MOBILIZING DIGITIZED MUSEUM SPECIMEN RECORDS TO HIGHLIGHT IMPORTANT ANIMAL POLLINATORS IN EAST AFRICA

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Abstract.—There is an increasing global demand for existing natural history information for use in education, conservation, and policy formulation. Museum specimen collection records, being voluminous, are particularly significant in addressing such demands. This is even more critical in developing countries where daily human life is intimately linked to the environment. We demonstrate how existing museum specimen collection records were mobilized to highlight important animal pollinators in three East African countries. The bulk of the records were obtained from a Specify database of existing zoological collections held at the National Museums of Kenya, and the rest were from such alternative sources as published material, discussions with pollination experts, and online taxonomic portals and other tools. Identified to genus or species level, pollinator-ranking criteria encompassed region-wide distribution, number of plants pollinated, importance index of plants pollinated, and plant dependency on pollination. Overall, insects, especially *Apis mellifera,* were the most important pollinators in the region, pollinating the largest number of plants of diverse domestic, socioeconomic, and ecological significance. The results underscore potential use of specimen record-based informatics to guide agricultural and economic policy in East Africa.

INTRODUCTION

Museum collection specimen records are conventionally used primarily as reference resources by taxonomists, natural history scientists, curators, and associated professionals (Suarez and Tsutsui 2004). The main uses by this sector include curatorial taxonomic identification, determination of bio-geographical occurrence, temporal quantitative trends, or invasiveness (Pettit 1991). Such restricted empirical use of specimen collection records has persisted for many centuries mainly because most institutions hosting such specimens have traditionally employed and relied on intrainstitutional or even just intrataxon systems of museum record management. This scenario still largely prevails and is in fact more acute in developing countries where it is compounded further by low capacities in human resource and appropriate record management technologies. This continues to greatly undermine the abilities of these countries to adopt effective methods to mobilize and use existing specimen, and other natural history records, for decision support in biodiversity conservation policy.

Nevertheless, the narrow range of uses for specimen collection records is now being challenged by a globally increasing demand for natural history information to be applied in decision support to tackle an equally increasing number of environmental problems (Pettit 1991). This demand for information has spurred the emergence of *biodiversity informatics* as a discipline and tool for mobilizing large volumes of existing, diverse natural history records and datasets in a quest to find solutions to such problems (Johnson 2007). Specimen collection records form a significant proportion of such datasets that can be tapped through biodiversity information systems (Page 2008). Museum specimen records are particularly crucial for this purpose because they typically constitute four vital components of biodiversity information systems: quantitative (large

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datasets), qualitative (taxonomic), spatial (species occurrence and distribution), and temporal (trends in occurrence and abundance covering long time periods). Being able to serve as information providers in this regard is an additional boost to the status and relevance of museums in the counties and states where they occur, in a rapidly changing modern world (Suarez and Tsutsui 2004).

In East Africa the bulk natural history information is still derived from specimen collection repositories, especially museums, which also serve as educational resources and the most reliable tools used in taxonomic referencing. Most of these specimens were collected and curated during East Africa's colonial period dating from the late 19th century. Collecting practices and curation did not develop much thereafter due in part to the advent of restrictive legislation to protect wildlife from collectors, and the exodus of European collectors after East Africa's independence, when native taxonomic capacity was still nascent. Despite these drawbacks, East Africa's natural history is still excellently preserved in a collection repository at the National Museums of Kenya (NMK). The specimen collections at NMK are representative of the region and comprise not only a fairly large number of vertebrates and invertebrates, but also plants in the East African Herbarium, the largest in Sub-Saharan Africa. Currently, the NMK specimen repository comprises some 2 million plants, 2 million invertebrates, 30,000 birds, 33,000 fishes, 30,000 herps, and 15,000 mammals. Record digitization, which is ongoing, currently stands at about 40% overall.

However, since its inception, the specimen records at NMK have been managed using several disparate systems and applications in each taxonomic unit, rendering cross-taxon references, inferences, or analyses impractical. This is still a major challenge in most museum data management systems worldwide (Page 2008). Furthermore, the collection records were infrequently used for such practical applications as providing decision support for stakeholders of biodiversity information use. A departure from this record management system occurred in 1995 when the Herbarium adopted a plant-specific record management regime to consolidate its records into one database system. This was followed by the Zoology Department a decade later, culminating in adoption in 2005 of a comprehensive biodiversity informatics regime using Specify software (http:specifysoftware.org). Although the system is designed for specimen-based collection record management, it is also used at NMK to manage species observation records, thus expanding record capture capabilities at the institution and making it possible to mobilize and integrate specimen collections and observation data for synergistic analyses.

