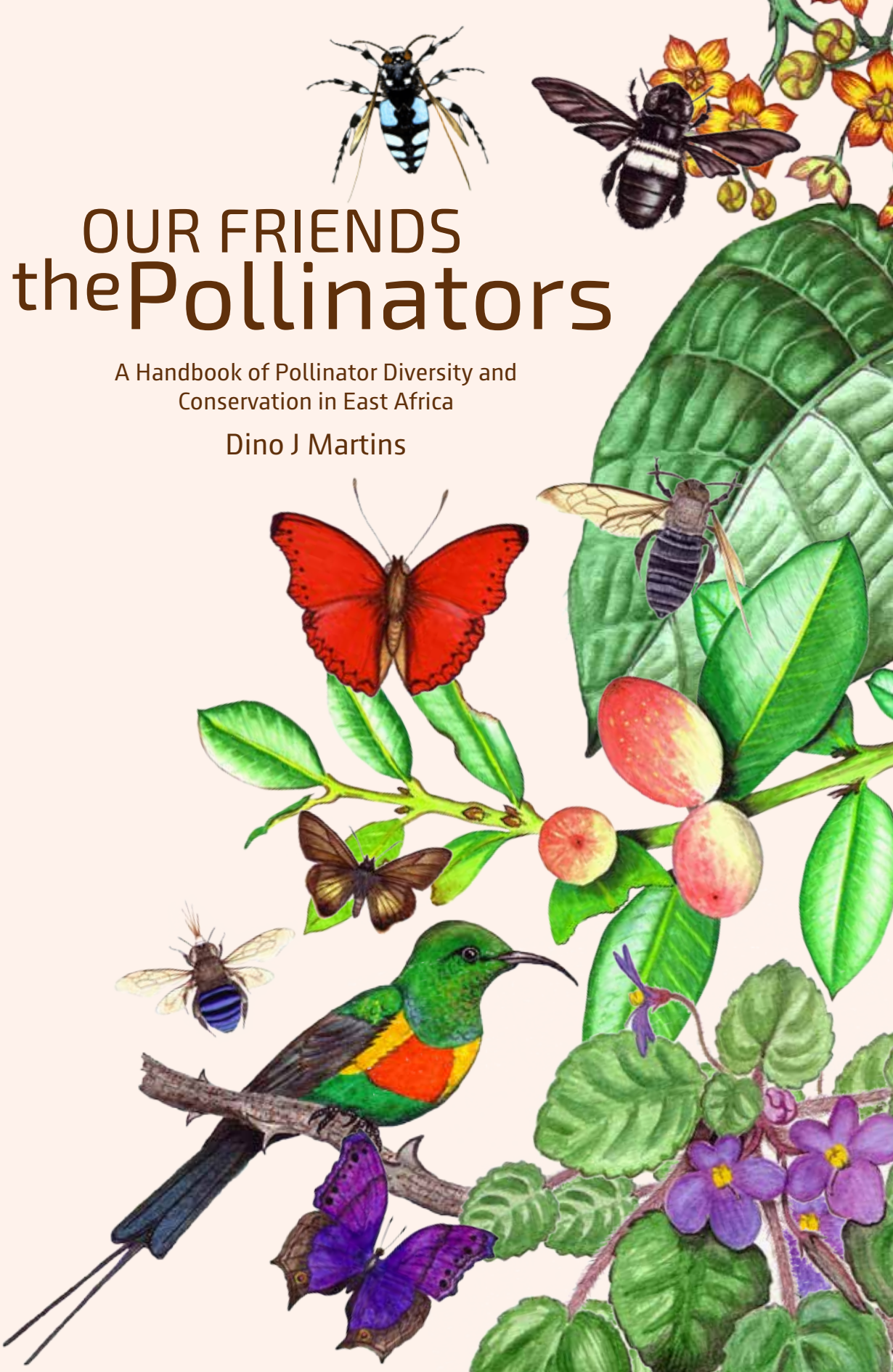

OUR FRIENDS the Pollinators

A Handbook of Pollinator Diversity and Conservation in East Africa

Dino J Martins

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A Handbook of Pollinator Diversity and Conservation in East Africa

Dino J Martins

KENYA POLLINATION PROJECT

gef UNEP FAO PLANT BANK NATIONAL MUSEUMS OF KENYA
WHERE HERITAGE LIVES ON

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National Museums of Kenya, Museum Hill
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Tel: (+254) (0) 20 3537568
or (0) 771 343138
office@naturekenya.org
naturekenya.org

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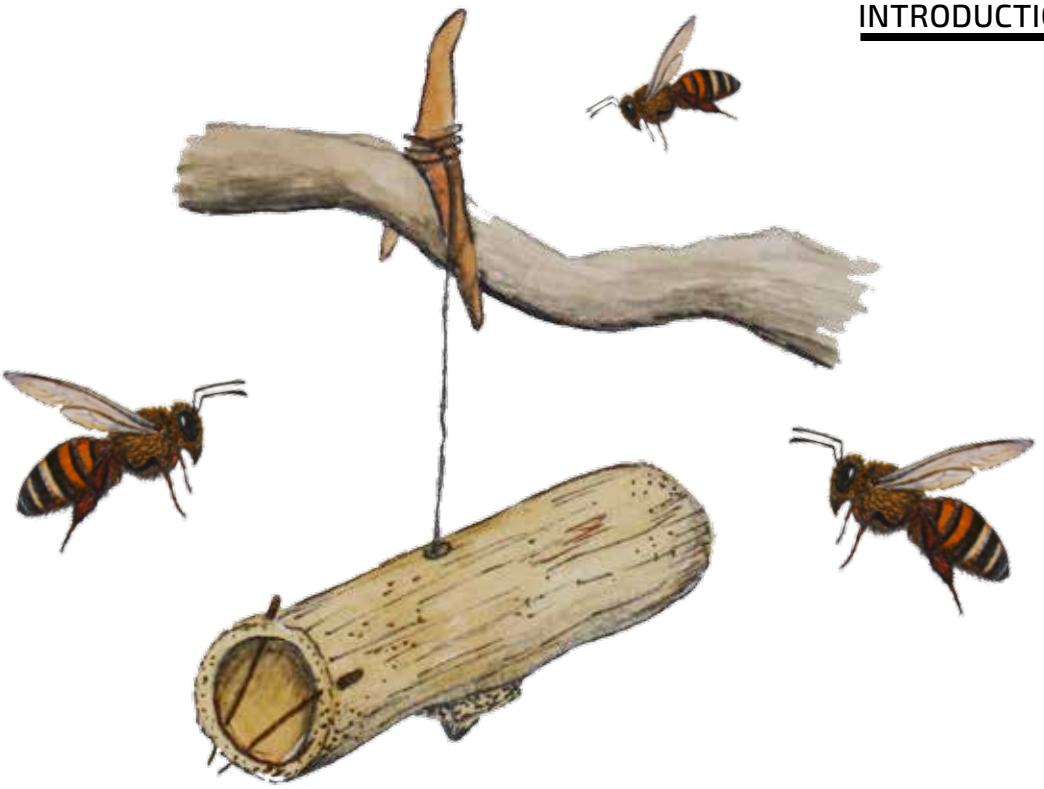

Every day people are connected to nature by those activities of pollinators that contribute to producing food. The goal of this book, *Our Friends the Pollinators*, is to inspire excitement about pollinators, and make the link with food, and people's livelihoods. This book also aims to create awareness, provide practical information on the diversity of pollinators in East Africa (Kenya, Uganda, Tanzania, Ethiopia, Rwanda, Burundi), and introduce you to a few of them.

The relationships between insects and flowers are ancient, intricate, and fragile. Working with pollinators helps us to glimpse, and understand some of the most wonderfully beautiful, and complex interactions on the planet.

We expect that the learning shared in this book will help to shape a strong grassroots movement that works for the protection of habitats, better farming practices, and the restoring of pollination services.

We hope that our sense of wonder at pollinators, and their interaction with flowers, will pass to future generations through this book. ■

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First and foremost I would like to thank the many farmers and communities I have been privileged to work with, and who participated in our pollinator projects across East Africa. Though far too many to mention individually, they hold the future of pollinators in their hands. Only with their help can we develop more sustainable agriculture, and ensure that pollinators persist as part of our heritage contributing to our lives and livelihoods.

This publication is the result of collaboration and support from many different institutions over the years including Nature Kenya, the National Museums of Kenya, the Turkana Basin Institute-Stony Brook University, the Museum of Comparative Zoology at Harvard, the Kenyan Horticultural Society, the Mpala Research Centre, the Kenya Agricultural Research Institute, the Pest Control Products Board, the Suyian Trust and the National Geographic Society. The Global Pollination Project of the Global Environment Facility – United Nations Environment Program – Food and Agricultural Organisation of the United Nations has directly supported this work in Kenya, as has the Whitley Fund for Nature.

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I am grateful too to Catherine Ngarachu for her energy and assistance, and to Job Ballard for his outstanding design.

We live in one of the most diverse and beautiful regions on the planet. In a part of the world where most people make their living from farming, and are directly connected to nature in their daily lives. This book is therefore an excellent effort to engage the general public on the diversity and importance of wild pollinators for agriculture and livelihoods.

We depend, in East Africa, on many different ecosystem services that come from nature for free. These include water resources, fertility of soil, energy from biomass, control of soil erosion, and pollination. To ensure we continue to have these vital services we need public awareness and education—two of the most important tools available for conservation and sustainable development.

Global awareness about the crisis surrounding the conservation of biodiversity and environment has grown significantly. However, it is important to connect this global movement to local action, and the information presented in this book will enable farmers, teachers, and schoolchildren across East Africa to better understand, celebrate, and conserve pollinators in their farms and gardens.

The Ministry of Environment, Water and Natural Resources–custodian of biodiversity in the country, salutes the supporting partners. With this publication the National Museums of Kenya, the GEF-UNEP-FAO Kenya Pollination Project, the Whitley Fund for Nature, and Nature Kenya are helping to raise awareness about better conserving pollinators. This beautifully designed guidebook, reminds us of how much we have to celebrate in pollinators and biodiversity as part of our national heritage.

H.E. Professor Judi Wakhungu
The Cabinet Secretary

Ministry of Environment, Water and Natural Resources
P. O. Box 30026-00100
Nairobi

Longhorn bee approaches an *Orthosiphon* sp. flower: pollinators are essential for the reproduction of flowering plants.

Why We Need Pollinators

When a flower is pollinated it can produce seeds, and fruits. Pollination is the transfer of pollen from the anthers to the stigma of a flower. Plants rely on wind, water, or animals called pollinators to move pollen between different flowers. In this way flowers can produce more seeds, and fruits.

Pollination, is an often overlooked 'ecosystem service'. An ecosystem service is a benefit that is provided free by healthy environments that is essential to the wellbeing of people. People find in the environment resources like water, food, fodder, and fuel. Through natural processes in the environment, ecosystem services also serve us with:

- Habitats for people, plants, and animals
- Water storing, and cleaning
- Soils that can support plant and animal life
- Interactions like pollination

Pollinators provide a vital link with nature supporting human life, and subsistence. In Africa pollinators are primarily insects that travel between farms and natural habitats,

and are extremely vulnerable to habitat loss, and destruction.

Small species-rich habitats, such as forest patches, hedgerows, strips of wildflowers and grasses, and fallow land need to be conserved to save pollinators.

The future of so many of these habitats relies upon rural farmers who need to be engaged as partners in conservation. The beauty of pollination is that it draws a strong and clear link between livelihoods, sustainability, and the protection of the environment. Working with farmers to foster an understanding of pollinators, and habitats, directly contributes to improving food security, and alleviating poverty through increased yields.

