; APO 2, Aponmu 2; OMI 1, Omifunfun 1; OMI 2, Omifunfun 2.

value, which now ranged between 0 and 9. The DBI value for the sites were determined using the habitat condition scale table adapted from Simaika and Samways (2012).

Results

Physico-chemical parameters of the water

The monthly mean values of the investigated physico-chemical characteristics of the water for the three water bodies are presented in Table 1. Water temperature (WT) of OMI was significantly different ($p < 0.05$) from the other two rivers (ISO and APO) throughout the sampling period. The DO values of ISO were also significantly different ($p < 0.05$) from OMI and APO for the period of investigation (Table 1).

There was no significant difference ($p > 0.05$) in pH, water depth (WD) and flow rate (FR) among the waterbodies. Likewise, there was no significant difference in the air temperature (AT) values recorded for all the sampling sites in August 2017. However, most of the values obtained for the physico-chemical parameters fell within the prescribed limit for tropical water bodies (McCaffrey, 2018)

Table 5. Total Dragonfly Biotic Index (tDBI) values for the six study sites in Ilara-Mokin.

Species	DBI ISO1	DBI ISO2	DBI APO1	DBI APO2	DBI OMI1	DBI OMI2
Phaon iridipennis	0	0	2	2	0	0
Umma cincta	4	0	4	4	0	0
Cerigrion glabrum	0	0	0	0	0	0
Pseudagrion kersteni	0	0	1	1	1	1
Pseudagrion serrlatum	0	0	1	1	0	0
Pseudagrion sjestedti	0	0	6	6	0	0
Pseudagrion sublacteum	0	0	2	7	2	7
Chlorocypha cancellata	0	0	7	7	7	7
Chlorocypha curta	0	0	7	2	7	2
Chlorocypha glauca	0	0	0	0	7	7
Chlorocypha victoriae	0	0	0	0	7	7
Mesocnemis singularis	3	3	3	3	3	3
Phyllomacromia hervei	0	0	4	4	0	0
Crenigomphus renei	0	0	5	5	0	0
Acisoma panorpoides	2	2	0	0	0	0
Brachythemis leucosticta	3	3	0	3	0	0
Crocothemis erythrae	0	0	1	1	0	0
Diplacode pumila	7	7	0	0	7	7
Hadrothemis infesta	0	0	2	2	2	0
Hadrothemis vrijdaghi	2	2	0	0	0	0
Neodythemis klingi	2	2	0	0	0	0
Nesciothemis farinosa	2	2	0	0	2	2
Orthetrum africanum	2	2	2	2	0	2
Orthetrum cancellumtun	0	0	0	2	2	2
Orthetrum julia	1	1	1	1	1	1
Orthetrum monardi	0	4	4	4	0	0
Orthetrum stemmale	4	4	4	4	0	0
Palpopleura lucia	0	2	2	2	2	0
Palpopleura portia	2	2	2	2	0	0
Palpopleura albifrons	0	0	2	2	0	0
Sympetrum fronscolombi	0	0	0	0	0	0
Trithemis aconita	0	0	4	4	4	0
Trithemis aenea	2	2	0	0	2	0
Trithemis annulata	1	1	1	1	1	1
Trithemis arteriosa	0	0	0	0	0	0
Trithemis dejouxi	2	0	0	0	0	2
Trithemis dorsalis	0	0	0	0	0	0
Trithemis grouti	0	0	0	0	0	0
Trithemis imitata	1	1	1	1	0	0
Trithemis kirbyi	0	0	0	0	0	0
Trithemis tropicana	2	0	2	0	0	0
tDBI	42	40	70	73	57	51

Abbreviations: ISO 1, Isokun 1; ISO 2, Isokun 2; APO 1, Aponmu 1; APO 2, Aponmu 2; OMI 1, Omifunfun 1; OMI 2, Omifunfun 2.

Odonata composition

A total of 348 Odonata individuals (293 dragonflies and 55 damselflies) represented by 41 species were recorded in this study. The odonate species recorded in this study are contained in seven families (three dragonfly families, Cordullidae, Gomphidae and Lielludidae; and four damselfly families, Calopterygidae, Ceonagrionidae, Chlorocyphidae and Platycnemididae). All the seven families reported in this study were recorded at Aponmu River while Isokun River (with the highest number of individuals) accounted for four families. A total of 29 species of Anisoptera were recorded at the study sites. The largest number (20) of Anisoptera species was recorded at APO 2 while the least number (11) was recorded at Omifunfun 2. *Trithemis arteriosa* was the dominant Anisoptera species in the study as it accounted for 112 individuals while *T. dejouxi* was the least represented Anisoptera species in the study area.