As the Kenyan public becomes more aware of NMK's biodiversity informatics endowment, there are an increasing number of requests for biodiversity information from the institution. The type and nature of information required by the public play a part in guiding and directing new explorative ways to tap into and mobilize data to address the public's requests. Accordingly, in the present study, we illustrate how we mobilized our existing natural history records from both specimen collection and field observation within East Africa to highlight important animals involved in provisioning the ecosystem function of pollination in the region. We specifically aimed to determine the most significant animal pollinators in East Africa.

Animal pollinators are not only important players in ecosystem function and stability but, through the pollination service they provide, account for millions of dollars in food exports in many countries. Globally, animal pollinators facilitate around 30% of all food production (Klein et al. 2007). In developing countries such as those in East Africa, pollinators are an integral part of the food security equation since many of the staple

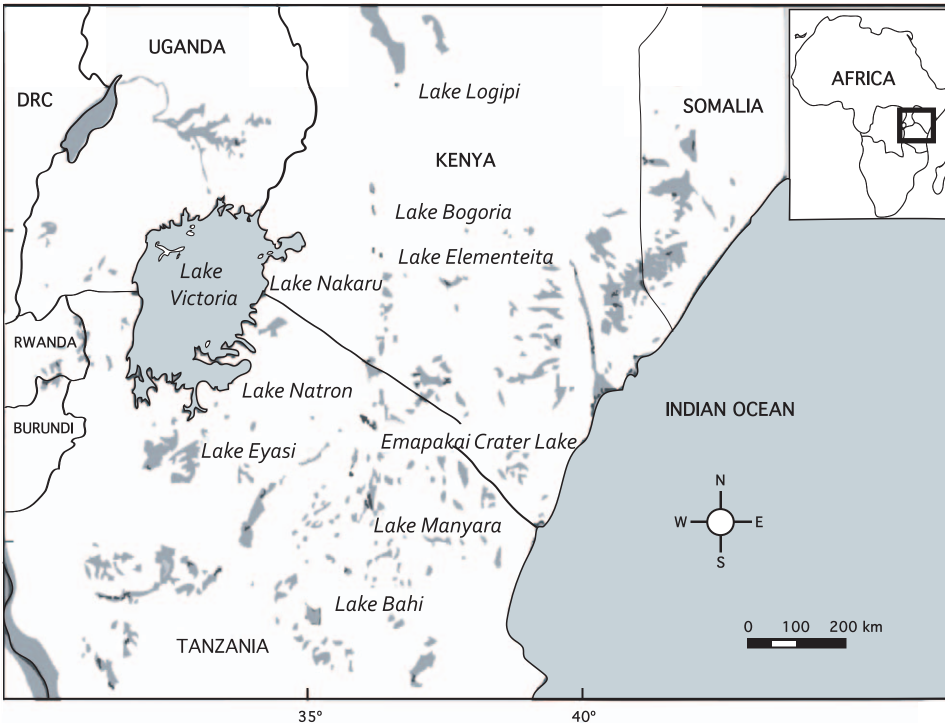

Figure 1. Map of East Africa, showing the countries covered by the study.

crops used by the low-income majority depend on them for development and high yields. It is estimated that at least 90% of all flowering plants in the tropics are cross-pollinated by animal agents, without which such plants would decline drastically in diversity, abundance, and distribution (Karanja et al. 2010; Ollerton et al. 2010). This is a vicious cycle as it is already established that global decline in pollinators can be traced to declines in flowering plant diversity (FAO 2008; Carvalhero 2010; Potts et al. 2010). This is augmented by the fact that plant reliance on self-pollination, such as by wind, tends to decline in tropical regions, making animal-aided cross-pollination more important in these areas (Schemske et al. 2009).

Materials and Methods

Study Area

The study covered the three East African countries of Kenya, Uganda, and Tanzania. The countries lie between latitudes 4°44′ N and 12°08′ S and between longitudes 29°51′ W and 40°45′ E (Fig 1). The region has a wide variation in climate, from arid to temperate conditions on slopes and peaks of high mountains. It straddles the equator, and the Great Rift Valley runs through it from northern Kenya and Uganda to southern Tanzania. Rainfall, which is typically bimodal in distribution, is influenced by monsoon winds. Temperatures are moderate, with maxima of around 25°C and minima of 15°C at a mean altitude of 1,500 m above sea level. Altitudes above 2,500 m above sea level experience frosts in dry seasons with maxima about 21°C or less. The diversity of habitat in East Africa includes arid and semiarid savanna, a humid coastal belt, mid- and high-altitude forest, moist grassland, and a semiequatorial lake basin. Such diversity in habitat and climate is mirrored by East Africa's biodiversity.