Once we recognize that something as fundamental as food production is tied to biodiversity, we can begin to tap into the great potential there is to do this in ways that directly improve human health, and nutrition. The recent global die-offs of honeybees for example, have shown the dangers of relying on just one species given the staggering diversity of just bees.

The decline of biodiversity is accelerating at a grim pace, just as we are beginning to learn about the intricate connections between nature, human life, and livelihoods. We stand to lose the very species, and interactions that underpin our subsistence, and the life support systems of our planet.

Blessed with some of the most diverse habitats on the planet, conservation in East Africa is up against the huge challenge of producing food for a growing population. We need to do this without sacrificing nature, and ecological processes.

The threats to pollinators however, don't just come from habitat destruction. The growing misuse of pesticides, for example, is a very real threat. In this case, there is hope that we can actually get it right here in Africa. We can prevent misuse by disseminating information about how chemicals affect wild insects, and what can be done to limit exposure. By carefully managing the use of pesticides we protect not just pollinators, but soils, streams, and human communities too.

In many parts of Kenya you can easily find over 100 bee species in a given landscape. Bees, and other pollinators are beautiful and fascinating—worth studying in their own right, offering us much pleasure.

Spend time outdoors watching bees, and other pollinators. Indeed, the main goal of this book is to inspire people across East Africa to get more engaged–watching, studying, appreciating, and conserving pollinators–on farms, gardens, villages, and protected areas. ■

"One in three bites of food is thanks to a pollinator"

Many of the crops we grow are dependent on wild insects pollinators.

Bees

Bees are insects. Together with ants and wasps they belong in the insect group Hymenoptera. You may be surprised that there are over 20,000 known species of bees in the world. Bees in East Africa include carpenter bees, *Amegilla* bees, stingless bees, longhorn bees, and honeybees.

These bees vary from each other physically—being of different sizes and shapes, and in their behaviour. Some wild bees nest in tree hollows, others build their nests underground; some will visit a variety of flowers to feed, others specialise, and feed from only one, or two families of flowers; many of these bees are active most of the day, while others may only be active in the early morning, or evening.

Most wild bees are solitary, though some like honeybees and stingless bees are social. Wild bees mostly collect pollen and nectar from flowers but there are those that also collect oils, and other substances from flowers.

Other bee families commonly found in East Africa are the leafcutter bees, which use leaves to line their nests, and the halictid bees, which is a large, diverse family of bees.

Wild bees pollinate about two-thirds of the vegetables and fruits grown in East Africa, and are one of the most important groups of pollinators for all flowering plants in the world. ■

Long-faced bee (*Thrincostoma* sp.) resting on a leaf at the edge of Kakamega Forest. Most wild bees are solitary and females forage and provision nests on their own.

Bees are the most diverse group of insect pollinators. TOP, LEFT TO RIGHT An *Amegilla* bee approaches some Cleome flowers, small carpenter bee (*Ceratina* sp.) on legume.

BOTTOM *Amegilla* on *Leucas* sp.

TOP, AND BOTTOM RIGHT *Amegilla* spp. on *Leucas*.

BOTTOM LEFT Halictid bee on cultivated basil.

Honeybees

Honeybees have developed an exceptional method of communication through movement. When a honeybee returns to the hive, and wants to inform her fellow bees of how to find a particular area with flowers, she performs a special dance called a 'waggle' dance. This dance conveys three different things about a patch of wildflowers to the other worker honeybees: the direction (relative to the sun and hive), the distance (from the hive to the wildflowers), and the quality of the food (nectar and pollen).

There are thousands of known species of bees in the world. But when most people think of a bee, they think of a honeybee. Honeybees, *Apis mellifera,* are just one kind of bee. They are in the family Apidae. They live socially in large colonies, and are commonly kept in domestic beehives, or are found in the wild inside hollow trunks.

Honeybees visit flowers to feed on nectar and pollen, and collect these foods to take back to the hive. Honeybees make use of nectar to produce honey. It takes four worker honeybees their entire lives to produce just one teaspoonful of honey. From honeybees come other useful products including beeswax, propolis, royal jelly, and bee venom.

There is a long history between honeybees and humans. African rock art depicting people harvesting wild honey date to thousands of years ago. Indeed, Honeybees originate in East Africa, and like humans migrated out of Africa to the rest of the world.

There are more wild varieties of honeybees in Africa than anywhere else in the world. In Kenya, there are two different kinds of honeybees:

Common Honeybee

This more familiar orange-and-black coloured bee is typically seen in grassland, bush, coastal, and forest areas.

Mountain Honeybee

This is a dark, chocolate-coloured honeybee that is adapted to the high altitude areas of Mount Kenya, the Aberdare range, and Mount Elgon where it can be found.

Honeybees pollinate many crops, herbs, wildflowers, and trees. ■

Common honeybee pollinating coffee flowers.

Honeybees on different flowers. TOP, LEFT TO RIGHT Common honeybees (*Apis mellifera scutellata*) on *Aloe* sp., and *Argemone mexicana*.

MIDDLE, LEFT TO RIGHT Mountain honeybee on *Leucas* sp., common honeybee on *Bauhinia* sp.

BOTTOM, LEFT TO RIGHT Common honeybees on *Euphorbia* sp., a member of the daisy family–Compositae sp., and cultivated basil (image cutout).

Stingless Bees

Many people simply harvest stingless bee nests by breaking open the nest, which results in the entire colony being killed.

Like the honeybee, stingless bees are social, and live in colonies, each having a queen and workers. They are also called 'Sweat Bees' as they are attracted to the salt in human sweat, and hover around the ears and eyes of people in hot areas.

Stingless bees are smaller than honeybees, and live in hollow trees, rocks, and even termite mounds. They often make vertical tubes from resin at the entrances to their nests. Inside their nests, they have special pots in which they store honey, and separate areas for storing pollen, and housing the larvae.

There are places in East Africa, with a tradition of keeping stingless bees but the knowledge is not widespread. Many people simply harvest stingless bee nests by breaking open the nest, which results in the entire colony being killed. This is very destructive, and has led to the disappearance of stingless bees from some areas.

Stingless bees are very important pollinators as they rely entirely on flowers for nectar and pollen to feed their larvae. They pollinate many forest and dryland plants, and are also valued pollinators of strawberries, mango, and avocado. ■

Large stingless bee (*Meliponula bocandei*) gathers pollen from the anthers of a lily.

Stingless bees. TOP, LEFT TO RIGHT Stingless bee, *Meliponula bocandei*, robbing nectar from a rainforest *Barleria* flower, stingless bee hives for honey production at Kakamega Forest, and stingless bee drinking moisture from leaf.

MIDDLE, LEFT TO RIGHT Close-up views inside the nest of the stingless bee *Meliponula ferruginea.*

BOTTOM, LEFT TO RIGHT Small stingless bee (*Hypotrigona* sp.), and large stingless bees–at their nest entrances.

Carpenter Bees

Carpenter bees are familiar to farmers and gardeners as the bees that fly noisily around wooden buildings, and on farms in the mornings. They include the widespread and abundant genus *Xylocopa*, the large carpenter bees, and *Ceratina* and *Allodapula* bees, which are known as small carpenter bees.

Carpenter bees include the largest bee in East Africa: *Xylocopa nigrita*, which has spectacular large females marked in black-and-white, and bright all-golden males.

Large carpenter bees are active earlier and later than most other bees as their larger size enables them to warm up and forage on cool mornings. They often fly at dusk visiting flowers that would typically not be available to bees. Large carpenter bees visit a wide range of flowers, where they serve as important pollinators of legumes that require 'tripping' of the flowers, and of plants that require buzz-pollination—such as *Solanum* spp. They also serve as pollinators of orchids, milkweeds (*Calotropis*), and cultivated passionfruit.

Most large carpenter bee nests are excavated in wood—hence their name. They burrow tunnels, and construct cells they fill with pollen from plants. Small carpenter bee nests are excavated in pithy dry stems of plants, including the old flowering spikes of aloes. ■

Carpenter bee (*Xylocopa inconstans*), approaches the flowers of *Cleome parvipetala* in Tarangire, Tanzania.

Carpenter bees. TOP, LEFT TO RIGHT Carpenter bee, *Xylocopa flavorufa*, approaches a flowering *Maerua*, carpenter bees on a coastal *Sterculiaceae* sp.

MIDDLE, LEFT TO RIGHT Carpenter bee on the flowering *Sterculiaceae*–note the large amounts of pollen on the bee's body, Blue-eyed carpenter bee on *Crotolaria* sp.

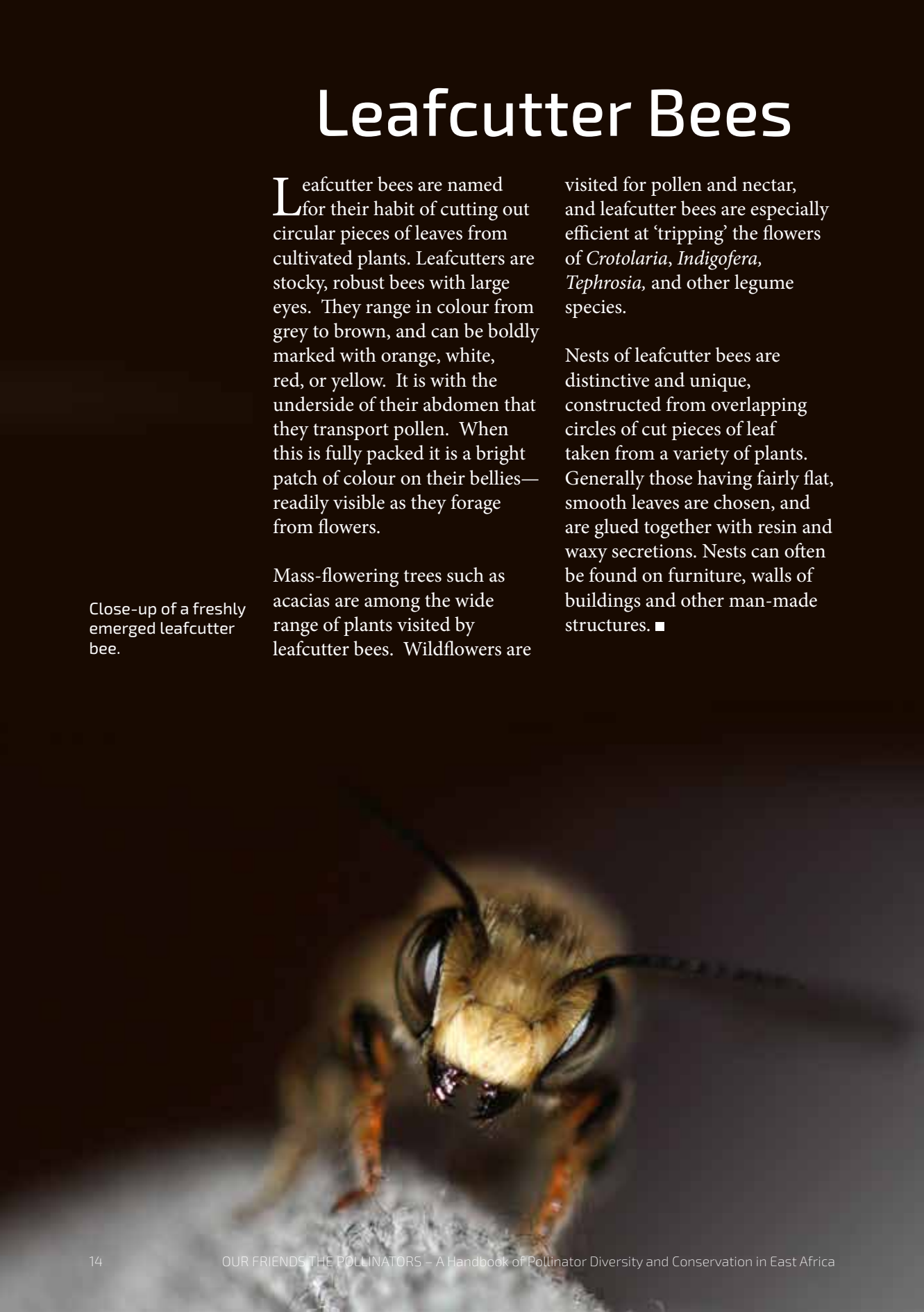
BOTTOM, LEFT Carpenter bee approaching wild basil (*Ocimum* sp.).

