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Range Forest Reserve, Bobiri Forest Reserve, Owabi Wildlife  
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## **Contribution to the knowledge of Odonata fauna of the Atewa Range Forest Reserve, Bobiri Forest Reserve, Owabi Wildlife Sanctuary and Ankasa Forest Reserve (southern Ghana)**

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### **Abstract**

Using a qualitative sampling approach to survey for Odonata along water systems inside and outside of four major protected areas in Southern Ghana (viz; Atewa Range Forest Reserve, Ankasa Forest Reserve, Owabi Wildlife Sanctuary and Bobiri Forest Reserve), a total of 66 Odonata species in seven families encompassing 28 Zygoptera and 38 Anisoptera were recorded. Libellulidae (n= 36) exhibited the highest number of species, followed by Coenagrionidae (n= 10), and Calopterygidae (n= 5). In considering the observed number of species exhibited by each protected area, the Atewa Range Forest Reserve exhibited the highest number of species (n= 51), followed by the Ankasa Forest Reserve (n= 47), the Owabi Wildlife Sanctuary (n= 44) and Bobiri Forest Reserve (n= 43). Disturbance tolerance species dominated in habitats outside the various forest reserves, while forest specialists predominated inside the reserves, indicating the quality of the forest cover therein.

**Key words:** Odonata, Southern Ghana, Water systems, Ponds, Riverine, forest degrading, species turnover, efficiency of protection regimes, importance of closed canopy, specialist and opportunistic taxa

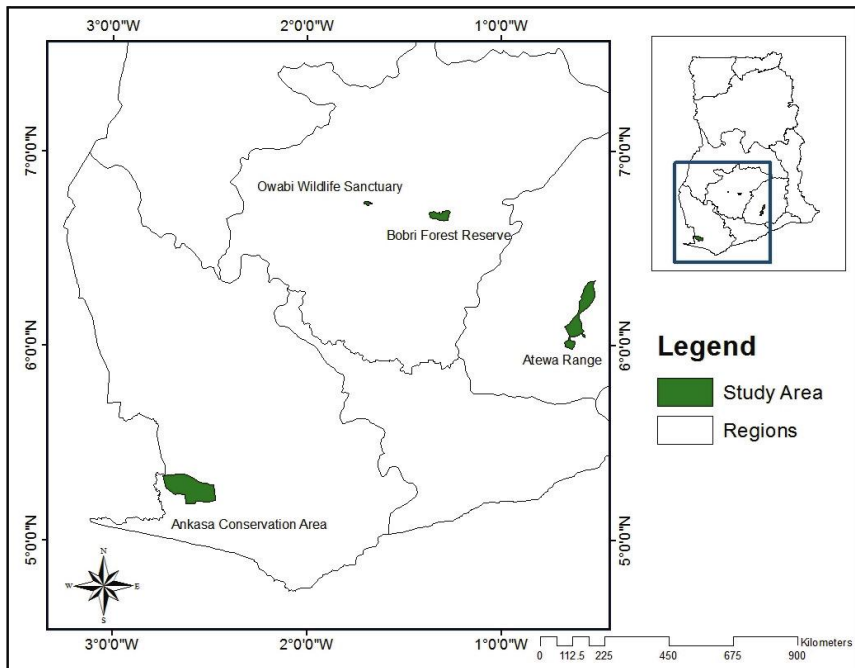
### **Introduction**

In Ghana, the Odonata fauna is poorly known and its distribution and species assemblages are relatively unknown. So far, 177 Odonata species have been recorded (Neville 1960; Pinhey 1962; Frempong & Nijjhar 1973; Marshall & Gambles, 1977; D'Andrea & Carfi 1994; O'Neill 1999; O'Neill & Paulson 2001; Dijkstra 2007), although the Odonata fauna of Ghana is estimated to be 226 species (Dijkstra & Clausnitzer 2006).

Regional studies demonstrate high species diversity in Ghana. For example, Dijkstra (2007), recorded in the Atewa Range Forest Reserve 72 Odonata species in streams, rivers and its associated standing water bodies that run through the reserve. Acquah-

Lamptey et al. (2013) recorded 47 Odonata species in and outside the Atewa Range Forest Reserve. Seidu et al. (2017, 2018) recorded 53 and 51 Odonata species in various rivers and streams that drain through the Atewa Range Forest Reserve and the East Akim Districts respectively. In the Owabi Wildlife Sanctuary, Bemah (2019) recorded 25 Odonata species consisting of 12 damselflies and 13 dragonflies. Further, Seidu et al. (2019) recorded 47 Odonata species encompassing 22 dragonflies and 25 damselflies in streams, rivers and ponds located inside and outside the Ankasa Conservation Area.

Our focus study areas, the Atewa Range Forest Reserve, Bobiri Forest Reserve, Owabi Wildlife Sanctuary and the Ankasa Forest Reserve are home to many West African endemic and threatened species of wildlife including mammals, butterflies and odonates. Some West African endemic Odonata species mostly recorded in these Forest Reserves includes, *Sapho ciliata* (Fabricius, 1781), *Chlorocypha selysi* (Karsch, 1899), *C. luminosa* (Karsch, 1893), *Phaon camerunensis* Sjöstedt, 1900 amongst others. In the framework of the National Biodiversity Strategy for Ghana, the Atewa Range forest and the Ankasa forest reserves are designated as Globally Significant Biodiversity Area (GSBA) and Important Bird Areas (IBA) (Abu-Juam et al. 2003). These reserves are important sources for major freshwater ecosystems both lotic and lentic systems in Ghana which support odonates and other freshwater invertebrates. They also serve as headwaters for major rivers in Ghana including Ayensu, Ankasa, Birim, Wankobi, Adensu and



**Figure 1. Map of the study areas showing the Atewa Range Forest Reserve, Ankasa Forest Reserve, Bobiri Forest Reserve and Owabi Wildlife Sanctuary in Southern Ghana.**

Densu Rivers amongst others. These freshwaters are the main sources of water for domestic, industrial and agriculture irrigation to the fringing rural communities as well as other urban and peri-urban communities. However, the reserves are under intense pressure from ongoing anthropogenic disturbances stemming chiefly from riparian deforestation, illegal logging, agriculture expansion, human settlement encroachment and small scale mining activities. These disturbances are degrading and threatening the adjacent freshwater ecosystems which harbour diverse odonates and other threatened sympatric freshwater invertebrate. Given the unprecedented rates of freshwater degradation, it is feared many species of odonates are likely to be exterminated totally before they have the chance to be discovered or described. It is against this background that this study aims to comprehensively survey for adult Odonata in freshwater habitats that have previously not been surveyed and also provide up-to-date comprehensive checklist of Odonata species on freshwater habitats located inside and outside these aforementioned forest reserves in Southern Ghana.

