Endogenous knowledge of necrophagous insects in criminal investigations in Sudanian and Sudano-Sahelian zones of Burkina Faso

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Abstract

Forensic entomology is used in criminal investigations for post-mortem dating of cadavers. Our study aimed at examining the endogenous knowledge of necrophagous insects of six target groups of workers in two climatic zones of Burkina Faso for their application in criminal investigations, from exhumed and exposed corpses to the air. The survey was conducted among 223 informants splited in six target groups in four cities and eight villages belonging to Sudano-Sahelian and Sudanian climatic zones. Chi-square tests and principal component analysis (PCA) were performed to check for species diversity distributions significant differences in knowledge and climatic zones of study. The different phases of insect succession on post-mortem corpses were noted. The results showed that knowledge of the species varies from one species to another. The most cited species belong to the *Calliphoridae* (Diptera) family. Their larvae and pupae are present on open corpses at a frequency of 16.36%. On the other hand, *Astrapaeus sp* (Coleoptera) was found at 32.25% on the exhumed corpses. The citation of species also varied according to locality climatic zone and function of the informants. Traditional funeral workers and gravediggers cited more species than other justice actors. The species of *Chrysomya albiceps* (Wiedmann, 1819), *Chrysomya sp*. and *Lucilia sp.* are species found to be specific to the West African area and were mentioned for the first time in Burkina Faso. The knowledge of necrophagous insects by the informants in this survey opens new perspectives for entomological expertise in criminal investigations in Burkina Faso.

Key words: Forensic entomology, necrophagous insects, exhumed corpses, open corpses, Burkina Faso.

Résumé

Connaissances endogènes des insectes nécrophages en enquête criminelle dans les zones soudanienne et soudano-sahélienne du Burkina Faso.

L'entomologie médico-légale est utilisée dans les enquêtes criminelles pour la datation post-mortem des cadavres. L'objectif de cette étude était d'évaluer les connaissances endogènes des insectes nécrophages de six groupes cibles de travailleurs dans deux zones climatiques du Burkina Faso en vue de leur application dans les enquêtes criminelles, à partir des cadavres exhumés et exposés à l'air. L'enquête a été menée auprès de 223 informateurs répartis en six groupes cibles dans quatre villes et huit villages appartenant aux zones climatiques soudano-sahéliennes et soudaniennes. Des tests du chi-carré et une analyse en composante principale (ACP) ont été effectués pour vérifier la diversité des espèces et les différences significatives.

Les résultats ont montré que la connaissance des espèces varie d'une espèce à l'autre. Les espèces les plus citées appartiennent à la famille des *Calliphoridae* (Diptères). Leurs larves et nymphes sont présentes sur les cadavres à l'air libre à une fréquence de 16,36 %. Par contre, *Astrapaeus sp* (Coleoptera) a été trouvé à une frequence de 32,25 % sur les cadavres exhumés. La citation des espèces variait selon la localité, la zone climatique et la fonction des informateurs. Les travailleurs funéraires traditionnels et les fossoyeurs connaissent mieux les espèces que les acteurs de la justice. Les espèces *Chrysomya albiceps* (Wiedmann, 1819), *Chrysomya sp.* et *Lucilia sp.* sont des espèces infeodées à la zone ouest-africaine et ont été citées pour la première fois au Burkina Faso. La connaissance des insectes nécrophages ouvre de nouvelles perspectives pour l'expertise entomologique dans les enquêtes criminelles au Burkina Faso.

Mots clés : Entomologie médico-légale, insectes nécrophages, cadavres exhumés, cadavres à l'air libre, Burkina Faso.

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Introduction

After death, corpses undergo a series of transformations involving physical, chemical or mixed phenomena (Schmitt, Cunha and Pinheiro, 2006). The use of this body of evidence is not always easy in the field (Leadbeatter, 1987). The postmortem interval is determined by taking into account cadaveric signs, cadaveric fauna, climatic data and the influence of the soil type (Matuszewski, 2021).

Forensic entomology combines the knowledge of entomology with forensic medical science and law, in order to clarify some of the unknowns that often surround corpses found in natural or unnatural conditions (Smith, 1986). It has been developed since 1993 in French-speaking Switzerland (Wyss and Cherix, 2006).

Arthropods (Diptera, Coleoptera, Hymenoptera, Lepidoptera) present at each stage of decomposition of the corpse according to the climatic zones were studied (Koffi, 2018). According to Amendt *et al*. (2011), the study of their succession on a corpse makes it possible to calculate the IPM (Post-Mortem Interval): The determining the minimum time since death in the event of a suspicious death mainly involves two routes: 1. estimating the age of the necrophagous insects that have developed on the corpse; 2. analyze the composition of insect species on the cadaver (Anderson, 2001a; J. Amendt *et al.*, 2010; Amendt *et al.*, 2011). Knowledge of necrophagous insects help to know the date of death of a person (Lefebvre and Gaudry, 2009). Insects may also indicate the possibility of a corpse moving from one site to another, or that it was disturbed at some point, either by animals or by the killer returning to the scene of the crime (Subedi, 2016).

Forensic entomology is a complement to forensic

medicine, which becomes ineffective after seventy-two hours (Frederickx et al., 2011). Moreover, insect species found on a decomposing corpse that do not correspond to species normally found in the given area, can be a good indicator that a body has been moved from one area to another (Wolff et al., 2001).

This discipline has been developed and has carefully detailed the predictable succession of arthropods associated with decaying corpses (Mégnin, 1894). At each state of decomposition, specific odours are released such as butiric, caseic and ammoniacal odors (Frederickx *et al*., 2011). Each one selectively attract different species of arthropods (Malgorn, 2001). The first insects come immediately after death. They are attracted by particular odours and lay their eggs in natural openings and on wounds (Malgorn, 2001).

