Chapter 13

The African *Chrysops*

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Abstract

African *Chrysops* are less studied than their European and American counterparts. The bionomics of only *Chrysops silacea* and *Chrysops dimidiata* is frequently reported. These two species feed on mammals in general but humans remain their main host. From the resting place in the canopy of the natural and secondary forest, they locate their hosts as they move but smoke of wood is a much better attractant than the movement. Other species live either in the rain forest or in the wooden savannah feeding on mammals and reptiles. *Chrysops* are biological and mechanical vectors of diseases in human and livestock. They also cause painful bites often resulting in open wounds, which can serve as open door for bacterial infections. In the past, control relied on the use of insecticides and clearing of vegetation around the habitations. Nowadays, recourse to repellents, trappings and destruction of the canopy around houses is recommended. The detailed geographical distribution of African *Chrysops* is still to be elucidated, as well as any genetic variability within and among species. The aims of the chapter are to provide the reader with the state-of-the-art knowledge on African *Chrysops*, and to present the gap in knowledge of this genus species.

Keywords: Africa, *Chrysops*, biting density, fly range, vector

1. Introduction

The genus *Chrysops* known as deer flies is under studied in Africa. Most of the knowledge on this genus date back to works performed in the years fifties to sixties. Interest was again raised on this genus in the years nineties when loiasis, a filarial disease transmitted by *Chrysops* species, stood as an obstacle to onchorcerciasis elimination programme. The literature on the topic is not only old but also very limited and scarce, probably because *Chrysops* species are mistakenly considered as of little economic importance and also because few species are anthropophilic while the majority is mainly zoophilic. Although a number of *Chrysops* species are transmitters of many pathogens to livestock, what is currently known on the genus *Chrysops* is mostly derived from studies on *Chrysops silacea* and *Chrysops dimidiata*, the main vectors of *Loa loa* to humans. Nowadays, *Chrysops* species in Africa are neglected, under studied flies in comparison to other flies of veterinary and medical importance such as ticks, tsetse flies, mosquitoes, sand flies or black flies. They are only mentioned in various studies pertaining to loiasis or sporadically in mere fauna studies. Apart from its role in the transmission of loiasis, its vectorial role in transmitting both human and livestock diseases evoked decades ago has not been fully investigated. In addition, their detailed geographical distribution is still to be elucidated, talkless of the investigation of any genetic variability within and among species that may impact their distribution and their disease transmission potential. The aims of the chapter are to provide the reader with the state-of-the-art knowledge on African *Chrysops*, to present the gap in knowledge and to develop interest for further studies of this genus.

2. Importance of African *Chrysops*

Chrysops species are of medical and veterinary importance. They do not only transmit loiasis to human and animals but also cause harm to their hosts. The losses incurred by *Chrysops* transmitted diseases or bites have not been estimated but coma, encephalopathy and death are some of the outcomes of loiasis in patients treated with diethylcarbamazine or ivermectine [1, 2]. Other clinical signs observed in patients with loiasis include generalized arthralgia, headache and painful oedema [2]. All these signs lead the patients to inactivity, resulting in economic unproductiveness. From the veterinary point of view, *Chrysops* are harmful to livestock, as they have been reported to feed on cattle, camels and dogs [3–5]. *Chrysops* are large bloodsucking insects. Therefore, heavy infestations of the animal may lead to anemia. They may also act as mechanical vectors of diseases to livestock [4].

3. Hosts and species

3.1. Hosts

There is very little detailed information on the host range of *Chrysops*. *Chrysops* species are known to feed on mammals in general. These include humans, wild animals and laboratory animals such as guinea pigs [2, 6]. Some species seem to feed preferably on some hosts referred to as "normal hosts" and accessorily on other hosts when their normal host is not available. Regarding the host preferences, Gouteux and Noireau [7] showed no significant difference between *C. silacea* and *C. dimidiata* in their preference for humans, with about 90% of blood meals taken on man. The other source of blood meal (10%) was shown to be taken from a range of nonhuman hosts which was of great variety and included hippopotamuses, rodents, reptiles, wild pigs and wild ruminants (antelopes, principally *Tragelaphus scriptus* and buffalos). The difference between the two *Chrysops* species regarding the preference for hippopotamuses

