Monitoring of environmental disturbance using abundance and distribution of red-vein and dark-vein species of genus *Trithemis* (Odonata: Libellulidae)

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Abstract

Environmental changes as a result of human disturbance in Akure Forest Reserve were investigated for a period of twelve months using abundance and diversity of Red-vein and Dark-vein *Trithemis* species as an assessment tool. Four study sites (AGO, ALA, APO, and ROD), based on type of water bodies and landscapes, were identified and selected for this study. Diversity indices and Dragonfly Biotic Index (DBI) were used to compare the assemblages of the odonate species in the study-sites. A total of 199 specimens were collected out of which 121and 78 were Red-vein and Dark-vein species respectively. Members of this genus differ in their dispersal capacities and coloration. Based on Dragonfly Biotic Index (DBI) used and the pattern of distribution of *Trithemis* (Red-vein and Dark-vein species), in the forest ROD and APO were the least disturbed site with the highest DBI value of 9. AGO with DBI value of 2 was the most disturbed site. The pattern of distribution of this species revealed that Akure Forest Reserve is degenerating, a situation that could lead to loss of biodiversity if urgent conservative measures were not put in place.

Keywords: Odonata; *Trithemis* spp; Akure Forest Reserve; diversity indices; Dragonfly; Biotic Index (DBD).

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Introduction

The genus *Trithemis* (family Libellulidae) called drop-wing due the characteristic posture when at rest is one of the largest genera in suborder Anisoptera (Samways 2008, Damm *et al* 2010, Picker *et al* 2004). The genus is known to have large ranges and presumably good dispersal capabilities, thus occupying a great variety of habitats, displaying high adaptation potential (Damm *et al* 2010). They are found in various habitats which include rain forest, savannah streams and rivers, and even in oasis of the deserts (Dijkstra and Clausnitzer 2015). Member of this genus are generally small with hindwing less than 34 mm, abdomen less than 30 mm. The main diagnostic feature of members of the genus is the distal angle of anal loop extending two cells beyond distal extremity of hindwing triangle. *Trithemis* dominate dragonfly communities across Africa with about forty known species. Members of the genus are generally grouped into Red-vein and Dark-vein species, based on the colour of the wing-vein (Samways, 2008; Damm *et al* 2010, Dijkstra and Clausnitzer, 2015; Ameilia *et al* 2006).

The assemblage of species of Odonata (*Trithemis* inclusive) is strongly determined by degree of shadiness, insolation and vegetation architecture (Dijkstra 2007, Adu and Ogbogu 2011). The Red-vein species are associated with open habitat while most dark-vein species prefer shady or fairly shaded environment (Dijkstra and Clausnitzer 2015 and Samways 2008). Red-vein *Trithemis* species are cosmopolitan and are associated with open landscapes. They are among the first colonizers of cleared riparian vegetation; a behavioural attribute connected to their tolerance to human disturbance. Most Dark-vein species are shade lovers, and often come out to sunbath and to mate, this characteristic behaviour of Red-vein and Dark-vein species of *Trithemis* is hypothesised as an attribute that could be used as a tool for monitoring environmental degradation. Hence, this study thus sought to determine the assemblage of Red-vein and Dark-vein *Trithemis*, compare and estimate the Red-vein and Dark-vein species in order to determine the environmental health of Akure forest reserve.

Materials and methods

Study area

This study was conducted in Akure Forest Reserve, located in Ondo State, south-west Nigeria. The forest reserve covers an area of 69.93 km^2 and located between Owena Town and Aponmu Village along Ondo-Akure Road, about 20 mm South of Akure (07°11.94′ N and 07° 13.57′ N and 005° 01.12′ E and 005° 02.92′ E). It is

under the management of the Department of Forestry, Ondo State Ministry of Agriculture and Natural Resources, in conjunction with the Federal Ministry of Environment, Nigeria. The water-bodies found within the forest include: River Owena, River Aponmu and Alatori Stream adjacent to River Aponmu. Other water bodies include Ago Store Pond and its surrounding swamp which dries during the dry season.