Based on the order of their appearance, the post mortem changes classify as: 1-The fresh state (1 day in west Africa) is characterised by the absence of odour; 2- The turgid state (1-3 days in west Africa) is characterised by a swelling of the corpse; 3-Advanced putrefaction (3-8 days in west Africa) is defined by the disappearance of soft tissue; 4-The dry and skeletal state (from day 9 onwards) is characterised by the total disappearance of soft tissue and the presence of bones and nails (Goff, 2000; Dekeirsschieter, *et al.*, 2012; Martin *et al.*, 2020).

Then, each new stage of decomposition will release new odours which will attract other species and will repel previous ones. One after the other, screwworms, will colonize a corpse from fresh stage to skeletal stage (Malgorn, 2001). This gradual invasion is the origin of the waves of necrophagous insects that arrive chronologically on the decomposing bodies: this is the notion of a squad (Mégnin, 1894). Insects and other arthropods are the primary organisms involved in the major decomposition of the body (Amendt *et al.*, 2010).

The common necrophagous insects belonging to Diptera order, mainly including *Sarcophagidae*, *Calliphorida*e and *Muscidae* family, remain critically important in forensic investigations (Ren *et al.*, 2018). They arrive at exposed corpses, often in less than 10 min, and quickly begin their activities (Amendt *et al*., 2010). These arthropods feed and live or breed in and on the corpse, depending on their biological preferences and on the decomposition stage (Benecke, 2001; Badenhorst and Villet, 2018). Diptera and Coleoptera are the most commonly insect orders used in criminal investigations (Mégnin, 1894; Robiche *et al*., 2002) .

The ecological roles of these arthropods may be put into four categories such as i) Necrophagous-the species feeding on corpse tissue, including Diptera (especially *Calliphoridae* and *Sarcophagidae*) and Coleoptera (*Silphidae* and *Dermestidae*) (*In* and Investigations, 1992), ii) Omnivores-species such as ants, wasps, and some beetles that feed on both the corpse and associated fauna (*In* and Investigations, 1992); iii) Parasites and Predators-such as Coleoptera (*Silphidae*, *Staphylinidae*, *Histeridae*), Diptera (*Calliphoridae*), and those Hymenoptera that parasitize immature flies and iv) Incidentals-arthropods that use the corpse as a concentrated resource extension of their normal habitat. Springtails, spiders, centipedes, pill bugs, and some mites (*Acaridae*, *Lardoglyphidae*, and *Winterschmidtiidae*) belong to this group (Charabidze and Bourel, 2007; Charabidze, 2012).

Several Researchers have done many efforts to advocate and legitimize the application of entomology in death investigations in many place such as in Europe (Masselin, 1993; Wyss and Cherix, 2006), United States (Goff, 2000) and Canada (Anderson, 2001).

Forensic entomology in Africa in general and in Burkina Faso in particular remains unknown. Few studies have been restricted to Algeria (Filalli, 2010; Boukhari and Bouraiou, 2017), Cameroon (Youmessi *et al.*, 2012), Benin (Robiche *et al*., 2002), South Africa and Ivory Coast (Koffi, 2018). A study carried out during field trips in Kenya and Malawi by Lutz *et al.*, (2017) have listed *Calliphoridae* flies of forensic entomological importance in certain areas. The first protocol for collecting insects from crime scenes was established by Catts and Haskell, (1990).

Although in the countries mentioned above several articles have been published on this subject (Wyss and Cherix, 2006).

Monitoring a decomposing corpse is an inconvenient operation, but it must be recognized that in some parts of the world, particularly in African villages, people who interact with human corpses are endowed with powers that enable them to manage what the ordinary citizen cannot (Pinheiroa et *al*., 2012; BUDA, 2019).

The selected survey groups are resource persons who know necrophagous insects. As such, they are involved in criminal investigations.

The objective of this study was to measure the endogenous knowledge on necrophagous insects of six target groups of people in contact with human corpses in two climatic zones of Burkina Faso for their implication in criminal investigations. The groups involved are four groups of justice actors, traditional funeral workers and gravediggers. This study allows us to draw up an inventory of the state of knowledge of necrophagous insects.

This work should provide the scientific community, forensic scientists and medical examiners with a local database to resolve the issue of determining post-mortem period.

Materials and methods

Study area

This study was conducted from September to November 2018. It covered four cities and eight villages in the Sudanian and Sudano-Sahelian zones of Burkina Faso. In the Sudanian zone, Tondogosso and Logofourousso (Bobo Dioulasso city), Tonkar and Niombini (Gaoua city) were selected. For the Sudano-Sahelian zone, Lattou and Peuiri (Koudougou city), Zekunga and Badnoogo (Ouagadougou city) were chosen (Figure 1). The choice of these areas is linked to their favourable security situation. In both climatic zones, the climate is tropical with two seasons: the dry season (October to April 2018) and the rainy season (May to September 2018). Average annual rainfall varied from 600 to 900 mm in the Sudano-Sahelian zone and from 900 to 1,200 mm in the Sudanian zone.

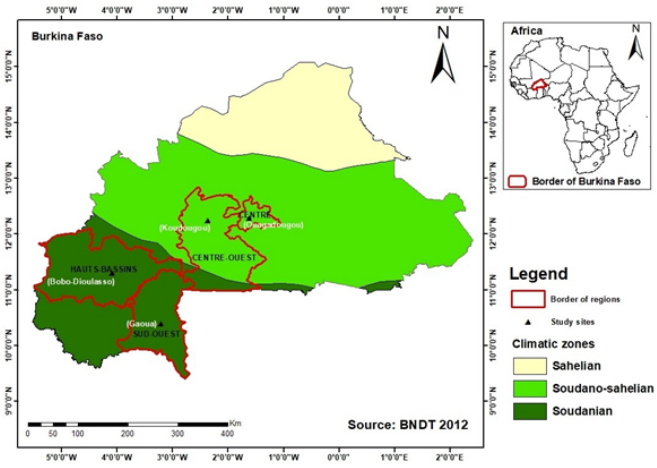


Fig 1. Map of study sites

Data collection

The survey involved six target groups which are: criminal investigators, crime scene investigators, health workers, magistrates, traditional funeral workers and gravediggers. This choice is justified by their involvement in forensic investigations. Various actors involved in study had to have at least five years' seniority for criminal investigators, crime scene investigators, health workers and magistrates; at least two years' seniority for gravediggers and traditional funeral workers (Table 2). In addition, these people must have at least 3 practiced cases (Table 2).