Data

Information on animal pollinators was obtained primarily from existing specimen collection and field observation records held in the biodiversity informatics project at the Zoology Department of the National Museum of Kenya. Data records were obtained from invertebrates, birds, and mammals. Vertebrates from the other taxonomic groups (reptiles, amphibians, and fish) were not included because the vast majority of them are not widely recognized as significant pollinators, while information about those known as pollinators such as some species of lizards is not appreciably extensive. Similarly, for both vertebrates and invertebrates, those that were are not known by to be actual pollinators, i.e., mere flower visitors were not included/considered in the pollinator list. Supplementary information on pollinators and plants pollinated was derived from various other sources including (1) published literature from libraries; (2) interviews with experts in pollination and pollinator ecology in the East African region, especially to confirm and distinguish between actual pollinators and mere flower visitors; (3) large-scale farms where pollinators are adopted or used for crop production; (4) pollination projects and enterprises such as apiaries; (5) relevant web-based sources including those dedicated to taxonomy, e.g., the Integrated Taxonomic Information System (ITIS) (2012) of the Global Biodiversity Information Facility (GBIF) portal (2012), Tanzanian Biodiversity Information Facility (TanBIF) (2012), BirdLife International (2013), Encyclopedia of Life (2013), and Discover Life (2010).

Information was gathered at three main levels: (1) taxonomic identity to family, genus or species, (2) spatial (geographic) occurrence or known presence/absence data in the three countries for both pollinators and plants they pollinate, and (3) plant function-pollinator linkage. Bird nomenclature followed that of BirdLife International; mammals, Wilson and Reeder (2005) and Encyclopedia of Life; and invertebrates, Parker (1982) together with Eardley (2000), and revisions in Eardley (1983 and 2004) and Eardley and Urban (2010) for the order.

Pollinated plants were evaluated for their regional distribution by determining the mean number of countries out of the three where they are found.

Data Analysis

The ranking of pollinators was derived from consideration of the regional distribution of the pollinators, the score of the plant's dependency on pollinators, the importance value of the plants they pollinate, and the total number and regional distribution of plants that the pollinator pollinates. From this, an index of importance was determined and used to rank the pollinators.

Pollinator regional distribution was evaluated by scoring the total number of the three countries in which the pollinator is known to occur. The Pollinator Dependency score refers to the plant's degree of reliance on animal-aided cross pollination for it to reproduce as outlined from studies by Klein et al. (2007) and Garibaldi et al. (2013) and based on specific crop yield data from the FAO crop production database (FAO 2013) such that

4 = essential (animal pollinators are absolutely essential for the crop and production yield can reduce by $>90\%$ in the absence of pollinators)

Table 1. An illustration of the criterion for determining plant importance scores. See the appendix for plant scientific names.

Plant importance score	Characteristic(s)	Examples
4	Plant is a significant regional primary food staple forming 50–90% of household diets in the region	Bean, banana, cowpea, tomato
3	A plant is significant cash crop contributing 1–5% of national GDP, or key ecological keystone in main ecosystems in the region	Coffee, cotton, rose flowers, acacia, figs, mangrove, baobab
2	Plant is significant food crop forming 30–50% of household diets in the region, or constitutes 20–30% use in agroforestry or as livestock forage	Mango, pigeon pea, avocado, grevellia, sesbania, lucerne
1	Plant forms less than 10% of diet or is largely used for noncommercial domestic/cultural purposes in the region	Guava, squash, orchid

3 = high (the crop has a very high dependence on animal pollinators, and production yield may decline by between 40% and 90% in absence of pollinators)
2 = modest (the crop has considerable dependence on animal pollinators, and yields can reduce by 10% and 40% in the absence of pollinators)
1 = little (the crop has little dependence on animal pollinators with a yield decline of 1–10% in the absence of pollinators).

In listing the pollinators and the plants they pollinate, it was taken into account that many plants have more than one pollinator and, likewise, a number of pollinators pollinate more than one plant species. Importance score for pollinated plants ranged from 4 to 1 and was derived from the merit of the plant based on its value in diet and economy, universal/region-wide distribution, and environmental or ecosystem role (Table 1).

For each pollinator, the total number of plants it is known to pollinate, which fall within the plant-importance framework outlined above, was scored.

The overall rank function for a pollinator was obtained from the following relationship:

$$P_R = \sum (D_C + P_I + D_P + P_{TP}),$$

where P_R = pollinator rank score, D_C is the mean number of countries within which the pollinator is known to occur, P_I is the mean plant importance score of plant pollinated by the specific plant, D_P is the mean degree of the plant's dependency on pollinators, and P_{TP} is the total number of plants pollinated by the pollinator species. Based on these ranks, a list of the top 100 pollinators was created, after which more detailed taxonomic group evaluations were carried out.

To further gauge the regional significance of the pollinators, the average of the plant importance and total number of plants they pollinates was determined and weighted by the regional distribution of those plants (total number of countries divided by 3). We refer to this as pollinator significance by plant importance (PSPI).