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or wild ruminants was not significant nor was that for rodents or reptiles. The authors also found that domestic animals (sheep, goat, cats and dogs) though available were not attractive to *C. silacea* and *C. dimidiata*. Nevertheless, this latter observation disagreed with a previous finding indicating that *C. silacea* feeds well on cattle and dogs under natural conditions and on rabbits while in the laboratory [3]. Detailed knowledge of the full host range of zoophilic species is not known. *Chrysops streptobalia*, a wild species, has recently been captured in an area harboring cattle, small ruminants (sheep, goats) and Equidae [4].

3.2. Species

Data on *Chrysops* species and on their exact number in Africa are scarce. Whatever their number, two of them *C. silacea* and *C. dimidiata* are the mostly recorded species. According to Fain [8], about thirty *Chrysops* species are known to occur in sub-Saharan Africa. Of these species, only a few are recorded to feed on human and livestock and to transmit diseases. The list of some of the species recorded in Africa, with their geographic location is presented below (**Table 1**). There is a huge gap in the knowledge of species and also in the genetic variability that may occur within and among species. Whether sibling species or subspecies occur in *Chrysops* species is not known. The genetic variability may affect both the ecological spread of the species and also its vectorial transmission potential. Thus, as for other species such as mosquitoes or black flies, molecular tools need to be developed for the accurate identification and genotyping of *Chrysops* in Africa.

***Chrysops* species**	**Geographic location**	**Reference**
C. silacea, Austen, 1907	Cameroon, Nigeria, Equatorial Guinea, Democratic Republic of Congo, Rwanda	[8–11]
C. dimidiata Wulp, 1885	Cameroon, Equatorial Guinea, Democratic Republic of Congo, Rwanda	[8–11]
C. flavipes Meigen, 1804	Egypt	[12]
C. streptobalia Speiser, 1912	Ethiopia	[4]
C. centurionis Austen, 1911	Nigeria	[8, 13]
C. distinctipennis Austen, 1906	Nigeria, Democratic Republic of Congo	[8, 13]
C. longicornis Macquart, 1838	Nigeria, Democratic Republic of Congo	[8, 13]
C. langi, Bequaert, 1930	Democratic Republic of Congo	[8]
C. laniger Loew, 1860	Democratic Republic of Congo	[8]
C. distinctipennis, Austen, 1906	Democratic Republic of Congo, Rwanda	[8]
C. obliquefasciata Macquart, 1838		[8]
C. funebris Austen, 1907	Democratic Republic of Congo, Rwanda	[8]
C. brucei Austen, 1907	Democratic Republic of Congo, Rwanda	[8]
C. griseicollis Bequaert, 1930	Democratic Republic of Congo	[8]
C. neavei Austen, 1911	Democratic Republic of Congo	[8]

Table 1. List of some *Chrysops* species recorded in Africa.

4. Classification

The taxonomy of *Chrysops* species is well known. The genus *Chrysops* is one of the three genera of veterinary and medical importance of the Tabanid family. There is no controversy on the taxonomic classification of *Chrysops* species.

Chrysops are members of the Arthropod (Arthropoda) phylum. Arthropods consist of invertebrates species whose major characteristic are the division of the body into clusters of segments notably the head, thorax and abdomen; the presence of a hard chitinous exoskeleton and jointed limbs. Each set of segments is known as tagma, with each tagma (head, thorax and abdomen) having specialized functions. Segmentation has almost disappeared in some species (mites) but still remains in the embryo.

They belong to the insect (Insecta) class with three pairs of legs in adults, a single pair of antennae and a broad tagmatisation (division into tagma) of the body into three distinct sections: the head, thorax and abdomen.

They are part of the dipterous (Diptera) order or true flies. True flies are characterized by a thorax bearing a single pair of functional wings. Other winged insects have two pairs of wings but in dipteran flies, the second pair of wings, the hind pair, is reduced to small knob-like sensory organs called halters which help the insect to maintain a balanced flight. The larvae are different in behaviour and structure to the adults so that the fly can parasitize the tissues of the host either as larvae or as adults but not in both states. Some are also mechanical or biological vectors of diseases.