The number of informants in each locality was based on the availability of each target group. A total of 223 informants were interviewed (Table 1). The interviewees were aged between 18 and 65 years with a level of education ranging from primary to tertiary, except for some uneducated gravediggers and traditional funeral workers (6.7%) (Table 3). Thus, semi-structured individual interviews were conducted. Respondents were selected regardless of their religious affiliation. The survey tool consisted of a questionnaire, covering socio-demographic data, knowledge of necrophagous insects on open and buried corpses (Table 3). The survey technique consisted first to present the interviewees pictures of real collections of insects found on pig carcasses exposed to open air and buried corpses. Then, they were given responses to a questionnaire provided on their knowledge of these insects. Throughout their responses, a connection was established between a kind of insects and stages of decomposition.

The pictures of insects presented are from samples preserved and identified at laboratory of fundamental and applied entomology (LEFA) of Joseph KI-ZERBO University, on the basis of identification keys from Irish et *al.*, (2014).

Table 1. Number of informants according to location and profession

Professions	Localities				
	Bobo-Dioulasso	Gaoua	Koudougou	Ouagadougou	Total
PI	31	9	11	15	66
CSI	13	0	0	11	24
M	7	5	4	10	26
HO	9	8	5	5	27
FW	-	-	5	9	14
TG	16	17	15	18	66
Total	76	39	40	68	223

PI: Police Investigators; CSI: Crime Scene Investigators; M: Magistrates; HO: Health Officials; FW: Funeral workers; TG: Traditional Gravediggers.

Table 2. Criteria for inclusion of respondents

Criteria	PI	CSI	M	HO	FW	TG
Duration of service (years)	05	02	05	05	02	05
Number of cases practiced (years)	05	05	03	05	10	05

PI: Police Investigators; CSI: Crime Scene Investigators; M: Magistrates; HO: Health Officials; FW: Funeral workers; TG: Traditional Gravediggers.

Table 3: Socio-demographic characteristics of justice actors and traditional gravediggers at study sites (n=123)

Variables	Classes	Percentage (%)
Sex	Men	94.17
	Women	5.83
Age (years)	18-20	0.83
	21-30	16.30
	31-40	46.80
	41-50	22.30
	> 50	13.77
Education level	Unschooled	6.70
	Primary	20.20
	Secondary	46.80
	Higher	26.30

Data analysis

XLSTAT-Premium 2016 statistical software was used to analyse the data. The chi-square test was used to determine whether there was a significant relationship between locality and knowledge of the species cited. The test results were analyzed at the 5% level. Principal component analysis (PCA) was used to compare the diversity and abundance of species cited between climatic zones, study localities and informants functions. The knowledge of the succession of species cited on decomposing bodies, according to the study sites was assessed. Bodies are most often found in the following order: 1- fresh corpse, 2- swelling, 3- active decomposition, 4- advanced decomposition, 5- skeletonisation (Dekeirsschieter *et al.*, 2012).

Results

Socio-demographic characteristics of informants

The results of the surveys show that in the study sites, there are more men (97.17 %) than women (5.83 %). The age of informants varies from 18 to over 50 years old; 46.80 % of them are between 31 and 40 years old. The majority of the informants has a high level of education, 46.80 % of them are high school graduates and 26.30 % have university level.

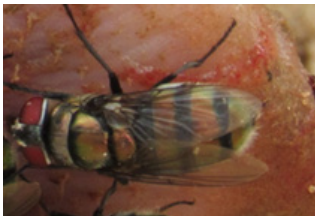
Extent of local knowledge on necrophagous insects in Burkina Faso

Knowledge of necrophagous insects cited on open corpses

Fourteen species of adult insects and two *Calliphoridae*

larval stages from open corpses, belonging to three orders and eleven families were cited by the six target groups of this survey (Fig. 2;3) (Table 5).

Figure 3 shows the knowledge of necrophagous insects in the open air. Diptera *Lucilia sp*. (15.56 %), *Musca domestica* adults (14.58 %), *Calliphoridae* larvae (16.54) and pupae (13.48 %) are the most cited.



Chrysomya sp.

Chrysomya albiceps (Wiedemann, 1830

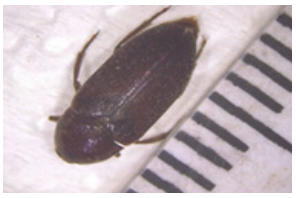
Sarcophaga carnaria (linnaeus, 1758)

Musca domestica (linnaeus, 1758)

Aglossa pinguinalis (Linneaus 1758)

Lucilia sp.

Necrobia rufipes (Fabricius, 1781)



Dermestes maculatus (De Geer, 1774)

Fig. 2 *Necrophagous Insects of four localities in Burkina Faso*

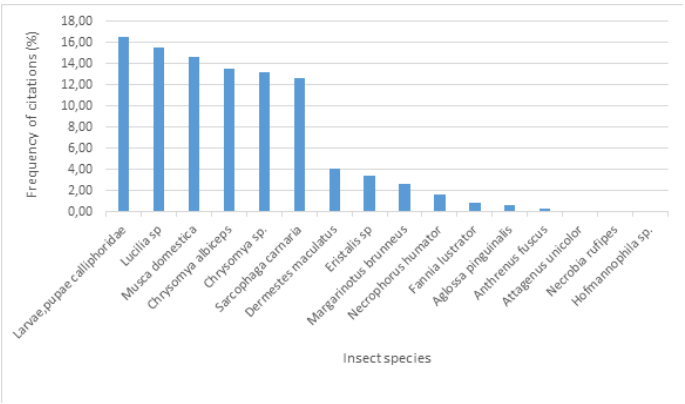


Fig. 3: Frequency of citation of necrophagous insect species on corpses in the open air

Table 5. Frequency of citations (%) of necrophogous insects according to localities