Leafcutter Bees

Leafcutter bees are named for their habit of cutting out circular pieces of leaves from cultivated plants. Leafcutters are stocky, robust bees with large eyes. They range in colour from grey to brown, and can be boldly marked with orange, white, red, or yellow. It is with the underside of their abdomen that they transport pollen. When this is fully packed it is a bright patch of colour on their bellies—readily visible as they forage from flowers.

Mass-flowering trees such as acacias are among the wide range of plants visited by leafcutter bees. Wildflowers are visited for pollen and nectar, and leafcutter bees are especially efficient at 'tripping' the flowers of *Crotolaria*, *Indigofera, Tephrosia,* and other legume species.

Nests of leafcutter bees are distinctive and unique, constructed from overlapping circles of cut pieces of leaf taken from a variety of plants. Generally those having fairly flat, smooth leaves are chosen, and are glued together with resin and waxy secretions. Nests can often be found on furniture, walls of buildings and other man-made structures. ■



Close-up of a freshly emerged leafcutter bee.

Various species of leafcutter bees in action.
TOP, LEFT TO RIGHT *Megachile* sp. on *Crotolaria*, *Gronocera* hovering near pigeonpea.

MIDDLE, LEFT TO RIGHT Leafcutter bee gripping flower with its mandibles, leafcutter bee on *Crotolaria*.

LOWER MIDDLE, LEFT TO RIGHT Leafcutter bee cutting leaf-circles from a capsicum, large leafcutter bee approaches *Crotolaria brevidens*–note the large patch of pollen carried on the bee's underside.

BOTTOM, LEFT TO RIGHT Leafcutter bee carrying leaf to nest.

Halictid Bees

This is a very large and diverse family of bees. They are small to medium-sized bees, and are often the most common bees encountered visiting flowers. About one-third of bees in East Africa are halictids.

Halictid bees nest in cavities, primarily in the ground as well as in wood. Halictids also have a wide range of social behaviour. While the vast majority are solitary, a few halictid bees have variable levels of social organisation including communal nesting, sharing nests, semi-social, and even those almost fully eusocial.

Eusocial bees are those like honeybees, with sterile workers who have given up reproducing, and instead support larvae from eggs laid by a fertile queen. This means that they are divided into a series of specialised castes.

Common genera of halictid bees in East Africa include *Lipotriches*, *Nomia*, *Pseudapis*, *Lasioglossum Patellapis*, *Seladonia*, *Thrincostoma*, *Nomioides*, *Cellariella,* and *Ceylalictus*. The biology, behaviour and diversity of most halictid bees in East Africa remains poorly studied. ■

Halictid bee, *Seladonia* sp., on flowers of *Bidens* sp.

Halictid bee diversity. TOP, LEFT TO RIGHT *Lasioglossum* sp. on *Justicia*, *Nomia* sp. approaching *Solanum* sp.

MIDDLE, LEFT TO RIGHT *Seladonia* sp. visiting *Bidens* sp., Tiny *Nomioides* in a flower of *Tribulus terrestris*.

BOTTOM, LEFT TO RIGHT *Systropha* sp. at an *Ipomoea* flower, long-faced bee *Thrincostoma* sp. on a member of the hibiscus family, unidentified halictid gathering pollen on a wild daisy (image cutout).

Fulvous hawkmoth, *Coelonia fulvinotata*, approaching flowers of the orchid *Aerangis brachycarpa.* The long-tongue of the moth and long spur of the orchid flower are one of the most famous examples of coevolution.

Butterflies and Moths

Butterflies are well known insects that are active by day. They land on flowers to feed, so they prefer large, or flat flowers where this is possible. Butterflies pollinate many red flowers with short tubes.

Flowers that are pollinated by moths, are often white or pale, and have a strong fragrance. The fragrance is often only released at night to attract nocturnal moths that come out in the evening, or at night to feed. Hawkmoths are very large moths that are active at flowers at dusk. With powerful wing beats they hover before a flower, and use their extra long tongues to access nectar in these flowers.

About 4 % of all the plants in Kenya, including Papaya (pawpaw) fruit, and many different African orchids, are pollinated by hawkmoths. ■

TOP, LEFT TO RIGHT Acraea butterflies on *Bidens* and *Sphaeranthus* flowers.

MIDDLE One-pip policeman skipper butterfly on *Acacia brevispica*.

BOTTOM Comma hawkmoth (*Nephele* sp.) probes the flowers of a *Grewia*.

TOP, LEFT TO RIGHT *Colotis* sp. on *Kalanchoe* flowers, Green-patch swallowtail sipping salts from mud.

MIDDLE Netted Sylph skipper butterfly on flowers of *Orthosiphon* sp.

BOTTOM Brown-veined white, *Belenois aurota*, on a *Sphaeranthus* flower.

An Acraea sips nectar from a wild daisy.

TOP, LEFT TO RIGHT *Colotis* sp. on fireball lily, Playboy butterfly sipping nectar.

MIDDLE, LEFT TO RIGHT Painted lady on *Pentanisia*, Green-patch Swallowtail on *Kleinia*, and an Acraea on *Bidens* sp. (image cutout).

BOTTOM, LEFT TO RIGHT Common Scarlet butterfly, *Axiocerses* sp. sips nectar, Hairstreak butterfly on *Justicia* sp.

Hawkmoths.
TOP Small verdant hawkmoth *Basiothia medea*, visits a flowering Carissa.

MIDDLE, LEFT TO RIGHT Unidentified hawkmoth on a forest Vernonia, Fulvous hawkmoth at Combretum flowers.

BOTTOM Skipper butterfly on *Impatiens* sp. in forest.

TOP, LEFT TO RIGHT Fulvous hawkmoth approaching Aerangis orchid, Convolvulus hawkmoth visiting flowers of *Turraea* sp.

MIDDLE Verdant hawkmoth and White-lined Sphinx at *Pergularia* flowers.

BOTTOM, LEFT TO RIGHT Skipper butterflies at *Bidens* sp. and at a member of the hibiscus family.

© P. Usher

Eastern violet-backed sunbird on acacia flowers.

Sunbirds

Sunbirds are colourful pollinators of many plants. They are generally small in size, and have long curved beaks.

Flowers pollinated by sunbirds are often red or orange, have long tubular flowers, with lots of sugary nectar. Giant lobelias that grow on the high mountains of East Africa are pollinated by sunbirds, as are Aloes and Red-hot Poker Trees.

Many of the plants pollinated by sunbirds have adapted to particular sunbirds, having a tubular shape, and size to correspond to the sunbird's beak. Other organisms cannot pollinate these flowers. Sunbirds also feed on insects that visit flowers. ■

POLLINATOR DIVERSITY

Collared sunbird on flowering poinsettia.

© C. Eardley

TOP Beautiful sunbird (illustration), and Scarlet-chested sunbird on aloe flower.

BOTTOM Marico sunbird on flowering aloe.

Many of the plants pollinated by sunbirds have adapted to particular sunbirds

TOP Scarlet-tufted Malachite sunbird–a high-altitude specialised pollinator of giant lobelias and other plants.

BOTTOM Shining sunbird female at nest–note the pollen coating her throat indicating she has been visiting flowering aloes.

Bats and Bushbabies

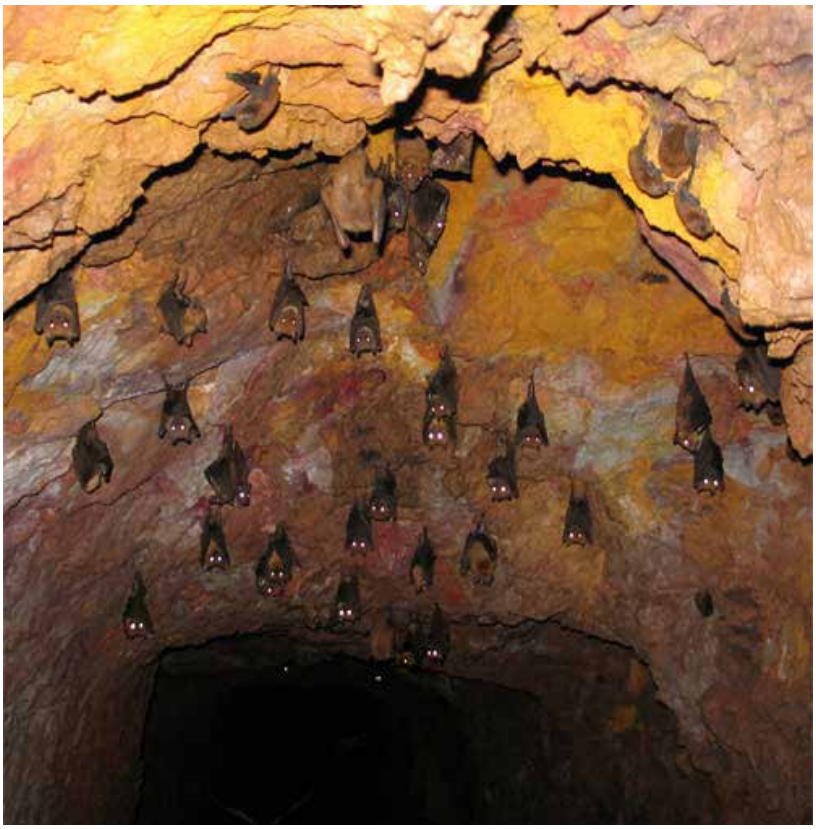
Moths are not the only pollinators active in the dark—bats and bushbabies are mammals that feed during the night. Flowers that are pollinated by bats open in the evening, or during the night, contain nectar, and have a fruity scent.

The white flowers of baobab trees are a good example. Baobab trees are pollinated by fruit bats, and occasionally by bushbabies. Bats feed not only on the nectar, but also on flower parts, and any insects in the flower.

In forest, over savannah, near farms or settlements, bats can travel great distances over a single night, and as they feed they may convey pollen from flower to flower pollinating many different trees along the way. Bats also pollinate sausage trees, mangoes, and bananas.

Bushbabies have very large eyes as they hunt at night, and feed on insects, acacia gum, seeds, bird eggs, fruit and flowers. When they feed on baobab flowers they eat parts of the flower, and while doing so take pollen from flower to flower. ■

Lesser galago (bushbaby) resting in an acacia.



TOP Fruit bats resting inside a cave.

BOTTOM, LEFT TO RIGHT Fruit bat, Yellow-winged bat at rest–this species mainly hawks insects at flowers.

Fruit bat and baobab flower illustrated. Baobab is a species pollinated by bats.

Wasps and Figwasps

Fig wasps (Agaonidae) are specialised pollinators that have co-evolved with figs, *Ficus* spp.

Many people think wasps are a nuisance, or are afraid of wasps because they sting. But wasps are also beneficial. As they are predatory, and capture insects they provide vital ecological pest control services. Wasps also require pollen and nectar, and are common visitors to flowers. They carry pollen as they move around flowers, and serve as pollinators.