Table 6. Habitat condition scale for interpretation of DBI value per site.

DBI value per site	Habitat status	Description
0–2.79	LL	Low biotope diversity
2.80–3.5	ML	Moderate to low biotope diversity
3.6–4.3	MM	Moderate biotope diversity
4.4–5.4	MH	Moderate to high biotope diversity
5.5–9.0	HH	High biotope diversity

Adapted from: Simaika & Samways (2012).

Table 7. Habitat condition for the sampled sites in Ilara-Mokin, April–August 2017.

Site	Number of species	Total DBI	DBI site value	Habitat status
ISO 1	21	42	2.0	LL
ISO 2	20	40	2.0	LL
APO 1	29	70	2.414	LL
APO 2	30	73	2.433	LL
OMI 1	21	57	2.714	LL
OMI 2	18	51	2.833	ML

Abbreviations: ISO 1, Isokun 1; ISO 2, Isokun 2; APO 1, Aponmu 1; APO 2, Aponmu 2; OMI 1, Omifunfun 1; OMI 2, Omifunfun 2.

Twelve Zygopteran species were recorded in the study area. Aponmu River accounted for the highest number of species (with APO 1 and APO 2 having equal number of 10 species). However, Zygoptera was poorly represented at River Isokun, with only three species recorded at the study site. Libellulidae was dominant as it accounted for the highest number of individuals (285). Gomphidae was only recorded at Aponmu, thus being considered scarce in the other sites (Table 2). The highest number of Odonata specimens was collected at ISO 1 while OMI 2 accounted for the least number of individuals (Table 3). The diversity indices revealed that APO2 (Simpson dominance: 0.94, Shannon–Wiener H′: 3.18 and Margalef: 7.38) was the most diverse sampled site while ISO 2 (Simpson dominance: 0.6678 and Shannon Wiener H′: 1.934) was the poorest (Table 4). Also, evenness and equitability tests indicated that APO 2 (evenness E: 0.79; and equitability 0.93) was the site with the best distribution of Odonata species while ISO 2 (evenness E: 0.35, equitability: 0.65) had the poorest species distribution (Table 4).

Dragonfly Biotic Index and habitat status of the six study sites

The total Dragonfly Biotic Index (tDBI) values for all the sampled sites are presented in Table 5. APO 2 had the highest tDBI (73) while APO 1 and ISO 2 had 70 and 40 respectively. The Simaika and Samways (2012) habitat condition scale was adapted (Table 6) for the determination of the DBI site value for the six sites.

The habitat statuses for the six sampled sites are presented in Table 7. Five out of the six study sites were LL (low biotope diversity) while OMI 2 with DBI site value of 2.833 was found to be moderate to low biotope diversity (ML).

Comparison of species diversity at the sampled sites using Shannon Wiener diversity t test

The diversities of Odonata species at the six sampled sites were compared based on this study's hypothesis: 'there will be no difference in the diversity of species of Odonata occurring at the water bodies'. The H′ diversity *t*-test conducted on paired 15 study sites (P1–P15) showed there

Table 8. Comparison of odonatan community structure of the three water bodies in Ilara-Mokin.

(a)	P1		P2		P3		P4		P5		P6		P7		P8	
	ISO1	ISO2	ISO1	APO1	ISO1	APO2	ISO1	OMI1	ISO1	OMI2	ISO2	APO2	ISO2	APO1	ISO2	OMI1
Taxa size	21	20	21	29	21	29	21	21	21	18	20	30	20	29	20	21
H′	2.12	1.93	2.12	3.11	2.12	3.18	2.12	2.75	2.12	2.65	1.93	3.18	1.93	3.11	1.93	2.75
Variance	0.025	0.044	0.025	0.011	0.025	0.016	0.025	0.022	0.025	0.021	0.044	0.016	0.044	0.011	0.044	0.022
t-value	0.72		–5.12		–5.16		–2.88		–2.42		–5.07		–4.98		–3.18	
df	121.3		144.6		136.9		120.8		109.9		96.5		89.5		99.66	
p-value	0.473		9.5E-07		8.5E-7		0.0046		0.0171		1.96E-06		3.03E-06		0.00195	