Orders	Families	species	Bobo	Gaoua	Koudougou	Ouaga
Coleoptera	*Cleridae*	*Necrobia rufipes (Fabricius, 1781)*	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
		Anthrenus fuscus (Olivier, 1789)	0.00^{a}	0.00^{a}	1.58^{b}	0.00^{a}
	Dermestidae	*Attagenus unicolor (Brahm, 1791)*	0.42^{b}	0.00^{a}	0.00^{a}	0.00^{a}
		Dermestes maculatus (De Geer 1774)	3.810^{c}	3.610^{b}	3.160^{a}	4.890^{d}
	Histeridae	*Margarinotus brunneus (Fabricius, 1775)*	2.54^{b}	1.20^{a}	3.16^{d}	2.93^{c}
	Silphidae	*Necrophorus humator (Gleditsch,1767)*	0.42^{b}	0.00^{a}	2.11^{c}	3.26^{d}
Diptera	*Calliphoridae*	Larvae	15.68^{a}	20.48^{d}	15.79^{b}	16.61^{c}
		Pupae	14.83^{c}	8.43^{a}	11.58^{b}	14.98^{d}
		Chrysomya sp.	11.44^{b}	18.07^{d}	10.53^{a}	14.98^{c}
		Lucilia sp.	16.95^{d}	12.05^{a}	16.84^{c}	14.66^{b}
	Fanniidae	*Fannia lustrator (Harris, 1780)*	0.42^{b}	0.00^{a}	1.05^{c}	1.30^{d}
	Muscidae	*Musca domestica (Linneaus, 1759)*	18.64^{c}	19.28^{d}	12.63^{b}	11.40^{a}
	Sarcophagidae	*Sarcophaga carnaria (Linneaus, 1758)*	11.86^{b}	14.46^{c}	16.84^{d}	10.10^{a}
	Syrphidae	*Eristalis sp.*	2.54^{b}	2.41^{a}	4.74^{d}	3.58^{c}
Lepidoptera	*Oecophoridae*	*Hofmannophila sp.*	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
	Pyralidae	*Aglossa pinguinalis (Linneaus 1758)*	0.420^{b}	0.00^{a}	0.00^{a}	1.30^{c}

The citation percentages of the same line bearing different letters are significantly different ($p < 0.05$)

Distribution of necrophagous insects collected from corpses exposed to air according to climatic zones

The citations of necrophagous insects species varied according to climatic zone (figure 4). More diversity of necrophagous insects was observed in Sudano-Sahelian zone than in Sudanian zone. Diptera *Chrysomya sp., Musca domestica, Lucilia sp., Sarcophaga carnaria, Fannia lustrator, Eristalis sp.;* Coleoptera *Dermestes maculatus, Necrophorus humator, Margarinotus brunneus, Anthrenus fuscus* and Lepidoptera *Aglossa pinguinalis* were cited by informants in the Sudano-Sahelian zone. However, in the Sudanian zone, the only species cited by informants was Coleoptera *Attagenus unicolor*.

In the study climate zones, significant differences were observed in knowledge of insects cited (Table 4). In the Sudano-Sahelian zone, knowledge of *Chrysomya albiceps, Sarcophaga carnaria, Calliphoridae* pupae and larvae, *Dermestes maculatus, Necrophorus humator*, by informants was significantly different as evidenced by the lower p-values (< 0.005) (Table 4). While *Chrysomya sp., Lucilia sp.*, Pupae and larvae of *Calliphoridae* were more cited than those of *Chrysomya albicps, Musca domestica, Sarcophaga carnaria, Fannia lustrator, Eristalis sp. Dermestes maculatus, Necrophorus humator, Margarinotus brunneus* and *Aglossa pinguinalis*in the Sudanian zone. The chi-square test shows that there is significant relationship between species knowledge and climate zones.

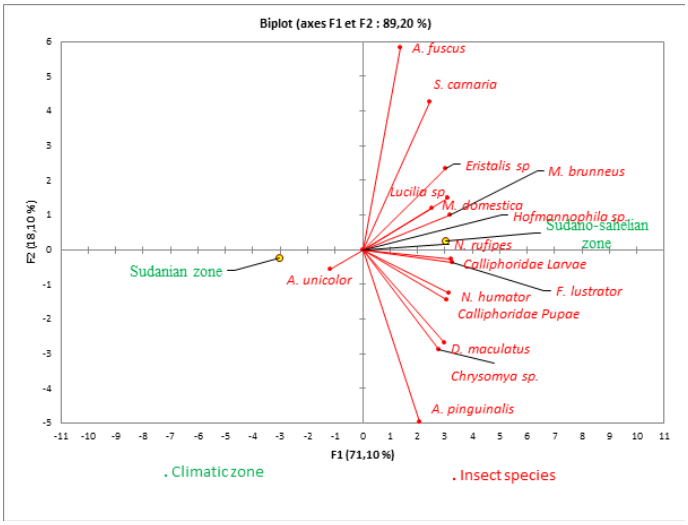


Fig. 4: Principal Component Analyses (PCA) of knowledge of necrophagous insects according to villages and climatic zones

Table 4: Chi-square tests among climatic zones

ORDER	Families	Species	Sudanian zone		Sudano-Sahelian zone	
			Khi² (Observed value)	p-value	Khi² (Observed value)	p-value
Coleoptera	*Dermestidae*	*Dermestes maculatus (De Geer, 1774)*	1.78	0.18	7.38	0.007
	Histeridae	*Margarinotus brunneus (Fabricius,1775)*	1.28	0.258	0	1
	Silphidae	*Necrophorus humator (Gleditsch,1767)*	0.52	0.472	5.32	0.021
Diptera	*Calliphoridae*	*Chrysomya sp.*	0.09	0.757	7.6	0.006
		Pupae and larvae	8.78	0.003	5.18	0.023
		Lucilia sp.	7.64	0.006	0.34	0.56
	Fanniidae	*Fannia lustrator (Harris, 1780)*	0.52	0.472	0.03	0.87
	Muscidae	*Musca domestica (Linneaus, 1759)*	2.94	0.086	0.03	0.87
	Sarcophagidae	*Sarcophaga carnaria(Linneaus, 1758)*	0.42	0.52	8.26	0.004
	Syrphidae	*Eristalis sp.*	0.31	0.581	0.26	0.61
Lepidoptera	*Pyralidae*	*Aglossa pinguinalis (Linneaus, 1758)*	0.23	0.63	2.78	0.096