Study sites

Four sites were selected based on types of water bodies and landscape. The water-bodies selected in the forest include: Ago Store Pond, Alatori Stream, River Aponmu and River Owena. Figure 1 presents the map of Akure Forest Reserve, the four "stars" are the study-sites in the forest.

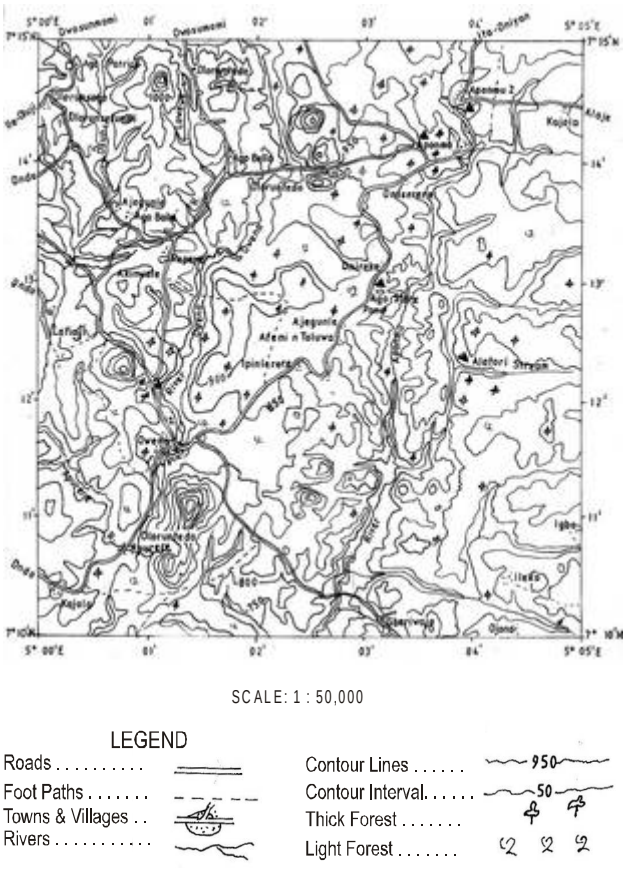

Figure 1. Map of Akure Forest Reserve. The "stars" (*) on the map indicate the four study-sites.

Description of the sites

Ago Store Pond, located in Ago Store Camp (AGO): The pond and the surrounding marsh is about 58 m^2 and is surrounded by shrubs, grasses and short crop trees. Adjacent to the pond is a cocoa plantation. There is also a palm oil mill located few meters to the pond. The pond provides water for cocoa farmers and for the oil palm mill. Liquid effluent coming from the mill are channelled into a canal that took its source from the pond. The canal, the marshy surroundings, and the surrounding vegetation within 50 meters constituted the Ago Store Pond study site.

Alatori Stream (ALA): Is a slow flowing stream across a foot path leading to Babaoku Village. A log of wood is placed across the stream which serves as pedestrian bridge. The stream is shallow with the deepest part being 0.9 m. The stream is characterized by sandy substrate, boulders and some quantity of organic matters. The surroundings of the stream are characterized by trees, which form shade on some part of stream channel. Other riparian vegetation at the stream includes shrub and grasses.

River Aponmu (APO): Aponmu River is characterized by rocky beds, boulder, sand and dead organic matter. APO is influenced by considerable anthropogenic activities as a result of polluted water channelled into the river from the village and adjacent oil palm mills at the bank of the river.

River Owena Dam (ROD): Part of the river is characterised by rocky river bed especially around the dam spillway. The dam area is opened with short trees, shrubs and grasses characterized the riparian vegetation. Away from the dam into the forest are tall trees which form shade on some part of the river. The study-site also includes the forest surrounding the dam. Table 1, presents the geo-reference coordinate of some of the prevailing anthropogenic activities at the study sites.