(b)	P9		P10		P11		P12		P13		P14		P15	
	APO1	APO2	APO1	OMI1	APO1	OMI2	APO2	OMI1	APO2	OMI2	OMI1	OMI2	ISO2	OMI2
Taxa size	29	30	29	21	29	18	30	21	30	18	21	18	20	18
H′	3.11	3.18	3.11	2.75	3.11	2.65	3.18	2.75	3.18	2.65	2.75	2.65	1.93	2.65
Variance	0.011	0.016	0.011	0.022	0.011	0.021	0.016	0.022	0.016	0.021	0.0215	0.0207	0.044	0.021
t-value	–0.43		1.98		2.59		2.21		2.78		0.510		–2.79	
df	109.32		85.59		74.62		89.23		79.68		78.62		94.7	
p-value	0.671		0.052		0.01162		0.0299		0.00683		0.611		0.00634	

Abbreviations: P1–P15, 1st to 15th pairs; ISO 1, Isokun 1; ISO 2, Isokun 2; APO 1, Aponmu 1; APO 2, Aponmu 2; OMI 1, Omifunfun 1; OMI 2, Omifunfun 2.

were significant differences in species diversity among the 11 paired sites in which the *p*-value was less than 0.05 (Table 8). Also, there was no significant difference in the species diversity among four paired study sites (ISO1: $H' = 2.124$ and ISO2: $H' = 1.934$ *p*-value $= 0.473$; APO 1: $H' = 3.107$ and APO2: $H' = 3.177$ *p*-value $= 0.671$; APO1: $H' = 3.107$ and OMI 1: $H' = 2.75$ *p*-value $= 0.052$; and OMI 1: $H' = 2.75$ and OMI 2: $H' = 2.645$ *p*-value $= 0.611$). As a result, the null hypothesis for the four paired study sites was therefore accepted.

Discussion

Physico-chemical parameters

Temperature is one of the fundamental properties of water and it is known to influence the amount of DO available in water. The relationship is usually inverse as increased water temperature may cause a reduction in the amount of DO in the waterbody. Water at 0°C will hold up to 14.6 mg l^{-1} of oxygen while at 30°C it will hold about 7.6 mg (McCaffrey, 2018). Aside from its impact on DO concentration in the waterbody, temperature has also been known to affect the rate of metabolism of aquatic organisms such as the rate of emergence of odonatan larvae to teneral adults (Corbet, 2004). There were marked variations in the water and air temperature recorded in this study. These observable differences could be attributed to the variations in the amount of canopy cover and the density of the riparian vegetation around the three waterbodies. This was evident as the two rivers (Aponmu and Isokun rivers) which had relatively less dense canopy and sparse riparian vegetation had higher water and air temperature for the entire period of study. Another possible factor that could have influenced the higher temperature values observed for the two rivers is the flow rate. The flow rate of Omifunfun was relatively higher than the rates recorded for the other waterbodies (Aponmu and Isokun). Flow rate has also been known to significantly limit the habitat of Odonatan larvae and other aquatic insects (Corbet, 2004). The upper lethal temperature for dragonfly larvae is 45°C and this can rarely be found in lotic water (Corbet, 2004). Water pH has not been known to significantly affect Odonata larvae assemblage as this group of insects tends to respond more to other environmental factors than pH (Corbet, 2004). This is because Odonata has been known to have a wide tolerance level. They can tolerate wide range of pH: strongly acidic (pH 4.0) to strongly alkaline (pH > 8.1). In this study, the pH did not significantly influence the abundance and distribution of the Odonata species. This is in agreement with Cannings and Cannings (1994) who inferred that Odonata species seemed to respond more to habitat's form and structure than to its pH or nutrient level.

The concentration of DO in water affects the behaviour, metabolism and survival of dragonfly larvae (Corbet, 2004). Variability in DO concentration within habitats is caused by factors such as water depth, proximity to the water edge and water current velocity and temperature. Edges of ponds or lakes are richer in DO than deep water. In this study, Isokun had the lowest DO concentration values while the highest concentration was recorded in Omifunfun.

EC is a measure of dissolved ions in waterbodies. The three waterbodies in the study area studied had low EC range characteristic of waterbodies in the Afrotropical region (Ezekiel, Hart, & Abowei, 2011). EC influences adult Odonata assemblage as it determines the location of their oviposition site and also serves as a clue to detecting polarization and reflected light suitable for habitat (Corbet, 2004). The range of conductivity values recorded for the three water bodies suggested they were convenient breeding sites for the Odonata species recorded in this study.