Chrysops are brachyceran flies (suborder Brachycera) whose short antennae are usually composed of different sized segments. These antennae project in front of the fly. The Brachycera face is bulbous and there is no arista on the antennae.

Chrysops belong to the Tabanidae family. This family gathers the large robust flies known as horse flies (*Tabannus*), deer flies (*Chrysops*) and clegs (*Haematopoda*). These are flies with antennae made up of three sections, the third one being enlarged and composed of four to eight segments; they have two-jointed palps with the second segment enlarged and feet with three pads.

The genus *Chrysops* is made up of flies having wings with a simple pattern of a dark band across the width. Their antennae are long with five segments and the proboscis is shorter than the head.

5. Geographic distribution and ecological zones

Studies on the geographic distribution of *Chrysops* species have so far aroused little interest. The only detailed study showing the confinement area of the fly at country level dates back to many decades ago [8]. Zouré et al. [14] provided a comprehensive distribution of loiasis

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(**Figure 1**) in Africa, which nearly corresponds to the distribution of *Chrysops* vectors [2, 8] because the transmission of loiasis is correlated to the distribution of its vectors. According to these authors, two main zones of highly endemic loiasis can be distinguished: a western zone that comprises part of the Equatorial Guinea, Gabon, Cameroon, Republic of Congo, Central African Republic and Chad, Democratic Republic of Congo (DRC) and Angola; the second hyper-endemic zone is mainly made up of the North-Eastern part of the DRC. Areas of low endemicity include most parts of DRC, north Cameroon and large sections of Angola, Nigeria, Chad and Sudan. Because some *Chrysops* are essentially zoophilic, the geographic distribution likely expands beyond the previously described area. For instance, *Chrysops* species have been described in Egypt [12] and in Rwanda [8], countries not mentioned in the previously described area of distribution.

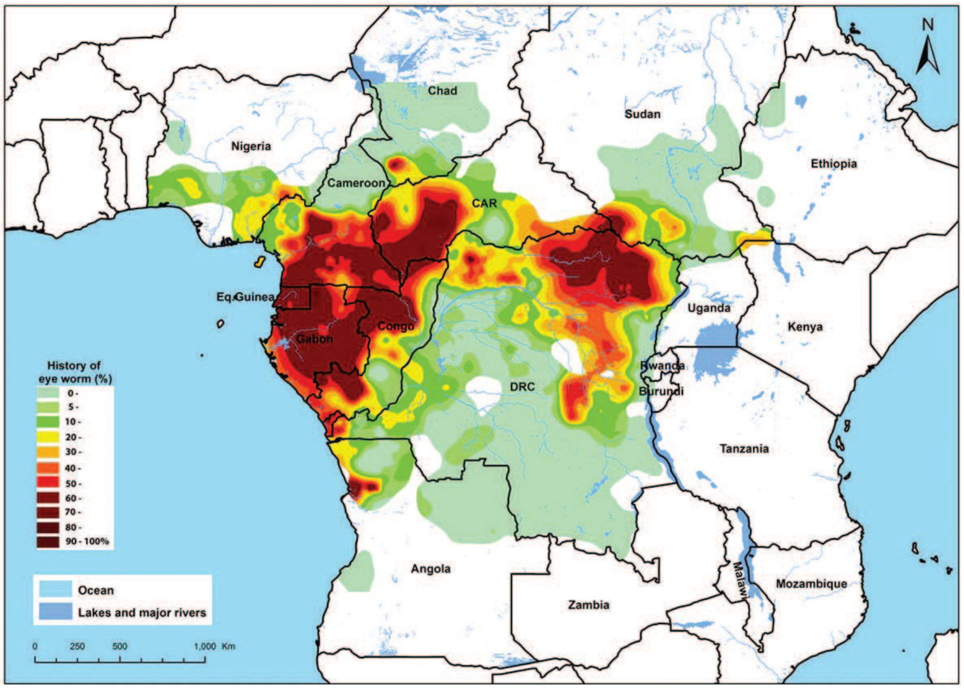

Figure 1. Geographic distribution of loiasis, a *Chrysops*-transmitted disease (reproduced from Zouré et al. [14]).

