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Spatio-Temporal Distribution and Bionomics of Blackfly Species in Ghana: A Narrative Review

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ABSTRACT

Blackflies (Simuliidae) are a diverse group of insects known for their blood-feeding habits and their potential role as vectors of various diseases. In Ghana, onchocerciasis (River blindness) is prevalent with reported sporadic outbreaks occurring in various host-spots across different ecozones as a result of the abundance of its vectors, however, blackfly species have been the subject of limited research and documentation. This narrative review aims to provide an overview of the known blackfly species in Ghana and their distribution, while highlighting the gaps in the existing literature. The findings emphasize the need for further studies to enhance our understanding of blackfly ecology, species diversity, and potential disease transmission risks in Ghana.

Keywords: Blackflies, onchocerciasis, Larviciding.

Background

Onchocerciasis is a significant public health concern in many affected regions [1,2]. According to the World Health Organization (WHO), in 2019, an estimated 21 million people worldwide were infected with onchocerciasis. Approximately 99% of these infections occur in Africa [3]. The primary vector responsible for the transmission of *Onchocerca volvulus*, the parasite causing onchocerciasis is the *Simulium damnosum* complex [4,5,6,7] and is made up of cytoforms; a group of related species that are morphologically indistinguishable but can be differentiated based on changes in the sex-linked inversion patterns of their larval polytene chromosomes [8,9].

Onchocerciasis is known as river blindness due to its association with the presence of blackflies, particularly species of the *Simulium* genus, which are found near fast-flowing rivers and streams [10,11]. Blackflies are small, dark-colored flies belonging to the family Simuliidae [12,13]. The diverse nature of the Simuliidae family reflects the wide range of habitats and ecological niches occupied by black flies around the world, particularly in areas with fast-flowing water bodies [14,15]. They are known to cause nuisance, biting and transmit diseases such as onchocerciasis [16,17]. Individuals infected with onchocerciasis may experience a range of symptoms, particularly related to the skin and eyes [18]. These symptoms can include: severe itching, dermatitis, which is characterized by inflammation, redness, skin rashes, and formation of subcutaneous nodules [19]. Ivermectin is an effective microfilaricide and the primary drug used for the treatment and control of onchocerciasis [20,21,22]. While ivermectin has been highly effective in reducing the transmission of onchocerciasis in many regions, there have been reports of persisting microfilariae in the skin and ongoing transmission in certain areas, particularly in Africa [23,24,25,26].

While Ghana is known to be endemic for onchocerciasis and has a significant blackfly population [27], there are still gaps in our understanding of the species diversity, distribution, and ecology of blackflies in the country. This narrative review aims to provide an overview of the known blackfly species in Ghana and their distribution, while highlighting the gaps in the existing literature. This would be crucial for effective disease control strategies and public health interventions.

Life Cycle of Black Flies

The family Simuliidae (Order Diptera), also known as the blackfly family, consists of more than 1,700 species worldwide [15,28,29]. Female black flies require blood meals to obtain the necessary nutrients for egg development [30]. They are known for anthropophagy as they feed on the blood of various vertebrate hosts, including humans [31,32]. In contrast, male black flies primarily feed on nectar and other plant fluids and do not bite [33,34,35,36]. While the majority of blackfly species lay their eggs in or on moving water, there are certain species that exhibit different egg-laying behaviors [37]. These species may attach their eggs to moist objects, including the blades of aquatic grass [15,34,38].

The duration of egg incubation can vary among species and is influenced by various environmental factors [28, 39]. The majority of species' eggs hatch within 4 to 30 days, although other species' eggs take up to several months to hatch [34]. The duration of black fly larval growth can vary significantly depending on various factors, including water temperature and food availability [40,41]. The development time of the blackfly larvae can range from as little as one month to as long as six months, or even more in some cases before pupation [42,43].

The pupa enters a non-feeding stage and undergo significant changes in preparation for their transition into adult flies [44,45,46,47]. The larvae and pupae grow in moving water, usually in unpolluted water with a lot of dissolved oxygen [48]. The average lifespan of adult black flies is relatively short, typically ranging from two to three weeks [49].

Blackfly Species in Ghana

Ghana has a history of implementing vector control measures and is actively involved in onchocerciasis control programs that include the distribution of ivermectin therapy [50]. However, despite these efforts, onchocerciasis transmission continues to be a problem in certain regions of the country [51,52,53]. Ghana can be divided into three main ecological zones; Coastal Savanna, Forest zone and Sahel Savanna [54]. These can be further divided into 6 agro-ecological zones: Guinea Savanna, Sudan Savanna, Coastal Savanna, Forest-Savanna Transitional zone, Deciduous Forest, and Rain Forest zones based on factors such as rainfall, temperature, soil types, and agricultural potential [55,56].