Results and Presentation

A total of 192 pollinator species were encountered made up of 79% Anthropoda and 21% Chordata. Class Insecta accounted for ~77.8% of all pollinators with ~16.2% Aves and 7.7% Mammalia (Fig. 2).

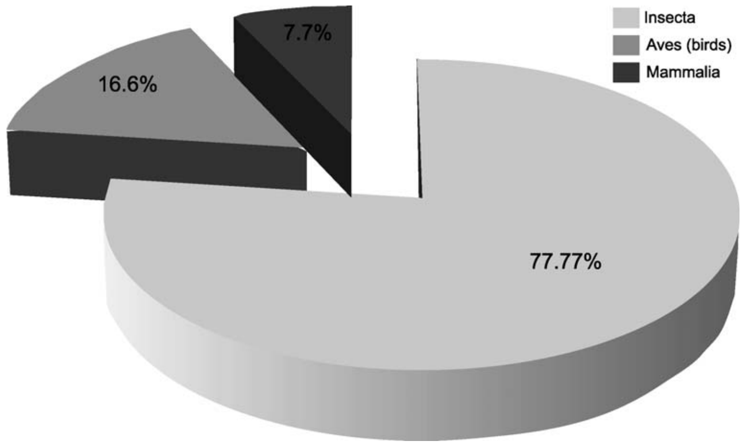

Figure 2. The proportional representation of the three animal classes constituting the 100 most important pollinators in East Africa.

All birds (Aves) were of the order Passeriformes with representation from five families (Nectariniidae, Ploceidae, Zosteropidae, Ploceidae, and Pycnonotidae). All mammals were of the order Chiroptera and the family Pteropodidae. Insect pollinators were from the four orders Lepidoptera, Hymenoptera, Diptera, and Coleoptera. Insecta had the largest number of families represented (Table 2). Overall, *Apis mellifera* (Insecta: Hymenoptera) emerged as the most important pollinator in the region (Fig. 3; Table 3). The most important avian pollinator was *Nectarinia kilimensis*, and *Rousettus aegypticus* was the most important Mammalia pollinator (Fig. 3).

Although Insecta emerged as the predominant agent of pollination in the region, the third and eighth most important species in the list of top 100 were a mammal and bird species, respectively (Fig. 3), indicating that the roles of these classes cannot be undervalued.

Apis mellifera, the top pollinator in the region, pollinated the largest total number (17) of plants that are of economic, dietary, and ecological importance for the people of the region (Table 3).

Table 2. A summary of the taxonomic distribution of within the list of 100 most important animal pollinators in East Africa.

Class	Order	Families (with number of species in parentheses)
Ave	Passeriiformes	Nectariniidae (9)
		Ploceidae (9)
		Zosteropidae (3)
		Pynonotidae (1)
Mam	Chiroptera	Pteropodidae (7)
Ins	Lepidoptera	Sphingidae (8), Syrphidae (5), Calliphoridae (4), Nymphalidae (4), Hesperiidae (2), Noctuidae (2)
	Hymenoptera	Apidae (29), Megachilidae (4), Halictidae (3), Pompilidae (1)
	Diptera	Muscidae (3), Tephritidae (1)
	Coleoptera	Scarabaeidae, Cerambycidae (1), Lycidae (1)

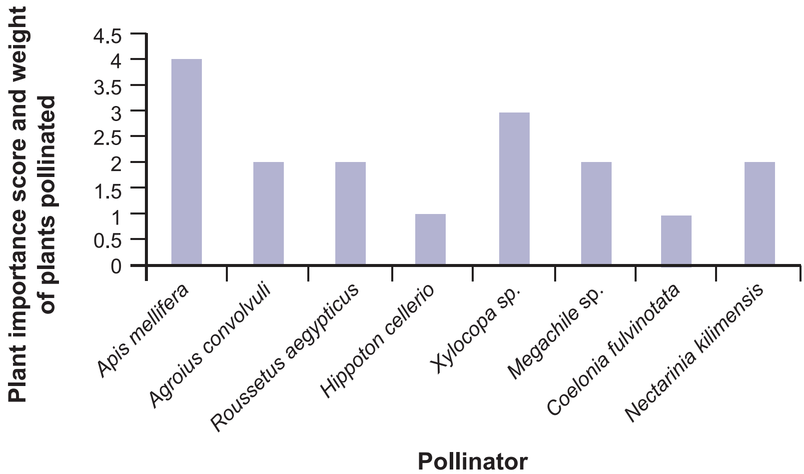

Figure 3. Pollinator significance by plant importance (PSPI) for the eight most important pollinators in East Africa. PSPI is derived from plant importance and total plants pollinated weighted by plants' regional distribution.