## **Material and Methods**

### **Study areas**

The study was conducted in water systems inside and outside the Atewa Range Forest Reserve, Ankasa Forest Reserve, Owabi Wildlife Sanctuary and Bobiri Forest Reserve, located in Southern Ghana (Figure 1 and Table 7).

#### **Atewa Range Forest Reserve (ARFR)**

The study was conducted along three rivers (i.e., Birim, Adensu and Supon Rivers) and four other streams that drain through the Atewa Range Forest Reserve (ARFR). ARFR is a combination of two major forest reserves viz, the Atewa Range Extension reserves and the Atewa Range. Altogether, the ARFR lies between latitude 5°58' to 6°20' North and longitudes 0°31' to 0°41' West. The total land area of the Atewa Range is 23,662 ha which is located within the East Akyem District Assembly of Begoro Forest District whilst the Atewa Range Extension has an area of 26,312 ha falling within West Akyem District Assembly under Kade Forest District. The mean annual precipitation is between 1200 mm and 1800 mm. The ARFR is characterized by two peak rainy season- April – June and October. The dry season falls in November to March. The ARFR covers about 75% of the Upland Evergreen Forest type (Hall & Swaine, 1976) in Ghana due to its isolated hilly nature of elevation between 200 m – 750 m. The hilly nature of the range has contributed to its enormous streams and high levels of species richness. Outside the reserve is characterized by various anthropogenic disturbance regimes including human settlement development, mining activities, agricultural cultivation and riparian deforestation. These activities are occurring almost adjacent to the major Rivers and streams that drain through the reserve.

#### **Ankasa Forest Reserve (AFR)**

The survey was conducted in two major rivers (Ankasa and Bowere Rivers), two streams and 10 ponds located in the Ankasa Conservation Area (5°17' N and 2°39' W). ACA is



**Figure 2.** Photo of representative sampling site of the Ankasa River in the Ankasa Forest Reserve (Photograph: Razak Antwi). *Sapho ciliata* and *Phaon camerunensis* typified Odonata species of this sampling site.



**Figure 3.** Photo of representative sampling site (a pond outside the Ankasa Forest Reserve) (Photograph: Martin Kusi). *Palpopleura lucia* and *P. portia* are typical odonate species recorded at this habitat type.



a twin Protected Area comprising Nini-Suhien National Park and the Ankasa Resource Reserve. It is about 500 km<sup>2</sup> situated in the Western Region of Ghana, and the only area in the Wet Evergreen Forest (Hall & Swaine 1976). AFR is designated as a Globally Significant Biodiversity Area (GSBA) and Important Bird Area (IBA) (Dowsett-Lemaire & Dowsett 2011). AFR presents an ideal ecosystems for this study as it boast of a significant number of complex and diverse freshwater systems including riverine, streams, swamps, pools, ponds, amongst others located outside and inside the reserve. The waterways situated outside the reserve are mostly subjected to diverse human-induced threats with rubber plantation predominating the entire stretches of the ponds and streams. These wetlands and their associated forest environment support the most biological diversity of any in Ghana. The climate of the area is characterized by a distinctive bi-modal rainfall pattern occurring from April to July and September to November, with average annual rainfall of 1700 to 2000 mm (Dowsett-Lemaire & Dowsett 2011).

### Owabi Wildlife Sanctuary (OWS)

Owabi Wildlife Sanctuary is located between latitudes 6° 47' 3.32" -- 6° 41' 52.31" N and longitudes 1° 44' 0.81" – 1° 37' 53.04" W of Kumasi in Ashanti region. It is one of the smallest wildlife sanctuaries in Ghana (National Wetlands Conservation Strategy, 1999). The sampling for Odonata was done in two major Rivers (Owabi and Sukobri River) and five streams that drain into the Owabi Dam. Main rivers are the Owabi, Sukobri, Akyeampomene, Pumpunase and Afu Rivers, which drains to the catchment flows through agricultural lands close to the village of Maase, upstream of Kumasi (McGregor et



**Figure 4.** Photo of a representative sampling site (Owabi dam outside the Owabi Wildlife Sanctuary) (Photograph: Razak Antwi). *Pseudagrion melanicterum* and *Orthetrum julia* are typical odonate species for this sampling site.

al. 2002). The reserve is 13 km<sup>2</sup> in size, and lies approximately 23 km northwest of Kumasi. It has an inner Sanctuary of about 7 km, which surrounds a lake, formed by the damming of the Owabi River in 1928. It is also the only inland Ramsar Site in Ghana. The reservoir is designed to produce 20% of the total potable water requirement in the Kumasi metropolis and nearby villages (Akoto et al. 2008).

### **Bobiri Forest Reserve (BFR)**

The Bobiri Forest Reserve lies on latitude 06° 40'N to 6° 44'N and longitude 01°15'W to 01°22'W. Survey for Odonata occurred in the Bobiri River, three other streams and five small ponds located inside and outside the reserve. The site falls within the moist semi-deciduous forest ecological zone, which is the most extensive closed canopy forest type in Ghana. The Reserve is home to many plants and animal species. About 400 species of tropical butterflies have been identified in this site, making this reserve the only butterfly sanctuary in Ghana and West Africa. It is known for its 2.4-hectare botanical arboretum with over 150 species of tropical forest trees and therefore serves as an ecotourism center for promoting nature conservation. Outside the reserve is a series of anthropogenic activities including logging and agricultural activities adjacent to the waterways.