Table 1. Geo-reference coordinate and some of the human disturbances at the four study sites in Akure Forest Reserve.

Study site	Geo-reference coordinate	Human disturbance activities
Ago-Store Pond (AGO)	07° 12. 54′ N and 005° 02.79′E	Clearing of the riparian vegetation, soap, and waste from oil palm mill.
Alatori Stream (ALA)	07°12 30′ N and 005° 03 63′ E	Clearing of the riparian vegetation by the grazing cattle, and detergent.
River Aponmu (APO)	07°13.57′ N and 005° 03. 63′ E	Trampling of vegetation by the grazing cattle, waste from oil palm mill, domestic waste and human excrement, detergent, clearing of riparian vegetation.
River Owena Dam (ROD)	07° 11.94′ N and 05° 01.12′ E	Damming, clearing of riparian vegetation, fish poaching.

All adjoining temporary water bodies such as water puddles on footpaths and roads, swamps and marshes

were also considered for this study. Surrounding vegetation within the vicinity of each of the study-sites were combed for adult red and dark *Trithemis* species.

Sampling of Trithemis species

Sampling of the adults was carried out between 10.00 am and 2.00 pm under favourable weather condition, once a month for a period of twelve months, using insect sweep net with 150 cm long handle and orifice of 25 cm in diameter. Red-vein and Dark-vein *Trithemis* species were the targeted taxa. Specimens that were difficult to identify at the field were taken to the laboratory for proper identification using standard identification manual; Vick (2003), Samway (2008), Dijkstra and Clausnitzer (2015). The specimens were also cross-examined with Odonata pictures on the internet.

Data analysis

Diversity indices were used to determine the species' richness at all the study-sites. This include Shannon-wiener diversity index, Evenness, Simpson Dominance index, Margerlef, Equitability index and Menhinick (Ricotta 2003, Liu *et al* 2008; Javaid and Pandit, 2013). Determination of the abundance of Red-vein and Dark-vein Trithemis species was based on the frequency of occurrence of the species at each of the study-sites. For this purpose a metric was allotted; 1-5 Not common (NC), 6-10 Common (C) and > (greater than) 11 Abundance (A). The tolerance of each of the species collected to perturbation and health of each of the study sites were determined with the aid of Dragonfly Biotic Index (DBI) (Samways, 2008). Dragonfly Biotic Index (DBI) was based on geographical distribution, conservation status and sensitivity of Odonata to changes in their environment. Each of the sub-themes was scored 0-3, making the minimum total score of 0 and the maximum of 9. A common and wide spread species which is highly tolerant of human disturbance is scored 0 while the range restricted, threatened and sensitive endemic species is scored 9. To enhance the validity of the DBI scoring in this study, previous study on dragonflies of West and Central Africa were accessed. Moreover, the IUCN assessment of each of the species were considered so as to get the accurate values of the sub-theme of DBI for the *Trithemis* species sampled at the forest (Vick, 2003; IUCN, 2010).

Results

A total of 199 adult of Red-vein and Dark-vein species of *Trithemis* were collected from Akure Forest Reserve. Sixty three (63) Dark-vein and 136 were Red-vein species were sampled at the four study-sites. Only eight out of about forty extant species of *Trithemis* occurring globally were collected from the forest. The *Trithemis* species inhabiting the forest were *aenea, annulata, arteriosa, hecate*, *furva*, *grout, kirby* and *imitata.*

Trithemis hecate (Dark-vein) was the least (2) species sampled in this study followed by *T. imitat* (Red-vein). The most abundant species in this study was *T. arteriosa* and was found abundant at all the study-sites. ROD study site had the largest numbers of individuals (92) followed by ALA (48), APO (46) and AGO (13) (Table 2). Same number of species (7) were recorded in APO and ALA sites. While all the *Trithemis* species sampled at the forest were represented at ROD.