Discussion and Conclusion

Interactions between flowering plants and their pollinators are instrumental in the maintenance of functional integrity of the ecosystem (Whelan et al. 2008; Ollerton et al. 2010). Animal pollination services also contribute substantially to crop production and foreign exchange income particularly in developing countries such as in East Africa (Klein et al. 2007). In Uganda, for example, pollination services can be associated with an estimated 50% of overall crop production yields, representing some US$0.49 billion

Table 3. A highlight of overall importance of *Apis mellifera* as a pollinator in East Africa, showing the main plants it is known to pollinate.

Common name	Scientific name	Plant functional role	Plant importance score from 4 (highest) to 1
Bottle gourd	*Lagenaria siceraria*	Cultural crop	2
Aloe	*Aloe* sp.	Biodiversity support	2
Avocado	*Persea americana*	Food and cash crop	2
Calliandra	*Calliandra calothyrsus*	Agroforestry	2
Cashew nut	*Anacardium occidentale*	Food and cash crop	3
Coffee	*Coffea arabica*	Cash crop	4
Cotton	*Gossypium* sp.	Cash crop	3
Guava	*Psidium guajava*	Food crop	1
Papaya	*Carica papaya*	Food crop	2
Passion fruit	*Passiflora edulis*	Cash crop	2
Pear	*Pyrus* sp.	Food and cash crop	2
Pigeon pea	*Cajanus cajan*	Food crop	3
Pumpkin	*Cucurbita pepo*	Food crop	1
Soybean	*Glycine max*	Staple crop	4
Squash	*Cucurbita* sp.	Food crop	1
Strawberry	*Fragaria ananassa*	Food and cash crop	3
Sunflower	*Helianthus annulus*	Cash crop	2
Thorn acacia	*Acacia tortilis*	Ecological keystone	2
Watermelon	*Citrullus lanatus*	Food crop	2

annually (Munyuli 2011). This has a direct bearing on food security and overall human health.

The findings from our study confirm that of all animal pollinators, insects, particularly honeybees *Apis mellifera,* play the most important role in plant pollination as an ecological function (Dag and Gazit 2000; Jensen 2005; Gikungu 2006; Kasina et al. 2009). Bees, due to food from bee-pollinated food crops, are thought to facilitate some 35% of calorie intake by humans every year (Klein et al. 2007). In fact, in the case of East Africa, a majority of the crops pollinated by insects are staple or important cash crops on which the human population depends for daily nutrition and food security, making the need for insect pollinator conservation even more acute in the region (Munyuli 2011).

However, the role of the other nonarthropod pollinators, though seemingly much less prominent, could be also considerably important, and their apparently lower significance might owe to the fact that their roles in pollination is still largely underexplored and less extensively documented, particularly in Africa. For instance, Anderson et al. (2011) showed that reduction in pollination, seed production, and plant density in *Rhabdothamnus solandri* (Gesneriaceae) corresponded to functional extinction of bird pollinators in some parts of mainland New Zealand compared to other nearby islands where the birds remained abundant. From the present study, birds account for one in every six and mammals one in every 14 of the most important animal pollinators in East Africa (Fig. 2). Thus, the nonarthropods together constitute 20% of the key pollinators in the region. In addition, bats (Pteripodidae) were found to pollinate some of the most important ecologically keystone plant species in the East African region such as baobab (*Adansonia digitata*) and many species of the African staple crop banana *Musa* sp.

Even more importantly, results of this study underscore the crucial role that natural history collection records can play in providing large datasets for use in scientific analyses of functional relationships of the various taxonomic groups at various scales. Specimen collection records can thus be mobilized, in conjunction with other field observation information, to help inform policy and address specific environmental, educational, management, and policy challenges in various circumstances.

However, for the records to be effective in addressing such issues in a robust way, an efficient data management system must be put in place at the institutions holding custody of such specimens or records. Fundamental to this is the process of standardizing specimen record digitization from which integration of additional supplementary records, such as from noncollection field work, can be facilitated. Furthermore, there has to be a sound and sustained specimen curatorial capacity to underpin and support the record digitization and maintenance process. In the case of Africa, a lack of sufficient taxonomic and curatorial capacity is among the most serious problems in natural history research based on specimen collections (Eardely et al. 2009). This is responsible for the large backlog and stockpiles of unidentified specimens in most museums across the continent. This continues to seriously hamper interinstitutional, regional, and continental collaboration in taxonomic work. Even at the National Museums of Kenya where this study was based, only the ornithological specimens are fully identified and curated, while a large number of invertebrates as well as many fish, mammal, and some amphibian specimens are yet to be identified and curated.