## **Methods**

### **Odonates sampling protocols**

We sampled adult individuals of all Odonata in a total of 37 different lotic and lentic systems (Rivers, Streams and Ponds) located inside and outside the Atewa Forest Reserve, Ankasa Forest Reserve, Owabi Wildlife Sanctuary and Bobiri Forest Reserve (Figure 1). A total of 87 sampling locations situated outside and inside of the various protected areas were surveyed (Table 7). In the ARFR, a total of 30 sampling locations of which 17 and 13 were situated outside and inside the reserve respectively. We surveyed 23 sampling locations (16 outside and 7 inside) in the AFR. We further sampled 22 sampling sites (13 outside and 9 inside) along the water systems at the OWS. At the BFR, 12 sampling locations (7 outside and 5 inside) were surveyed for Odonata. Sampling was done from April, 2017 to April, 2019 in both wet and dry seasons. We sampled all adult odonates during the day between the hours of 9 am and 5 pm. We adopted the qualitative sampling approach to survey for all Odonata species in each sampling location. Two researchers sampled simultaneously, collecting and noting the species occurring until no new species were encountered for approximately one hour in each location. We captured adult odonate individuals where possible, using a hand net. We identified each specimen to species level in situ, using Dijkstra & Clausnitzer (2014) identification keys. We photographed all species where identification was not possible on the field and then used the African Dragonflies and Damselflies Online database (ADDO) (ADDO, 2017) for subsequent identification and for classifying the Odonata species into lotic and lentic systems.

All tables are presented in the appendix section of this paper.



## Results and Discussion

A total of 66 Odonata species in seven families encompassing 28 Zygoptera and 38 Anisoptera were recorded in all freshwater habitats inside and outside the four protected areas (Table 1 and 2). Libellulidae (n= 36) exhibited the highest number of species, followed by family Coenagrionidae (n= 10), and Calopterygidae (n= 5). The highest number of species exhibited by Libellulidae results from high preponderance anthropogenic activities occurring outside these protected areas (Seidu et al. 2017). All the three study areas have been subjected to some degree of anthropogenic activities which include human settlement encroachment, mining activities, agricultural cultivation and riparian deforestation especially at the downstream of the various waterways located outside the reserves. These degradations led to the reduction in canopy cover which creates more favourable thermal microhabitat for opportunistic or disturbance tolerant dragonflies especially members of the Libellulidae family (Seidu et al. 2018). Furthermore, there is a general consensus that when a habitat is subjected to disturbance, it may be colonized by vagrant and opportunistic species like the Libellulidae which can tolerate the disturbed landscape, while rendering the habitat unsuitable for the native community and contribute to turnover in the entire Odonata community assemblages (Dijkstra & Lempert 2003). These may have contributed to the increasing number of species belonging to Libellulidae families and hence resulting in the turnover of Odonata assemblages outside these protected areas. This finding corroborate with other studies that found higher number of species belonging to Libellulidae family (Seidu et al. 2017 and 2019).

Further, it was not uncommon for Coenagrionidae to exhibit the second highest number of species. Most species in the Coenagrionidae family such as *Pseudagrion* spp. and some *Ceriagrion* spp. are widespread and widely distributed species which can inhabit in all forms of habitat both open and closed canopy. Also, species of the Coenagrionidae family inhabit diverse water systems and are favoured in various microhabitats including pools, marshy patches, puddles, dense and open edge of rain pools (Dijkstra & Clausnitzer 2014). This explains partly why most species from the Coenagrionidae were recorded in both inside and outside of these protected areas which were characterised by various microhabitats conditions. Species of the Calopterygidae and Chlorocyphidae families are highly favoured in fast flowing waters with dense canopy cover. It is therefore not surprising to record high number of these species inside the four protected areas which were characterised by both fast flowing lotic systems and closed canopy cover. However, some species especially of the Chlorocyphidae (e.g. *Chlorocypha curta* (Hagen in Selys, 1853)) despite liking some cover may prefer to inhabit open rivers and seasonal streams. Most damselflies belonging to Calopterygidae and the Platycnemididae have been classified as perchers in nature, which utilized the vegetation structure as perching substrate (Corbet & May 2008). The perchers most invariably oviposit endophytically and require vegetated oviposition substrates to carry out their reproduction activities (Corbet & May 2008). Their reproductive requirements coupled with their generally degree of specialization explain partly why most species belonging to these family were encountered mostly in the lotic systems inside and at the forest margin of these protected areas, which were characterised by both dense and partial vegetation cover.

Lestidae and Aeshnidae represented by one and two species respectively exhibited the least recorded families. Our sampling activities were carried out only in the day time where most adult Odonata were active and this may have resulted in the least number of Aeshnidae species being encountered. Members belonging to the Aeshnidae family as *Gynacantha* spp. are favoured and easily recognized during sunset, dawn, dusk and especially during rainy periods which were not taken into account during our sampling expedition. Further, our sampling approach only focused on adult Odonata and did not take into consideration other life stages including larvae and teneral of odonates. Members belonging to the Gomphidae family inhabit rivers and streams, where adults can be elusive and furtive, and larvae are easier to find (Dijkstra & Clausnitzer 2014). Our sampling approach targeting only adult stage Odonata may have contributed to the missing of elusive and crepuscular species like members of the Gomphidae and Macromiidae family. We therefore recommend future studies to focus on sampling both adults and larvae stages of odonates in Southern Ghana and other areas as well. Only that can aid in detecting elusive and crepuscular species and providing a full checklist of odonates present.

In considering the observed number of species exhibited by each protected area, the ARFR exhibited the highest number of species ( $n= 51$ ), followed by the AFR ( $n= 46$ ), the OWS ( $n= 44$ ) and BFR ( $n= 43$ ) (Table 1 and 2). Of the 51 species recorded in the ARFR, 20 species belong to the Zygoptera (nine inside and 13 outside reserve), while 31 belong to the Anisoptera (eight inside and 29 outside reserve), which was substantially lower than the 72 species that have been recorded previously inside and outside the ARFR (Dijkstra 2007). The lower number of species recorded in the ARFR in the current study may be attributed to the on-going level of anthropogenic disturbances reposed on the formerly known pristine forest habitats and its surroundings. In 2007, there were little human disturbances surrounding the ARFR and this resulted in a healthy watershed, with limited pollution and streambed erosion (Dijkstra, 2007). Dijkstra (2007) stated that if the forest cover and the natural stream morphology are retained, the present dragonfly fauna is expected to persist. However, currently the downstream of most rivers including the Birim, Supon and Adensu Rivers which were previously not degraded have all been subjected to intensive anthropogenic disturbances resulting chiefly from small scale mining and agricultural activities which have completely removed the forest cover, favouring certain opportunistic species only. Furthermore, Dijkstra (2007) sampled both adult and larvae Odonata in all the major rivers inside and outside the Reserve including Densu, Birim and Ayensu Rivers and may have led to the record of higher number of lotic species including secretive gomphids and macromiids which was not the case in this study.