Within a given area, *Chrysops* are found in some particular ecological zones. In general, most species dwell in forested areas. *C. silacea* was found to be predominant in the cleared forest, particularly in the villages and in their immediate vicinity, whereas *C. dimidiata* prefers natural vegetation, particularly in the forest [15]. Whether the natural or artificial vegetation, presence of the canopy seems to be the most important criteria for *Chrysops* to settle, as this offers a resting place from where the host is spotted [2]. The artificial vegetation found as suitable ecological area include cacao farms, crop fields, mixed crop fields and inhabited areas [9, 16], regenerated forest [17] and commercial plantations such as rubber tree plantations [2]. Some but few species also live in savanna areas, as is the case for *Chrysops flavipes* collected in the Sinai in Egypt [12].

6. Morphology

Species of the genus *Chrysops* are relatively large biting flies with size varying from 5 to 30 mm in length. The head is large, presents bulky eyes with brightly coloured marks and a prominent proboscis (**Figure 2**). The short, stout, anteriorly projecting antennae have no arista and consist of three markedly different segment. The three segments are expanded and the third is marked by five annulations that make the genus antenna look as though it consists of more than three units. The wings have a dark band across the width and when the fly is at rest, they are held apart over the abdomen (**Figure 3**). The wing venation is characteristic, especially the branching of the fourth longitudinal vein.