Figwasps are the tiny pollinators of mighty fig trees, with whom they have a very special relationship. Figs trees have their flowers inside the fruit. The figwasp is adapted to be able to burrow its way through a tiny opening into the fruit to bred, and pollinate the flowers.

There are many species of fig trees in East Africa, and each can be pollinated only by a particular species of figwasp. The tree cannot survive without the figwasp, and the wasp cannot survive without the tree. They are wedded together forever. It is female figwasps who pollinate, being able to fly between trees. Males never leave the fig they are born in. ■

Life-cycle of fig wasp and pollination of fig. TOP, LEFT TO RIGHT Green figs (are actually enclosed flowers, called a synconium), detail of a synconium in cross-section with an approaching wasp to scale.

BOTTOM Female fig wasp ovipositing in short-styled female flower next to fertile long-styled female flower that she pollinates with pollen from the pockets on her side.

These eggs develop and flightless male fig wasps hatch out (as in bottom left) and mate with females. Then mature females hatch out, gather pollen and depart the fig to repeat the whole cycle.

Wasps.
TOP, LEFT TO RIGHT Mud dauber wasp visiting flowers in garden, Spechid wasp on euphorbia flowers.

BOTTOM Mammoth wasp on wild daisy flowers.

TOP, LEFT TO RIGHT Spider-hunting wasp on euphorbia, parasitic wasp on acacia flowers.

MIDDLE Spechid wasp on euphorbia flowers.

BOTTOM Male velvet ant (Mutillidae) on euphorbia.

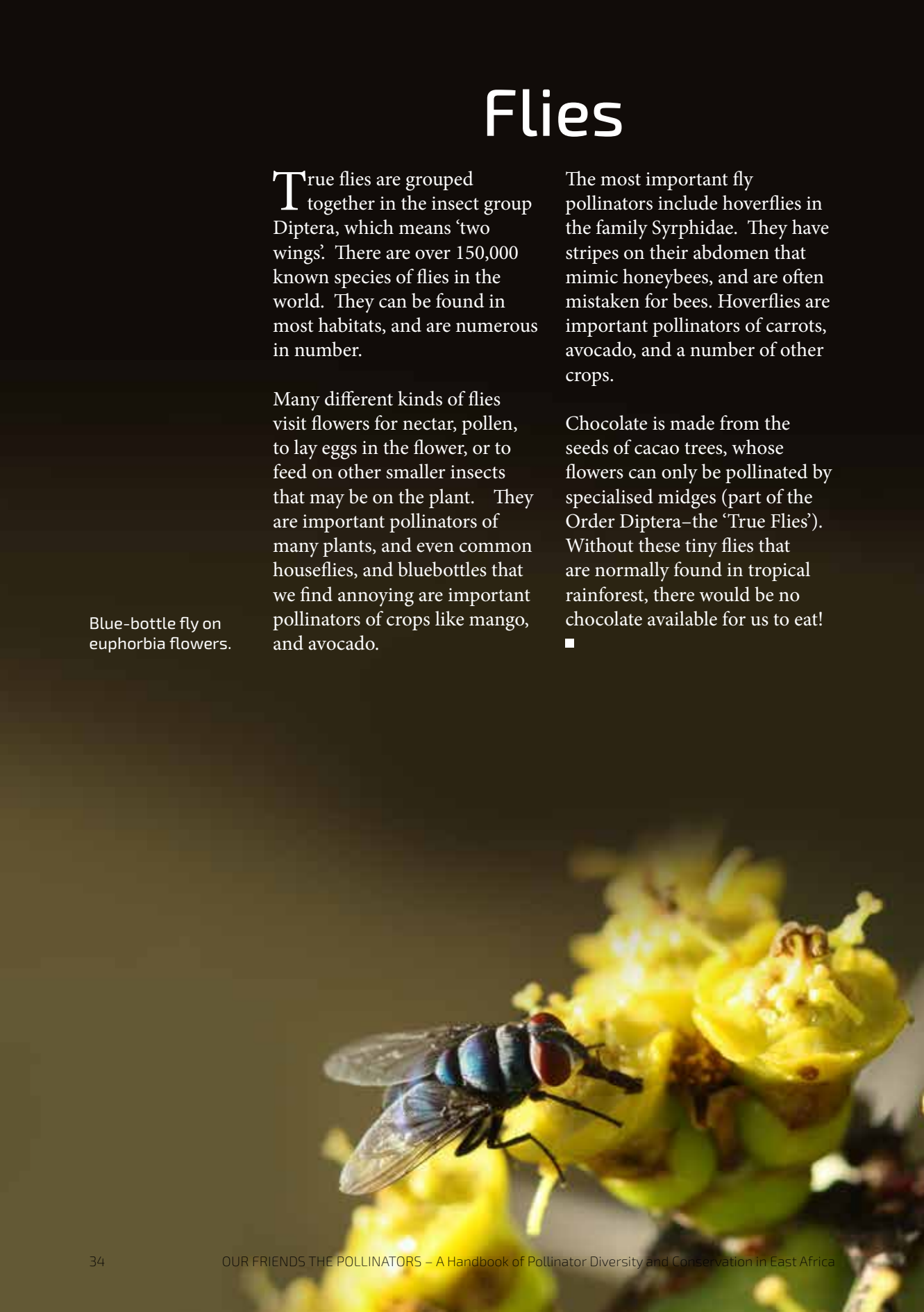
Flies

True flies are grouped together in the insect group Diptera, which means 'two wings'. There are over 150,000 known species of flies in the world. They can be found in most habitats, and are numerous in number.

Many different kinds of flies visit flowers for nectar, pollen, to lay eggs in the flower, or to feed on other smaller insects that may be on the plant. They are important pollinators of many plants, and even common houseflies, and bluebottles that we find annoying are important pollinators of crops like mango, and avocado.

The most important fly pollinators include hoverflies in the family Syrphidae. They have stripes on their abdomen that mimic honeybees, and are often mistaken for bees. Hoverflies are important pollinators of carrots, avocado, and a number of other crops.

Chocolate is made from the seeds of cacao trees, whose flowers can only be pollinated by specialised midges (part of the Order Diptera–the 'True Flies'). Without these tiny flies that are normally found in tropical rainforest, there would be no chocolate available for us to eat! ■



Blue-bottle fly on euphorbia flowers.

TOP, LEFT TO RIGHT
Black scavenger fly (Sepsidae) on *Rhus* flowers, Tachinid fly on *Rhus*, Blue-bottles and Tiny Gem butterfly on euphorbia.

BOTTOM Hoverfly (Syrphidae) on *Euphorbia magnicapsula.*

TOP, LEFT TO RIGHT Hoverfly (*Syrphidae* spp.) on euphorbia, unidentified fly on euphorbia.

BOTTOM Hoverfly on *Harungana madagascariensis*.

TOP, LEFT TO RIGHT Tabanid fly on *Orthosiphon* sp., root maggot fly on onion flowers.

MIDDLE, LEFT TO RIGHT Hoverfly (Syrphidae) on *Impatiens* sp., pollen-feeding fly on *Maerua* sp.

BELOW *Philoliche*, a long-tongued Tabanid fly.

Beetles

Flowers that are pollinated by beetles tend to be larger and produce a musty or fruity scent to attract the beetles.

There are more different kinds of beetles on the planet than any other group of creatures. Beetles have been around for a very long time, hundreds of millions of years in fact. Some beetles developed relationships with plants as specialised pollinators even before bees had appeared on the scene! Beetles are important pollinators in some habitats where bees are scarce, including some very arid areas.

Flowers that are pollinated by beetles tend to be larger and produce a musty or fruity scent to attract the beetles. A number of palm tree species, including the Oil Palm, are pollinated by specialised beetles.

In East Africa one ancient group of plants, the cycads, are pollinated by beetles, including weevils, that complete their life-cycle within the reproductive cones produced by the plants. As there are separate male and female cycads, the pollinators are essential for the survival of some of these magnificent, rare plants in the wild.

Beetles of many different kinds including chafers, longhorns and leaf beetles, do visit flowers in large numbers. However, they mostly feed on the flowers causing some damage and don't serve as efficient pollinators.

Net-winged beetle (Lycidae) on euphorbia.

TOP, LEFT TO RIGHT Groove-winged flower beetle (Melyridae) on euphorbia, Net-winged beetle on euphorbia.

CENTRE Small longhorn beetle (Cerambycidae) on wild daisy.

BOTTOM, LEFT TO RIGHT Rose chafer (*Pachnoda* sp.) on *Euphorbia magnicapsula*, leaf beetle on acacia flower.

Ants

While ants are among the most abundant, diverse and ecologically important groups of insects in the ecosystem, they are on whole not good pollinators. A few succulents and other plants (including some Euphorbias) are pollinated by ants. Plants in harsh, arid drylands are the ones that seem to rely on ants as there might be few other pollinators available. Ant-pollinated succulent plants also tend to be low-growing close to the ground where ants can more easily access the flowers.

Why don't ants make good pollinators? Well, firstly the worker ants that visit flowers lack wings and typically forage short distances between their nests and the plants. This means that they are not efficient at carrying pollen over long distances.

Secondly, ants are obsessed with keeping clean, and by constantly grooming and producing glandular secretions, they often remove grains of pollen. These chemical secretions produced by the ants are for killing germs, but have an impact on pollen too.

Ants will often visit flowers for nectar, and occasionally to hunt other insects. Many plants encourage ants to visit by secreting nectar from special glands that are located outside the flowers (hence called extra-floral nectaries). These glands encourage ants, and they end up patrolling the plant providing some protection from greedy herbivorous insects who might want to feed on the plant. ■

Camponotus ants foraging on euphorbia flowers.

TOP *Camponotus braunsi* ants on *Euphorbia heterspina* ssp. *baringoensis*.

MIDDLE *Camponotus* ants foraging on ornamental euphorbia.

BOTTOM, LEFT TO RIGHT *Camponotus* ants foraging on euphorbias, Polyrachis ants attending hemipteran bugs on a flowering parasitic plant.

Crop Pollination

Pollination takes place when pollen is transferred from the male part of a flower (the anthers) where pollen is produced, to the female part (the stigma) of another flower of the same species, where the pollen germinates. Pollinators (like bees, wasps, moths, bats) transport pollen between flowers, ensuring that flowers produce seeds and fruits. Many crops cultivated in East Africa require pollination.

Common crops that benefit from pollination include avocado, coffee, cowpeas, eggplant, mangoes, pigeon peas, pumpkins, okra, and tomatoes.

Indeed, studies have shown that 75% of all crop species, and over 80% of all flowering plant species are dependent on pollinators, primarily wild insects. Crops like passionfruit, cocoa, strawberries, eggplant, watermelon, cucumber, and pumpkin are wholly dependent on pollinators. For other crops, like coffee, avocado, mango and runner beans, pollinators contribute to increased yields and quality.

For trees, and plants in natural habitats, the contribution of pollination to ensuring habitats regenerate with healthy seeds and fruits is yet to be measured or fully understood.

Studies have estimated that pollination services provided by wild insects globally are

Sunflower field at Kaptagat, Kenya.

worth over €150 billion (or over US $200 billion). In the Baringo region of Kenya alone, watermelons worth KES 900 million (US $9 million) are produced. All of these watermelons are the result of pollination by wild insects, primarily bees.