Therefore, to encourage, develop, and foster full utilization of the potential of natural history specimen collections and associated records for mobilization in research and sustainable development, capacity building in taxonomy, and biodiversity information systems management is critically needed. In addition, a great proportion of natural history specimens and records originating from Africa are still held in institutions outside the continent. A deliberate and collaborative initiative to share some of these records with ''home'' institutions, curators, and data handlers could provide a universally acceptable and mutually beneficial mechanism for spurring scientific output while boosting potential application of such information to inform relevant policy for domestic national development.

To conclude, the results indicate the importance of museum specimen records supported by a sound biodiversity informatics infrastructure as a source of information for national development in East Africa. A similar exercise could be undertaken to highlight and evaluate key pests and invasive species in the region. Furthermore, the temporal dimension of the database infrastructure can be used to design modeling analyses for climate change and future impacts on biodiversity (Babin-Fenske et al. 2008). It therefore shows the value and potential of mobilizing museum specimen collection records for practical application in education, public information, and policy formulation such as in agriculture, health, conservation, and economics.

Another main challenge hindering the effective management of specimen collections data in Africa is limited internet access, putting such resources as online tools taxonomic and georeferencing largely out of reach. Together with very low central government funding rates for museum management and operations, compared to other sectors of the economy, museums on the continent have to adopt innovative ways to attract self-sustaining resources to remain relevant. Offering specimen collections as a properly packaged and readily usable product to policy makers presents one of the best promises to propel museums to the mainstream of civil governance and national development.

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Appendix. Here we give a full list of 100 most important animal pollinators in the East African countries of Kenya, Uganda, and Tanzania. Species information and distribution from various sources including the National Museums of Kenya zoological collection, Specify databases, IT IS (2012), GBIF (2012), and TanBIF (2012).

Rank	Phylum	Class	Order	Family	Scientific name	Common name	Swahili name
1	A	Ins	Hymenoptera	Apidae	*Apis mellifera*	Honey Bee	Nyuki Mzinga
2	A	Ins	Lepidoptera	Sphingidae	*Agrius convolvuli*	Convolvulus Hawk-Moth	Nondo
3	A	Ins	Hymenoptera	Apidae	*Xylocopa inconstans*	Large Carpenter Bee	Nyuki
4	C	Mam	Chiroptera	Pteropodidae	*Rousettus aegypticus*	Roussete or Fruit Bat	Popo
5	A	Ins	Hymenoptera	Apidae	*Xylocopa* sp.	Large Carpenter Bee	Nyuki
6	A	Ins	Hymenoptera	Megachilidae	*Megachile* sp.	Leaf Cutter Bee	Nyuki
7	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia kilimensis*	Bronze Sunbird	Chozi
8	A	Ins	Lepidoptera	Sphingidae	*Hippotion cellerio*	Short-Tongued Hawk Moth	Nondo
9	A	Ins	Hymenoptera	Apidae	*Xylocopa calens*	Large Carpenter Bee	Nyuki
10	A	Ins	Hymenoptera	Apidae	*Xylocopa nigrita*	Unknown	Unknown
11	A	Ins	Hymenoptera	Apidae	*Ceratina* sp.	Small Carpenter Bee	Nyuki
12	A	Ins	Lepidoptera	Sphingidae	*Coelonia fulvinotata*	Fulvous Hawk Moth	Nondo
13	A	Ins	Hymenoptera	Megachilidae	*Heriades* sp.	Leaf-Cutter Bees	Nyuki
14	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia amethystina*	Amethyst Sunbird	Chozi
15	A	Ins	Hymenoptera	Megachilidae	*Pachyanthidium* sp.	Leaf-Cutter Bees	Nyuki
16	A	Ins	Hymenoptera	Halictidae	*Pseudapis* sp.	Sweat Bee	Nyuki
17	A	Ins	Hymenoptera	Apidae	*Xylocopa flavorufa*	Large Carpenter Bee	Nyuki
18	C	Mam	Chiroptera	Pteropodidae	*Epomophorus wahlbergi*	Epauletted Fruit Bat	Popo
19	A	Ins	Lepidoptera	Sphingidae	Family Sphingidae	Hawkmoth	Nondo
20	A	Ins	Hymenoptera	Apidae	*Hypotrigona* sp.	Stingless Bee	Nyuki
21	A	Ins	Hymenoptera	Halictidae	*Lipotriches* sp.	Sweat Bee	Nyuki
22	A	Ins	Hymenoptera	Halictidae	*Nomia* sp.	Sweat or Alkali Bee	Nyuki
23	A	Ins	Lepidoptera	Noctuidae	Family Noctuidae	Owlet Moths	Nondo
24	C	Mam	Chiroptera	Pteropodidae	Family Pteropodidae	Fruit Bats	Popo
25	A	Ins	Hymenoptera	Megachilidae	*Gronocera* sp.	Leaf-Cutter Bees	Nyuki
26	A	Ins	Hymenoptera	Halictidae	*Lasioglossum* sp.	Solitary Bee	Nyuki
27	A	Ins	Hymenoptera	Apidae	*Meliponula* sp.	Stingless Bee	Nyuki
28	A	Ins	Diptera	Muscidae	*Pyrellia acaciae*	No specific	Unknown
29	A	Ins	Lepidoptera	Hesperiidae	*Gorgyra johnstoni*	Skipper Butterfly	Kipepeo
30	C	Ave	Passeriniiformes	Zosteropidae	*Zosterops senegalensis*	Yellow White-Eye	Unknown
31	A	Ins	Hymenoptera	Apidae	*Amegilla atrocincta*	Bee	Unknown

