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Africa under attack: a continent-wide mapping of pathogens, parasites and predators afflicting the hived honey bee *Apis mellifera* L. (Hymenoptera: Apidae)

D.R. KUGONZA
Department of Agricultural Production, College of Agricultural and Environmental Sciences (CAES), Makerere University, P. O. Box 7062, Kampala, Uganda.
Correspondence Author: donkugonza@caes.mak.ac.ug

ABSTRACT
Several major honeybee pests and diseases have been reported in different parts of the world. In Africa initially, reports were from a few countries that participated in the first continent-wide assessment four decades ago. Over the years, there have been reports on individual or combinations of pathogens/parasites/predators either in sites within one country or across a number of countries. This paper reviewed several peer-reviewed publications and mapped the status of these bacterial, fungal, and viral pathogens, mites, as well as pests and predators of honeybees in Africa. Of the 35 countries with data, all the countries have reported presence of at least three of the various categories of enemies of honeybees. For the other 20 countries, it was not possible to declare absence, but one can claim no information. This does not mean that the countries are safe, far from it. Instead, by considering the geographical spread of these pathogens and parasites, it can be predicted that the entire African continent is under a massive attack. Of the bacterial diseases, American foulbrood has spread from three countries in 1980 to 12 to date while European foulbrood is found in only three new countries over the period. Fungal pathogens are present in countries along the eastern African coast and their western neighbours. Of the 23 viruses that afflict honeybees globally, nine are present in ten African countries. The Varroa mite that is currently a pan-global pest is present in 23 African countries across all geographical regions while the tracheal mite has invaded seven new countries to the eleven over four decades ago. Hive beetles, flies, bee conopoid, bee lice, wax moths, termites, ants, birds and mammals are present all over the continent. The key implication of this mapping is that we cannot rely on the bees themselves to fight off these invaders, but must proactively counterattack using integrated approaches if the African continent is to continue having its rich biodiversity, crop production and food.

Key words: Africa, *Apis mellifera*, diseases, honeybee pests, pathogens, prevalence

RÉSUMÉ
De nombreuses maladies et ravageurs majeurs des abeilles mellifères ont été signalés dans différentes parties du monde. Par le passé, seuls quelques pays Africains fournissaient les rapports. Ce sont les pays qui ont participé, il y a quatre décennies, à la première évaluation continentale. Au fil des ans, il y a eu des rapports sur des agents pathogènes pris individuellement ou des combinaisons d'agents pathogènes/parasites/prédateurs, soit dans des sites au sein d'un pays, ou soit dans plusieurs pays. Le présent article a passé en revue plusieurs articles publiés dans des revues à comité de lecture et cartographié le statut de ces agents pathogènes bactériens, fongiques, viraux, ainsi que les acariens, ravageurs et prédateurs des abeilles mellifères en Afrique. Tous les 35 pays disposant de données ont signalé la présence d'au moins trois des différentes catégories d'ennemis de ces abeilles. Pour les 20 autres pays, il n'a pas été possible de déclarer une absence, mais on ne peut prétendre à aucune information. Cela ne veut pas dire que les pays sont exemptes d'attaques des abeilles. Plutôt, en considérant la propagation

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géographique de ces agents pathogènes et parasites, on peut prédire que l'ensemble du continent africain est soumis à une attaque massive. Parmi les maladies bactériennes, la loque américaine s'est propagée de trois en 1980 à douze pays à ce jour, tandis que la loque européenne ne se trouve que dans trois nouveaux pays au cours de la période. Les agents pathogènes fongiques sont présents dans les pays situés le long de la côte Est de l'Afrique et leurs voisins occidentaux. Sur les 23 virus qui affectent les abeilles mellifères dans le monde, neuf sont présents dans dix pays africains. L'acarien Varroa, qui est actuellement un ravageur connu au plan mondial, est présent dans 23 pays africains à travers toutes les régions géographiques, tandis que l'acarien trachéal a envahi sept nouveaux pays sur onze il y a plus de quatre décennies. Les coléoptères des ruches, les mouches, le conopoïde d'abeille, les poux d'abeille, les papillons de nuit, les termites, les fourmis, les oiseaux et les mammifères sont présents sur tout le continent. L'implication clée de la présente cartographie est que, si l'Afrique souhaite conserver sa riche biodiversité, sa capacité de production agricole et de production de nourriture, il faut arrêter de compter sur la capacité des abeilles à lutter elles-mêmes contre ces envahisseurs. Il faut plutôt contre-attaquer de manière proactive, en utilisant les approches de lutes intégrées.

Mots clés: Afrique, Apis mellifera, maladies, ravageurs des abeilles, agents pathogènes, prévalence

INTRODUCTION

Naturally, honey bees (*Apis mellifera* L.) that are either wild or managed remain crucial for the pollination of many plants and crops (FAO, 2019) and contribute not only to food security through pollination service but also contribute massively to the economies of all countries of the world (van Engelsdorp and Meixner, 2010). Honey bees also give special insights into social evolution being that they are considered a model organism (Paxton, 2020). A conservative figure of 87.5% has been proposed as the proportion of all flowering plant species that are pollinated by members of the kingdom Animalia (Ollerton *et al.,* 2011) to produce food, medicines, materials and also to feed livestock (Potts *et al.,* 2010). Honey bee work on pollination alongside other species such as other insects, birds, bats and other animals (FAO, 2019) are responsible for the production of 70% of the 124 world main crops (Klein *et al.,* 2006; Eilens *et al.,* 2011). Among the other insect pollinators are moths, hoverflies, beetles, wasps, flies and butterflies. The important pollinator bird groups on the African continent include sunbirds and spiderhunters (Nectariniidae) while elsewhere are honey-eaters (Meliphagidae), hummingbirds (Trachilidae) and mammals (e.g. bats) (Potts *et al.,* 2010; Samuels and de Zylva, 2015). Globally, the managed honeybee colonies contribute to pollination of crops worth US$215 billion (vanEngelsdorp *et al.,* 2008; Gallai *et al.,* 2009; Smith *et al.,* 2013). The contribution of pollination services in Ghana was put at 11.1% of national annual agricultural production, of about US$7 million (Gallai and Vaissière, 2009). Add to this is the fact that pollinator-dependent crops have higher prices than non-dependent crops. (Allsopp *et al.,* 2008) Also, Africa is the only region that has large populations of native honey bees still existing in the wild (Pirk *et al.,* 2014), and has about 310 million honey bee colonies (Dietemann *et al.,* 2009). This is a major proportion of the 20,000 species of bees in the world, being that Africa is not only the cradle of mankind but also of the honey bee.

These vital roles of honeybees notwithstanding, there is a general decline in honey bee numbers and this is frightening given their important role in providing ecosystem services (Vanbergen *et* *al.,* 2013; FAO, 2019). As predicted, a decline in abundance and diversity of pollinators will result in loss of pollinator services and will culminate into significant reduction in wild plant diversity, wide ecosystem destabilisation, loss in crop production, food insecurity and inadequate human welfare (Regan *et al.,* 2015). In Africa, the managed bee colonies make a small percentage of all the existing honey bee colonies (Johannsmeier, 2001). To add to that, the worry regarding declining honey bee numbers is justified considering that there is a growing demand for crop pollinators as well as need for an adequate source of honey bee colonies (Goulson *et al.,* 2015; Pirk *et al.,* 2016).

Large colony loses have been experienced in many parts of the world (Moritz, 2010; Neumann and Carreck, 2010; Smith, 2013) and the trend will continue unless clear steps are taken to curb the decline. This decline in the diversity of pollinators has been attributed to several drivers that include: land use change and damage and associated loss of natural habitats, agriculture, pollution, invasive alien species, pathogens and unprecedented climate change (JRS Biodiversity Foundation, 2016) and unregulated hunting. On the other hand, the longevity of honey bee colonies is negatively affected by several factors that include: parasites, pathogens, pesticide exposure, poor nutrition, reduced genetic diversity and management practices (Muli *et al.,* 2014; Akol *et al.,* 2016; Namayanja, 2018). Colony losses have been primarily attributed to global trade in honey bees and bee products and this becomes the vehicle for active means of introduction and spread of introduced species of pathogens, parasites and pests (Nixon, 1982). It is clear that the three sets of drivers mentioned above show convergence.