Inside the ARFR, species belonging to the Calopterygidae and Chlorocyphidae such as *Umma cincta* (Hagen in Selys, 1853), *Chlorocypha luminosa*, *Sapho ciliata* amongst others dominated habitat therein (Table 4). The dominance of these species inside the reserve is an indication of the quality of the forest habitat, as species of these families prefer closed canopy cover with fast flowing water bodies. On the other hand, outside the reserves was the dominance of the *Ceriagrion*, *Pseudagrion* and *Africallagma* species (Table 4). Members of *Ceriagrion* and *Africallagma* favour open and mostly

stagnant habitats while the *Pseudagrion* species inhabit diverse habitats both open and closed canopy as well as stagnant and lotic systems. The small scale mining regimes outside the reserve created open stagnant drains and this combined with other habitats such as patches of gallery forest created heterogeneous habitat for the colonization of these species with diverse habitat requirements. The *Orthetrum* members are common and conspicuous at freshwater habitats, especially when these are open and this may explain why high number of species belonging to the *Orthetrum* genus was recorded outside the reserve.

A total of 25 species belonging to the Anisoptera (15 inside and 19 outside reserve) and 22 Zygoptera (18 inside and five outside reserve) were also recorded in the AFR. We observed similar pattern of association, in the AFR where Calopterygidae, Chlorocyphidae, and Platycnemididae were mostly found in lotic systems, while Libellulidae and Coenagrionidae were found in both lentic and lotic systems but showed strong affinity to lentic systems (ponds). In the BFR, 24 anisopterans (11 inside and 19 outside reserve) and 19 zygopterans (eight inside and 13 outside) were recorded. Several pond-associated species, such as the *Ceriagrion* spp., *Acisoma inflatum* (Selys, 1871), *Chalcostephia flavifrons* Kirby, 1889, *Olpogastra lugubris* (Karsch, 1895), *Trithemis arteriosa* (Burmeister, 1839), *Palpopleura lucia* (Drury, 1773), and *P. portia* (Drury, 1773) have been classified as stagnant water tolerance species which were mostly found in open habitats (Seidu et al., 2017; African Dragonflies and Damselflies Online (<http://addo.adu.org.za>)) which follow similar pattern in habitats outside the AFR and the BFR.

In the Owabi Wildlife Sanctuary, 26 species belonging to the Anisoptera (14 inside and 11 outside reserve) and 18 Zygopteran (seven inside and 13 outside reserve) were recorded, which was higher than the 25 Odonata species recorded previously (Bemah, 2019). The higher number of species recorded in the OWS in this study may be attributed to the higher number of waterways surveyed. In this current study, we sampled the Owabi and Sukobri River and other streams interspersed inside and outside the reserve which may have increase our chances of recording high number of Odonata species. However, Bemah (2019) sampled only the Owabi River and recorded *Pseudagrion glaucum* (Sjöstedt, 1900), *Africallagma vaginale* (Sjöstedt, 1917), *Agriocnemis maclachlani* Selys, 1877, *Orthetrum chrysostigma* (Burmeister, 1839) and *Hemistigma albipunctum* (Rambur, 1842) which were not detected in this study. On the other hand, other dragonflies including *Micromacromia zygoptera* (Ris, 1909), *Orthetrum abboti* Calvert, 1892, *Rhythemis notata* (Fabricius, 1787) amongst others and all species belonging to the Chlorocyphidae and Calopterygidae with the exception of *Phaon iridipennis* (Burmeister, 1839) recorded in this study were also not detected by Bemah (2019) (Table 5).

In general, the number of opportunistic Anisoptera species was higher in all the habitats outside the four protected areas, which was characterised by different anthropogenic regimes. Further, damselflies mostly belonging to the Calopterygidae and Chlorocyphidae predominated inside the various reserves, which indicate the quality of the forest cover and lotic systems still retained therein. It is therefore imperative for water managers and conservationists to gear their conservation efforts towards protecting the forest cover and waterways running through the four protected areas to continue protecting these forest dwellers Odonata species and other freshwater biodiversity.



Figure 5. *Palpopleura portia* photographed at the Owabi Wildlife Sanctuary, Ghana. They were abundant in open habitats outside the four protected areas. (photograph: Issah Seidu).



Figure 6: *Acisoma inflatum* photographed along a pond outside the Ankasa Conservation Area. They were abundant almost in habitat outside the four protected areas (Photograph: Issah Seidu).



Figure 7: *Ceriagrion glabrum* recorded and photographed outside the Bobiri Forest Reserve. (Photograph: Martin Kusi).



Figure 8: *Orthetrum chryostigma* cf. photographed in the Atewa Range Forest Reserve. (Photograph: Issah Seidu).



Figure 9: *Chlorocypha curta* photographed outside the Atewa Range Forest Reserve (Photograph: Martin Kusi).



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## Appendix

**Table 1. Checklist of Zygoptera (damselflies) species recorded in streams, rivers, and ponds in the Southern Ghana. Species that occurred exclusively in streams are represented by (\*), exclusively in rivers (#), and exclusively in ponds (!). Species shared between streams and rivers are represented by (\* #), between streams and ponds (\* !), and between rivers and ponds (# !)**