In Ghana, the Simulium damnosum complex has been found in various regions throughout the country, particularly in areas with suitable breeding sites and ecological conditions [57,58]. These are *S. damnosum* sensu stricto (s.s.) Vajime and Dunbar; *S. sirbanum* Vajime and Dunbar; *S. sanctipauli* Vajime and Dunbar; *S. yahense* Vajime and Dunbar; the Beffa form of *S. soubrense* Vajime and Dunbar [59] and *S. squamosum* (Enderlein, both C and E forms) [58]. Each of these species has its own ecological preferences and is found in specific regions or ecological zones of the country [35,58,60].

The presence and abundance of specific blackfly species may differ due to variations in climate, vegetation, and breeding site preferences [58,61,62]. This can impact the transmission dynamics of onchocerciasis in different regions of the country. Because of this, *Simulium damnosum* sensu lato (s.l.) has been further classified into forest and savanna varieties in Ghana [54,61,63]. The most common *S. sanctipauli*, *S. soubrense*, and *S. yahense* forest strains are found throughout Ghana [58,64,65]. *Simulium damnosum* sensu stricto and *Simulium sirbanum* are savanna strains and more widespread while *Simulium squamosum* is commonly found in the transitional areas between the Forest Zone and the Northern Savannah Zone, which include the highland zones [60]. It is believed that the savanna strains are more virulent, antigenic, and responsible for more blinding manifestations of the disease [66].

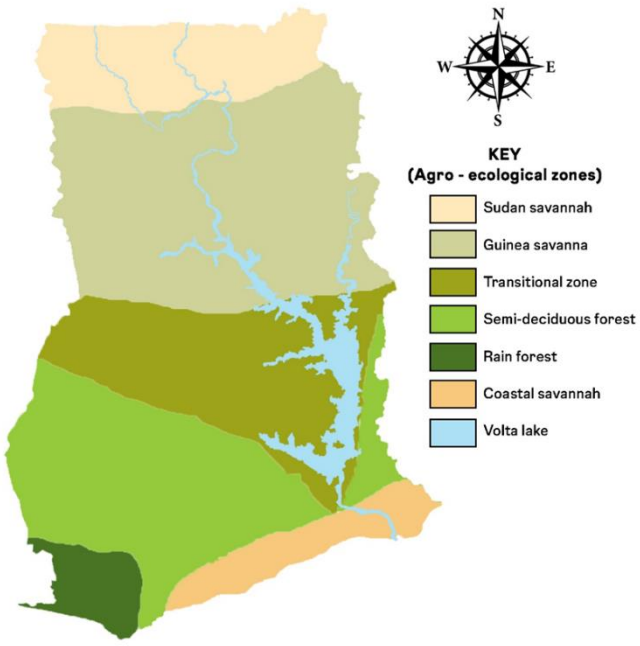

Figure 1: A map showing agro-ecological zones in Ghana

Distribution of Blackfly Species in Ghana

The study conducted in the Twifu-Heman Lower Denkyira district in Ghana had the objective of investigating the diversity and abundance of blackfly species over a one-year period [61]. The findings of this study provide valuable insights into the blackfly species composition in that specific area. The location is in the forest zone with the River Pra being the main river draining the location [67,68]. It has been reported that pre-adult stages of *S. adersi*, *S. damnosum* sensu lato and *S. unicornutum* occurred in 4 sub-catchment areas; Twifu Prasu, Heman, Mokwa, and Jukwa of the district. The *S. damnosum* s. l. species was reported to be the most abundant and widely distributed. Adult flies were caught in the Eduaben and Brofoyedur catchment areas with significantly higher numbers occurring in the wet season (14,890 flies) than dry season (7,720). The study reported on the occurrence of savanna strains (*S. damnosum* s. s., *S. sirbanum*) in the catchment areas [61]. Though the numbers of the savanna strains were reported to be low, their occurrence in the forest zone poses a health concern as they are known to cause more virulent blinding disease form [69]. The report suggested that a reason for this occurrence may be as a result of massive deforestation which allowed a creation of conducive environment for the thriving of the savanna strains. The numbers and distribution of the adult flies in the forest zone district was reported to be dependent on the rainfall pattern and distance of breeding sites from settlements [61]. Rainfall cause increase in the average current speed and nutritive status of the river bodies. This leads to an expansion of the breeding sites of the larvae, hence increase in larval population [70]. An increased infection rate was reported among settlements close to the breeding sites of the blackfly species, a factor which affects the numbers and distribution of the vectors [61]. The data provided highlights the importance of considering seasonal variations when studying blackfly populations and its associated diseases.