Interest in the global mapping of bee diseases and parasites was pioneered in 1981 with surveys of American foul brood, European foul brood, Sac brood, Chalk brood, nosema, amoeba disease, acarine disease and the bee louse (Nixon, 1982) under the auspices of the International Bee Research Association. This effort published the preliminary world maps of honey bee diseases and parasites. Within one year, following the compilation of a broad record of Varroa and Tropilaelaps mites, another set of updated world maps for the then ten major diseases and parasites of honey bees was published (Nixon, 1983) to wide acclaim. By 1987 when the next world distribution of the same major honey bee diseases and pests was released (Bradbear, 1988), the brood diseases were showing a wider distribution but information was getting limited on other diseases. The proliferation of the ten mentioned honey bee diseases and pests continued as reported in 1993 (Matheson, 1993). Later on, Allen and Ball (1996) focused on the world distribution of honey bee viruses, with increased interest in viruses due to their association with Varroa jacobsoni and the realization that until then, published honey bee disease distribution did not contain substantial information on viruses. The continued interest in the spreading of honeybee diseases and pests and their associated threats on the global beekeeping sector led to the next worldwide health status assessment of honey bees (Ellis and Munn, 2005). Since then, there have been invited reviews looking at literature and these paint the global picture from different perspectives. Among these has been the focus on decline of managed honey bees in Europe (Potts *et al.,* 2010a), decline in global pollinators (Potts *et al.,* 2010b), general honey bee colony losses (Neumann and Carreck, 2010) and drivers of honey bee colony declines and losses (Smith *et al.,* 2013).

Honeybee colonies in Africa are affected by the introduction of new pathogens, parasites and pests, particularly Varroa mites, American foulbrood, and *Nosema ceranae*, in addition to habitat loss (Nixon, 1983; Hussein 2001a; Dietemann *et al.,* 2009). Introductions to Africa are either accidental through importation of bees with increased transport of queen honeybees from country to country (Nixon, 1982) or are by the bees themselves arriving as stow away. Indeed, most of the parasites and pathogens disturbing global honey bee colony health have been found present all over Africa (Bradbear, 1988; Matheson, 1995; Allen and Ball, 1996; Hussein 2001b; Ellis and Munn, 2005; Mumoki *et al.,* 2014). However, Africa is still lucky. This is because, Africa: (a) is home to a large reservoir of endemic feral population of honey bees, (b) the honey bees show a much higher genetic diversity than honey bee populations elsewhere, (c) in Africa, bee keeping in most countries is based on traditional practices and only a small part of the honey bee colonies are commercially managed (Pirk *et al.,* 2016). Both developing and adult honey bees are attacked by bacteria, fungi, microsporidians, mites, protozoans, and viruses as well as several predators. Additionally, honey bee equipment is attacked by other insects. The aim of this review paper is to present the current status and mapping of Africa regarding these enemies of honey bees and give options for their management centering on continuous vigilance by the bee keepers.

List of known honey bee pathogens, parasites, pests and predators in Africa

Honey bee pathogens, parasites, pests and predators (the ones that have two asterisks** have been found in Africa, those with no asterisk are found in other parts of the world)

1. Bacterial diseases
1.1 American foul brood (*Paenibacillus larvae*)** (Figure 1A)
1.2 European foul brood (*Melissococcus plutonius)*** (Figure 1B)
2. Fungal diseases (Figure 1C)
2.1 *Nosema apis*, *Nosema ceranae* and *Nosema neumanii***
2.2 Chalkbrood (*Ascosphaera apis*)**
2.3 Stonebrood
2.4 Dysentry (Amoeba disease, *Malphighamoeba mellifecae*)
3. Viral diseases**(Figure 1D)
3.1 Acute bee paralysis virus (ABPV),
3.2 *Apis mellifera filamentous* virus (AmFV),
3.3 Black queen cell virus (BQCV),
3.4 Chronic bee paralysis virus (CBPV),
3.5 Deformed wing virus (DWV),
3.6 Lake Sinai virus (LSV),
3.7 Israeli acute paralysis virus (IAPV),
3.8 Sacbrood virus (SBV),
3.9 *Varroa destructor* virus 1 (VDV1)
4. Parasitic mites
4.1 Varroa mite (*Varroa destructor*)** (Figure 2A)
4.2 Tracheal mite (*Acarapis woodi*)** (Figure 2B)
4.3 Tropilaeps mite (*Tropilaeps clareae*)
5. Associated honey bee pests and predators
5.1 Beetles (Coleoptera)** (Figure 3A)
5.2 Flies (Diptera)** (Figure 3B)
5.3 Moths (Lepidoptera)** (Figure 3C)
5.4 Termites (Isoptera)**
5.5 Ants (Figure 3D), wasps (Figure 3E) and honey bees (Hymenoptera)**
5.51 Ants
5.52 Wasps
5.53 German yellow jacket
5.54 Honey bees
5.6 Bee pseudoscorpion (*Ellingsenius* spp.)**
5.7 Birds (Figure 3F) and Mammals (Figure 3G)**

Bacterial Diseases

American foulbrood (AFB). American foulbrood (AFB) is caused by the spore-forming Paenibacillus larvae (previously classified as a *Bacillus larvae*). It is the most prevalent and destructive of the honey bee brood diseases, characterised by high morbidity. It is a chronic endemic and epidemic contaminant with worldwide distribution. In 1981, AFB was reported in Algeria, Morocco and Tunisia and was absent in central and southern Africa (Nixon, 1982; Kugonza, 2009) but presently the distribution in Africa is in 12 countries (Table 1 and Figure 1A). Only north and southern Africa currently have a broad spread of the disease, and much of eastern, central and western Africa are still free of the disease. However, considering that AFB is present in Uganda, and no major barrier exists with its neighbours, swarming bees could move the disease across eastern and central Africa region. American foulbrood affects the larval stage of honey bees especially after capping of the comb cells. It can be transmitted by adult honey bees within a colony from honey bee to honey bee; and transmitted between colonies. It is the worst of all brood diseases, very pernicious and most difficult to eliminate completely, and it is categorised among notifiable diseases of the *Office International des Epizooties*/World Organisation for Animal Health (OIE).

European foulbrood (EFB): European foulbrood (EFB) is the second major bacterial disease of honey bees, is caused by *Melissococcus plutonius* and is very predominant in Africa (Table 1, Figure 1B) compared to AFB that is less common (Figure 1A) but it is also a notifiable disease of the OIE. Half of the southern Africa part of the continent is infected and so is three quarters of northern Africa. With the exception of Tanzania, the rest of Eastern Africa is still free of EFB, while Central Africa is still unstudied. By 1981, the disease was already present in all the countries currently afflicted (Nixon, 1982), with exception of Eritrea, Ghana and Libya. Larvae that are infected with EFB die before their cells are capped, which is a major difference with AFB. On examination, infected larvae are seen twisted in the cell floor, their colour changes from characteristic white to cream and they have a smooth “melted” appearance. Considering that EFB bacteria do not form spores that persist in nature, this disease is not as dangerous as AFB. European foulbrood is frequently considered a “stress” disease – that is, a disease that only becomes dangerous if the colony is already under stress from other influences. Colonies that are infected with EFB sometimes recover without external influence usually after the start of a good nectar flow.

Fungal Diseases. The distribution in Africa of fungal pathogens in the last 20 years is presented in Table 1 and Figure 1C. The pathogens are present in countries along the eastern African coast and their neighbouring countries to the west. Exception to this are Somalia and Mozambique that are still free of the fungal diseases. All the countries of northern Africa are infected and were so in 1981 when the benchmark global assessment was conducted (Nixon, 1982). Most of central and western African countries are largely unstudied and may therefore not be free of the pathogens.

Nosema - Nosema apis, Nosema ceranae and Nosema neumanni: Nosema is a microsporidian of much significance in the world (Smith *et al.,* 2013). Numerous reports confirm the presence of *Nosema apis* in the African continent, however, only two reports describe the presence of *Nosema ceranae* in honey bee colonies from Algeria and Benin (Higes *et al.,* 2009; Cornelissen *et al.,* 2011) and one report of *Nosema neumanni* in Uganda (Chemurot, 2017). *Nosema apis, Nosema cerana*e and *Nosema neumanni* are microsporidian gut parasites that cause nosema disease (nosemosis) in adult honey bees. Nosema attacks the intestinal tracts specifically the ventriculus of adult honey bees and leading to the condition termed –the nosema disease.

In honey bees, the typical symptoms produced by *N. apis* in honey bees include crawling and inability to fly, tembling, and spotting or dysentery (Sammataro and Avitabile, 2011). The symptoms of *Nosema ceranae* are not obvious and does not have seasonality influences as it can occur across the span of a year (Bourgeois *et al.,* 2010). Nosema not only affects colony mortality rates but honey and brood production as well. Though an association between Nosema and the black queen-cell virus has been documented, opposing reports exist regarding the seasonality, virulence and overall effect of the Nosema types (Williams *et al.,* 2014; Natsopoulou *et al.,* 2015). The incidence of *N. neumanni n*. sp. in Ugandan honey bees was found to be much higher than for the other two Nosema species (Chemurot, 2017).