Taxonomic composition of Odonata

The Odonata species collected in this study are distributed in seven families. The dominant family was Libellulidae as it had the highest frequency of occurrence. The dominance of Libellulidae

in this area is not surprising as over 1000 species has been recorded and they have been reportedly found all over the world (Pilgrim & von Dohlen, 2008). *Trithemis arteriosa* was the dominant species and it was found to be abundant in all the sampled sites with a total of 112 individuals recorded. This species is common and it is known to inhabit different reaches of waterbodies or slow-flowing rivers (Dijkstra & Clausnitzer, 2014; Samways, 2008). The dominance of this species in this area could be attributed to the fact that it belongs to the red-vein groups which are known to tolerate disturbed environments and also have good dispersal and adaptation potentials (Damn et al., 2010); these attributes accounted for their occurrence at variety of habitats. The least common family was the Macromiidae, as it accounted for the lowest number of individuals. It was represented by only *Phyllomacromia hervei* and this made it a mono-specific family in the area. Macromiidae are characterized by long clubbed abdomen and have been known to be endemic to Africa where they are found associated with rivers and hovering over forest streams (Dijkstra & Clausnitzer, 2014).

Water quality and Odonata composition

The marked differences observed in the physico-chemical parameters that were determined for the sampled sites did not greatly influence the composition and distribution of the Odonata species. For instance, Isokun River, in which the lowest DO values were recorded, accounted for the highest number of individuals of Odonata. Conductivity values were also highest in this waterbody and Odonata species are generally known not to thrive very well in water with high conductivity. However, this river accounted for 46% of the entire Anisoptera species collected (136 of the total 293 individuals). *Trithemis arteriosa* also had its highest abundance in this site. *T. arteriosa* collected at Isokun River accounted for 68% (76 of the total 112) of the total Anisoptera species collected in the study. This was an indication that the Odonata species which tolerate disturbed water thrive well at the water body. Another possible reason for this observation could be that the water quality parameters fell within the tolerance threshold of the species recorded in the study. Other factors that could have been responsible for high number of individuals and taxa in Isokun include the presence of aquatic macrophytes on the water banks. For instance, the aquatic weeds are known to be a good oviposition sites for mature female insects (Corbet, 2004).

Habitat status

Diversity and species richness in the waterbodies were assessed using five diversity indices in order to overcome the deficiencies or limitation of a single index (Purvis & Hector, 2000). The range of values obtained for Simpson index in the sampled stations was 0.7–0.9 and this was indicative of a stable community (Dash, 2001). Shannon–Weiner index (H′) also suggested stable environmental condition in the sampled sites as most of the values obtained were closer to 3, which was indicative of a stable environmental condition (Stub, Appling, Hatstetter, & Hass, 1970).

Equitability and evenness indices also indicated that the distribution of Odonata species at the sampled sites was good. The equitability values obtained for most of the sampled sites were $>$ 0.9 and this was indicative of a good distribution of the insects within the area. APO 2 can be considered the site with the highest diversity and best distribution of Odonata species amongst the sampled sites. This is because most of the biodiversity indices had their highest values in this site. OMI 2 was observed to be the least diverse sampled site as it accounted for the lowest number of taxa and individuals.

Shannon-diversity *t*-test revealed significant differences in the community assemblages of the Odonata species in the sampled sites when paired. Twelve of the 15 pairs showed significant differences in their composition. These observed differences in the community assemblage may be attributed to variation in the water quality and nature of substratum in the sampled sites (Gichimu & Mwaniki, 2015).

The assessment of the habitat conditions in the sampled sites using DBI analysis revealed that OMI 2 had the best habitat condition among the six sampled sites. The standardization of DBI values for the habitat showed that the habitat status fell within the ML range (moderate to low biotype diversity) while the other five sites fell within the LL range (low biotype diversity) (Simaika & Samways, 2009).

In conclusion, the sampled sites were considered to have reflected stable environmental conditions. The study area showed high diversity and fairly good distribution of the Odonata species. This was also evident in the high values obtained for the diversity indices recorded for most of the sampled sites. However, the low biodiversity indices values and DBI obtained for ISO 1 and ISO 2 suggested that these sites were moderately polluted. It is suggested that certain measures be put in place to ensure that these waterbodies are protected in order to preserve the aquatic resources therein.

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