Appendix. Continued.

Rank	Phylum	Class	Order	Family	Scientific name	Common name	Swahili name
32	A	Ins	Hymenoptera	Againidae	*Ceratosolen arabicus*	Fig Wasp	Bunzi
33	A	Ins	Hymenoptera	Againidae	*Ceratosolen galili*	Fig Wasp	Bunzi
34	A	Ins	Lepidoptera	Sphingidae	*Daphnis nerii*	Short-Tongued Hawk Moth	Nondo
35	A	Mam	Chiroptera	Pteropodidae	*Eidolon helvum*	Straw-Colored Fruit Bat	Popo
36	A	Ins	Diptera	Syrphidae	*Episyrphus balteatus*	Marmalade Hoverfly	Unknown
37	A	Ins	Diptera	Syrphidae	*Eristaliaus quinqualineatus*	Fly (no specific)	Unknown
38	A	Ins	Diptera	Tephritidae	Family Tephritidae	Fruit Flies	Unknown
39	A	Ins	Hymenoptera	Apidae	*Liotrigona* sp.	Carpenter Bee	Nyuki
40	A	Ins	Diptera	Muscidae	*Musa domestica*	House Fly	Nzi
41	A	Ins	Hymenoptera	Apidae	*Nannotrigona perilampoides*	Stingless Bees	Nyuki
42	A	Ins	Hymenoptera	Apidae	*Nomia angustibibialis*	Sweat or Alkali Bee	Nyuki
43	C	Ave	Passeriniiformes	Ploceidae	*Ploceus melanocephalus*	Black-Headed Weaver	Unknown
44	C	Ave	Passeriniiformes	Ploceidae	*Ploceus baglafecht*	Baglafecht Weaver	Kwera
45	C	Ave	Passeriniiformes	Pycnonotidae	*Pycnonotus barbatus*	Common Bulbul	Unknown
46	A	Ins	Hymenoptera	Againidae	*Sycophaga sycomori*	Fig Wasp	Bunzi
47	A	Ins	Hymenoptera	Apidae	*Xylocopa flavicollis*	Large Carpenter Bee	Nyuki
48	A	Ins	Hymenoptera	Apidae	*Xylocopa hottentota*	Large Carpenter Bee	Nyuki
49	A	Ins	Hymenoptera	Apidae	*Halictus* sp.	Sweat Bees	Nyuki
50	A	Ins	Hymenoptera	Apidae	*Amegilla* sp.	Small Carpenter Bee	Nyuki
51	A	Ins	Hymenoptera	Megachilidae	*Megachile felina*	Leaf-Cutter Bees	Nyuki
52	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia senegalensis*	Scarlet-Chested Sunbird	Chozi
53	A	Ins	Hymenoptera	Apidae	*Xylocopa caffra*	Large Carpenter Bee	Nyuki
54	A	Ins	Hymenoptera	Againidae	*Alfonsiella natalensis*	Fig Wasp	Bunzi
55	A	Ins	Lepidoptera	Syrphidae	*Allograpta nasuta*	Hoverfly	Unknown
56	A	Ins	Hymenoptera	Apidae	*Amegilla acraensis*	Small Carpenter Bee	Nyuki
57	A	Ins	Hymenoptera	Apidae	*Amegilla calens*	Small Carpenter Bee	Nyuki
58	A	Ins	Diptera	Syrphidae	*Betasryphus adligatus*		Unknown
59	A	Ins	Lepidoptera	Calliphoridae	*Chrysomya chloropygya*		Unknown
60	A	Ins	Hymenoptera	Megachilidae	*Megachile (Creightonella)* sp.	Solitary Bee	Nyuki
61	A	Ins	Hymenoptera	Againidae	*Elisabethiella allotriozoonoides*	Fig Wasp	Bunzi
62	C	Mam	Chiroptera	Pteropodidae	*Epomophorus* sp.	Epauletted Fruit Bats	Popo
63	A	Ins	Hymenoptera	Apidae	*Lipotriches orientalis*	Sweat Bee	Nyuki

Appendix. Continued.