Chalkbrood *(Ascophaera apis):* Chalkbrood is a fungal brood disease that develops when *Ascophaera apis* affects the gut of larvae. *Ascophaera apis* has been found in several African countries namely: Algeria, Egypt, Ethiopia, Nigeria, South Africa and Tunisia (Table 1), but had only been present in Tunisia when a global assessment of the status of honey bee diseases was made in 1981 (Nixon, 1982). The fungus causes the honey bee larvae to become mummified, making detection easy. The colour of the mummies varies from white (like chalk, hence the name chalkbrood) to black (Aronstein and Murray, 2010). The disease may cause a reduction in colony strength and losses of colonies (Jensen *et al.,* 2013). Chalkbrood disease is usually not considered a serious disease but one of the "stress diseases" because its fungal spores are always present but are always manageable by a healthy colony. Proper beekeeping practices such as good ventilation could help to limit the effects of the Chalkbrood disease.

Dysentry (Amoeba Disease). *Malphigamoeba mellificae*, a single celled parasite causes the amoeba disease (amoebiasis) and affects malphigian tubules in adult bees failing their excretory role (Liu, 1985). This contagious disease mostly affects the worker caste of the western honeybee causing death, and is closely associated with nosemosis. The Amoeba is classified as Eukaryota (Domain), Amoebozoa (Phylum), Tubulinea (Class), Tubulinida (Order), Amoebidae (Family), Malphigamoeba (Genus) and *M. mellificae* (Species). Amoebiasis is mostly found in Europe, America and Oceania because it only attacks the western honey bee (Apis mellifera), however, the 1981 world mapping of the disease (Nixon, 1982) reported it present in Tunisia and Zimbabwe. No other status report on the pathogen in Africa is forth coming. Sick bees are weak, shake their wings and faulter in flight and have yellow diarrhoea (Mehlhorn, 2008) that give off a strong foul smell. Heavily infested colonies should be destroyed to stop the disease from spreading, but lightly infected colonies may recover on their own.

Viral Diseases. By 2017, there were at least 23 viruses directly associated with honey bee health globally and of these, nine have been reported in many African countries (Table 1, Figure 1D). Most viruses are single stranded RNA and belong to the Order Picornavirales that are further classified into five families two of these, namely Iflaviridae and Dicistroviridae having the common viruses (Otim, 2019). Countries infested by virus(es) are five in north Africa (namely: Algeria, Egypt, Libya, Morocco and Tunisia), in East Africa only Kenya and Uganda are infected, in Southern Africa it is South Africa, while in West Africa, only Benin reported occurance. The viruses reported in Africa include: Acute bee paralysis virus (ABPV), *Apis mellifera* filamentous virus (AmFV), Black queen cell virus (BQCV), Chronic bee paralysis virus (CBPV), Deformed wing virus (DWV), Israeli acute paralysis virus (IAPV), Lake Sinai virus (LSV), Sacbrood virus (SBV) and *Varroa destructor* virus 1 (VDV-1). Five of these, namely: ABPV, BQCV, CBPV, DWV and SBV have been confirmed present in Uganda (Kajobe *et al.,* 2010; Otim, 2019) either singly in a honeybee colony or in co-infections involving 2-4 different bee virus species (Otim, 2019).

Acute bee paralysis virus (ABPV). ABPV is a wide spread infective pathogen of bees. It belongs to the Dicistroviridae family of viruses, just like the IAPV and BQCV and is detected in apparently healthy colonies. Uganda was found free of this virus by Kajobe *et al*. (2010).

***Apis mellifera filamentous* virus (AmFV).** Though this virus causes no noticeable symptoms in adult honey bees, in some of the infected honey bees, white haemolymph may be found. AmFV has been positively confirmed only in South Africa. At colony level, the *Apis mellifera* filamentous virus does not have

Table 1. Pathogens, parasites, pests and predators of honey bees reported present (+), absent (-), or not reported (n.i) in Africa

	Country	Bacteria		Fungi	Viruses	Mites		Pests and Predators					Birds	Mammals	References
		AFB	EFB			Varroa	Acarapis	Beetles	Flies	Moths	Ants	Wasps			
1	Algeria	+	+	+	+	+	+	-	+	+	+	+	+	-	1,2,3,4,5,6
2	Angola	-	+	-	-	+	+	+	+	+		+	+	+	2,4,5,6,7,8
3	Benin	-	-	+	+	+	-	+		+	+	+	+	+	6,9,10,11
4	Botswana	+	-	-	-	+	-	+	+	+	+	+	-	+	2,4,5,6,7,12
5	Burkina Faso	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
6	Burundi	-	-	-	-	-	-	-	+	-	-	-	-	-	5,13
7	Cameroon	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
8	Cape Verde	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
9	Central Afr. Rep.	+	+	-	-	-	+	+	+	+	-	+	-	-	2,4,5,6,7
10	Chad	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
11	Comoros	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
12	Congo	-	-	-	-	-	+	+	+	+	+	+	-	-	2,4,5,6,7
13	Dem. Rep. Congo	-	-	-	-	-	+	+	+	-	-	-	+	+	2,5,6,7
14	Djibouti	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
15	Egypt	-	-	+	+	+	+	+	+	+	+	+	+	-	1,2,3,4,5,13
16	Equatorial Guinea	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
17	Eritrea	+	+	-	-	-	-	+	-	-	-	-	-	-	5
18	Eswatini	-	-	-	-	+	-	-	-	-	-	-	-	-	5,12
19	Ethiopia	-	-	+	-	+	+	+	+	+	+	-	+	+	1,2,4,5,6,14,15
20	Gabon	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
21	Gambia	+	-	-	-	-	-	+	-	-	-	-	-	-	5
22	Ghana	-	+	+	-	+	-	+	+	+	+	+	-	-	1,4,5,6,16
23	Guinea	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
24	Guinea-Bissau	+	+	+	-	-	+	+	+	+	-	-	-	-	1,2,4,5,6,13
25	Ivory Coast	-	-	+	+	+	-	+	-	-	-	+	-	-	6
26	Kenya	-	-	+	+	+	-	+	+	+	+	+	+	+	1,2,4,5,6,17
27	Lesotho	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
28	Liberia	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
29	Libya	+	+	+	+	+	-	-	-	-	-	+	+	-	1,2,4,5,18

30	Madagascar	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
31	Malawi	-	+	+	-	-	+	+	+	+	+	+	+	+	4,5,6,7
32	Mali	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
33	Mauritania	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
34	Mauritius	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
35	Morocco	+	+	+	+	+	+	+	+	+	+	+	+	-	1,2,4,5,6,18
36	Mozambique	-	-	-	-	+	+	+	+	+	+	+	-	+	2,5,6,7,12
37	Namibia	-	-	-	-	-	-	+	+	-	-	-	-	-	5
38	Niger	-	-	+	-	+	+	-	-	-	-	-	-	-	5
39	Nigeria	-	-	+	-	+	-	+	+	+	+	-	+	+	1,5, 6,10
40	Rwanda	-	-	-	-	+	+	-	+	+	-	+	-	-	2,5,6,7,25
41	Sahrawi Rep.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
42	São Tomé and Principe	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
43	Senegal	+	+	+	-	+	+	+	+	+	+	+	+	+	1,2,5,6
44	Seychelles	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
45	Sierra Leone	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
46	Somalia	-	-	-	-	-	-	+	+	-	-	+	-	+	1,6
47	South Africa	+	+	+	+	+	+	+	+	+	+	+	+	+	2,5,6,7,19
48	South Sudan	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
49	Sudan	-	-	-	-	+	-	+	+	+	+	+	+	+	1,20
50	Tanzania	-	+	+	-	+	-	+	+	+	+	+	+	+	1,2,5,6,21
51	Togo	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.	
52	Tunisia	+	+	+	+	+	+	-	+	+	+	-	+	-	1,2,3,4, 5,6,13
53	Uganda	+	-	+	+	+	-	+	+	+	+	-	-	+	1,2,5,6,16,22,23,24,26,27
54	Zambia	-	+	-	-	-	-	+	+	-	-	+	-	+	2,5,6,7
55	Zimbabwe	-	-	+	-	+	-	+	+	-	+	-	+	+	2,5,6,7,12

AFB = American Foul Brood
EFB = European Foul Brood
n.i. means no information available.
Central Afr. Rep. = Central African Republic; Dem. Rep. Congo = Democratic Republic of the Congo; Eswatini was formerly called Swaziland
1. Hussein (2001a), 2. Bradbear (1988), 3. Allen and Ball (1996), 4. Matheson (1993), 5. Ellis and Munn (2005), 6. Hepburn and Radloff (1998), 7. Hussein (2001b), 8. WAHID Interface (2015), 9. Amakpe *et al*. (2015), 10. Mumoki et al. (2014), 11. Paraiso *et al*. (2011), 12. Allsopp (2006), 13. Matheson (1995), 14. Begna (2014), 15. Jatema and Abebe (2015), 16. Frazier *et al*. (2010), 17. Muli *et al*. (2014), 18. Haddad *et al*. (2015), 19. Baxter (2009), 20. El-Niweiri (2004), 21. Mumbi *et al*. (2014), 22. Kajobe *et al*. (2010), 23. Chemurot (2016), 24. Chemurot (2017), 25. Mwiza *et al*. (2013), 26. Kugonza *et al*. (2008), 27. Otim (2019)

an impact at the colony level when on its own (Hartmann *et al.,* 2015).