Family	Zygoptera	Ankasa		Afewa		Owabi		Bobiri	
		Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Calopterygidae	<i>Phaon camerunensis</i> Sjöstedt, 1900*	1	0	1	0	0	0	1	0
	<i>Phaon iridipennis</i> (Burmeister, 1839) #	1	0	1	0	1	0	1	0
	<i>Sapho bicolor</i> Selys, 1853*	1	0	0	0	0	0	0	0
	<i>Sapho ciliata</i> (Fabricius, 1781) #	1	0	1	0	1	0	0	0
	<i>Umma cincta</i> (Hagen in Selys, 1853)*	1	0	1	0	1	0	0	0
Chlorocyphidae	<i>Chlorocypha curta</i> (Hagen in Selys, 1853) #	0	0	0	1	0	1	0	1
	<i>Chlorocypha luminosa</i> (Karsch, 1893) #	1	0	1	0	1	0	1	0
	<i>Chlorocypha radix</i> Longfield, 1959* #	1	0	1	1	0	0	0	0
	<i>Chlorocypha selysi</i> Karsch, 1899* #	1	0	1	0	0	0	1	0
	<i>Lestes dissimulans</i> Fraser, 1955*	0	0	1	0	1	0	1	0
Coenagrionidae	<i>Africallagma vaginale</i> (Sjöstedt, 1917) #	0	0	0	1	0	0	0	0
	<i>Africallagma glaucum</i> (Burmeister, 1839) #	0	0	0	1	0	0	0	1
	<i>Agriocnemis</i> sp. #	0	0	0	1	0	0	0	0
	<i>Agriocnemis exilis</i> Selys, 1872!	0	1	0	0	0	1	0	1
	<i>Agriocnemis zerafica</i> Le Roi, 1915!	0	1	0	0	0	1	0	1
	<i>Ceragrion corallinum</i> Campion, 1914*!	1	1	0	1	0	0	0	1
	<i>Ceragrion glabrum</i> (Burmeister, 1839)!	0	1	0	1	0	1	0	1
	<i>Ceragrion rubelloccerum</i> Fraser, 1947* #	1	0	0	1	0	1	1	1
	<i>Pseudagrion hamoni</i> Fraser, 1955* #	1	0	0	1	0	1	1	0
	<i>Pseudagrion isidromorai</i> Sart, 1967* #	1	0	0	1	0	1	0	0
	<i>Pseudagrion kesteni</i> (Gerstaecker, 1869)*	1	0	0	0	0	1	0	1
	<i>Pseudagrion melanicterum</i> Selys, 1876* #	1	1	1	1	1	1	1	1
	<i>Pseudagrion sjostedti</i> Förster, 1906#	1	0	0	0	0	1	0	0
	<i>Allocnemis</i> sp.	0	0	0	1	0	1	0	0
	<i>Elatoneura nigra</i> Kimmins, 1938#	0	0	0	1	1	1	0	1
	<i>Mesocnemis singularis</i> Karsch, 1891#	1	0	0	0	0	0	0	1
	<i>Elatoneura balli</i> Kimmins, 1938* #	1	0	0	0	0	0	0	1
	<i>Elatoneura villersi</i> (Fraser, 1948)* #	1	0	0	0	0	1	0	1

**Table 2a. Checklist of Anisoptera (dragonflies) species recorded in streams, rivers, and ponds in the Southern Ghana. Species that occurred exclusively in streams are represented by (\*), exclusively in rivers (#), and exclusively in ponds (!). Species shared between streams and rivers are represented by (\* #), between streams and ponds (\* !), and between rivers and ponds (# !)**

Family	Anisoptera	Ankasa		Atewa		Owabi		Bobiri	
		Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Aeshnidae	<i>Gynacantha bullata</i> Karsch, 1891*	1	0	1	0	1	0	1	0
	<i>Gynacantha cymatara</i> Karsch, 1891*	1	0	0	0	1	0	1	0
Libellulidae	<i>Acisoma inflatum</i> Selys, 1882!	0	1	0	0	1	0	1	0
	<i>Aethriamanta reza</i> Kirby, 1889!	0	1	0	0	1	0	1	0
	<i>Brachythemis lacustris</i> (Kirby, 1889) #	0	0	0	0	0	0	1	0
	<i>Brachythemis leucosticta</i> (Burmeister, 1839) #	0	0	0	0	1	0	1	1
	<i>Chalcostephia flavifrons</i> Kirby, 1889!	0	1	0	0	1	0	1	0
	<i>Cyanothemis simpsoni</i> Ris, 1915#	1	0	0	0	1	0	1	1
	<i>Diplacodes lefebvrei</i> (Rambur, 1842) #	0	0	0	0	1	0	1	0
	<i>Diplacodes luminans</i> (Karsch, 1893) #	0	0	0	0	1	0	0	0
	<i>Eufthemis bueffikeri</i> Ris, 1910#	1	0	0	0	1	0	1	1
	<i>Neodythemis klingi</i> (Karsch, 1890)*	1	0	1	1	1	1	1	1
	<i>Micromacromia zygoptera</i> (Ris, 1909)*	1	0	1	0	1	0	1	0
	<i>Olpogastira lugubris</i> (Karsch, 1895) #!	1	1	0	1	0	1	0	1
	<i>Ortheum abbotii</i> Calvert, 1892#	0	0	0	0	1	1	1	0
	<i>Ortheum africanum</i> (Selys, 1887)*	0	0	0	0	1	0	0	0
	<i>Ortheum angustiventre</i> (Rambur, 1842) #	0	0	0	0	1	0	0	0
	<i>Ortheum austrii</i> (Kirby, 1900)!	0	1	0	1	1	1	1	0
	<i>Ortheum chrysosigma</i> (Burmeister, 1839) #	0	0	1	1	1	0	0	0
	<i>Ortheum guineense</i> Ris, 1909#	0	0	0	0	1	0	0	0
	<i>Ortheum icteromelas</i> Ris, 1910#	0	0	0	0	1	0	0	0
	<i>Ortheum julia</i> Kirby, 1900!	1	1	1	1	1	1	1	1
	<i>Ortheum microsigma</i> Ris, 1911!	0	1	0	1	0	0	1	1
	<i>Ortheum monardi</i> Schmidt, 1951 #	0	0	0	0	1	0	0	0
	<i>Ortheum sternmale</i> (Burmeister, 1839)*!	1	1	1	1	1	0	0	1
	<i>Ortheum timacra</i> (Selys, 1841)!	0	1	0	1	0	0	0	0
	<i>Ortheum sp</i>	0	0	1	1	0	0	0	0
	<i>Palpopleuralucia</i> (Drury, 1773)!	1	0	1	0	1	0	1	0
	<i>Palpopleura porfiria</i> (Drury, 1773)!	0	1	0	1	0	1	0	1
	<i>Pantala flavescens</i> (Fabricius, 1798)!	0	1	0	1	0	1	0	1
	<i>Rhyothemis notata</i> (Fabricius, 1781) #!	1	1	0	0	0	0	1	0
	<i>Rhyothemis semihyalina</i> (Desgöarins, 1832)!	0	1	0	1	0	0	0	0

**Table 2b. Checklist of Anisoptera (dragonflies) species recorded in streams, rivers, and ponds in the Southern Ghana. Species that occurred exclusively in streams are represented by (\*), exclusively in rivers (#), and exclusively in ponds (!). Species shared between streams and rivers are represented by (\* #), between streams and ponds (\* !), and between rivers and ponds (# !)**