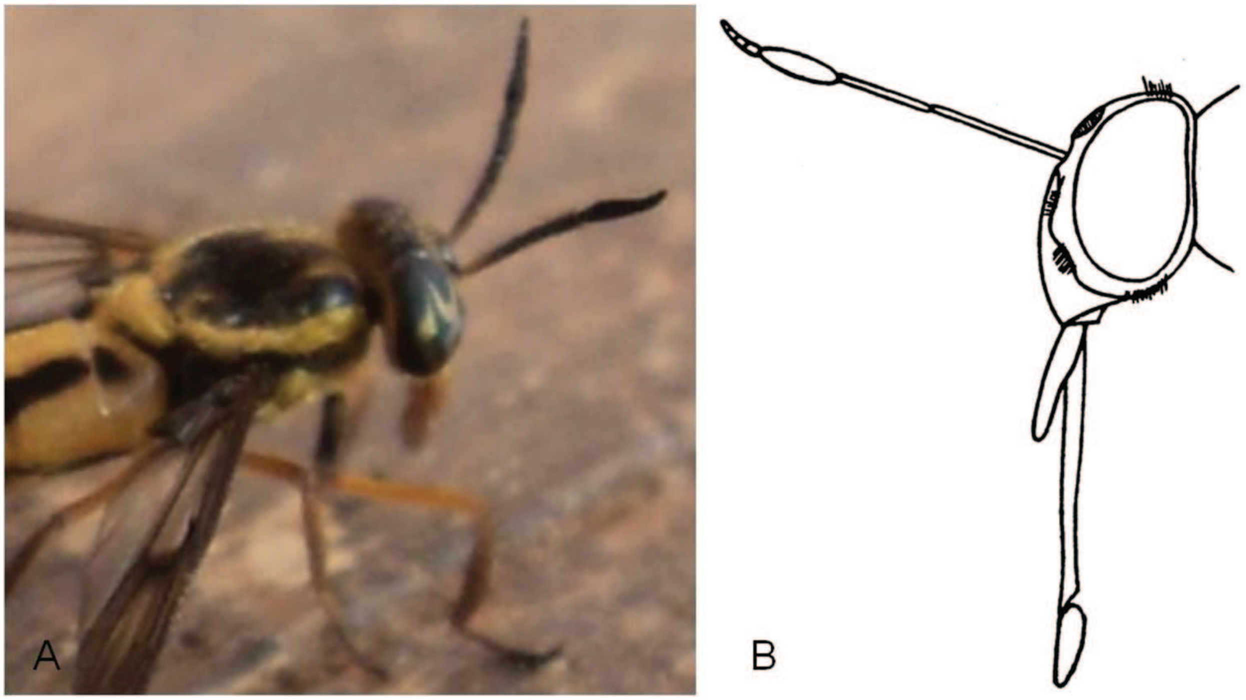

Figure 2. Morphology of *Chysops dimidiata's* head (A) (photograph by Dr Marc Kouam) and diagrammatic representation of *C. silacea*'s head (B) showing the three-segmented antenna (reproduced from Gordon and Crewe [6].

Figure 3. Female *Chrysops silacea*, dorsal (A) and ventral view (B) and female *Chrysops dimidiata*, dorsal view(C) (photographs by Dr Marc Kouam).

C. silacea and *C. dimidiata*, the two mains vectors of diseases among African *Chrysops* species are presented below. In *C. silacea*, the two longitudinal stripes on the yellow abdomen never extend beyond the third abdominal segment and may be so attenuated or interrupted as to be almost absent. In *C. dimidiata*, the abdominal stripes are broader and reach the fourth segment, where they usually become merged into the darker brown colour of the terminal segments. The wing markings of the two species are similar.

7. Life cycle

It should also be noticed that recent information on the life history of *Chrysops* is untraceable and no published work on this topic on African *Chrysops* species, apart for *C. silacea* [3] is available. Adult females of the Tabanidae are known to live on a mixed diet, feeding on sugar and blood, whereas adult males feed exclusively on carbohydrates. In the Tabanidae, development of the ovaries is dependent on the taking of a previous blood meal and after the ovoposition, a further blood meal is required before a further batch of eggs will develop.

After mating, the female *C. silacea* seeks a blood meal until sufficient blood has been ingested and then retires for egg maturation. During the "gestation period", the fly feeds on carbohydrates obtained from fruits or flowers to keep alive or active. The eggs are then laid after development and a new cycle is resumed after which other eggs are laid. The complete development of the ovaries and subsequent ovoposition take not less than about 6 days after blood meal. The normal development of the ovaries was shown to occur when the blood meal was larger than 8 mg and if the blood meal happened to be insufficient, the fly must return to attack another host to feed and retire to gestate, only when the blood amount is sufficient to initiate ovaries development [3]. The ovoposition sites of various species of *Chrysops* have been described to be over water. Female *Chrysops* laid the eggs in the mud along the rivers and lakes, on various objects (vegetation, stones) in the water near the shore, in permanent swamps and in small swampy patches formed throughout the rain forest during the wet season [18–21]. The eggs laid in batch of 100–800 units are 1.1 mm long and 0.2 mm wide at the broadest part and tapering more towards the apex than towards the base.

The eggs hatch between 5 and 9 days after ovoposition and all the larvae from one egg mass hatch almost simultaneously. After hatching, the larvae leave the substratum to sink in the mud that is covered with very shallow slowly running water. Larvae are saprophageous, whitish in colour, vermiform and hemicephalous. Larval development is very slow, consisting of 7–10 instars according to environmental conditions [19]. In the rainy season, the duration of a larval live history is estimated at 27 days for *C. dimidiata* and 15 days for *C. silacea* [19]. During the dry season, the duration of the larval stage is longer for all *Chrysops* species. For instance, the normal life history of *C. silacea* appears to occupy 1 year but the eighth or ninth instar fail to pupate in any year before the onset of unfavourable conditions, then the fly can apparently survive in the larval stage for a considerable period; this would account for the small number of pupae and adult flies which are found even during the driest and therefore unfavourable season [3]. Before pupation, the mature larvae of *C. silacea* moves to the edge of the stream or swam in which it is living and takes up a position in the mud just beyond and above the water's edge. Pupation takes place at the edge of water and the pupa, first pale yellow in colour becomes brown or yellow brown as it ages, showing a size varying from 10 to 13mm. The time slot between pupa and imago is 4 to 7 days, but the commonest period is 5 or 6 days. When the pupa is about to emerge to imago, it moves upwards to the surface of the mud until the thorax completely get out. The adult fly gradually works its way out from the puparium, taking several minutes to emerge completely and then rests on the mud for up to 1 hour until the body and winds are sufficiently hardened for it to fly away for the resting site in the canopy.