DDL=1

Khi² (Critical value) = 3,84

Alpha= 0,05

Distribution of necrophagous insects identified on corpses in the open air according to locality

Table 5 shows the frequency of citations of necrophagous insects in the cities of Koudougou, Ouagadougou, Bobo Dioulasso and Gaoua. *Attagenus unicolor* is the only species cited in Bobo Dioulasso while *Anthrenus fuscus* is only cited in Koudougou. In the city of Bobo Dioulasso, the most cited species were *Musca domestica* (18.64 %), *Lucilia sp.* (16.95 %), *Sarcophaga carnaria* (11.86 %) and *Chrysomya putoria* (11.44 %). In Gaoua city, *Musca domestica* (19.28 %), *Chrysomia sp.* (18.07 %), *Sarcophaga carnaria* (14.46 %) and *Lucilia sp.* (12.05 %) were well known. In the city of Koudougou, informants cited *Lucilia sp.* (16.84 %), *Sarcophaga carnaria* (16.84 %), *Musca domestica* (12.63 %) and *Chrysomia sp.* (10.53 %). The main species cited in the city of Ouagadougou were *Chrysomya sp.* (14.98 %), *Lucilia sp.* (14.66 %), *Musca domestica* (11.40 %) and *Sarcophaga carnaria* (10.10 %). However, *Aglossa pinguinalis* was only known in the cities of Bobo Dioulasso (0.42 %) and Ouagadougou (1.30 %). In the city of Gaoua, few of informants cited *Fannia lustrator* and *Necrophorus humator. Attagenus unicolor* was the only one known in Bobo-Dioulasso (0.42%). *Anthrenus fuscus* was the only one mentioned in Koudougou (1.58 %). *Necrobia rufipes* and *Hofmannophila sp.* were not observed in all localities. The larval stages (larvae and pupae of *Calliphoridae*) were widely cited in all localities. Depending on the locality, significant differences were observed in the knowledge of *Chrysomya sp., Sarcophaga carnaria, Lucilia sp. Eristalis sp.* Knowledge of the adult species *Necrophorus humator, Dermestes maculatus,* and the larval forms of the *Calliphoridae* were significantly different between the localities. But, no significant differences were observed in the knowledge of *Margarinotus brunneus, Fannia lustrator, Musca domestica* and *Aglossa pinguinalis* and the localities studied (Table 6).

Table 6: Frequency of citations (%) of necrophogous insects according to orders

Orders	Families	Species	Khi² (Observed value)	p-value
Coleoptera	*Dermestidae*	*Dermestes maculatus (De Geer, 1774)*	9.88	0.02
	Histeridae	*Margarinotus brunneus (Fabricius, 1775)*	5.42	0.14
	Silphidae	*Necrophoru shumator (Gleditsch 1767)*	22.89	< 0.0001
Diptera	*Calliphoridae*	Larvae	29.13	< 0.0001
		Pupae	33.87	< 0.0001
		Chrysomya sp.	25.51	< 0.0001
		Lucilia sp.	32.87	< 0.0001
	Carcophagidae	*Sarcophoga carnaria (Linneaus, 1758)*	25.17	< 0.0001
	Fanniidae	*Fannia lustrator(Harris, 1780)*	5.78	0.12
	Muscidae	*Musca domestica(Linneaus, 1759)*	4	0.26
	Syrphidae	*Eristalis sp.*	8.58	0.04
Lepidoptera	*Pyralidae*	*Aglossa pinguinalis (Linneaus 1758)*	5.09	0.17

DDL=3

Alpha=0.05

Khi² (Critical value)= 7.81

Distribution of necrophagous insects identified on open corpses according to informants professsion

Table 7 presents the knowledge of necrophagous insects according to profession. *Lucilia sp.* (20.00 %), *Musca domestica* (16.25 %), *Chrysomya sp.* (14.38 %) and *Sarcophaga carnaria* (13.75 %) were the most cited by criminal investigators. Health officials have cited, *Chrysomia albiceps* (20.69 %), *Lucilia caesar* (17.24 %), *Musca domestica* (14.94 %) and *Sarcophaga carnaria* (8.05 %). For the magistrates, *Chrysomya albiceps* (25.00%), *Lucilia sp* (25.00 %), *Musca domestica* (12.63 %) and *Sarcophaga carnaria* (16.67 %) are most frequently mentioned. As for funeral workers, *Lucilia sp.* (13.59 %), *Sarcophaga carnaria* (12.62 %), *Chrysomia sp.* (11.65 %), *Musca domestica* (7.77 %) and *Eristalis sp* (7.77 %) are the most cited. Crime scene investigators cited *Musca domestica* (17.86 %), *Lucilia caesar* (16.07 %), *Sarcophaga carnaria* (11.61 %), *Chrysomya sp.* (10.71 %) *Musca domestica* (14.33 %), *Sarcophaga carnaria* (13.45 %), *Lucilia sp.* (13.16 %). While *Chrysomya sp.* (11.70 %), *Aglossa pinguinalis* (1.46 %), *Attagenus unicolor* (0.29%) and *Anthrenus fuscus* (0.88 %) were only mentioned by traditional gravediggers. *Fannia lustrator* was only cited by Funeral workers (1.94 %) and gravediggers (1.46 %). *Necrobia rufipes* and *Hofmannophila sp.* are not cited by all informants. However, *Dermestes maculatus* is not mentioned by magistrates and crime scene investigators. The larval stages (larvae and pupae) were widely cited by all informants. The PCA (Figure 5) shows that Funeral workers and traditional gravediggers have more cited necrophagous insects than other informants. Among these two target groups funeral workers have cited more necrophagous species than the traditional gravediggers.