Family	Anisoptera		Ankasa		Akwewa		Owabi		Bobiri	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
			1	1	1	1	1	1	1	1
<i>Trithemis aconita</i> Liefinck, 1969*										
<i>Trithemis artemesia</i> (Burmeister, 1839) (#)			1	1	1	1	1	1	1	1
<i>Trithemis bifida</i> Pinhey, 1970 (#)			1	1	0	0	0	0	0	0
<i>Trithemis dichroa</i> Karsch, 1893 (#)			1	1	0	0	1	1	1	1
<i>Trithemis grouffii</i> Pinhey, 1961 #			0	0	0	0	1	0	0	0
<i>Urothemis edwardsii</i> (Selys, 1849) (#)			1	1	1	0	0	0	0	0
<b>Total number of Anisoptera</b>			<b>15</b>	<b>19</b>	<b>29</b>	<b>21</b>	<b>21</b>	<b>21</b>	<b>21</b>	<b>21</b>

**Table 3. Checklist of Odonata species recorded inside and outside the Ankasa Forest Reserve.**

	Zygoptera inside forest	Zygoptera outside	Anisoptera inside	Anisoptera outside
	<i>Phaon carneimensis</i>	<i>Agriocnemis exilis</i>	<i>Gynacantha cylindrata</i>	<i>Acisoma inflatum</i>
	<i>Phaon litabpennis</i>	<i>Agriocnemis zeraffica</i>	<i>Gynacantha bullata</i>	<i>Aethriamanta reza</i>
	<i>Sapho bicolor</i>	<i>Ceragrion corallinum</i>	<i>Cyanothemis simpsoni</i>	<i>Chalcostephia flavifrons</i>
	<i>Sapho ciliata</i>	<i>Ceragrion glabrum</i>	<i>Eleuthemis buettikoferi</i>	<i>Olpogastrea lugubris</i>
	<i>Umma cincta</i>	<i>Pseudagrion melanicterum</i>	<i>Neodythemis kilingi</i>	<i>Orthemium austeni</i>
	<i>Chlorocypha luminosa</i>		<i>Micromacromia zygoptera</i>	<i>Orthemium julia</i>
	<i>Chlorocypha radix</i>		<i>Olpogastrea lugubris</i>	<i>Orthemium microstigma</i>
	<i>Chlorocypha selysi</i>		<i>Orthemium julia</i>	<i>Orthemium stemmale</i>
	<i>Ceragrion corallinum</i>		<i>Orthemium stemmale</i>	<i>Orthemium tinacata</i>
	<i>Ceragrion rubellocerium</i>		<i>Rhyothemis notata</i>	<i>Palpopleura lucia</i>
	<i>Pseudagrion hamoni</i>		<i>Trithemis aconita</i>	<i>Palpopleura porifera</i>
	<i>Pseudagrion sjoestedti</i>		<i>Trithemis artemesia</i>	<i>Pantala flavescens</i>
	<i>Pseudagrion kersteni</i>		<i>Trithemis dichroa</i>	<i>Rhyothemis notata</i>
	<i>Pseudagrion melanicterum</i>		<i>Trithemis bifida</i>	<i>Rhyothemis semihyalina</i>
	<i>Pseudagrion isidromorai</i>		<i>Urothemis edwardsii</i>	<i>Trithemis aconita</i>
	<i>Mesocnemis singularis</i>			<i>Trithemis artemesia</i>
	<i>Elattoneura villersi</i>			<i>Trithemis dichroa</i>
	<i>Elattoneura balli</i>			<i>Trithemis bifida</i>
				<i>Urothemis edwardsii</i>



**Table 4. Checklist of Odonata species recorded inside and outside the Atewa Range Forest Reserve.**

Zygoptera inside	Zygoptera outside	Anisoptera inside	Anisoptera outside
<i>Phaon camerunensis</i>	<i>Chlorocypha curta</i>	<i>Gynacantha bullata</i>	<i>Acisoma inflatum</i>
<i>Phaon iridipennis</i>	<i>Chlorocypha radix</i>	<i>Neodythemis klingi</i>	<i>Aethriamanta rezia</i>
<i>Sapho ciliata</i>	<i>Africallagma vaginale</i>	<i>Micromacromia zygoptera</i>	<i>Brachythemis lacustris</i>
<i>Umma cincta</i>	<i>Africallagma glaucum</i>	<i>Orthetrum chryso stigma</i>	<i>Brachythemis leucosticta</i>
<i>Chlorocypha luminosa</i>	<i>Agriocnemis</i> sp.	<i>Orthetrum julia</i>	<i>Chalcostephia flavifrons</i>
<i>Chlorocypha radix</i>	<i>Ceragrion corallinum</i>	<i>Trithemis aconita</i>	<i>Diplacodes luminans</i>
<i>Chlorocypha selysi</i>	<i>Ceragrion glabrum</i>	<i>Orthetrum</i> sp	<i>Diplacodes lefebvreii</i>
<i>Lestes dissimulans</i>	<i>Ceragrion rubelloцерinum</i>	<i>Orthetrum stemmale</i>	<i>Neodythemis klingi</i>
<i>Pseudagrion melanicterum</i>	<i>Pseudagrion isidromorai</i>		<i>Olpogastra lugubris</i>
	<i>Pseudagrion hamoni</i>		<i>Orthetrum abbotfi</i>
	<i>Pseudagrion melanicterum</i>		<i>Orthetrum africanum</i>
	<i>Alloenemis</i> sp.		<i>Orthetrum angustiventre</i>
	<i>Elatoneura nigra</i>		<i>Orthetrum austeni</i>
			<i>Orthetrum chryso stigma</i>
			<i>Orthetrum guineense</i>
			<i>Orthetrum icteromelas</i>
			<i>Orthetrum julia</i>
			<i>Orthetrum micro stigma</i>
			<i>Orthetrum monardi</i>
			<i>Orthetrum stemmale</i>
			<i>Orthetrum trinacia</i>
			<i>Orthetrum</i> sp.
			<i>Palpopleura lucia</i>
			<i>Palpopleura portia</i>
			<i>Pantala flavescens</i>
			<i>Rhyothemis semihyalina</i>
			<i>Trithemis aconita</i>
			<i>Trithemis arteriosa</i>
			<i>Trithemis grouti</i>