Black queen cell virus (BQCV). It is a dicistroviridae and as implied by its name, the BQCV causes the queen larva to turn black and die. It may have some association with Nosema though this is not yet confirmed. This virus was confirmed present in Uganda in both adults and brood almost a decade ago (Kajobe *et al.,* 2010).

Chronic bee paralysis virus (CBPV). Honey bees that are infected by CBPV either show crawling, trembling, irregular wing position and stretched abdomens or show a black or greasy appearance and being hairless. CBPV may affect all the honey bee life stages and the transmission of the CBPV virus is mostly horizontal with limited information regarding vertical transmission routes. Uganda was previously found free of this virus by Kajobe *et al*. (2010) but has recently been found infected, with samples from Northern (Lira district) and Western Uganda (Kabarole district) district returning positive results (Otim, 2019). This virus was found to significantly affect colony strength, with weak colonies showing more devastation (Otim, 2019).

Deformed wing virus (DWV). This virus, noticeable from its name, causes the wings of infected honey bees to become deformed. Characteristically, it is associated with the mite *Varroa destructor* and has been proposed as a causative factor to Colony Collapse Disorder that is ravaging the globe. Uganda was found free of this virus (Kajobe *et al*., 2010).

Israeli acute paralysis virus (IAPV). This virus is related to ABPV and was first described globally in 2004. Though it is named after Israel, the country where it was first discovered, its true origin is still unknown. This virus has been suggested as one of the indicators for colony collapse disorder. Uganda was found free of this virus (Kajobe *et al*., 2010).

Lake Sinai virus (LSV). The presence of LSV in adult honey bees has only been recently described (Runckel *et al.,* 2011) and in Africa, the only report has been from Benin (Amakpe *et al.,* 2015). The economic importance of this virus for Africa as well as its association with other viruses and parasites are not known.

Sacbrood virus (SBV). The virus that causes sacbrood disease is quite widespread globally since its report in 1981 and has continued to spread. The disease has now spread from Egypt and South Africa where it was reported present in 1981 (Nixon, 1982), to ten African countries. Uganda was found recently to be free of this virus (Kajobe *et al.,* 2010). Larvae on being infected change colour from pearly white to grey and then finally to black. Death of the larvae occurs when the larvae are upright, just before pupation. Subsequently, affected larvae are found in comb cells that are capped. Larvae that are diseased have typically retarded head development and the head region of diseased larvae is usually darker than the other parts of the body. When carefully removed from their cells, affected larvae appear to be in a sac filled with water. Typically, the scales in the cells are brittle but easy to be removed. Larvae that are diseased by the Sacbrood virus have no characteristic odour.

Varroa destructor virus 1 (VDV-1). This virus relates closely with DWV and can cause wing deformation in honey bees. It affects larvae, pupae and adults. The presence of the VDV-1 is of significant concern due to it being associated with *Varroa destructor*.

Parasitic Mites

Varroa mites (*Varroa destructor*). *Varroa destructor* is an ectoparasitic mite that feeds on the body fluids/haemolymph of larval, pupal and adult bees and is an IOE notifiable infestation. The curved body of Varroa fits into the abdominal folds of the adult bee and are held in place by the shape and arrangement of ventral setae, thus get protection from the bees normal cleaning habits. Varroa mites are visible to the naked eye and appear as small red or brown spots on the thorax of a honeybee or on the larva, about the size of a pinhead. First discovered in 1904 in South East Asia and named *Varroa jacobsoni*, it has now spread worldwide. It is currently widespread in Uganda though farmers together with beekeeping extension workers are not fully aware about its presence (Kasangaki *et al.,* 2016). Taxonomically, *Varroa destructo*r was first described by Anderson and Trueman (2000) as a eukaryote of the Kingdom: Animalia, Phylum: Arthropoda, Class: Arachnida, Order: Parasiformes, Suborder: Mesostigmata, Family: Varroidae, Genus: Varroa, and Species: *Varroa destructor.*

Varroa mites are global pests except in a few areas of the world such as Australia and a few islands (Potts *et al.,* 2010) and are currently present in over 23 African countries (Table 1 and Figure 2A). This indicates a geographically widespread attack over much of the continent. The true spread is not clear due to limited availability of data. The mites are mobile and move from one bee to another within the hive. According to Calderone (2005), they are found twice as often on bees in the brood chamber as in the honey supers, and ten times as often on brood nest bees as on foragers. The spread of the mites across honey bee colonies is facilitated by adult bees through drifting, robbing and swarming. Drifting occurs when foragers enter a hive different from their own especially when hives are located a few metres from each other, robbing occurs when a strong colony invades a weaker one to steal their honey, while swarming occurs when one or several parts of the colony vacates a hive and establishes itself in a new location. Beekeeper activities like colony unification, migratory beekeeping and transfer of colonies from location to location for restocking also promote the spread of the mites.

Effects of the Varroa mites: The mites (a) affect flight behaviour, (b) affect several physiological parameters and (c) reduce longevity of honey bees in addition to (d) transmitting several viruses within and between colonies. Varroa mites either directly (f) feed on the haemolymph of the adult bees or on bee larvae and pupae in the brood cell, eventually (g) weakening the honey bee colonies, (h) lowering honey production (varroatosis), (i) with heavy infestation cause absconding. Honey bee colonies that are parasitized by Varroa have (j) reduced honey and brood production, (k) abnormally early foraging, (l) increased drift, (m) changed wing shape, (n) reduced virgin queen acceptance, (o) reduced mating success, (p) higher bee mortality; parasitized foragers show (q) decreased capacity of non-associated learning, (r) prolonged absence from the colony and (s) a lower rate of return to the colony. The viruses transmitted by Varroa mites include acute bee paralysis virus (ABPV), Israeli acute paralysis virus (IAPV), Kashmir bee virus (KBV) (Ribiere 2008; Highfield *et al.,* 2009; Genersch and Aubert 2010), Deformed Wing Virus (DWV) (Genersch *et al.,* 2010), black queen cell virus (BQCV) and others. In Africa, there are no reports of heavy honey bee colony losses directly associated with mites or the viruses they propagate, even though there are no known control measures for both. This suggests that the honeybees on the African continent are not as threatened or are resistant in comparison to honey bees in other areas of the planet.