Another study conducted by Lamberton and colleagues reported on the occurrence of three blackfly species: *S. sanctipauli*, *S. yahense*, and *S. squamosum*, in Asukawkaw Ferry, Dodi Papase, and Pillar 83 in the Volta region; Bosomase in the Western region; and Gyankobaa in the Ashanti region of Ghana [71]. The *S. sanctipauli* species caught were not of the Djodji forms as these forms were eliminated by the Onchocerciasis Control Programme (OCP) in 1988 [64]. While the C type of *S. squamosum* were reported to have only occurred in the Volta region, *S. squamosum* type E occurred in the Ashanti region (Gyankobaa) [71]. Furthermore, savanna strains, *S. damnosum* s. s. and *S. sirbanum* were reported to have been sampled from all the sites in the Volta region and Gyankobaa which is in the Ashanti region. It was suggested that deforestation in the Southern part of Ghana might have contributed to the existence of the savanna strains at these forest zones [71]. In these identified locations, it is crucial to assess the prevalence and intensity of onchocerciasis among the human population. This involves studying the presence of *Onchocerca volvulus* larvae (microfilariae) in human hosts, as well as evaluating the daunting effects of the disease burden and impact on affected communities.

In a similar study conducted over a two-year period, Lamberton et al. [71] reported on the blackfly species caught for cytotaxonomic identification in two communities: Asubende and Agborlekame. These sites are situated in the Savanna region and located on the river Pru and Black Volta River respectively. It was reported that blackfly species of *S. damnosum* s. s. and *S. sirbanum* were caught at Asubende (2,497 flies) and Agborlekame (807 flies). The predominant species was *S. damnosum* s. s. and there were no forest strains caught. However, flies which do not belong to the *S. damnosum* complex were caught in the study sites. At Asubende and Agborlekame, about 212 blackfly species of *S.* (Phoretomyia) *berneri*, *S.* (Lewisellum) *ovazzae*, *S.* (Meilloniellum) *adersi* and *S.* (Pomeroyellum) were caught in the dry seasons of the study period.

In Tanfiano in the Nkoranza North District of the Bono East region of Ghana, the occurrence and relative abundance of Simulium flies were reported in a study by Otabil and colleagues [60]. Their findings reported that the predominant blackfly species in the location was *Simulium damnosum* s. s. The area is in the forest-savanna transitional zones having fast flowing rivers such as Tanko, Fanu, Fia, and Tanfi [60]. The study further revealed that the relative abundance of Simulium vectors was high during the dry season. These findings contrast with the findings of Opoku [61], who reported a high abundance of Simulium vectors during the rainy season.

The Blackfly Menace: Implications for Human Health

The blackfly menace poses a significant threat to human health, primarily through the transmission of onchocerciasis and, to a lesser extent, other diseases [72,73,74]. Addressing the challenges associated with blackflies requires a multi-faceted approach, including vector control strategies, access to healthcare, community education, and improved socio-economic conditions [75,76].

While onchocerciasis is the most well-known disease transmitted by blackflies, they can also transmit other pathogens [77]. For example, some species of blackflies can transmit the filarial worm Mansonella spp., which causes a condition known as Mansonellosis [78,79]. This disease is generally less severe than onchocerciasis but can still lead to symptoms such as skin rashes, joint pain, and fever [79,80]. Blackfly bites can cause allergic reactions in some individuals [81]. The saliva injected by the blackflies during feeding can trigger localized reactions, resulting in skin redness, swelling, itching, and discomfort [82,83]. Intense scratching of blackfly bites can lead to secondary infections. Bacteria present on the skin can enter the broken skin, causing skin infections such as cellulitis [83,84]. The relentless biting activity of blackflies, particularly in heavily infested areas, can have a significant psychological impact on affected populations [85]. The constant annoyance and discomfort caused by the blackflies can lead to stress, anxiety, and frustration, affecting mental well-being and overall quality of life. The blackfly menace can have substantial economic consequences for communities living in infested areas [86,87,88]. The debilitating effects of onchocerciasis, including visual impairment and reduced work capacity, can hinder productivity, impair educational opportunities, and limit economic development [88]. The economic burden extends to healthcare costs associated with treatment and control efforts [89,90].

Vector control measures for Blackflies

The occurrence of black flies and the prevalence of onchocerciasis in specific locations have significant implications for disease control efforts in Ghana [51,91]. The occurrence of disease transmission at areas which had previously been covered by the Onchocerciasis Control Programme (OCP) suggests the need for a 'thorough' knowledge on the distribution and spatio-temporal changes of the various blackfly vectors [58]. Understanding the distribution of black fly species and the prevalence of onchocerciasis allows for the implementation of targeted control strategies [92]. By focusing interventions on areas with higher black fly abundance and disease prevalence, resources can be allocated efficiently, maximizing the impact of control measures [32,58, 61].