**Table 5. Checklist of Odonata species recorded inside and outside the Owabi Wildlife Sanctuary.**

Zygoptera inside	Zygoptera outside	Anisoptera inside	Anisoptera outside
<i>Phaon iridipennis</i>	<i>Elatoneura villiersi</i>	<i>Gynacantha bullata</i>	<i>Trithemis dichroa</i>
<i>Sapho ciliata</i>	<i>Elatoneura nigra</i>	<i>Gynacantha cylindrata</i>	<i>Trithemis arteriosa</i>
<i>Umma cincta</i>	<i>Alloenemis</i> sp	<i>Cyanothemis simpsoni</i>	<i>Trithemis aconita</i>
<i>Chlorocypha luminosa</i>	<i>Pseudagrion melanicterum</i>	<i>Diplacodes luminans</i>	<i>Rhyothemis notata</i>
<i>Lestes dissimulans</i>	<i>Pseudagrion isidromorai</i>	<i>Eleuthemis buettikoferi</i>	<i>Pantala flavescens</i>
<i>Pseudagrion melanicterum</i>	<i>Ceragrion rubelloцерinum</i>	<i>Neodythemis klingi</i>	<i>Palpopleura portia</i>
<i>Elatoneura nigra</i>	<i>Ceragrion glabrum</i>	<i>Micromacromia zygoptera</i>	<i>Palpopleura lucia</i>
	<i>Agriocnemis zerafica</i>	<i>Orthetrum abbotfi</i>	<i>Orthetrum julia</i>
	<i>Agriocnemis exilis</i>	<i>Orthetrum angustiventre</i>	<i>Orthetrum austeni</i>
	<i>Chlorocypha curta</i>	<i>Orthetrum austeni</i>	<i>Orthetrum abbotfi</i>
	<i>Pseudagrion hamoni</i>	<i>Orthetrum julia</i>	<i>Olpogastra lugubris</i>
	<i>Pseudagrion kersteni</i>	<i>Orthetrum stemmale</i>	
	<i>Pseudagrion sjoestedfi</i>	<i>Trithemis aconita</i>	
		<i>Trithemis dichroa</i>	

**Table 6. Checklist of Odonata species recorded inside and outside the Bobiri Forest Reserve.**

Zygotera inside	Zygotera outside	Anisoptera inside	Anisoptera outside
<i>Phaon camerunensis</i>	<i>Elattoneura villiersi</i>	<i>Gynacantha bullata</i>	<i>Acisoma inflatum</i>
<i>Phaon iridipennis</i>	<i>Elattoneura balli</i>	<i>Gynacantha cylindrata</i>	<i>Brachythemis lacustris</i>
<i>Chlorocypha luminosa</i>	<i>Mesocnemis singularis</i>	<i>Brachythemis leucosticta</i>	<i>Chalcostephia flavifrons</i>
<i>Chlorocypha selysi</i>	<i>Elattoneura nigra</i>	<i>Cyanothemis simpsoni</i>	<i>Cyanothemis simpsoni</i>
<i>Lestes dissimulans</i>	<i>Pseudagrion melanicterum</i>	<i>Eleuthemis buettikoferi</i>	<i>Diplacodes lefebvrei</i>
<i>Ceragrion rubellocerinum</i>	<i>Pseudagrion kersteni</i>	<i>Neodythemis klingi</i>	<i>Diplacodes luminans</i>
<i>Pseudagrion hamoni</i>	<i>Ceragrion rubellocerinum</i>	<i>Micromacromia zygoptera</i>	<i>Eleuthemis buettikoferi</i>
<i>Pseudagrion melanicterum</i>	<i>Ceragrion glabrum</i>	<i>Orthetrum julia</i>	<i>Neodythemis klingi</i>
	<i>Ceragrion corallinum</i>	<i>Orthetrum microstigma</i>	<i>Oligogastra lugubris</i>
	<i>Agriocnemis zeratica</i>	<i>Trithemis aconita</i>	<i>Orthetrum julia</i>
	<i>Agriocnemis exilis</i>	<i>Trithemis arteriosa</i>	<i>Orthetrum microstigma</i>
	<i>Africallagma glaucum</i>		<i>Orthetrum stemmale</i>
	<i>Chlorocypha curta</i>		<i>Palpopleura lucia</i>
			<i>Palpopleura portia</i>
			<i>Pantala flavescens</i>
			<i>Rhyothemis notata</i>
			<i>Trithemis aconita</i>
			<i>Trithemis arteriosa</i>
			<i>Trithemis dichroa</i>

**Table 7a-d. Sampling locations at the various protected areas.**

Ankasa Sampling localities: coordinates		Inside/outside forest	Habitat type	Date of sampling
N 05°16'30.6"	W 002°43'49.1"	Inside	Forest	18/02/2017
N 05°16'33.9"	W 002°43'45.2"	Inside	Forest	18/02/2017
N 05°16'33.5"	W 002°43'46.3"	Inside	Forest	18/02/2017
N 05°13'06.5"	W 002°39'05.5"	Inside	Forest	19/02/2017
N 05°13'13.1"	W 002°39'01.6"	Inside	Forest	19/02/2017
N 05°13'14.8"	W 002°38'58.3"	Inside	Forest	19/02/2017
N 05°13'21.2"	W 002°38'57.5"	Inside	Forest	19/02/2017
N 05°12'59.9"	W 002°39'07.4"	Outside	Gallery forest	19/02/2017
N 05°13'04.9"	W 002°39'14.8"	Outside	Gallery forest	19/02/2017
N 05°12'59.3"	W 002°38'53.5"	Outside	Gallery forest	19/02/2017
N 05°10'27.9"	W 002°39'28.5"	Outside	Farmland	20/02/2017
N 05°10'21.8"	W 002°39'29.5"	Outside	Farmland	20/02/2017
N 05°10'33.2"	W 002°40'08.9"	Outside	Farmland	20/02/2017
N 05°10'24.3"	W 002°39'34.1"	Outside	Farmland	20/02/2017
N 05°10'17.3"	W 002°39'19.5"	Outside	Farmland	20/02/2017
N 05°10'44.4"	W 002°39'20.5"	Outside	Farmland	20/02/2017
N 05°11'26.8"	W 002°39'28.1"	Outside	Gallery forest	21/02/2017
N 05°11'22.6"	W 002°39'33.3"	Outside	Gallery forest	21/02/2017
N 05°11'27.7"	W 002°39'23.1"	Outside	Gallery forest	21/02/2017
N 05°10'42.2"	W 002°40'19.6"	Outside	Farmland	22/02/2017
N 05°12'00.0"	W 002°41'58.6"	Outside	Farmland	22/02/2017
N 05°12'51.5"	W 002°42'24.5"	Outside	Farmland	22/02/2017
N 05°13'17.2"	W 002°43'07.6"	Outside	Farmland	22/02/2017