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8. Pathology

8.1. Cutaneous effect

African *Chrysops* not only cause deep painful bites but also cause irritation that result in painful wounds in some people (**Figure 4**). These wounds are potential entry doors for many pathogens.

Figure 4. Photograph of a healing wound (see arrow) following a *Chrysops* bite on a woman leg in Kokodo, Central Cameroon (photograph by Dr Marc Kouam).

8.2. General effect (vector of diseases)

African *Chrysops* are vectors of *L. loa* in human and *Loa papionis* in monkeys [2, 9, 22]. Due to the biting habit of *Chrysops* whereby several hosts are often necessary to feed to repletion, they are responsible for the mechanical transmission of diseases [23]. They are vectors of many pathogens to livestock; this includes bacteria, viruses, protozoa, *Trypanosoma evansi* in equines, dogs and camels, *Trypanosoma equinum* in equine, *Trypanosoma simiae* in pigs *Trypanosoma vivax* and *Trypanosoma brucei* in equine, cattle, sheep and other ungulates [4, 5, 24]; other *Trypanosoma* transmitted by *Chrysops* are *Trypanosoma gambiense* and *Trypanosoma rhodesiense*, the causative agent of human African trypanosomiasis [24].

9. Epidemiology

Chrysops species are either nocturnal or diurnal biters. The feeding time is correlated with the time when the host is active and available. Thus, *C. silacea* and *C. dimidiata* which feed on humans are diurnal feeders [9, 17]. In contrast, *Chrysops langi* and *Chrysops centurionis* having monkeys as hosts are crepuscular biters. Environmental conditions probably influence the biting habits of *Chrysops*. Temperature, humidity and light intensity are some interdependent factors influencing the biting activity of *Chrysops*. Brilliant sunshine and very dull days were reported to reduce the biting activity of *Chrysops* [3], whereas the daily biting cycle of *C. silacea* was showed to present two peaks of activities, 9–11 a.m. and 2–4 p.m. [17]. The *Chrysops* biting density has been shown to vary according to ecological zones, being higher in forested than in clear areas and habitations [15, 16]. In the Lekie Division in central Cameroon, Demanou et al. [16] reported a *Chrysops* biting density of 568 and 4696 bites/man/year in inhabited and forest areas, respectively. In general, *Chrysops* species bites all over the year but *Chrysops* biting density is the highest in the rainy season (the favourable breeding season) for some species such as *C. silacea* and *C. dimidiata* [16, 17], whereas some species (*Chrysops neavi*) have been collected solely in the dry season [8]. Meanwhile, other species (*Chrysops brucei*, *Chrysops distinctipennis*) have been reported solely in the rainy season [8]. To feed on human, African *Chrysops* usually fly up to the habitations to attack the host at the veranda and even inside well lighted houses [9, 16]. They are persistent and furtive, mostly attacking the legs or walk on the clothing probably in search of a biting site. They can be observed flying around the human host but the usual sign of their presence is the great pain of the bite, since they are pool feeders. In the forest, African *Chrysops* have also been reported to follow a moving vehicle like other Tabanids and to pursue a human being on foot for at least half a mile [3]. The population density of adults *Chrysops* is fairly low (~1000/km^2) and their flight range usually not great (theoretical range: <6000 m and maximum distance: 4500 m) in the secondary forest [25]. Adult female *Chrysops* spot their hosts using visual or olfactory means. Females are attracted by the movement of people or animals who are directly visible from the canopy [3]. Smoke of wood fire is extremely attractive to *C. silacea* [26, 27]; this therefore increases the opportunity of contact between human and the flies. The attraction to fire may be related to the diffusion of odorous molecules other than CO_2, contained in the smoke in the canopy [2, 27]. Catches carried out around a wood fire is multiple fold higher than in catches without wood fire [2, 28–30]. As reported by Duke [31], this visual attraction to humans appears to be less than that of a wood fire.