Table 7: Frequency of citations (%) of necrophogous insect according to profession

Orders	Families	Species	PI	HO	M	FW	CSI	TG
Coleoptera	*Cleridae*	*Necrobia rufipes (Fabricius, 1781)*	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
	Dermestidae	*Antrenus fuscus (Olivier, 1789)*	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.88^{b}
		Attagenus unicolor (Brahm, 1791)	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.29^{b}
		Dermestes maculatus (De Geer, 1774)	1.25^{b}	3.45^{c}	0.00^{a}	6.80^{e}	0.00^{a}	6.14^{d}
	Histeridae	*Margarinotus brunneus (Fabricius, 1775)*	0.00^{a}	1.15^{b}	0.00^{a}	5.83^{d}	0.00^{a}	4.39^{c}
	Silphidae	*Necrophorus humator (Gleditsch, 1767)*	0.00^{a}	0,00^{a}	0,00^{a}	5,83^{c}	0,00^{a}	2,63^{b}
Diptera	*Calliphoridae*	Pupae	13.75^{d}	13.79^{e}	0.00^{a}	12.62^{c}	21.43^{f}	11.40^{b}
		Chrysomya sp.	14.38^{d}	20.69^{e}	25.00^{f}	11.65^{b}	10.71^{a}	11.70^{c}
		Lucilia sp.	20.00^{e}	17.24^{d}	25.00^{f}	13.59^{b}	16.07^{c}	13.16^{a}
		Larvae	19.38^{d}	19.54^{e}	8.33^{a}	13.59^{b}	22.32^{f}	13.74^{c}
	Muscidae	*Musca domestica (Linneaus, 1759)*	16.25^{d}	14.94^{c}	25.00^{f}	7.77^{a}	17.86^{e}	14.33^{b}
	Sarcophagidae	*Sarcophaga carnaria (Linneaus, 1758)*	13.75^{e}	8.05^{a}	16.67^{f}	12.62^{c}	11.61^{b}	13.45^{d}
	Syrphidae	*Eristalis sp.*	1.25^{c}	1.15^{b}	0.00^{a}	7.77^{e}	0.00^{a}	4.97^{d}
		Fannian lustator (Harris, 1780)	0.00^{a}	0.00^{a}	0.00^{a}	1.94^{c}	0.00^{a}	1.46^{b}
Lepidoptera	*Oecophoridae*	*Hofmannophila sp.*	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
	Pyralidae	*Aglossa pinguinalis (Linneaus 1758)*	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1.46^{b}

The citation percentages of the same line bearing different letters are significantly different ($p < 0.05$); PI: Police Investigators; CSI: Crime Scene Investigators; M: Magistrates; HO: Health Officials; FW: Funeral Worker; TG: Traditional Gravediggers.

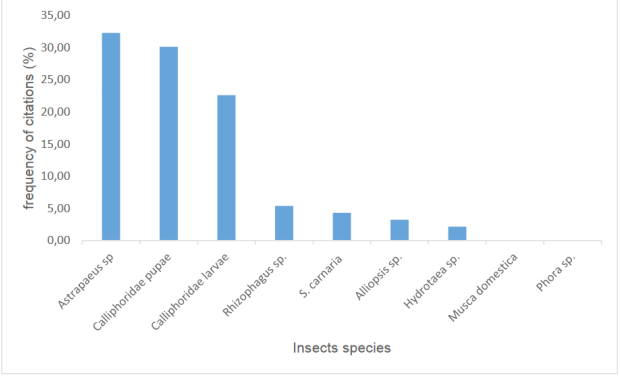


Fig. 5: Principal Component Analysis (PCA) according to profession

Knowledge on the succession (% quotation) of necrophagous insects according to the stages of cadaveric decomposition

Tables 8 and 9 show the order of arrival of insects on decomposing corpses according to informants of Bobo-Dioulasso and Ouagadougou cities. Five stages of decomposition have been defined. We have fresh corpse, swelling, active decomposition, advanced decomposition and skeletonization (Dekeirsschieter *et al*., 2012).

In Bobo Dioulasso (Table 8), as well as in Ouagadougou (Table 9), *Chrysomya sp*. and *Musca domestica* were found first on decomposing corpses, according to the informants. Cadavers are found more frequently depending on their state of decomposition.

Table 8: Necrophagous insects in connection with decomposing corpses according to Bobo-Dioulasso informants

			Stage of decomposition					
Orders	**Families**	**Species**	**1**	**2**	**3**	**4**	**5**	**6**
Coleoptera	*Dermestidae*	*Dermestes maculatus (De Geer, 1774)*	-	-	35	-	10	-
Diptera	*Calliphoridae*	*Chrysomya sp.*	45	-	-	-	-	-
		Lucilia sp.	5	25	25	-	-	-
	Fanniidae	*Fannia lustrator (Harris, 1780)*	-	-	-	-	-	-
	Muscidae	*Musca domestica (Linneaus, 1759)*	50	35	-	-	-	-
	Sarcophagidae	*Sarcophaga carnaria (Linneaus, 1758)*	-	35	20	-	-	-
	Syrphidae	*Eristalis sp.*	-	-	-	30	-	-
Lepidoptera	*Pyralidae*	*Aglossa pinguinalis (Linneaus, 1758)*	-	-	-	5	-	10

1- fresh corpse, **2**- swelling, **3**- active decomposition, **4**- advanced decomposition, **5**- skeletonization

Table 9: Necrophagous insects in connection with decomposing corpses according to Ouagadougou informants