The landscape of the study-sites, the colour of the species and the number of individual species collected per site is presented in Table 3. All the species were sampled at the reaches of the rivers and streams ranging from weak to moderate flow rate.

Table 2. *Trithemis* species of Akure Forest Reserve sampled within 12 months of survey.

Taxa Encountered	AGO	ALA	APO	ROD	Total
Trithemis aenea Pinhey, 1961	0	8	3	4	15
Trithemis annulata (Palisot de Beauvoi, 1805)	0	8	9	14	31
Trithemis arteriosa (Burmeister, 1839)	7	6	13	22	48
Trithemis hecate	0	0	1	1	2
Trithemis kirby	0	11	9	16	36
Trithemis grouti Pinhey, 1961	6	7	6	11	30
Trithemis furva	0	5	5	21	31
Trithemis imitata Pinhey, 1961	0	3	0	3	6
Table	**13**	**48**	**46**	**92**	**199**

Table 3. Specific characteristics of study sites colour of species and number of individuals (*Trithemis*) sampled at the study-sites in Akure Forest Reserve.

Taxa encountered	Study-site	Number	Abundance status	Colour	Water-bodies	Landscape
Trithemis aenea Pinhey, 1961	ALA	8	C	Dark	Weak flow	Half open
Trithemis aenea Pinhey, 1961	APO	3	NC	Dark	Moderate flow	Open
Trithemis aenea Pinhey, 1961	ROD	4	NC	Dark	Moderate flow	Open
Trithemis annulata (Palisot de Beauvoi, 1805)	ALA	8	C	Red	Weak flow	Open
Trithemis annulata (Palisot de Beauvoi, 1805)	APO	9	C	Red	Weak flow	Open

Table 3 (cont'd)

Taxa Encountered	Study-site	Number	Abundance status	Colour	Water-bodies	Landscape
Trithemis annulata (Palisot de Beauvoi, 1805)	ROD	14	A	Red	Weak flow	Open
Trithemis arteriosa (Burmeister, 1839)	AGO	7	C	Red	Weak flow	Open
Trithemis arteriosa (Burmeister, 1839)	ALA	6	C	Red	Weak flow	Open
Trithemis arteriosa (Burmeister, 1839)	APO	13	A	Red	Moderate flow	Open
Trithemis arteriosa (Burmeister, 1839)	ROD	22	A	Red	Weak Moderate	Open
Trithemis hecate	APO	1	NC	Dark	Weak flow	Half open
Trithemis hecate	ROD	1	NC	Dark	Weak flow	Half open
Trithemis kirby	ALA	11	A	Red	Weak flow	Open
Trithemis kirby	APO	9	C	Red	Weak flow	Half open
Trithemis kirby	ROD	16	A	Red	Weak flow	Half open
Trithemis grouti Pinhey, 1961	AGO	6	C	Dark	Weak flow	Half open
Trithemis grouti Pinhey, 1961	ALA	7	C	Dark	Weak flow	Half open
Trithemis grouti Pinhey, 1961	APO	6	C	Dark	Moderate flow	Open
Trithemis grouti Pinhey, 1961	ROD	11	A	Dark	Moderate flow	Open
Trithemis furva	ALA	5	NC	Dark	Moderate flow	Half open
Trithemis furva	APO	5	NC	Dark	Moderate flow	Half open
Trithemisfurva	ROD	21	A	Dark	Weak flow	Open
Trithemis imitata Pinhey, 1961	ALA	3	NC	Red	Moderate flow	Open
Trithemis imitata Pinhey, 1961	ROD	3	NC	Red	Moderate flow	Open

Abbreviation A: Abundance, C: Common and NC: Not Common.

ROD and ALA had DBI score of 9 while APO and AGO had 5 and 2 respectively (Table 4). Shannon Wiener index (H') varied from 0.69 at AGO to 1.88 at ALA (Table 5). Evenness index varies from 0.77 at ROD to 0.99 at AGO while the Simpson dominance index for the 4 study sites ranged from 0.5 to 0.84. The occurrence of Red-vein and Dark-vein *Trithemis* species at Akure Forest Reserve is presented in Figure 2. The Highest number of *Trithemis* species (Dark-vein and Red-vein) was recorded for ROD while the least number was in AGO.