Targeting the immature stages of blackflies is an effective approach to control their population [93]. Larviciding involves applying larvicidal agents, such as insecticides or microbial agents, to the breeding sites of blackflies [94,95]. This can help kill the larvae before they develop into adult flies. Larviciding can be done through aerial or ground-based applications, depending on the accessibility and size of the breeding sites [96,97]. Another important vector control measure is the use of insecticide-treated bed nets. This can also be effective in reducing blackfly bites during sleep [98,99,100]. The nets provide a physical barrier between humans and the blackflies, while the insecticide repels or kills the insects that come in contact with the netting material [99,101]. Encouraging individuals in blackfly-infested areas to wear protective clothing, such as long sleeves, long pants, and hats, can reduce their exposure to blackfly bites [102]. Applying insect repellents to exposed skin areas can also provide additional protection [103].

Furthermore, it has been reported that higher temperatures, lower humidity and rainfall, prolonged periods of sunshine increase the relative abundance of blackfly vectors; suggesting the need for area-specific entomological and epidemiological studies prior to mass drug administration [51,60,104]. For example, in Tanfiano in the Bono East region, it was suggested that ivermectin should be best administered during the rainy season, which typically occurs between April and October where blackfly populations are usually higher [60].

Promoting community education and awareness programs can help individuals understand the risks associated with blackfly bites and the importance of preventive measures. Informing communities about the signs and symptoms of onchocerciasis and other diseases transmitted by blackflies can lead to early detection and treatment-seeking behaviors [99,105,106]. It is important to implement a combination of these vector control measures to achieve effective blackfly control. Integrated vector management approaches that combine multiple strategies based on the local context and available resources are often the most successful.

Research Gaps and Future Directions:

Despite the importance of blackflies in public health and ecological studies, there are still gaps in the knowledge of blackfly species diversity and distribution in Ghana. Further research is needed to conduct comprehensive surveys across different regions of Ghana to identify additional blackfly species and understand their ecological preferences. While certain blackfly species have been documented in Ghana, there is a need to expand the knowledge base by identifying and cataloging other species that may be present within the country and contributing to disease transmission. Comprehensive surveys will help uncover the full extent of blackfly species diversity in Ghana and contribute to a more complete understanding of their distribution patterns. Blackfly species can exhibit variations in their ecological preferences, including their choice of breeding sites, feeding habits, and environmental requirements. Conducting detailed surveys across different regions of Ghana will provide insights into the ecological preferences of various blackfly species. This information is crucial for understanding their habitat requirements, population dynamics, and potential impact on disease transmission.

Investigating the genetic and phenotypic variations within the *Simulium damnosum* complex is an important area of research that can refine our understanding of its cytoform distribution and implications for disease transmission in Ghana. Chromosomal differences, known as cytoforms, have been associated with variations in ecological behavior and transmission potential. By studying the genetic and phenotypic variations within the complex, researchers can refine the understanding of cytoform distribution across different regions, providing insights into the specific species or cytoforms present in various areas of Ghana. By analyzing genetic markers, using microsatellites or mitochondrial DNA sequencing, researchers can assess the genetic diversity, gene flow, and population structure of different cytoforms. This information is valuable for understanding the evolutionary history, dispersal patterns, and potential for genetic adaptation within the complex.

Assessing the vectorial capacity (VC) of different blackfly species, including their competence in transmitting various pathogens of public health importance, is crucial for understanding disease transmission dynamics and developing effective control strategies. For blackflies, assessing vector competence involves investigating their ability to acquire pathogens from infected hosts, support pathogen replication or development within their bodies, and successfully transmit the pathogen to susceptible individuals. Experimental studies, such as laboratory infection assays, can help determine the vector competence of different blackfly species for specific pathogens. Blackflies can potentially transmit various pathogens of public health importance, including parasites, bacteria, and viruses. Assessing the vectorial capacity requires understanding the range of pathogens associated with blackfly species in a particular region. This involves identifying the pathogens present in blackflies through techniques such as molecular assays or pathogen isolation. Blackflies interact with both human and animal hosts, and the transmission dynamics of pathogens can vary depending on host preferences, host range, and the potential for cross-species transmission. These traits may be relevant in assessing zoonotic transmission. Investigating the interactions between blackflies, pathogens, and different host species provides insights into the potential for zoonotic transmission and the overall risk to public health.

Conclusion

The spatio-temporal distribution and bionomics of blackfly species in Ghana play a significant role in disease transmission and public health. The presence of suitable breeding sites, influenced by climate, geography, and human activities, contributes to the proliferation of blackfly populations. Effective control strategies, including larviciding, vector surveillance, and community-based interventions, are necessary to mitigate the impact of blackflies and associated diseases. Further research and monitoring efforts are needed to enhance our understanding of blackfly biology and their interactions with environmental factors, facilitating more targeted and sustainable control measures in Ghana.

List of abbreviations

OCP: Onchocerciasis Control Programme; WHO: World health organization; VC: vectorial capacity

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests

Author Contributions

All authors participated equally to the work

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