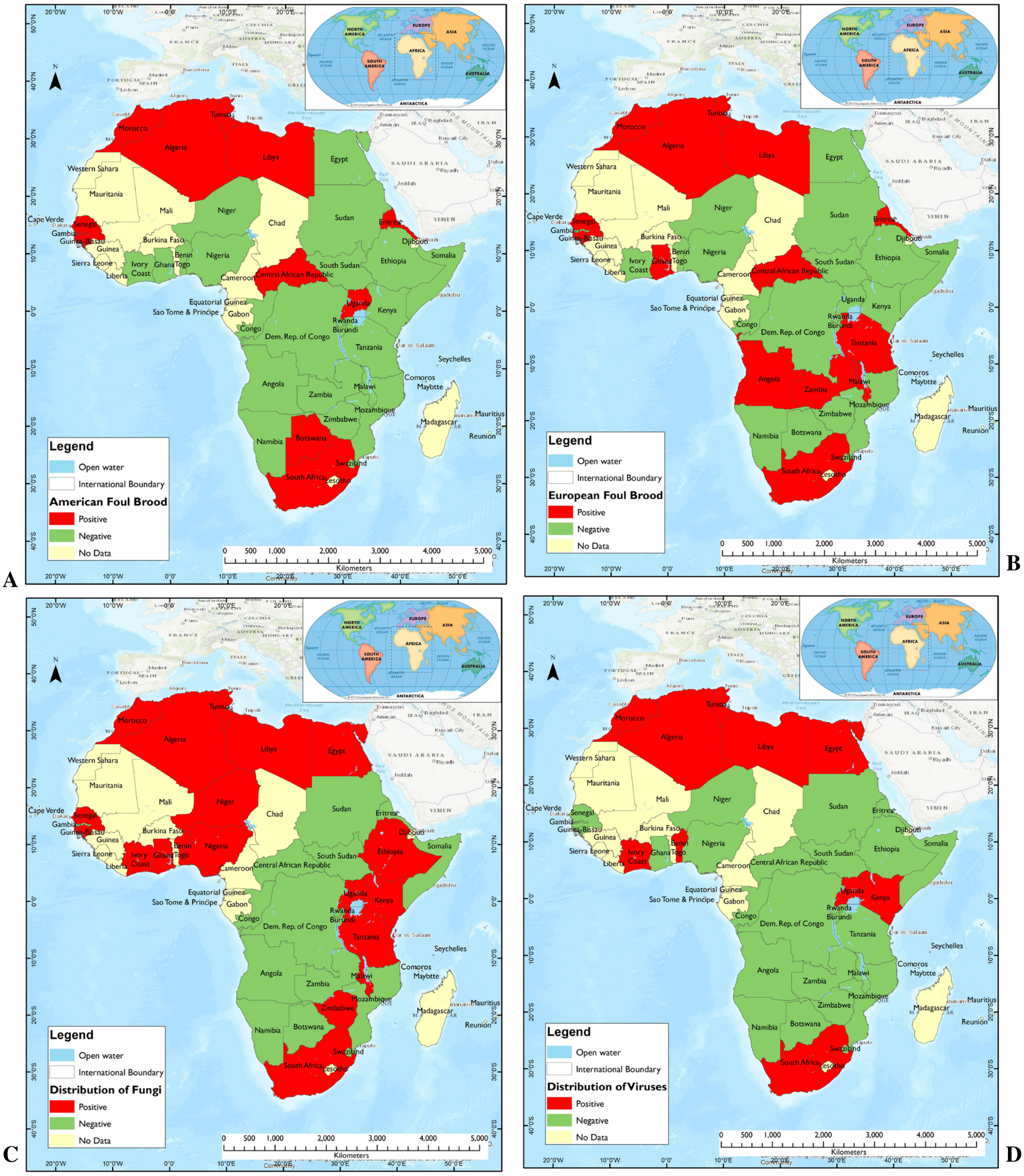


Figure 1. Distribution of pathogens in honeybee colonies in Africa A: American Foul Brood B: European Foul Brood C: Fungi D: Viruses

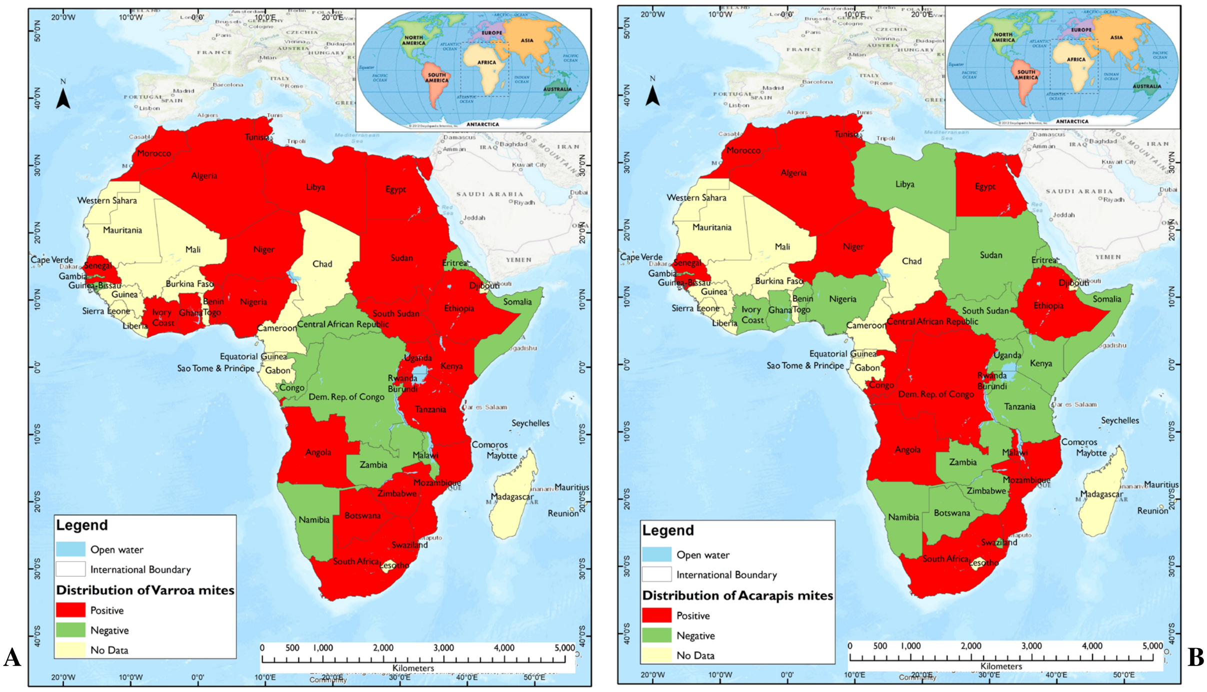


Figure 2. Distribution of parasites in honeybee colonies in Africa A: Varroa mites B: *Acarapis* mites

Tracheal mite (*Acarapis woodi*). This is a small endoparasitic tracheal mite that has been documented in at least 16 African countries (Figure 2B), and by 1981 was present in all except Central Africa Republic, Ethiopia, Malawi, Niger, Rwanda, Senegal, and Tunisia (Nixon, 1982). It is an infestation that requires that OIE is notified. Adult Acarapis mites infest the tracheal airways of honey bees, blocking air exchange and they also pierce the walls of the air tubes so as to feed on haemolymph. Most of the damage that is attributed to Acarapis mites has been documented on honey bees of European sub-specific race that over-winters. The observed damage includes low honey production, high mortality rates as well as reduced lifespan for honey bees. The symptoms described for Acarapis resemble those of Nosema whereby bees become weak, are seen to crawl at the hive entrance and may sometimes uncouple their wings such that all their four wings are visible.

Tropilaelaps mite (*Tropilaelaps clareae*). *Tropilaelaps* spp. are of Asian origin and have been reported on the African continent in Kenya by Kumar and others (1993), however, there are reservations by others such as Anderson and Roberts (2013) regarding the accuracy of the sample that was used in the identification. The furthest western point at which it had been found is Iran close to the Pakistan and Afghanistan borders. Tropilaelaps is a serious parasitic mite that affects both developing brood and adult honeybees. Parasitisation by these mites causes abnormal brood development, may cause bees to abscond from the hive or death of both brood and bees leading to colony decline and collapse. The natural host of the mite is the giant Asian honeybee, *Apis dorsata*, but Tropilaelaps can readily infest colonies of *Apis mellifera*, the western honeybee.

Associated Honey Bee Pests and Predators

Beetles (Coleoptera). Small hive beetles (SHB) (*Aethina tumida*). *Aethina tumida*, first described by Murray in 1867 is a small, darkcoloured insect with a characteristic armour-plated shell that the honey bee can neither crack using mandibles nor sting through to kill the beetle. The natural distribution of the beetle is confined to sub-Saharan Africa where this beetle is regarded as a negligible pest. Nevertheless, infestation with the small hive beetle is listed as a notifiable infestation by the OIE. The beetles were first discovered in the western hemisphere in the USA as well as in Australia where they are reported to have devastating effects (Neumann and Elzen, 2004; Neumann *et al.,* 2013). As indicated in Table 1, of the 34 African countries listed, it is absent only in Algeria, Burundi, Libya, Niger, Rwanda, Eswatini (Swaziland), and Tunisia (Figure 3A). A pioneering study in Uganda by Agaba *et al*. (2016) found the beetles present in 80.2% of the hives studied, and all the 27 apiaries sampled were infested. The mean load infestation per hive per district varied from 78.4±43.2 to 5.8±8.3 adult beetles.