Rank	Phylum	Class	Order	Family	Scientific name	Common name	Swahili name
64	A	Ins	Hymenoptera	Apidae	*Macronmia rufipea*	Carpenter Bee	Nyuki
65	A	Ins	Hymenoptera	Apidae	*Meliponula ferruginea*		Unknown
66	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia cyanolaema*	Blue-Throated Brown Sunbird	Chozi
67	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia olivacea*	Olive Sunbird	Chozi
68	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia superba*	Superb Sunbird	Chozi
69	C	Ave	Passeriniiformes	Nectariinidae	*Cinnyris venustus*	Variable Sunbird	Chozi
70	C	Ave	Passeriniiformes	Zosteropidae	*Zosterops kikuyuensis*	Kikuyu White-Eye	Unknown
71	A	Ins	Hymenoptera	Apidae	*Meliponula bacondei*	Honey Bees	Nyuki Mzga
72	A	Ins	Hymenoptera	Apidae	*Dactylurina* sp.	Stingless Bees	Nyuki
73	A	Ins	Lepidoptera	Nymphalidae	*Danaus chrysippus*	Plain Tiger Butterfly	Kipepeo
74	A	Ins	Lepidoptera	Nymphalidae	*Junonia hierta*	Yellow Pansy	Kipepeo
75	A	Ins	Lepidoptera	Nymphalidae	*Junonia oenone*	Blue Pansy	Kipepeo
76	A	Ins	Coleoptera	Buprestidae	*Sternocera orissa*	African Sternocera	Unknown
77	A	Ins	Hymenoptera	Apidae	*Xylocopa somalica*	Large Carpenter Bee	Nyuki
78	A	Ins	Hymenoptera	Againidae	*Alfonsiella brongersmai*	Fig Wasp	Bunzi
79	A	Ins	Hymenoptera	Againidae	*Alfonsiella longiscapa*	Fig Wasp	Bunzi
80	A	Ins	Hymenoptera	Apidae	*Allodapula* sp.	Hoverfly	Unknown
81	A	Ins	Hymenoptera	Apidae	*Anthophora* sp.	Fur Bee	Nyuki
82	A	Ins	Hymenoptera	Apidae	*Braunsapis* sp.	Bee (no specific)	Nyuki
83	A	Ins	Hymenoptera	Apidae	*Braunsapis fascialus*	Bee (no specific)	Nyuki
84	A	Ins	Hymenoptera	Apidae	*Braunsapis rolini*	Bee (no specific)	Nyuki
85	A	Ins	Lepidoptera	Nymphalidae	*Byblia ilythia*	Spotted Joker Butterfly	Kipepeo
86	A	Ins	Diptera	Calliphoridae	*Calliphora vicina*	Blue-Bottle Fly	Unknown
87	A	Ins	Lepidoptera	Hesperiidae	*Ceoliades* sp.	Skipper Butterfly	Kipepeo
88	A	Ins	Lepidoptera	Sphingidae	*Cephonodes hylas*	Pellucid Hawk Moth	Nondo
89	A	Ins	Lepidoptera	Hesperiidae	*Coeliades* sp.	Skipper Butterfly	Kipepeo
90	A	Ins		Pompilidae	*Cyphononyx* sp.	Spider-Hunting Wasp	Bunzi
91	C	Mam	Chiroptera	Pteropodidae	*Epomophorus labiatus*	Small Fruit Bat	Popo
92	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia* sp.	Sunbird	Chozi
93	C	Ave	Passeriniiformes	Nectariinidae	*Nectarinia veroxii*	Mouse-Colored Sunbird	Chozi
94	A	Mam	Chiroptera	Pteropodidae	*Pteropus* sp.	Flying Fox	Popo
95	A	Ins	Hymenoptera	Apidae	*Hypotrigona* sp.	Stingless Bees	Nyuki

Appendix. Continued.

Rank	Phylum	Class	Order	Family	Scientific name	Common name	Swahili name
96	A	Ins	Hymenoptera	Apidae	*Xylocopa senior*	Large Carpenter Bee	Nyuki
97	C	Ave	Passeriniiformes	Zosteropidae	*Zosterops abyssinicus*	Abyssinian White-Eye	Kengenenge
98	A	Ins	Hymenoptera	Apidae	*Ceratina tanganyicensis*	Small Carpenter Bee	Nyuki
99	A	Ins	Hymenoptera	Apidae	*Macrogalea candida*		Unknown
100	A	Ins	Diptera	Syrphidae	*Eristaliaus quinqualineatus*	Fly (no specific)	Nzi

A = Arthropoda.
C = Chordata.
Ins = Insecta.
Mam = Mammalia.
Ave = Aves.