			Stage of decomposition							
Orders	**Families**	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Coleoptera	*Dermestidae*	*Dermestes maculatus (De Geer, 1774)*	-	-	-	11.76	17.65	-	-	-
	Silphidae	*Necrophorus humator (Gleditsch, 1767)*	-	-	-	-	-	-	-	-
Diptera	*Calliphoridae*	*Larvae*	-	5.88	5.88	5.88	11.76	5.88	11.76	-
		Pupae	-	-	5.88	5.88	5.88	11.76	5.88	11.76
		Chrysomya sp.	52.94	-	-	-	-	-	-	-
		Lucilia sp.	5.88	41.18	47.06	-	-	-	-	-
	Fanniidae	*Fannia lustrator (Harris, 1780)*	-	-	-	-	-	-	-	-
	Muscidae	*Musca domestica (Linneaus, 1759)*	58.82	52.94	-	-	-	-	-	-
	Sarcophagidae	*Sarcophaga carnaria (Linneaus, 1758)*	-	-	41.18	35.29	-	-	-	-
	Syrphidae	*Eristalis sp.*	-	-	-	-	-	-	-	-
Lepidoptera	*Pyralidae*	*Aglossa pinguinalis (Linneaus, 1758)*	5.88	-	-	-	-	11.76	-	-

1- fresh corpse, **2**- swelling, **3**- active decomposition, **4**- advanced decomposition, **5**- skeletonization.

Knowledge of necrophagous insects cited by respondents on exhumed corpses.

General knowledge of necrophagous insects cited by respondents on exhumed corpses

Figure 6 shows the knowledge of necrophagous insects cited on exhumed corpses. Seven species of adult insects, two larval stages, belonged to seven families, two orders are cited by the informants. The most cited species from all localities are *Astrapaeus sp., Calliphoridae* pupae and larvae. While *Musca domestica* and *Phora sp.* were not cited.

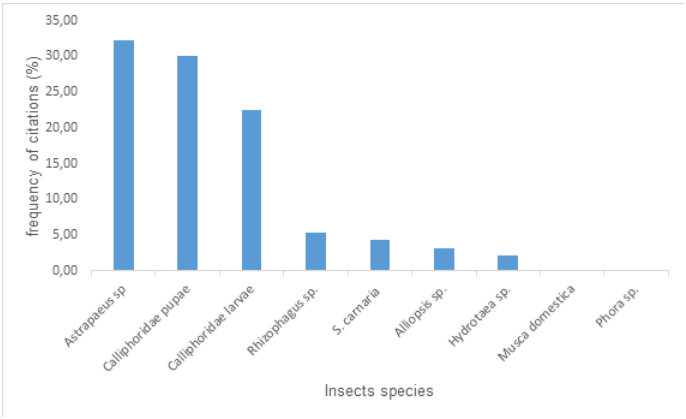


Fig. 6: Overall frequency of citation necrophagous insects of exhumed corpses

Knowledge of insects in exhumed bodies according to locality and climate zone

The PCA shows the distribution of species by locality (Figure 7) according to two climatic zones (Sudano-Sahelian and Sudanian zones). This figure shows on the y-axis that necrophagous insects on exhumed corpses are cited more by informants in the city of Bobo Dioulasso than in the other localities.

Tables 9 and 10 presents the frequency of citations of necrophagous insects found on exhumed corpses by locality. *Astrapaeus sp.* is the only species cited in all four localities. *Rhizophagus sp., Alliopsis sp Anthomyia sp., Sarcophaga carnaria, Calliphoridae* larvae and pupae, *Hydrotaea sp.* were cited by informants located in the city of Bobo Dioulasso and nowhere else. The most cited species in this city was *Rhizophagus sp.* (29.41 %).

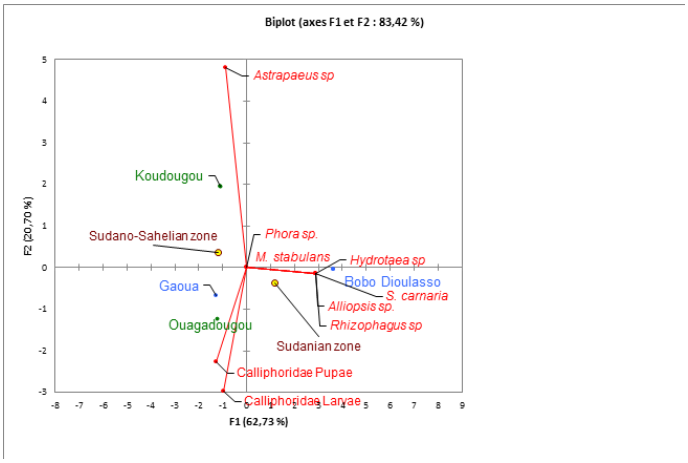


Fig. 7: Principal Component Analysis (PCA) of knowledge of necrophagous insects according to climatic zones

Table 10: General Knowledge of necrophagous Insect according to all locaties

Orders	**Families**	**Species**	**Bobo Dsso**	**Gaoua**	**Koudougou**	**Ouagadougou**
Coleoptera	*Monotomidae*	*Rhizophagus sp.*	29.41	0	0	0
	Staphylinidae	*Astrapaeus sp.*	17.65	21.05	100	13.83
Diptera	*Anthomyidae*	*Alliopsis sp.*	17.65	0	0	0
	Calliphoridae	*Larvae*	0	0	0	22.34
		Pupae	0	78.95	0	13.83
	Muscidae	*Hydrotaea sp.*	11.76	0	0	0
		Musca domestica (Linneaus, 1759)	0	0	0	0
	Phoridae	*Phora sp.*	0	0	0	0
	Sarcophagidae	*Sarcophaga carnaria (Linneaus 1758)*	23.53	0	0	0

Frequency of citation according to informant occupation

Table 11 reports the frequency of citation of necrophagous insects on exhumed corpses by informants. It shows the species *Astrapeus sp*. cited by the traditional gravediggers

and the hygiene officers. The other species *Rhizophagus sp., Alliopsis sp. Chrysomya sp*. and *Hydrotea sp.* are only mentioned by traditional gravediggers.