The following section describes pollination systems, and pollinators of some of the most common pollinator-dependent crops in our region. ■

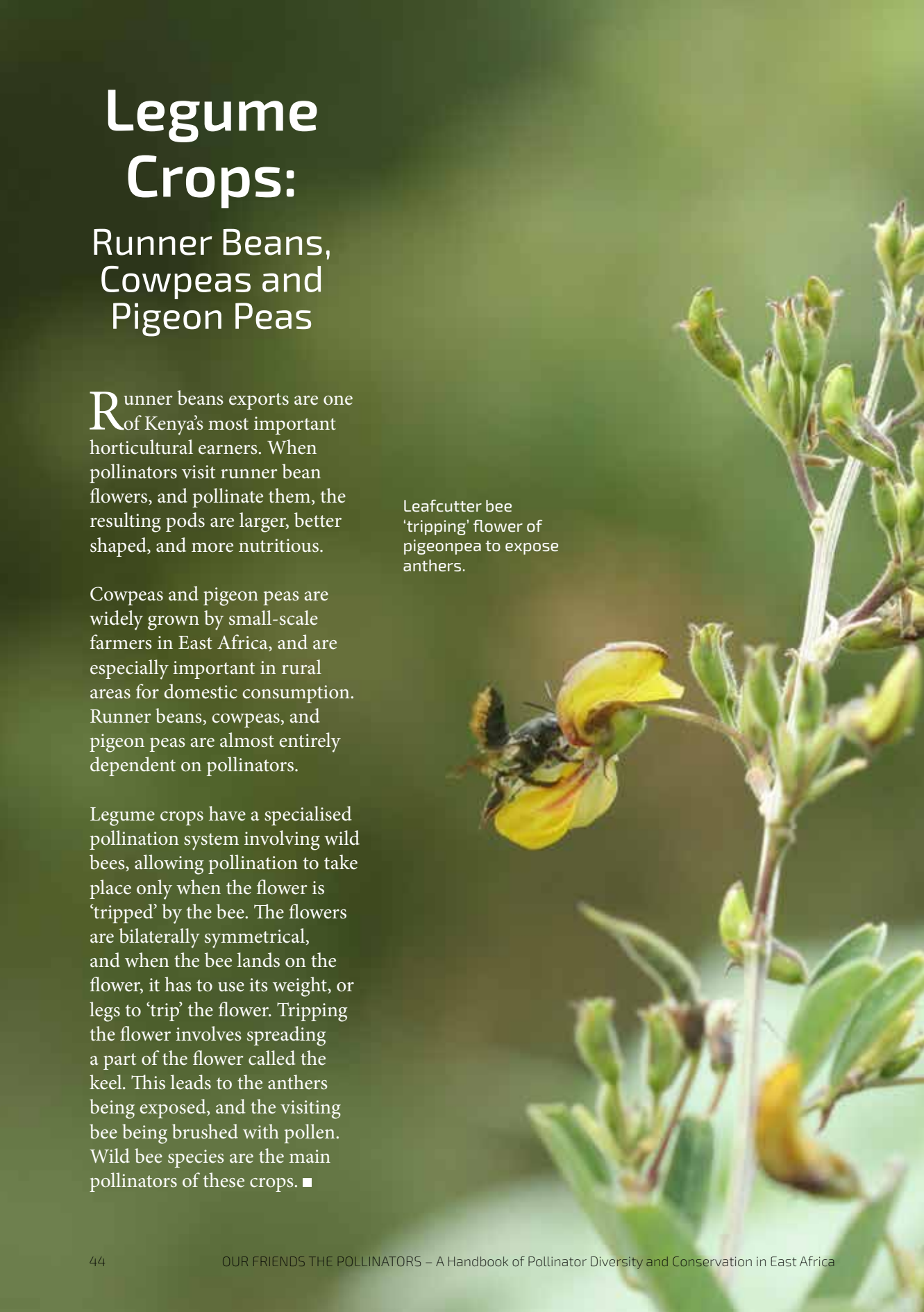
Legume Crops:

Runner Beans, Cowpeas and Pigeon Peas

Runner beans exports are one of Kenya's most important horticultural earners. When pollinators visit runner bean flowers, and pollinate them, the resulting pods are larger, better shaped, and more nutritious.

Cowpeas and pigeon peas are widely grown by small-scale farmers in East Africa, and are especially important in rural areas for domestic consumption. Runner beans, cowpeas, and pigeon peas are almost entirely dependent on pollinators.

Legume crops have a specialised pollination system involving wild bees, allowing pollination to take place only when the flower is 'tripped' by the bee. The flowers are bilaterally symmetrical, and when the bee lands on the flower, it has to use its weight, or legs to 'trip' the flower. Tripping the flower involves spreading a part of the flower called the keel. This leads to the anthers being exposed, and the visiting bee being brushed with pollen. Wild bee species are the main pollinators of these crops. ■



Leafcutter bee 'tripping' flower of pigeonpea to expose anthers.

TOP Carpenter bee (*Xylocopa* sp.) pollinating pigeonpea.

MIDDLE Small carpener bee (*Ceratina* sp.).

LEFT Pigeonpea farmer in Mwanza, Tanzania.

BOTTOM LEFT Carpenter bee (*X. hottentota*).

Carpenter bee (*Xylocopa inconstans*).

Passionfruit

Passionfruit is nutritious, and delicious. It grows as a creeper, and spreads by way of numerous strong tendrils. Demand for passionfruit has largely been driven by the fruit juice market, with increasing numbers of farmers growing passionfruit in Kenya.

Passionfruit flowers are unique, and incredibly beautiful. They are also complex with anthers arranged above a 'ring', and nectaries having lids on them. It takes a hefty pollinator to lift the lid to the nectary, and the most efficient pollinators able to do this are large carpenter bees (mainly *Xylocopa* spp.).

To set fruit passionfruits are 100% dependent on pollinators like carpenter bees, and without them there would be no passionfruits for us to eat, or to make juice. It is unfortunate that farmers often mistake the large carpenter bees for beetles, or pests, and kill them.

Carpenter bees like to nest in wood, and are attracted to hedgerows with a variety of wildflowers. ■

TOP Passionfruit flower.

BOTTOM, LEFT TO RIGHT Passionfruit from the hard work of bees, honeybees visiting passionfruit flower.

Eggplant

(also known as Aubergines or Brinjals)

Local demand for eggplants has increased significantly in East Africa. Eggplants are a high nutritious vegetable, and can grow in hot, dry areas where vegetables are harder to grow. Eggplants belong to the nightshade family (*Solanaceae*), which include tomatoes and potatoes.

Flowers of plants in this family have a specialised pollination system called 'buzz pollination' involving wild bees. Buzz pollination involves the bee holding the flower with its mouthparts, and causing it vibrate, by using the motion from its wing muscles to transfer the vibration energy into the flower. Only when this is done at the correct frequency is pollen forcibly released from the anthers.

Eggplants are 100% dependent on pollinators to produce fruit, with solitary (non-social) species of wild bees, being the exclusive pollinators of eggplant flowers. Maintain natural habitat patches around fields of eggplant to support solitary wild bee pollinators. ■

Nomia bee approaching eggplant flower with stingless bee on it.

TOP, LEFT TO RIGHT
Freshly harvested eggplants thanks to hard-working bees, eggplant farmer admires part of her harvest in Turkana.

BOTTOM
Meliturgula sp. and stingless bee on an eggplant flower.

Mango

Sometimes called the 'king of fruits', the area under mango cultivation has grown considerably in East Africa. It is eaten as fresh, or dried fruit, and used to make juice, jam, and chutney.

Kenya's average mango yield per hectare is about 16 tons of fruit. A single large healthy mango tree can annually produce over one thousand fruits for sale. The farmer may be able to sell each mango for up to KES 50, giving him an annual income of KES 50,000 (around US $600) from each tree!

Mango trees flower in synchrony bearing many flowers at the same time. Mango trees are dependent on optimal weather, and sufficient numbers of pollinators to set fruit with success.

Mango tree flowers are simple, open, and small in size. They are visited, and pollinated by different kinds of wasps, and even ants, but flies, and stingless bees are thought to be the main pollinators of mangoes. As mangoes flower only seasonally, a grower of mangoes will need to maintain patches of natural habitat, and wildflowers, for wild insect pollinators to visit when the mango trees are not in flower. ■

Pollen-feeding fly on a mango flower.

TOP, LEFT TO RIGHT Fly pollinating mango flower, mango farmer with fruit in the Kerio Valley.

MIDDLE Eucharitid wasp.

LEFT *Camponotus* ants.

BOTTOM LEFT Bluebottle fly.

Coffee

Kenya's arabica coffee is well know, and sought after around the world. Coffee sales are a major contributor to the country's Gross Domestic Product, and the industry employs millions of Kenyans.

Coffee bushes flower synchronously at different times of the year, usually at the beginning of the rains. Coffee varieties can be self-pollinated, but the presence of pollinators improves the quality, and size of the coffee beans. Some varieties of coffee in East Africa, such as robusta coffee, appear to be completely dependent on pollinators.

The main pollinators of coffee flowers are different kinds of bees. Honeybee hives can be placed amongst coffee bushes to improve coffee yields. Other pollinators of coffee are many different kinds of wasps, large flies, butterflies, moths, and even sunbirds.

To support wild bee pollinators of coffee it is important to provide other sources of nectar. These can include areas of wildflowers, or indigenous shade trees along the edges of coffee plantations.

Protecting pollinators of coffee from pesticides is important, and should be managed carefully. Spraying when coffee is in flower could negatively impact the pollinators, and therefore coffee yields. ■

TOP Bee-hives near coffee–can improve yields of high quality coffee through the efforts of pollinators.

LEFT Ripening coffee berries.

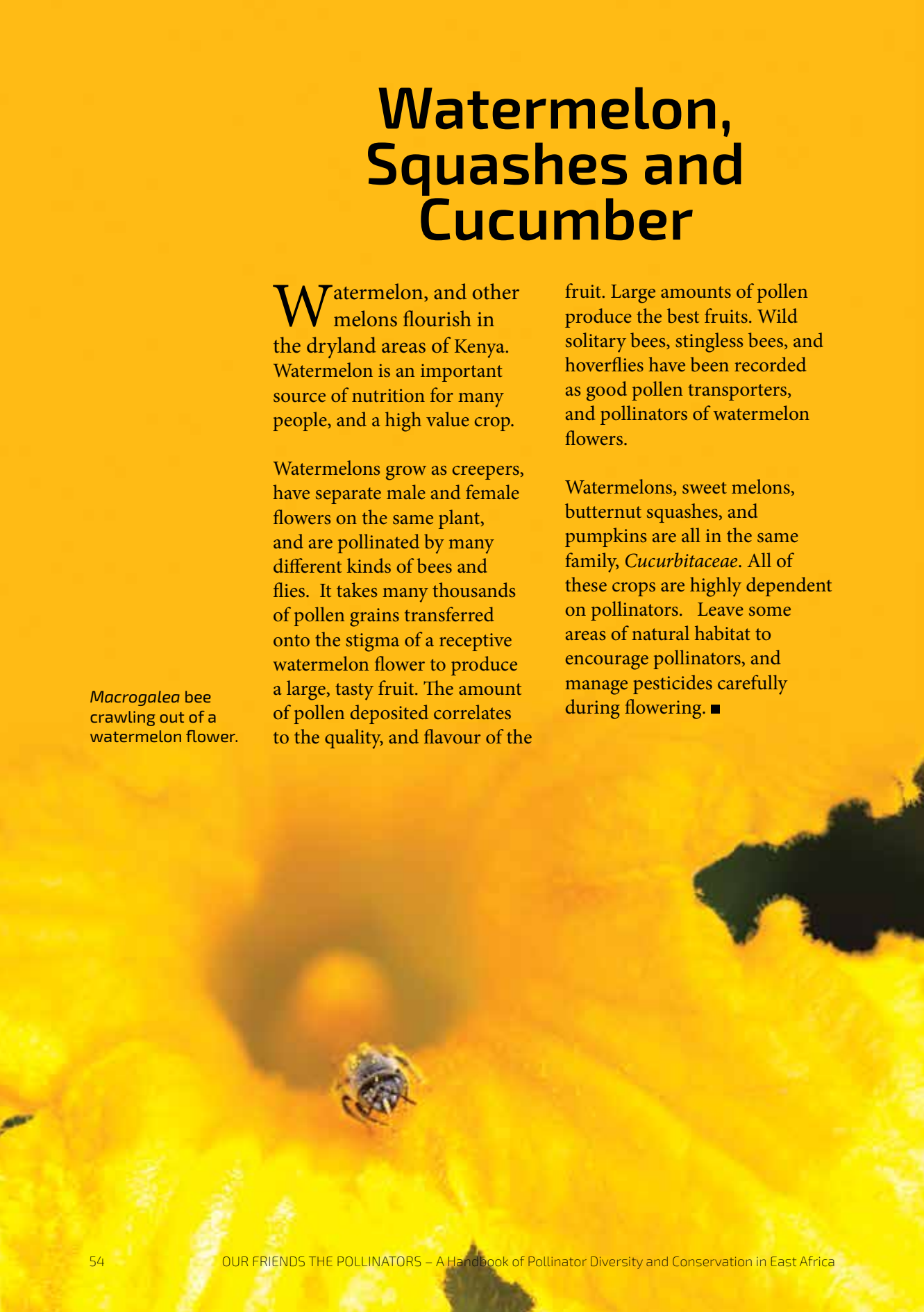
BELOW Honeybee pollinating coffee flower.