10. Laboratory diagnosis

The coloration of the wing and the three-segmented antennae is used in differentiating the three major genera of the family Tabanidae (**Figure 5**). In *Chrysops* species, the three antennal segments are expanded and the third is marked by five annulations that make the genus *antenna* look as though it consists of more than three units. The wings have dark bands across the width and when the fly is at rest, they are held apart over the abdomen. *Tabanus* species have transparent wings and the first two antennal segments are small and the terminal segment has a tooth-like projection on its basal part and four annulations. *Haematopota* species have characteristically mottled wings that are held divergent when at rest; its first antennal segment is large, the second is narrower and the third presents three annulations.

Figure 5. Specimen of the genus *Chrysops* (A), *Haematopota* (B) and *Tabanus* (C). A=*C. dimidiata* (photograph by Dr Marc Kouam); B=*Haematopota pluvialis* (reproduced from De grote, http://www.eaaci.net/site/content.php?l1=17&sel=400); C= *Tabanus* (*Tabanus*) *gertrudae* (reproduced from Maity et al. [32]).

11. Control

Attempts to large scale control of *Chrysops* population in the past relied on the use of insecticides. Dieldrin, DDT and Gamma-BHC have been used in Kumba in the southwest region of Cameroon against *C. silacea* and *C. dimidiata* larvae and pupae. The treatment was successful, leading to a drop in the fly density of 30%, 2 years after dieldrine spreading [21]. Although the result was promising, the method was not recommended due to difficulties to access to breeding sites in densely vegetated areas, the high cost of the treatment and the risk of environmental pollution and contamination of food and water [2]. A 60% solution of dimethylphtalate has also proven to be a good repellent of *Chrysops* in Kumba. Another promising method attempted was the creation of anthropic savanna hostile for *Chrysops* development around habitations [33]. Nowadays, it is well established that adults fly dwell in the canopy where they locate their host, that the fly range and density are limited (less than 6000 m and 785–3682 flies/km^2) and that the smoke of wood is attractive to *Chrysops*. So, based on these current knowledge on the biology and ecology of *Chrysops*, control measures against

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these pests may encompass: the clearance of large area of bush around habitations in order to destroy the habitats (canopy) of the adult flies, use of repellents for crop or forest workers and livestock, trapping with attractant to reduce the fly density. In this respect, Morlais [30] showed that smoke of wood increased the Loapi trap performance to 14 fold. Also, the Harris trap has been reported to be efficient on wooded savanna–dwelling *Chrysops* and need to be tested on forest-dwelling *Chrysops* [2]. If traps have been developed and largely used for other disease vectors in Africa (tsetse flies, mosquitoes), little has been done as regards African *Chrysops*. Yet, traps have the advantages of being cheap, harmless to the environment and can be used by a common man. For a rapid and large scale control of *Chrysops*, modern chemicals without a permanent effect on the environment need to be developed.

12. Conclusion

The gap in the knowledge of African *Chrysops* is huge. The *Chrysops* fauna in Africa still needs to be elucidated, as well as the role of each species, subspecies or genotype in the transmission of diseases to human and livestock. But before this is done, molecular tools need to be developed for epidemiological studies to clarify whether currently known species vary genetically across geographic areas. Research works are also to be focused on repellents, attractants, traps and environment-friendly insecticides that can be used for an efficient control of *Chrysops*. With the present knowledge on the biology, ecology and behavior of *Chrysops*, different control measures could be combined at small and large scale level. At small scale level, insecticide-treated traps or Harris-type traps could significantly reduce the fly density in rural areas if they are set next to firewood smoke (attractant). At large scale level, aerial spraying of insecticides at the resting sites (canopy) could be done but the most efficient technique would involve limiting or preventing female from breeding by using its natural enemies or the “sterile male” technique. This technique consists of introducing barren males in the population to compete with wild males for mating, as is the case in tsetse fly control. In sum, there is still a lot to know on African *Chrysops* and a long way to go before their successful control or eradication.

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