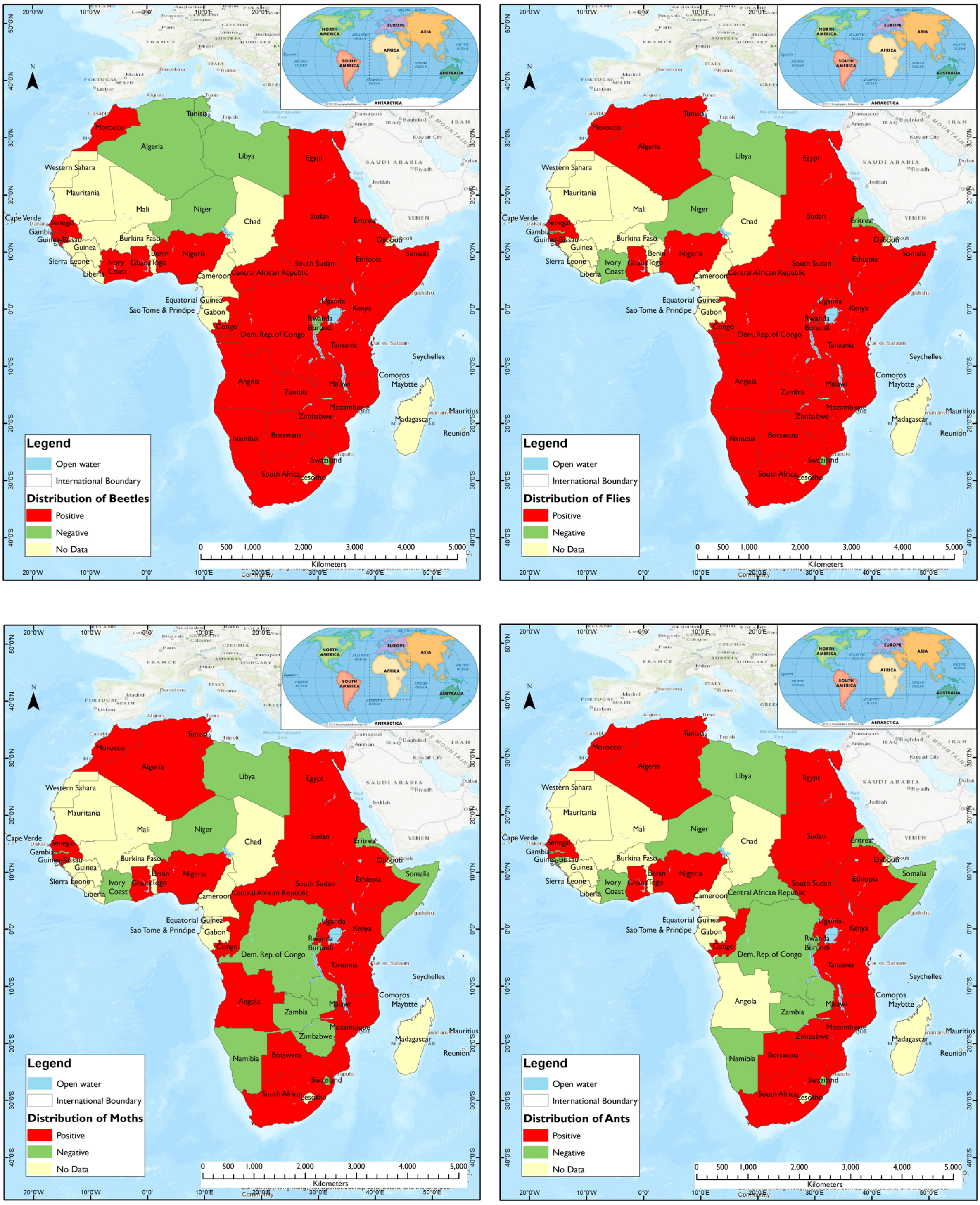
Larvae and adult beetles exist within the honey bee colony causing damage to developing brood, and stored pollen and honey that they feed upon, and within a few days, everything is turned into a stinking mass by the maggots. The life cycle of this beetle follows the regular insect metamorphosis cycle only that pupation is in the ground outside of the hive. Based on this review, the small hive beetle appears not to present a major threat to bee keeping industry, but is more of a nuisance. It is plausible that the honey bees co-evolved with the small hive beetle considering that it is endemic in many parts of Africa. However, considering that they act more as vectors of honey bee bacteria and viruses, they could soon become a more serious concern.

Large hive beetles (LHB) (*Oplostomus* spp). Several large hive beetles (Cetoniids) are found in Africa and include *Oplostomus fuligineus* and *Oplostomus haroldi* that invade honey bee colonies. The main effect of adult beetles is consuming food stores collected by the honeybee colony as well as consuming honey bee brood. These beetles may become a problem when they are many. Generally, the LHB are not considered a serious pest of honey bee colonies on the African continent. The Large hive beetle (*Oplostomus fuligineus*) have been found together with ants (*Monomorium minimum*) in bee hives in Uganda (Agaba *et al.,* 2016). Other contemporary studies have reported seasonal cyclic variation in colony infestation levels by SHB and LHB (*Oplostomus fuligineus* and *Oplostomus haroldi*) for the same agro-ecologies (Otim *et al*., 2019). Co-infestation of honey bee colonies by *Oplostomus haroldi* and *Acherontia Atropos* in Uganda reduced honey production (Otim, 2019).

Flies (Diptera)

Tachnid fly (*Rondanioestrus apivorus*). This fly belongs to the family Tachinidae, and is one of the few fly species known to parasitize honey bees. Specimens of this fly have only been collected from South Africa and Uganda. However, when we consider the aggregate of all types of flies, Africa appears overrun (Table 1 and Figure 3B), with exception of Central Africa and French West Africa. On average only 3-5% of adult honey bees are parasitized though in South Africa, an infestation level of 30% was reported in 1983 (Anderson *et al*., 1983).

In terms of life cycle, female flies deposit larvae on the abdomens of the honey bee hosts, enabling their immediate penetration into the honey bee. The larva grow quickly inside the honey bee and after four weeks, the larva now possessing two visible black spiracles emerge from the honey bee. The larva then undergo pupation in the soil and the adult fly is fully developed within ten days. The fly is of minimal economic importance for the African honey bee sector due to the low parasite levels.


Legend
Open water
International Boundary
Distribution of Beetles
Positive
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Distribution of Flies
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Negative
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0 500 1,000 2,000 3,000 4,000 5,000
Kilometers
Morocco
Algeria
Tunisia
Libya
Egypt
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Eritrea
Djibouti
Somalia
Ethiopia
South Sudan
Cape Verde
Senegal
Gambia
Guinea Bissau
Guinea
Sierra Leone
Liberia
Ivory Coast
Ghana
Togo
Benin
Burkina Faso
Nigeria
Cameroon
Central African Republic
Equatorial Guinea
Sao Tome & Principe
Gabon
Congo
Dem. Rep. of Congo
Uganda
Kenya
Rwanda
Burundi
Tanzania
Seychelles
Comoros
Maybtte
Angola
Zambia
Malawi
Mozambique
Zimbabwe
Madagascar
Mauritius
Reunion
Namibia
Botswana
Swaziland
South Africa
Lesotho

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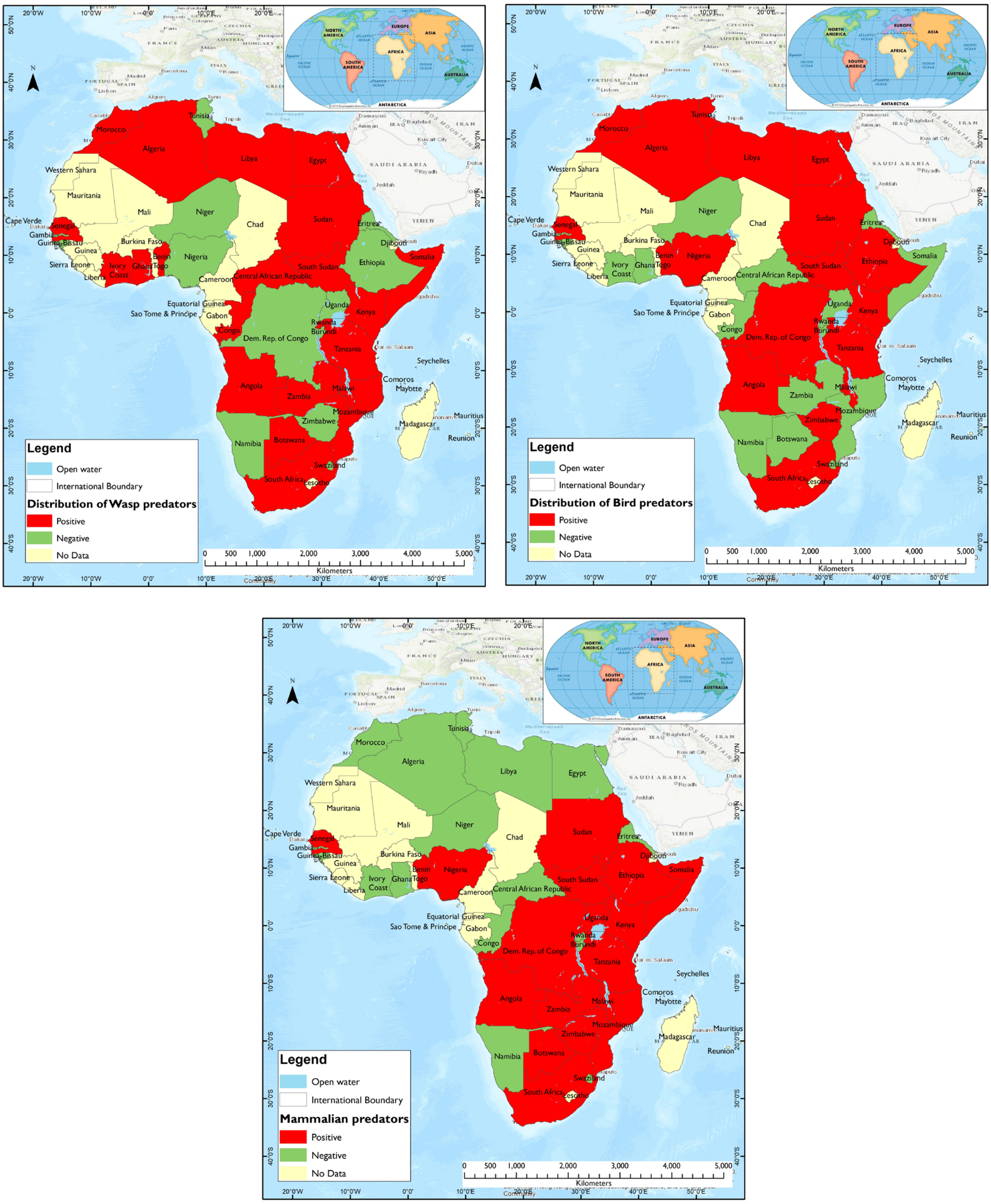

Figure 3. Distribution of other honeybee pests and predators in Africa A: Beetles B: Flies C: Moths D: Ants E: Wasps F: Birds G: Mammals

Bee conopid *(Physocephala* spp.). This fly has a wasp-like appearance and it parasitizes honey bees in a similar way to the hornet. Matured larvae and pupae can be differentiated from those of *R. apivorus* by the spike-like spiracles they possess. Like the Tachnid fly, the bee conopoid is limited to South Africa and Uganda. The key difference with *R. apivorus* is that larvae of the bee conopoid pupate inside the bee abdomen. The flies are observed infrequently with varying levels of infestation. The bee conopoid appears to pose no significant threat to the health of African honey bees.