Watermelon, Squashes and Cucumber

Watermelon, and other melons flourish in the dryland areas of Kenya. Watermelon is an important source of nutrition for many people, and a high value crop.

Watermelons grow as creepers, have separate male and female flowers on the same plant, and are pollinated by many different kinds of bees and flies. It takes many thousands of pollen grains transferred onto the stigma of a receptive watermelon flower to produce a large, tasty fruit. The amount of pollen deposited correlates to the quality, and flavour of the fruit. Large amounts of pollen produce the best fruits. Wild solitary bees, stingless bees, and hoverflies have been recorded as good pollen transporters, and pollinators of watermelon flowers.

Watermelons, sweet melons, butternut squashes, and pumpkins are all in the same family, *Cucurbitaceae*. All of these crops are highly dependent on pollinators. Leave some areas of natural habitat to encourage pollinators, and manage pesticides carefully during flowering. ■



Macrogalea bee crawling out of a watermelon flower.

Stingless bee on cucumber.

Amegilla bee on cucumber.

Papaya

Papaya, also known as pawpaw, is an important fruit crop for many smallholder farmers in East Africa, who are fully dependent on pollinators to pollinate their papaya.

Papaya has separate male and female plants. Male flowers are produced in large numbers on male plants, while female flowers are produced is smaller numbers at the base of the leaves on female papaya plants. Papaya pollinators have to visit male flowers, collect pollen, then visit female flowers to ensure pollination, and fruit set.

The pollinators of papaya in East Africa are primarily hawkmoths, and a few skipper butterflies. Hawkmoths are efficient pollinators as they can move rapidly between different papaya plants on a farm.

Hawkmoths, and skipper butterflies need other plants for nectar. They also require wild plant species, called host-plants, to provide a place to lay their eggs, and from where caterpillars can feed, and grow. ■

Hawkmoths are the main pollinators of papaya.

TOP Papaya trees in fruit thriving in this natural habitat.

LEFT Papaya farmer in the Kerio Valley.

BELOW Close-up of young fruit and male flowers of papaya.

Ceratina bee on coriander flowers.

Spices and Seeds

Spices are tasty, high value, and often health supporting components of our diet. Pollinators contribute by pollinating the flowers that develop into the seeds and fruits that we harvest, and use as spices. Examples of spices that are pollinated by insects in East Africa include chillies (pollinated by bees), bell peppers (pollinated by bees), cardamom (pollinated by bees), and coriander—also called cilantro (pollinated by bees, wasps, flies). ■

TOP, LEFT TO RIGHT Wasp visiting coriander flowers, almonds–a crop that depends on pollinators.

BOTTOM Lycaenid butterfly and cuckoo wasp on coriander flowers.

Traditional Vegetables

Different kinds of indigenous vegetables are grown as traditional food plants across East Africa, and contribute to food, and nutritional security in rural areas. Each region often has special plants that make the cuisine, and diet of that area distinctive. Common traditional vegetables in the region include the blackbean (njahe), wild spinach (terere), leafy amaranth varieties, and a number of legumes.

Bees, and other insects pollinate traditional vegetables. For example, in western Kenya, 'Mitoo', *Crotolaria brevidens*, is a legume, which has a specialised pollination system that involves leafcutter bees, and carpenter bees serving as its pollinators. 'Mchicha', *Gynandropsis gynandra*, is another popular plant whose long brush-like flowers are pollinated by both hawkmoths, and bees.

Pollination systems of most of our traditional vegetables have not been studied. ■

Convolvulus hawkmoth (*Agrius convolvuli*) visiting flowers of 'Mchicha' *Gynandropsis gynandra.*

TOP, LEFT TO RIGHT Young pods of blackbeans or 'Njahe', carpenter bee (*Xylocopa flavorufa*) pollinating flowering blackbean.

BOTTOM White-lined Sphinx (*Hippotion celerio*) visiting flowers of 'Mchicha' *Gynandropsis gynandra.*

Forage and Fodder Plants

Forage, and fodder plants are crops that comprise livestock feed. Different animals will feed on different kinds of plants, depending the region, and habitat.

Important forage crops for cattle in East Africa are legumes like lucerne (also known as alfalfa), which help increase meat, and milk production. Wild bees are the main pollinators of Lucerne. Other legume species used by livestock include: *acacias*, *Indigofera,* and *Crotolaria.* All of these are dependent on pollinators.

The highly nutritious pods of the Umbrella Thorn Acacia, *Acacia tortilis,* are widely consumed by livestock in arid and semi-arid regions. Without these pods, it would be harder for livestock to survive in arid areas. The pods are so valuable for supporting livestock that *Acacia tortilis* trees are carefully guarded, and passed as an inheritance from parents to children in parts of northern Kenya. Acacia pods are the result of pollination by a wide range of insects, primarily wild bees.

Indigofera are small sturdy shrubs that grow in the desert, and are an important forage plant for camels. In many parts of the Horn of Africa, free-ranging camels browse on the leaves, and pods of *Indigofera*. Without them camels would not be able to survive in these areas. *Indigofera* is dependent on wild bee species for pollination.

These examples show how pollinators are connected to us, not just through cultivated crops, but through our livestock too. ■

Camels are one of the livestock species whose diet is highly dependent on pollinators.

TOP Leafcutter bee pollinating *Indigofera spinosa.*

LEFT Grass jewel butterfly on *I. spinosa* flower.

RIGHT *Pseudapis* sp. also at *Indigofera* flower, goat grazing on *Indigofera* plants.

Plants for Pollinators

Canola growing at Timau, in north central Kenya.

Trees and shrubs for bees and other pollinators:

TREES	NOTES
Acacias: *Acacia xanthophloea* *Acacia kirkii* *Acacia senegal* *Acacia tortilis*	All indigenous acacias are key resources for pollinators. An abundance and diversity of insects can be found swarming around flowering acacias. *Acacia tortilis,* and *Acacia senegal* are just two of many important dryland species.
Albizia spp.	These trees flower synchronously, and are an important resource for bees, butterflies, and sunbirds.
Combretum spp.	Important in the drylands and savannah, these species are visited by both bees, and flies.
Cordia africana	An important tree in highland forest areas for bees, including honeybees, and carpenter bees.
Croton spp.	As these trees often flower synchronously they are of considerable significance seasonally. *Croton megalocarpus* can grow in many different zones—from forest to river-banks, and bush; it is visited by bees, butterflies, and flies.
Dombeya spp.	Used by honeybees, and carpenter bees. In the drylands this tree species is often found on hilltops where it visited by a wide range of insects.
Eucalyptus spp.	While these trees can be invasive and use a lot of water, in highlands where they are planted for timber, they support large numbers of honeybees. *Eucalyptus ficifolia* is one species that is especially attractive to honeybees.
Maerua spp.	These are important nectar sources for hawkmoths, and carpenter bees. Honeybees, and solitary bees also visit them for pollen.
Mangroves	Most mangroves have open generalised flowers visited by large numbers of bees. Mangroves species important for honeybees include: *Avicennia, Bruguiera, Ceriops, Heritiera,* and *Rhizophora.*

Markhamia lutea	One of Kenya's loveliest flowering trees, its yellow flowers are visited, and pollinated by a wide range of bees including carpenter bees, and larger leafcutter bees.
Melia spp.	Very attractive to bees, and butterflies, especially in the drylands.
Milletia dura	This species produces large bunches of flowers that can be swarming with bees, including carpenter bees, and leafcutter bees in large numbers.
Moringa oleifera	This useful multi-purpose tree is also great for bees, flies, and other pollinators.
Ochna spp.	Used by bees primarily, including carpenter bees, and honeybees.
Senna spp.	Important for a wide range of bees, and flies. Some specialised bees visit these flowers.
Syzygium spp.	Crucial to honeybees especially in the highlands. Also supports carpenter bees, and sunbirds.
Terminalia spp.	Supports bees, flies, and other insects in the drylands.

Trees for bats: both Nandi Flame (illustrated below), and Baobab trees are important resources for bats and other creatures.

PLANTS FOR POLLINATORS

TOP, LEFT TO RIGHT *Erythrina lysistemon*, and *E. abyssinica* (illustrated) are important for sunbirds, *Melia* attracts bees.

MIDDLE Acacias (branch illustrated)– are essential for bees, *Maesopsis*–large forest trees like this also support a lot of insects.

BOTTOM Fig trees–need fig wasps, and also support other species.

SHRUBS & CREEPERS	NOTES
Acacia brevispica *Acacia mellifera* *Acacia drepanolobium*	*Acacia mellifera* is one of the most important nectar species for honeybees, and produces a light and creamy, delicious honey. All shrubby acacias support large numbers of bees, butterflies, wasps, and flies. Their open flowers make it easy for insects to access nectar and pollen.
Abutilon spp.	These are important plants whose flowers open and close depending on the light, and warmth. Amegilla bees, and longhorn bees (*Tetraloniella* and *Tetralonia* spp.) visit these plants.
Aloe spp.	Aloes are important for sunbirds, butterflies, moths, and bees. Most aloe species have evolved to be pollinated by sunbirds, and butterflies. Many different bees collect pollen from aloes, and several species nest in the pithy old flowering stems.
Aspilia spp.	A good source of pollen for many bees, this species is attractive to both bees and butterflies.
Caesalpinia decapetala	Flowering at the edges of forest, woodland and rivers, this species is favoured by carpenter bees, and other large-bodied bees.
Calotropis spp.	Very important for a number of different bees, wasps, and butterflies, in dryland and arid areas. The pollen is formed into pollinia that attach to the legs of visiting bees, and wasps, and virtually impossible to remove once they are in place!
Dichrostachys cinerea	A shrub that is often found in overgrazed areas, it supports a wide range of solitary bees, and wasps.
Dodonaea angustifolia	This is a species that flowers seasonally, and is visited by flies, and large numbers of honeybees.
Dovyalis spp.	Commonly known as kei-apple, and used as a hedgerow species, the flowers are very attractive to both bees, and flies.
Euphorbia spp.	The succulent euphorbias are sometimes the only plant that might be flowering in arid locations, or at periods of drought. Important to a wide range of insects, a single flowering euphorbia could easily have over one hundred different insects swarming about it.