Table 4: Dragonfly Biotic Index for *Trithemis* species occurring at four study sites in Akure Forest Reserve.

Taxa Encountered	Study Sites			
	AGO	ALA	APO	ROD
	Dragonfly Biotic Index (DBI)			
Trithemis aenea Pinhey, 1961	-	1	1	1
Trithemis annulata (Palisot de Beauvoi, 1805)	-	1	1	1
Trithemis arteriosa (Burmeister, 1839)	1	1	1	1
Trithemis hecate	-	-	4	4
Trithemis kirby	-	0	0	0
Trithemis grouti Pinhey, 1961	1	1	1	1
Trithemis furva	-	0	0	0
Trithemis imitata Pinhey, 1961	-	1	1	1
Total DBI	**2**	**5**	**9**	**9**

Table 5: Diversity of *Trithemis* species at the four study-sites in Akure Forest Reserve.

Density Indices ROD	Study Sites			
	AGO	ALA	APO	ROD
Number of Species	2	7	7	8
Total Abundance	13	48	46	92
Simpson Dominance	0.5	0.84	0.81	0.82
Shannon H`	0.69	1.88	1.76	1.82
Evenness E	0.99	0.94	0.83	0.77
Margalef	0.39	1.55	1.57	1.58
Equitability J	0.99	0.97	0.91	0.88
Number of species	2	7	7	8

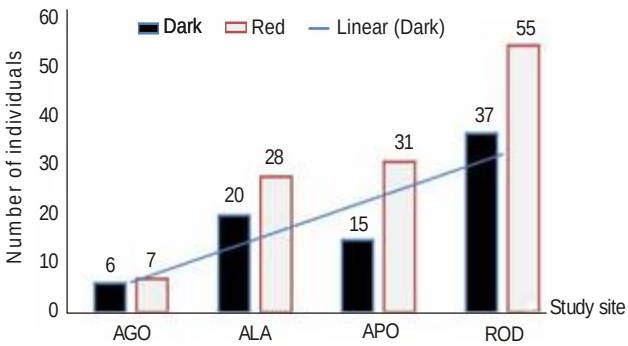

Figure 2. Occurrence of Dark-vein and Red-vein of Odonata at the four study-sites in Akure Forest Reserve.

Discussion

Trithemis species are generally endemic to Guineo-congolia forest. Akure Forest Reserve is in this forest zone therefore sampling *Trithemis* species was anticipated. Moreover, the presence of *Trithemis* spp at the sites is an evidence that the forest reserve is perturbed (Samways 2008, Damm *et al* 2010). The presence of only two *Trithemis* species at AGO is an evidence that disturbance at the site is minimal when compared with other study-sites (Table 2). The two species (*T. arteriosa* and *T. grouti*) are found to be common at the site, ecologically the best habitat for the species are still waters which include ponds (Clausnitzer *et al* 2010, Boudot *et al* 2013). However studies have shown that they can be found in all kinds of fresh-water habitat (Damm *et al* 2010 and Clausnitzer and Dijkstra 2015). Generally *Trithemis* spp. have large and presumably good dispersal capability (Damm *et al* 2010). Most *Trithemis* species prefer sluggish waters or edges of rivers or marshy land. The least occurring species, *T. hecate* is associated with reaches of slow flowing water or pool in hot areas. Sampling only one individual species of *T. hecate* at APO and ROD is an evidence that the species is localised. *Trithemis imitata* was the least sampled Red-vein species in this study. *Trithemis imitata* is very similar to *T. monardi* (synonym). Although the two species has no major widespread threat (IUCN 2010).The paucity of this species could be due to destruction of their habitat as a result of agrochemical runoff at the forest.