Bee louse (*Braula* spp.). The bee louse (*Braula* spp) is actually a fly, but a wingless one. It is in the family Braulidae, and comprising two genera, Braula and Megabraula and contains only eight species. The louse used to have a global distribution and has been reported in Africa in Egypt, Morocco, DRC, Kenya, Tanzania and all the way to South Africa in Asia from India to Russia, in Australia to Tasmania, and in most of Europe and the Americas. However, the chemical treatment of *Varroa destructor* has affected bee louse populations and has influenced the distribution of the bee louse in areas where mite treatment is not in use, such as on the African continent. The lice attach themselves to an adult honeybee, then rob food from the mouth of the host bee. One or two lice may be found on individual workers or drones, but more usually, they tend to go for the queen bee probably because the lice enjoy consuming royal jelly, therefore, the lice would be the first to eat food every time the queen is served. Despite this annoyance and loss, the lice are never attacked by worker honey bees.

There is debate on the parasitic status of *Braula* with some claims that bee lice cause minimal or no harm whatsoever to honey bee colonies other than losses of pollen and honey stores. *Braula* (a) disfigure honey combs by burrowing under the cappings, (b) cause paralysis or (c) death of developing honey bees as well as (d) decreasing the queen's egg laying efficiency and (e) stealing her food. When using the frame hives, most bee keepers practice mechanical control unknowingly by extracting honey because the Braula larvae are eliminated while removing wax cappings before extraction.

Moths (Lepidoptera)

Wax moth (*Galleria mellonella* and *Achrola grisella*). The greater wax moth (*Galleria mellonella*) as well as the lesser wax moth (*Achrola grisella*) are common in honey bee colonies all over the African continent, with *Galleria mellonella* being more prevalent and damaging (Hepburn and Radloff, 1998). The moth does not attack honey bees directly but feeds on the wax that has been used by the honey bees to make their honey combs. The wax moth larvae are generally perceived as hive cleaners since they consume all combs, pollen and honey stores once the honey bees have absconded or migrated (Pirk *et al.,* 2016). As indicated in Table 1, of the 55 African countries listed, it is absent only in one fifth of them all, namely: Burundi, DRC, Eritrea, Eswatini (Swaziland), the Gambia, Cote d'Ivoire, Libya, Namibia, Niger, Somalia, Zambia and Zimbabwe (Figure 3C).

Life cycle. The full development of the wax moth to adulthood requires brood comb that has been used, or simply, cleanings or wastes from brood cells. This is because these materials contain proteins that are essential for development of their larvae; and to form brood cocoons. Adult moths lay their eggs close to beeswax combs and when their larva hatch, they burrow through combs and consume the debris in the comb cells. The wax combs get destroyed by the moth larvae and in addition, the moth larvae plaster the resulting waste with their webbing and faeces. When colonies are strong, honey bees are quite good in ensuring protection of their colonies from the devastating moth larvae.

Despite being perceived as hive cleaners; moth larvae may lead to total destruction when they burrow through combs containing brood and honey, as well as the hive wood. Furthermore, larval tunnelling may cause galleriasis and bald brood (Ellis *et al*., 2013). Damage by the wax moth is most severe in colonies that are weakened or stressed. Therefore, to reduce damage and losses of colonies, beekeepers should practice good management (Swart *et al.,* 2001). Wax moths are currently not a big threat to African honey bees (Pirk *et al.,* 2016). In general, moth damage is a result of other challenges such as loss of a queen that lead to weakening of the colony, and damage is most rapid in stored honey boxes of frame hives containing wax combs.

In terms of control, the stored honey supers should be protected by stacking them to a maximum of five hive boxes. All cracks in the walls of the hive boxes should be taped/closed and paradichlorobenzene crystals placed at the top of each stack and then the boxes covered with a lid. The crystals should be replaced when they have evaporated, however, Naphthalene (moth balls) should not be used as it accumulates in the wax and this may kill the bees or contaminate the honey stores.

Death's head hawkmoth (*Acherontia atropos*). Acherontia occurs all over the African continent and adult moths are identified through the distinct skull design on the thorax. The moth invades honey bee colonies in search of honey. They have a unique ability to mimic the queen piping sounds and their use of chemical camouflage to prevent worker honey bees from attacking them (Moritz *et al.,* 1991). The death's head hawkmoth only consumes honey/nectar unlike the wax moth that goes beyond to cause obvious damage. Acherontia are hence not viewed as economically important (Pirk *et al.,* 2016).

Termites (Isoptera)

Termites do not directly attack honeybees, but they eat up bee hives, bee suits and other equipment in their reach. Suspending the hives on wires between trees or non-timber posts instead of using wooden posts prevents the termite invasion. Other alternatives include treating posts with spent engine oil or placing hive supports/stands in tins of old oil. The use of earthen/ unburnt bricks as hive supports should be avoided as they encourage the termites.

Ants, wasps and honey bees (Hymenoptera)

Ants. Several ant species either native to Africa or introduced, have been reported in honey bee colonies in most African countries (Figure 3D) and examples of these ants are: *Anoplolepis custodiens, Dorylus fulvus, Linepithema humile, Pheidole megacephala* (Pirk *et al.,* 2016) and *Monomorium minimum* (Kugonza *et al.,* 2009). All categories of ants: black, brown, grey, red, big or small – are significant natural enemies of honey bees and are all dangerous to the hive occupants. Among their effects, ants eat brood, honey, nectar, and even the bees' body (www.fao.org). Ants naturally enjoy living in hollows just like the honey bee and hence, the man-made empty bee hive meant for the honey bees is just as good as a home for the ants. Protection from ants is a must if the hives are to be of use by the honey bees (Kugonza *et al.,* 2009). This is because continued disturbance by ants can cause honey bee colonies to abscond. As such, serious economic losses to the bee keeper will result from the dual loss of hive products and the colony itself as a result of bee colony invasion by ants, hence prevention is better than cure. Where possible, all the wires used to suspend hives or the 'legs' of hive stands should be protected judiciously using chemicals that repel insects (Kugonza, 2009).

Wasps: **Bee pirates (*Palarus latifrons* and *Philanthus triangulum*).** The banded bee pirate (*Palarus latifrons*) and the yellow bee pirate (*Philanthus triangulum*) are active predators on the African continent (Table 1 and Figure 3E). These wasps capture honey bees as food for their own nourishment or to feed their growing young. Whereas *Palarus latifrons* catches the honey bees at the hive entrance, *Philanthus triangulum* catches them as they forage. The threat and aggression of wasps can prevent honey bees from going for foraging trips and in the long term, could influence productivity of the colony in addition to reducing the number of colony members.

German yellow jacket (*Vespula germanica*). *Vespula germanica* originates from northern Africa but has spread to west and Southern Africa. It is a social wasp and is an opportunistic predator that feeds on an array of invertebrate species including honey bees, and it also consumes nectar and honey (Masciocchi *et al*., 2010). Yellow jackets also eat dead honey bees and after dismembering their victims they carry some body parts back to their nests (Coelho and Hoagland, 1995). They nevertheless do not pose a substantial risk to the honey bee population.

To control the yellow jacket, holes in the hive should be filled/covered and hive entrances made small enough for the bees to defend themselves. It may be prudent to avoid having a landing board at the hive entrance that is usually a long slit at the bottom of the trapezoid end piece in the Kenya Top bar hive. Instead, it may be better to have the bees land on the holes drilled into the trapezoid end. A trap can be made by cutting a plastic bottle with a narrow mouth into half and the top part is inverted over the other half. A mixture of water and jam poured in this cut out bottle will attract the wasps that will enter and drown. Never bait with honey, as the honey bees themselves will also be killed. Instead of the mixture, raw meat also makes a good attractant trap for the wasps.