PLANTS FOR POLLINATORS

Shrubs for pollinators. TOP, LEFT TO RIGHT Dry wood, is essential as a nesting site, *Acokanthera* (illustrated) is useful for bees and hawkmoths.

MIDDLE, LEFT TO RIGHT *Clerodendrum myricoides* and acacia pod illustrated. *Clerodendrum myricoides* attracts large bees and butterflies.

Acacias and euphorbias are important in drylands for large animals as well as for insect pollinators.

Thriving area of natural habitat in Laikipia, Kenya.

Grewia spp.	One of the most important bee plants. It is visited by carpenter bees, and a large number of other solitary bee species.
Hibiscus spp.	Visited by a wide range of bees, especially in dryland and arid areas.
Ipomoea spp.	These mass-flowering creepers can paint the entire landscape in colour. Many different bees visit the flowers including some like *Systropha* spp. that are specialised on collecting *Ipomoea* pollen almost exclusively.
Lantana spp.	While *Lantana camara* is a serious invasive that should not be planted, indigenous *Lantana trifolia* is especially attractive to butterflies, and bees.
Rhus spp.	Shrubs that are visited by bees, and flies.
Rubus spp.	Visited and pollinated by honeybees, hoverflies, and some solitary bees.
Scutia myrtina	When in flower they are very attractive to a number of bees, and large numbers of wasps, and flies.
Sesbania spp.	These legumes are attractive to carpenter bees, and other solitary bees. They can be cultivated at farm edges to encourage pollinators to visit.
Ziziphus spp.	Seasonally flowering, they are visited by large numbers of flies, and a few bees.

Desert rose growing in Morogoro, Tanzania.

Shrubs and creepers.
TOP, LEFT TO RIGHT *Acacia brevispica*, *Mucuna* sp., *Ipomoea* sp.

MIDDLE, LEFT TO RIGHT *Acanthus* sp. and *Calotropis procera* a milkweed that attracts bees and butterflies.

BOTTOM, LEFT TO RIGHT Wild hibiscus sp., *Triumfetta* sp. (image cutout).

Wildflowers for bees and other pollinators:

WILDFLOWERS	NOTES
Clematis spp.	Found in woodland, and highland forest edges. *Clematis* are important for bees, including honeybees.
Cleome spp.	Seasonally important for many different kinds of bees, butterflies, and hawkmoths.
Gynandropsis gynandra	An important resource in grassland, bush, and savannah for honeybees, solitary bees, hawkmoths, and butterflies.
Kalanchoe spp.	One of the most attractive and important nectar sources for butterflies and moths.
Kleinia spp.	An important resource for butterflies in the drylands, grasslands, and savannah.
Cyathula spp.	Important for bees, butterflies, and flies seasonally.
Tribulus spp.	Even though the spiky seeds of this weed can annoyingly get stuck in boots and tyres, it is an important resource for many different kinds of bees in arid areas.
Impatiens spp.	Plant species important for bees, butterflies (especially skipper butterflies), and hawkmoths.
Commicarpus spp.	Weedy herbs that attract a lot of different bees.
Mormodica spp.	An important genus of plants for some beautiful and rare and specialised bees (*Ctenoplectra* spp.) that collect oils from the flowers.
Tephrosia spp.	A legume that attracts many different kinds of bees including *Pseudapis* spp., and leafcutter bees.
Indigofera spp.	Perhaps one of the most crucial plants for bees in the arid and seasonal habitats of eastern Africa. Many different kinds of bees visit *Indigofera* spp. for both nectar and pollen.

Wildflowers.
TOP, LEFT TO RIGHT *Leucas* sp., wild daisy family sp.

MIDDLE, LEFT TO RIGHT *Delphinium* sp., *Commelina* sp.

BOTTOM, LEFT TO RIGHT *Gloriosa superba*–a good plant for butterflies, *Justicia* sp. one of the most useful plants for bees.

Vigna spp.	As with most of the legumes, this group of plants are pollinated by bees, and are especially attractive to large carpenter bees, and leafcutter bees. Other important legumes: *Dolichos* spp., *Lablab purpurea, Eriosema* spp., *Lupinus* spp. in the highlands, and *Trifolium.*
Crotolaria spp.	This genus is primarily pollinated by bees, and is essential for them. As with all legumes, the flowers need to be 'tripped', and many different kinds of bees have learned to do this.
Cyphostemma & Cissus	Both of these plants are creepers that are visited by bees, flies, wasps, and butterflies. The related *Rhoicissus tridentata* is also popular with insect pollinators.
Gomphocarpus spp.	Bees, wasps, and butterflies visit these milkweed species. They are important food-plants for butterflies especially the lovely African Monarchs (*Danaus* spp.).
Pentas & Pentanisia	Vital for butterflies and hawkmoths. It appears that it is mostly these insects that pollinate them.
Vernonia spp.	One of the most significant wildflowers for pollinators in general. Many different bees, butterflies, and other insects visit the open accessible flowers of *Vernonia*. Some related species: *Gutenbergia*, *Anisopappus, Sphaeranthus, Helichrysum, Conyza, Emilia,* and *Senecio.*
Bidens spp.	These common weedy plants are important for solitary bees (especially halictid bees) that can almost always be found visiting the flowers.
Heliotropium spp.	These lovely flowers are visited by large numbers of insects including bees, wasps, flies, and butterflies for both nectar and pollen.
Solanum spp.	These plants are often considered weedy, but are visited by many bees that are able to 'buzz' the flowers so as to release pollen. This is a specialised pollination system, and the bees that visit wild *Solanum* species also pollinate eggplants, tomato (which are related), passionfruit, and legume crops.

Wildflowers.
TOP, LEFT TO RIGHT *Cleome parvipetala*, attracts bees, hawkmoths and butterflies, *Solanum* sp. are great for bees.

MIDDLE, LEFT TO RIGHT *Ocimum* and *Bidens*, are two of the most useful 'bee-plants'.

BOTTOM, LEFT TO RIGHT *Crotolaria* sp. are visited by large bees, and aloes by sunbirds, bees and butterflies.

Thunbergia spp.	Visited by bees, including *Macrogalea* bees that are important pollinators of crops.
Blepharis spp.	Important for many different kinds of solitary bees especially in arid and dryland areas.
Barleria spp.	This is an important group of wildflowers for both bees and butterflies. They tend to flower sparsely for longer periods, and are thereby a chief resource when other plants may not be flowering.
Justicia spp.	An exceptional wildflower resource for bees found at forest edges, grassland, savannah, and in agricultural areas. Planting *Justicia* in wildflower strips will draw in bees, and support honeybees for honey production. Related species visited by bees include *Hypoestes* and *Leucas.*
Ocimum spp.	These herbs are one of the most important 'bee plants', supporting and attracting all kinds of bees and other insects. *Ocimum* can be readily established from seed, and will naturally re-seed areas once in place. It is a good plant for honeybees, and the resulting honey has a distinctive herbal flavour.
Plectranthus spp.	These wildflowers are really important for all kinds of bees. They are free flowering once established, and can be grown from cuttings. The related *Orthosiphon* spp. is also an important floral resource.
Commelina spp.	Carpenter bees, honeybees, and other bees visit these attractive flowers. These wildflowers are a complex creation that both attract bees for pollen, and fools them with false pollen lures. Related plant species: *Aneilema, Cyanotis,* and *Murdannia*.
Bulbine spp. and *Chlorophytum* spp.	Visited by bees, and flies, these plants often appear early at the start of the rains, and are an important resource at that time.

Wildflowers.
TOP, LEFT TO RIGHT Tiny lily growing in grassland, *Justicia* sp.

MIDDLE, LEFT TO RIGHT *Plectranthus* sp., *Gutenbergia* sp.

BOTTOM, LEFT TO RIGHT *Leonotis* sp., and *Justicia flava*–an important plant for bees and butterflies.

Grasses & Sedges

A number of bees (especially *Lipotriches* spp.), and a few flies, collect pollen from grasses and sedges. These plants are wind pollinated so they don't need pollinators. However, the pollen from grass and sedge is an important resource for bees. Honeybees will often take pollen from grasses (including *Cynodon* and *Cenchrus),* as well as from cultivated maize and sorghum.

Grasses are important pollen sources for bees, but they do not depend on pollinators.

BELOW Grasslands in forest provide open habitats that are magnets for pollinators, especially bees and butterflies.

Grasses and grasslands. TOP, LEFT TO RIGHT *Lipotriches* bee gathering pollen from Buffel grass, grassland in Turkana–areas like this provide nesting habitat for bees.

MIDDLE Star grass loaded with pollen–this is what bees are after from grasses.

BELOW Open grasslands like the northern Serengeti are seasonally filled with bees and other insects.

Help pollinators by conserving and creating natural habitat

Diverse landscapes provide adequate resources for pollinators.

The *Flora of Tropical East Africa* provides descriptions of over 12,000 wild plant species. Two-thirds of the flowering plants are dependent on wild pollinators, and many of these plants have co-evolved, over millions of years, with the wild pollinators that pollinate them.

Most pollinators are wild insects. For plants and wild insects to thrive, natural habitat areas are critical, and perhaps the single most important prerequisite.

Natural habitat areas near or within farms provide two essential things to support pollinators: **sources of food** (nectar, pollen, and host plants) for pollinators and their larvae, and equally important, secure **nesting sites**.

Farmers, and gardeners can encourage wild insects, and other pollinators by maintaining, and creating spaces of natural habitat. Natural habitat can include:

- a forest edge area rich with wildflowers
- roadside verges, which are not consistently shorn
- a hedgerow composed of different flowering plants
- wildflowers conserved, or planted within a field.

It is insects of five different Orders that provide us with pollination services for our crops: the Hymenoptera (Ants, Bees and Wasps), Diptera (True Flies), Lepidoptera (Butterflies and Moths), Coleoptera (Beetles), and Thysanoptera (Thrips). A few bats, and birds

Natural habitats. TOP Clearing natural vegetation on steep slopes for farming, as is happening here in Tanzania's Uluguru Mountains, destroys vital wild plants and nesting sites for pollinators as well as causing soil erosion.

MIDDLE, LEFT TO RIGHT Agapanthus around a tea plantation in the Nandi Hills, Western Kenya–flowers on the verges of crop fields can help support pollinators, and a verge of natural grasses and flowers by a maize field in Tabora, Central Tanzania.

BOTTOM Wildflowers and patches of natural habitat along fences are essential habitats for pollinators, as demonstrated here on a passionfruit farm in the Kerio Valley, Kenya. Bees visit the crop when in flower, but also depend on the surrounding wildflowers for survival.

ABOVE Honeybee approaches a sunflower. Pollen is an essential resource for bees to feed their larvae and produce new generations of pollinators.

BELOW *Ocimum*, also known as 'bee-balm' is one of East Africa's most useful plants as it is very attractive to bees.

also provide pollination services for a smaller number of plants. Bees, both solitary and social species, pollinate the majority of our crop and fodder, being entirely dependent on pollen and nectar from flowers for their survival.

Some bees, like honeybees and stingless bees convert nectar into stores of honey. Most bees, especially the solitary bees, collect pollen, and store this as food for their larvae. Many bees only forage a short distance from where they build their nests, so endeavour to have a diversity of wildflowers close to their nesting sites.

The more diversity of plants that are present and flowering across seasons, the better the conditions for bees. The type of plants in an area will depend on the habitat. In seasonal areas (which is most of Kenya) both annual, and perennial plants are important. Wildflowers that grow at the edges of forests or woodland areas tend to flower for longer periods of time.

Ocimum, Justicia, Leucas, Bidens, Indigofera, Crotolaria, Cleome, Commicarpus, Barleria, Aspilia, Crassocephalum, Emilia, Gutenbergia, and *Vernonia* are some of the wildflowers that are particularly attractive to bees.