Table 11: Knowledge of necrophagous Insect according to function

Orders	Families	Species	PI	HO	M	CSI	TG
Coleoptera	*Monotomidae*	*Rhizophagus sp.*	0	0	0	0	29.41
	Staphylinidae	*Astrapeus sp.*	0	69.23	0	0	179.15
Diptera	*Anthomyidae*	*Alliopsis sp.*		0	0	0	17.65
	Calliphoridae	*Chrysomya sp.*	0	0	0	0	23.53
		Hydrotaea sp	0	0	0	0	11.76
	Muscidae	*Musca domestica (Linneaus, 1759)*	0	0	0	0	0
Diptera	*Phoridae*	*Phora sp.*	0	0	0	0	0

PI: Police Investigators; CST: Crime Scene Investigators; M: Magistrates; HO: Health Officials; TG: Traditional Gravediggers.

Discussion

Knowledge of necrophagous insect on open corpses

Fourteen species of necrophagous insects and two in the larval stage were cited by the informants in this current survey upon open corpses. This number was lower than those reported by Kientega *et al*., (2019), in Burkina Faso. He reported 21 species, including Diptera, Coleoptera and Hymenoptera. Many studies in other countries have reported more species than those reported in our survey (Koffi, 2018) such as in Côte d'Ivoire, where 30 species belonging to eleven (11) families were identified. In Algeria, Filalli, (2010) reported 108 species, Zed and Houda, (2017), reported over 500 species. In Cameroon, Youmessi *et al*., (2012) reported five families belonging to Diptera order during the inventory of the necrophagous entomofauna. In our survey, four species belonging to the order Diptera such as *Chrysomya putoria*, *Musca domestica, Lucilia sp., Sarcophaga carnaria* were predominants. Wyss and Cherix, (2006) and Koffi, (2018) found the same species. But in this survey, the species *Necrobia rufipes* and *Hofmannophila sp.* found on decaying corpses were not found by the informants. *Chrysomya sp.* and *Chrysomya albiceps* according to Rickenbach *et al.,* (1962) were known to be specific to West Africa. Despite what Lutz et *al.,* (2017) reported about the absence of *Lucilia sericata* in West Africa, informants clearly noticed the resemblance to *Lucilia sp.* and *Lucilia sericata*. Other studies should confirm the presence of these species in Burkina Faso, West Africa.

Knowledge of necrophagous insects in connection with climate zone

The frequency of citation of necrophagous insects varied according to the two climatic zones. Climatic factors influence the diversity and abundance of necrophagous insect species. The principal component analysis shows that the species were more cited in the Sudano-Sahelian zone than Sudanian zone. That could be explained by the annual rainfall recorded in the two areas. *Attagenus unicolor* was restricted to the Sudanian zone; it is possible that this species breeds exclusively in particular conditions of rainfall (900-1000 mm) and humidity. The Sudano-Sahelian zone showed more insects cited by informants than the Sudanian zone; this could be explained by the specific climatic conditions. In this place, the climate is hot, dry and the average rainfall varies from 600 to 900 mm (Yelemou *et al*., 2017; Séré *et al*., 2018; Sanou *et al*., 2019). These climatic factors of the Sudano-Sahelian zone enhance the life cycle of insects compared to the Sudanian zone because it rains less in this zone and it is also warm zone.

Knowledge of necrophagous insects regarding profession and locality

Knowledge of necrophagous insects also varied according to function and locality. Traditional gravediggers and Funeral workers were more familiar with necrophagous insects than other informants. For example, *Attagenus unicolor, Anthrenus fuscus, Aglossa pinguinalis* were only known by traditional gravediggers. This could be explained by the specificity of this profession. Their knowledge could be linked to the stage of decomposition of the corpses in their care. But it is very important to do not underestimate their traditional knowledge in this field. These workers are more likely to find these insects because they are in contact with the bodies in specific conditions. This profession is an attribution of the traditional society to a clan that practices it from generation to generation. The knowledge is therefore inherited from father to son. This could explain the level of knowledge of necrophagous insects by traditional gravediggers compared to the others.

Link between insects and stages of decomposition

Our results are similar to those found by Dekeirsschieter *et al.*, (2010) who showed that insects occur in consecutive waves according to the stage of decomposition. According to the informants responses, *Musca domestica* comes first followed by *Chrysomya sp.* and *Lucilia sp.* whatever the locality. When the decay stage starts, *Sarcophaga carnaria, Dermestes maculatus* were present on the corpse. Dekeirsschieter, (2007) showed that *Calliphoridae* were the first to colonise fresh corpses.

Knowledge of necrophagous insects of exhumed corpses

Seven of the nine species of forensic insects presented to the informants were cited. Among these informants, only the traditional gravediggers and funeral workers have a good knowledge of necrophagous insects of exhumed corpses. This could be explained by the specificity of their work. In Burkina Faso, funeral workers are specialists in exhumations. They are called for judicial and administrative exhumations. They are often escorted by the technical and scientific police team. Among the necrophagous insects of exhumed corpses, *Astrapaeus sp.* is the only one cited in all the localities, while *Musca domestica* and *Phora sp.* were not cited. This situation could be explained by its family likeness and size, which is relatively small. Some informants linked the presence of some insects (*Astrapaeus sp.*) to the announcement of misfortune. Some informants also mentioned the fear of the death that would not allow a thorough search of the crime scene (Wyss and Cherix, 2006).

Conclusion

In this current study, twenty-one necrophagous insects, including fourteen from open corpses and seven from exhumed corpses, were cited by informants in eight villages and four cities. The Knowledge of necrophagous insects varied from one locality to another and from one climatic zone to another. *Chrysomia sp* was the most commonly cited in the Sudano-Sahelian zone. *Chrysomia albiceps* was the most cited in the Sudanian zone. Necrophagous insects were well known to traditional funeral workers and gravediggers. Our study showed a diversity of necrophagous insects in both the Sudano-Sahelian and Sudanian climatic zones of Burkina Faso. This work provide precious data that could be exploited in criminal investigations. The study highlighted the lack of

knowledge among justice actors to the value of necrophagous insects in criminal investigation. This situation motivates us to conduct research for future entomological expertise in Burkina Faso.

Ethics Committee approval

This protocol was approved by Joseph KI-ZERBO University ethics committee: CE-UJKZ/2022-11.

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