Honey bees

The Cape bee (*Apis mellifera capensis*). This is a social parasite in the South African bee keeping industry. The country is faced by the problem of human-mediated attack of *A. mellifera capensis* into the natural range of the other honeybee sub-species, *Apis mellifera scutellata*. *A. mellifera capensis* is spread by migratory bee keepers during pollination and has resulted in large-scale colony losses with significant economic implications for the South African bee keeping industry (Allsopp and Crewe, 1993; Pirk *et al*., 2014). The problem is still growing 25 years since it was first studied.

In terms of the effects of the social parasite bees, after entering *A. m. scutellata* colonies, *A. m. capensis* workers, which have the tendency to become social parasites compete for reproduction. *A. mellifera capensis* workers are able to lay diploid eggs and produce queen-like signals. These *A. mellifera capensis* social parasites do not contribute to the work force and their offspring do not replace the host workers, but these social parasites and their clonal offspring just reproduce which then results in the collapse of the host colony (Hillesheim *et al*., 1989; Neumann *et al*., 2001; Moritz, 2002).

Dwarf honey bee *(Apis florea).* *Apis florea* originated from Asia and the first detection on the African continent was in 1985 at Khartoum in Sudan (Lord and Nagi, 1987; Radloff *et al*., 2011). The distribution of the dwarf honey bee has expanded to the entire Sudan (Moritz *et al*., 2010b) and into neighbouring countries such as Ethiopia (Bezabih *et al*., 2014). Considering that the climate and floral conditions in Africa are comparable to the natural distribution range of the dwarf honey bee, the species may eventually colonise the entire African continent (Pirk *et al*., 2016). The local *Apis mellifera sudanensi*s and the introduced *Apis florea* compete for pollen. Currently, the impact of *Apis florea* on native honey bee species appears to be minimal (El Shafie *et al*., 2002; Bezabih *et al*., 2014).

Bee pseudoscorpion (*Ellingsenius* spp.). Bee pseudoscorpions (not true scorpions) are small in size with proportionately large pincers (Judson, 1990). They belong to the Class Arachnida and are further sub-divided into eight species. They have spread throughout the African continent.

They were first observed in Uganda in 2008 but wrongly reported together with mites (Kugonza *et al.,* 2009). The pseudoscorpions feed exclusively on *biological detritus* (Tharpa *et al.,* 2013). They are therefore perceived to be harmless in honey bee colonies (Allsopp *et al.,* 2003).

Birds and mammals. A wide spectrum of birds and mammals that impact honey bee colonies are found all over Africa (Figure 3F and 3G). Some of the most significant mammals are: humans, honey badgers, baboons, monkeys and mice (Pirk *et al.,* 2016). Among birds, probably the most notorious are bee-eaters (Meropidae), drongos (Dicruridae) and honey-guides (Indicatoridae). Honeyguides are famed for directing animals such as baboons, honey badgers (Crane, 1999) as well as humans (Isack and Reyer, 1989) to find honey bee nests. All over the African continent, these two enemies of honey bees are found. Of all the African countries, 12 countries have both birds and mammals while another 12 have not yet reported either birds or mammals and these are: Burundi, Central Africa Republic, Congo (central Africa), Eritrea, Rwanda (Eastern Africa), Gambia, Ghana, Guinea-Bissau, Cote d'Ivoire, Namibia, Niger (West Africa) and Eswatini/Swaziland (southern Africa).

The honey-guide bird (*Indicator indicator*) does not feed directly on honey bees but it eats beeswax and brood that remain after the nest has been robbed and/or damaged by the guided mammal (Swart *et al.,* 2001). Bee-eaters and drongos are direct predators of honey bees and dramatically remove the bee sting before ingesting them. When the rate of predation by these birds is severe, honey bees may stop forage collection (Hepburn and Radloff, 1998), and as these authors reported, a bee-eater may eat up to 600 honey bees every day! Among the mammals, honey badgers and human beings are the most destructive.

Honey badgers (*Mellivora capensis*) are nocturnal mammals with uniquely strong claws that they use to dig, climb and break hives open, they then eat honey, combs and brood and this eventually causes loss of honey bee colonies. Human damage ranges from theft of honey and at times, entire hives with their colonies, vandalism, fire, intentional poisoning of honey bee colonies to total destruction of colonies as happens in traditional honey hunting (Crane, 1999; Dietemann *et al.,* 2009). Prevention/ Control of honey badgers is achieved by hanging the hives securely at least 1.5 m above the ground. This is to stop the badger knocking the hives down. In addition to suspending the hives, the hive lids should be securely tied with wire and stones placed on the hive lids to stop the badgers from breaching the hives. Humans are difficult to stop but electric and razor wire fencing can help. Bee eaters are limited by ensuring the hive entrance lacks the landing board where the birds tend to perch to eat the bees.

CONCLUSION

Current efforts on prevention and control of honey bee pathogens, parasites and predators. Due to the seriousness of the honey bee diseases, pests, pathogens, parasites and predators to the global beekeeping industry, there is need to have a concerted effort to control them. Optimum health and nourishment of honey bees ensures that their resistance to hostile conditions is higher than normal. Several environment-related challenges especially agro-chemicals used for crop protection against entomological organisms and weeds have detrimental effects on the health of honey bees most especially when the organisms are vectors of disease-causing pathogens. The world organisation for animal health (OIE) lists six honey bee diseases as notifiable diseases, namely: Acarapisosis of honey bees, American foul brood of honey bees, European foul brood of honey bees, Small hive beetle infestation, Tropilaelaps infestation of honey bees, and Varroasis of honey bees (https://www.oie.int/). The prevention and control of honey bee pests and pathogens can be generally grouped into: mechanical, cultural and genetics, as well as colony health and sanitation.

Mechanical prevention and control ensures that pests and pathogens stay away from the honey bee colony through sealing off openings and cracks in the beehive walls to stop insects, mites and other arthropods. Inserting a screened bottom stops Varroa mites. Hanging or placing beehives on stands keeps them away from crawling pests, large walking predators; and it also ensures a continuous supply of air into the hive and hence dryness that keeps relative humidity inside the hive low. Use of mouse/rat guards on the hive stands keeps out these widespread vermin.

Cultural means of prevention and control are not only practical but are also low cost. A sure way of starting clean is to start with healthy colonies, so when sourcing colonies, ensure that they are healthy. Avoid interchanging hive components for instance frames and top-bars, honey supers, etc. This is most critical when honey bee parasites/pests/pathogens are suspected to be present. Buying of used equipment should be minimized and if at all bought, should be inspected and certified by the seller. Proper storage of all bee keeping equipment and gadgets. During storage, efforts must be put on regular inspection to prevent growth of the invaders.

Genetics can be used for long lasting control of pest and pathogen effects on honey bee colonies, through identification, screening and breeding of honey bees that possess resistance to pests and diseases. A few species of honey bees possess innate resistance to some diseases and parasites and can through long term selection programs be bred to confer superiority over a parasite or pathogen. One such effort is the three decade of selecting honey bees against Varroa destructor (Guichard *et al*., 2020). For the majority of honey bee species, this ability is lacking but can be introduced through induction of immune bee genes through reverse-genetics of RNA viruses (Ryabov *et al.,* 2019), engineering of symbiotic honey bee gut bacteria to induce host RNA interference (RNAi)-based self-defence (Leonard *et al.,* 2020; Paxton, 2020), though the latter faces an uphill task of getting acceptance due to wide spread opposition to genetic modification (Mitchell *et al.,* 2020). Breeding for hygienic behaviour has been of focus for some time because it is a heritable trait of individual worker honey bees as it gives resistance against various brood diseases. The goal is to multiply bees that have a high propensity for cleaning their hive and combs. Several studies have demonstrated the superiority of some honey bee races in expressing hygienic behaviour (Spivak, 1996; Spivak and Gillian 1998; Goode *et al.,* 2006; Oldroyd and Thompson, 2006; Morais *et al.,* 2009; Bigio *et al*., 2013; Pereira *et al.,* 2013; Toufailia *et al.,* 2018).

Sanitation practices can massively contribute to preventing the spread and impacts of honey bee pests and pathogens. Use of alcohol to sanitise hands ensures that a wide majority of pathogens are killed. Not only should this be done when handling infected hives, it is good as a routine practice to completely cut out the chances for likely infection. Sterilisation of beekeeping tools and equipment can be done using an open flame, or alcohol. Bleach solution, soap and other disinfectants should be used for cleaning clothes, bee suits, and gloves. This ensures avoidance of cross-contamination and cross-infection between colonies.

Africa is under attack by several honeybee pathogens, parasites, pests, and predators. The mapping of the various enemy organisms poignantly shows the extent of infestation, infections and invasions. These enemies cause death of the bees, parasitize on the bees or make their hive stay difficult by destroying the combs, stealing their food or destroying the hives. These attacks on the African honeybees largely remain below the thresholds for economic injury that necessitates serious intervention. Even then, proactive methods for managing these organisms that have been discussed above need to be implemented.

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STATEMENT OF NO-CONFLICT OF INTEREST

The author declares that there is no conflict of interest in this paper.

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