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Atewa Sampling lo calities: coordinates		Inside/outside forest	Habitat type	Date of sampling
N 06°16'24.5"	W 0°30'37.2"	Outside	Mining	10/2/2017
N 06°16'26.7"	W 0°31'03.7"	Outside	Mining	10/2/2017
N 06°16'17.3"	W 0°31'11.2"	Outside	Mining	10/2/2017
N 06°15'36.9"	W 0°30'35.0"	Outside	Mining	10/2/2017
N 06° 06' 01.8"	W 0° 34' 07.6"	Outside	Farmland	11/2/2017
N 06° 13' 59.6"	W 0° 30' 10.3"	Outside	Farmland	11/2/2017
N 06° 14' 23.3"	W 0° 31' 03.4"	Outside	Farmland	11/2/2017
N 06° 14' 24.6"	W 0° 31' 05.2"	Outside	Farmland	11/2/2017
N 06° 14' 02.2"	W 0° 31' 09.6"	Outside	Human settlement	14/2/2017
N 06° 14' 03.4"	W 0° 30' 54.7"	Outside	Human settlement	14/2/2017
N 06°15'26.4"	W 0°30'09.7"	Outside	Human settlement	14/2/2017
N 06°15'52.9"	W 0°29'57.6"	Outside	Human settlement	14/2/2017
N 06°16'19.3"	W 0°31'23.7"	Inside	Forest	17/2/2017
N 06°16'19.7"	W 0°31'28.8"	Inside	Forest	17/2/2017
N 06°16'18.9"	W 0°31'29.9"	Inside	Forest	17/2/2017
N 06°16'20.1"	W 0°31'33.4"	Inside	Forest	17/2/2017
N 06° 14.893'	W 0° 32.103'	Inside	Forest	19/3/2017
N 06° 14.873'	W 0° 32.039'	Inside	Forest	19/3/2017
N 06° 14.859'	W 0° 31.993'	Inside	Forest	19/3/2017
N 06° 14.814'	W 0° 31.904'	Inside	Forest	19/3/2017
N 06° 14.779'	W 0° 31.707'	Inside	Forest	19/3/2017
N 06° 14.848'	W 0° 31.423'	Outside	Forest margin	23/3/2018
N 06° 14.814'	W 0° 31.395'	Outside	Forest margin	23/5/2018
N 06° 14.735'	W 0° 31.308'	Outside	Forest margin	23/5/2018
N 06° 13.962'	W 0° 33.119'	Inside	Forest	20/5/2018
N 06° 13.957'	W 0° 33.177'	Inside	Forest	20/5/2018
N 06° 13.972'	W 0° 33.086'	Inside	Forest	20/5/2018
N 06° 13.978'	W 0° 33.045'	Inside	Forest	20/5/2018
N 06° 13.877'	W 0° 31.682'	Outside	Forest margin	21/5/2018
N 06° 13.846'	W 0° 31.668'	Outside	Forest margin	22/5/2018

Owabi Sampling localities: coordinates		Inside/outside forest	Habitat type	Date of sampling
N 6°43'39.73"	W 1°42'0.61"	Outside	Farmland	5/7/2018
N 6°43'52.84"	W 1°42'3.64"	Outside	Farmland	5/7/2018
N 6°43'39.26"	W 1°41'43.88"	Outside	Farmland	5/7/2018
N 6°43'55.28"	W 1°41'38.63"	Outside	Farmland	7/7/2018
N 6°43'44.25"	W 1°41'20.94"	Outside	Farmland	7/7/2018
N 6°43'44.14"	W 1°40'49.39"	Outside	Farmland	7/7/2018
N 6°43'53.07"	W 1°41'0.08"	Inside	Forest	16/9/2018
N 6°43'53.84"	W 1°41'6.76"	Inside	Forest	16/9/2018
N 6°43'56.53"	W 1°41'12.41"	Inside	Forest	16/9/2018
N 6°44'11.46"	W 1°42'1.62"	Inside	Forest	16/9/2018
N 6°44'21.17"	W 1°40'34.34"	Inside	Forest	16/9/2018
N 6°44'21.49"	W 1°40'24.73"	Inside	Forest	16/9/2018
N 6°44'33.75"	W 1°40'27.94"	Inside	Forest	18/9/2018
N 6°44'45.00"	W 1°41'10.95"	Inside	Forest	18/9/2018
N 6°44'50.10"	W 1°41'6.85"	Inside	Forest	18/9/2018
N 6°44'59.57"	W 1°41'0.05"	Outside	Human settlement	14/2/2019
N 6°44'45.38"	W 1°40'23.84"	Outside	Human settlement	14/2/2019
N 6°43'30.60"	W 1°40'33.64"	Outside	Human settlement	14/2/2019
N 6°43'23.40"	W 1°40'27.85"	Outside	Human settlement	14/2/2019
N 6°43'37.27"	W 1°40'28.12"	Outside	Human settlement	15/2/2019
N 6°43'27.87"	W 1°39'51.50"	Outside	Human settlement	15/2/2019
N 6°43'23.76"	W 1°39'45.84"	Outside	Human settlement	15/2/2019

Bobiri Sampling localities: coordinates		Inside/outside forest	Habitat type	Date of sampling
N 6°40'33.40"	W 1°14'56.74"	Outside	Farmland	3/3/2019
N 6°41'12.39"	W 1°15'8.14"	Outside	Farmland	3/3/2019
N 6°40'9.58"	W 1°15'40.20"	Outside	Farmland	3/3/2019
N 6°39'22.92"	W 1°16'49.19"	Outside	Farmland	3/3/2019
N 6°39'28.72"	W 1°18'15.97"	Outside	Farmland	3/3/2019
N 6°41'3.66"	W 1°16'27.44"	Inside	Forest	24/3/2019
N 6°41'32.25"	W 1°16'44.24"	Inside	Forest	24/3/2019
N 6°40'53.90"	W 1°16'13.05"	Inside	Forest	24/3/2019
N 6°41'9.72"	W 1°15'46.62"	Inside	Forest	25/4/2019
N 6°40'17.32"	W 1°16'32.25"	Inside	Forest	25/4/2019
N 6°40'43.66"	W 1°17'10.58"	Outside	Forest margin	25/4/2019

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