The high DBI value (9) shows that ROD and ALA were the least disturbed sites. Although the DBI score for AGO was the least. It cannot be concluded that the study-site is the most disturbed site since very few species of genus were sampled at the site for a whole year (12 months). Shannon-Wiener diversity index in this study varies from 0.69 in AGO (minimum) to 1.88 (maximum) in ALA. The Evenness and Equitability indices was high in all the study sites with the minimum value at ROD (0.77 and 0.88 respectively). Only two *Trithemis* species occurred at AGO study-site, this was responsible for low diversity index recorded for the site. The paucity of *Trithemis* at the site was responsible for the high Evenness and Equitability indices (0.99) recorded for the site which was also responsible for the low DBI score observed at the site. However the outcome of all the diversity indices used revealed that AGO is disturbed which is in agreement with the DBI value obtained for the study site.

According to Dash (2003), Javaid and Ashok (2013) mature and stable communities will have high Simpson dominance index value (0.6 to 0.9), while the communities under stress conditions will exhibit low diversity index which is usually close to zero values (Dash 2003). AGO had a value of 0.5 which is less than the threshold of 0.6. Thus confirming AGO to have experienced larger anthropogenic pressures and the poorest site. Alatori Stream (ALA) had the most diverse species of *Trithemis* in the forest (Simpson-Dominance = 0.84, Shannon (H‘) = 1.88, Margalef = 1.55 (Table 6). The distribution of the taxa was good, although it was not the best in the forest (Evenness (E) = 0.94). River Owena Dam (ROD) was next to ALA in term of species richness. Simpson-Dominance = 0.82, Shannon (H‘) = 1.82, Margalef = 1.55. The distribution of the taxa at the site was however the least (Evenness (E) = 0.77) (Table 2). River Aponmu (APO) was next to River Owena Dam (ROD) but the taxa were better distributed than that of ROD (APO: Simpson-Dominance = 0.81, Shannon (H‘) = 1.76, Margalef = 1.57, Evenness (E) =0.83).

Trithemis is known to be sensitive to structural habitat quality just like most other dragonflies. The openness of the habitat as a result of vegetation architecture and flow rate of the water bodies (lotic or lentic) play a major role on the biotope of this genus (Damm *et al* 2010). Most red species *Trithemis* are eurytopic (they have broad niche); they inhabit both indigenous and cultivated landscape that are opened. Thus are more abundant than the black ones.

There were some variations in the distribution of the different species of *Trithemis*. Only two *Trithemis* species inhabited Ago Store Pond (one red and dark species) which is a semi-permanent pond. *Trithemis arteriosa* was the most abundant species and was found in large numbers at the reaches of the dam (ROD). *Trithemis furva* was the scarcest species in this study. This dark *Trithemis* prefer fairly shaded and weak flowing water and was found at the reaches of the study-sites. This distributional variation may be due to the environmental requirements of the species. For instance, *Trithemis arteriosa, T. grouti* and *T. dichroa* are in abundance at reaches of the water bodies where they were sampled. This shows that the species require shallow and weak flowing water.

The presence of dead organic material at these sites was a proof that the species could thrive in eutrophic water. Generally all the four study-sites could be referred to as open, because only very few portion of the sites were fairly shaded (or half open). This openness is attributed to be the optimal habitat requirement for most members of this genus. It is also easy for them to forage and interbreed at open places.

In conclusion, most *Trithemis* species are associated with disturbed environment, especially the red species. The study investigated the degenerations occurring in some specific parts of the forest using red and dark *Trthemis* species as a monitoring tool, bearing in mind the anthropogenic activities prevailing in the forest. All the species sampled at the sites were those that have broad adaptation except *Trithemis hartwigi* (a red species).

This study has shown that the presence of *Trithemis* species in an habitat is an indication that the environment is experiencing perturbation especially the dominance of the ubiquitous type. Besides, most species of this

genus are habitat opportunistic and are usually among the first set of species of Odonata to occupy a temporary habitat.

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