The following section outlines some of the threats to pollinators, and what can be done to reduce them. ■

TOP Verges of wildflowers support pollinators. They also provide other ecosystem services such as fodder for grazing, aesthetic spaces, erosion control, and enhanced soil fertility.

These are useful even in areas where crops don't require pollinators, as is the case here on a tobacco farm in Tanzania.

LEFT AND BELOW Mud, grass, and wooden structures on farms can serve as important nesting sites for cavity-nesting bees.

Here is a farm storage building with a special grass hut constructed beside it to draw away 'spirits' from the harvest in Tabora, Tanzania. These traditional buildings are great nesting sites for bees and wasps.

A summary of threats and resource needs of wild pollinators

Ants

Resource Needs
Across Africa many will be familiar with ant-hills—they are one type of ant nest. Ants require areas of ground, decaying wood, and the canopy of trees for nesting.

To successfully establish an ant colony, they will also need an adequate prey food base.

Flies

Resource Needs
Flies will breed in a variety of places—in manure, rotting food, in rubbish for example.

They also require to be near water, and to be protected from pesticide exposure.

Thrips

Resource Needs
Thrips require alternative host-plants to survive when crops are not in cultivation.

They also need to be protected from pesticide exposure.

Butterflies

Habitat destruction due to activities like charcoal production presents the greatest threat to butterflies. Loss of host-plants, and larval host-plants prevent butterflies from

Charcoal pit in an area of *Acacia tortilis* in Turkana, northern Kenya.

Charcoal production is a serious threat to pollinators as removing large trees, like these acacia, destroys the nectar and pollen resources, and nesting sites for thousands of individual pollinating insects.

finding sufficient food, and places to reproduce.

Pesticide exposure also harms butterflies.

Resource Needs
Butterflies need access to wild nectar resources, and protection from pesticides.

Wasps

Resource Needs
Fig wasps can only breed in figs. To sustain fig wasps wild *Ficus* populations need to be conserved.

Wasps will prey on mosquitos, caterpillars, spiders, flies, or even beetle larvae, so a healthy environment is needed to have sufficient food for wasps.

Beetles

Resource Needs
Generally beetles need habitats with adequate host plants to thrive.

Bats

Bats are adversely affected by habitat destruction around them, loss of habitat along migratory routes, and when their roost sites are deliberately destroyed. In some parts of the world bats are hunted for food.

Resource Needs
Bats require: adequate food resources year-round, protection of communal roost sites, protection from hunting, available habitat for dispersal, and migration.

Birds

There are numerous activities that threaten birds, including human disturbance of nesting, and roosting sites, exposure to pesticides and other toxins, habitat changes and degration, hunting, and loss of stopover sites needed on migration.

Resource Needs
Birds require healthy habitats to survive. Their nesting and breeding sites should not be disturbed, and they need protection from the misuse of pesticides, and unsustainable hunting practices.

ABOVE Severe soil erosion, in the Kerio Valley, Kenya.

LEFT Overgrazing by livestock, Turkana, northern Kenya.

Soil erosion and overgrazing affects pollinators by reducing the availability of safe long-term nesting sites. Removing wildflowers and the herbaceous ground-cover drastically reduces the number and diversity of bees, butterflies and other insects that can survive in an area.

CURRENT THREATS	Honeybees	Stingless bees	Carpenter bees	Leafcutter bees	Solitary halictid bees
Habitat destruction	✔	✔	✔	✔	✔
Loss of wildflowers	✔	✔	✔	✔	✔
Destructive harvesting of wild colonies	✔	✔			
Diseases and parasites	✔				
Loss of sites for nesting, and foraging (due to activities like charcoal production)	✔	✔	✔	✔	✔
Exposure to pesticides	✔	✔	✔	✔	✔
Killing of bees mistaken as pests			✔		

Wild bees

Current Threats Listed in the table above: *(boxes are ticked indicating a particular threat to a wild bee group)*

Resource Needs
All wild bees species will require:

- Plants and flowers throughout the year for nectar and pollen
- Protection from destructive harvesting practices
- Migratory corridors of plants and flowers for species and varieties that migrate seasonally.

Carpenter bees also require tree branches, or old wood to use as nesting sites.

Leafcutter bees also require leaves from the right kinds of plants, which they will use in their burrows for nesting.

Halictid bees requirements for nectar and pollen peak when nesting as they provide each larva all of its food at one time. ■

Small patches of habitat help pollinators.

Even a few wildflowers growing along a fence line can provide resources for many different kinds of pollinators, and ultimately support better yields in crops.

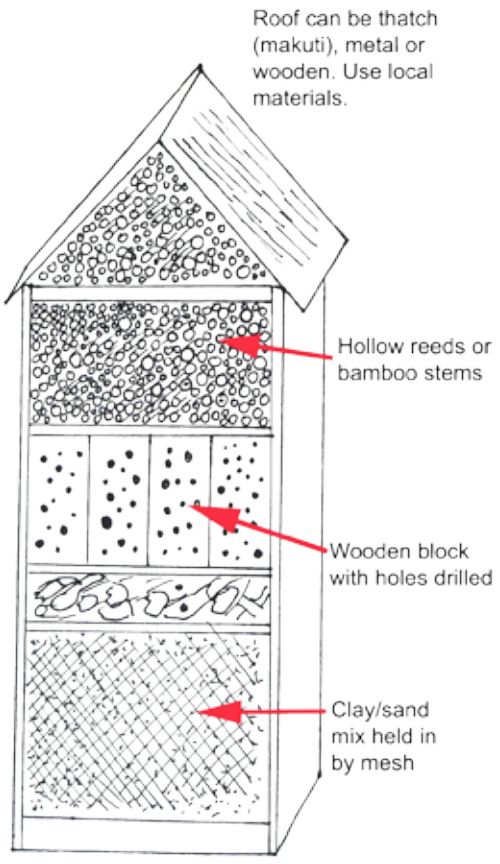
Bee Hotels

A 'bee hotel' may sound like a strange idea, but it is simply a nest for bees of different species. It offers a practical way of attracting pollinators to your farm, or garden. The bee hotel could consist of just a tube filled with hollow reeds, or be more complex.

Hollow reeds are very appealing to leafcutter bees, and other solitary bees. Larger hollow reeds, and dry wood will attract carpenter bees that are likely to use the nest from year to year.

Packed earth will draw a wide range of ground nesting bees.

Set your bee hotel at the edge of the farm, within strips of wildflowers, or even in erosion control areas where you have cultivated. Beans, cowpeas, pigeon peas, traditional vegetables, passionfruit, coffee, aubergines, tomatoes, watermelons, and pumpkins—are some of the crops that will benefit from the construction of your bee hotel. ■



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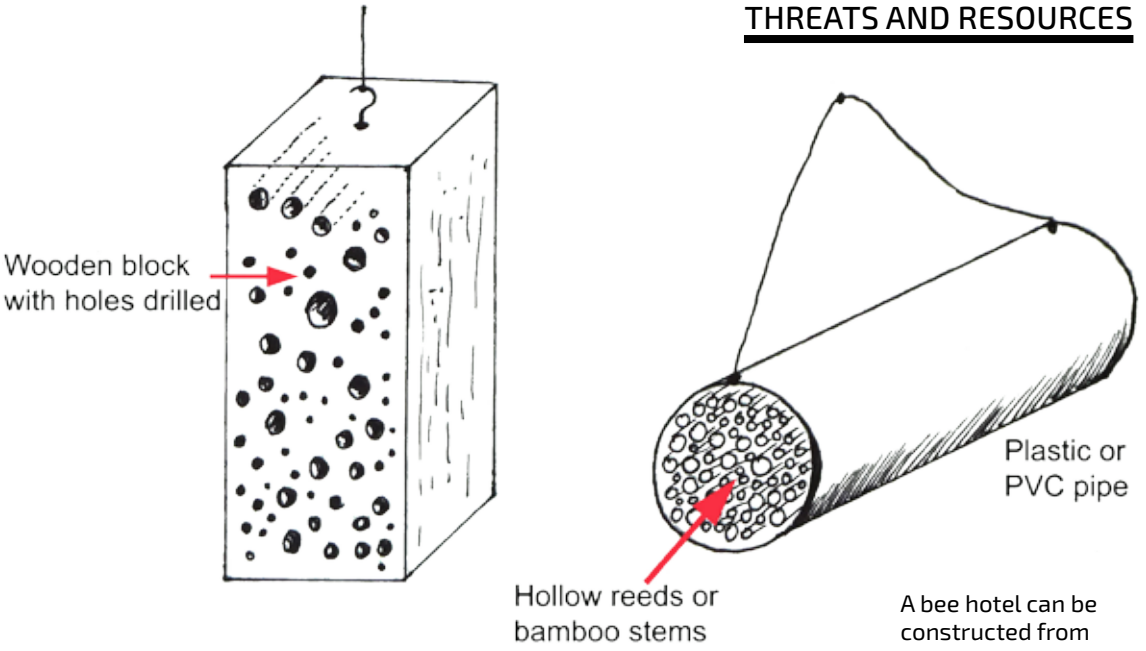


A bee hotel can be constructed from simple materials, and create nesting habitat for bees.

Pollinators and Pesticides

Pesticides kill pollinators. It is important to use agricultural chemicals safely and wisely so as not to affect the health of both people and pollinators.

Pesticides present us with a challenge. Most wild pollinators are insects, and pesticides are substances designed to kill or control insects. Pest control is important in small-scale, and commercial farming systems, yet insects are critical pollinators of our crops.

The application of pesticides must take into account potential negative effects on biodiversity, and especially avoid contact between pesticides, and insect pollinators.

This first question to ask is:

Does my crop or plants require pollinators?

If the answer is yes, then there are steps that farmers and gardeners can take to minimize exposure of pollinators to pesticides:

- It is essential to read the label and follow instructions carefully.
- Find out what is the pesticide toxicity is to bees.
- Use the product in accordance with the label instructions—overuse, misuse, and poor disposal of pesticides pose

threats to bees, and to human health.
- Identify the pollinators that visit your crops!
- DO NOT spray when the crop is in flower!
- DO NOT spray when insects are visiting the flowers!
- Avoid spraying crop field verges, compacted earth sites, sheltered banks!
- Know the location of colonies, and aggregated pollinator nest sites, and have a plan for protecting them!
- Carefully study pollinator activity throughout the day, from dawn to dusk, to help develop spraying regimes that avoid main foraging periods of wild insect pollinators.
- Take into consideration potential exposure of pollinators through pesticide residues on foliage, and in the soil.

Consider reducing your reliance on pesticides, and incorporate other pollinator-friendly methods—often referred to as Integrated Pest Management (IPM).

In IPM you use knowledge about the pest habits and activities, and an understanding of your farm or garden environment, to enable biological pest control. ■

Disposal of pesticides/ chemicals.
BELOW LEFT
Poor disposal of pesticides and other chemicals can contaminate soils and affect ground nesting bees.

BELOW RIGHT
Even proper disposal methods as employed here at a French bean farm in Kenya, may still lead to soil contamination.

There is need for more research and support for farmers for proper disposal of containers and unused chemicals.

Monocultures produce a lot of food, but also use a lot of pesticides. It is important to manage these carefully to reduce drift into surrounding areas where they can affect pollinators.

A carpenter bee (*Xylocopa inconstans*) on the flowers of pigeonpea in southern Tanzania.

Many crops depend on wild insect pollinators.

Crops dependent on pollinators grown in East Africa

This is a general list of crops grown in the region that are dependent on pollinators. For most of these crops, we have not had the benefit of extensive studies, and much remains to be learnt about their interactions with pollinators.

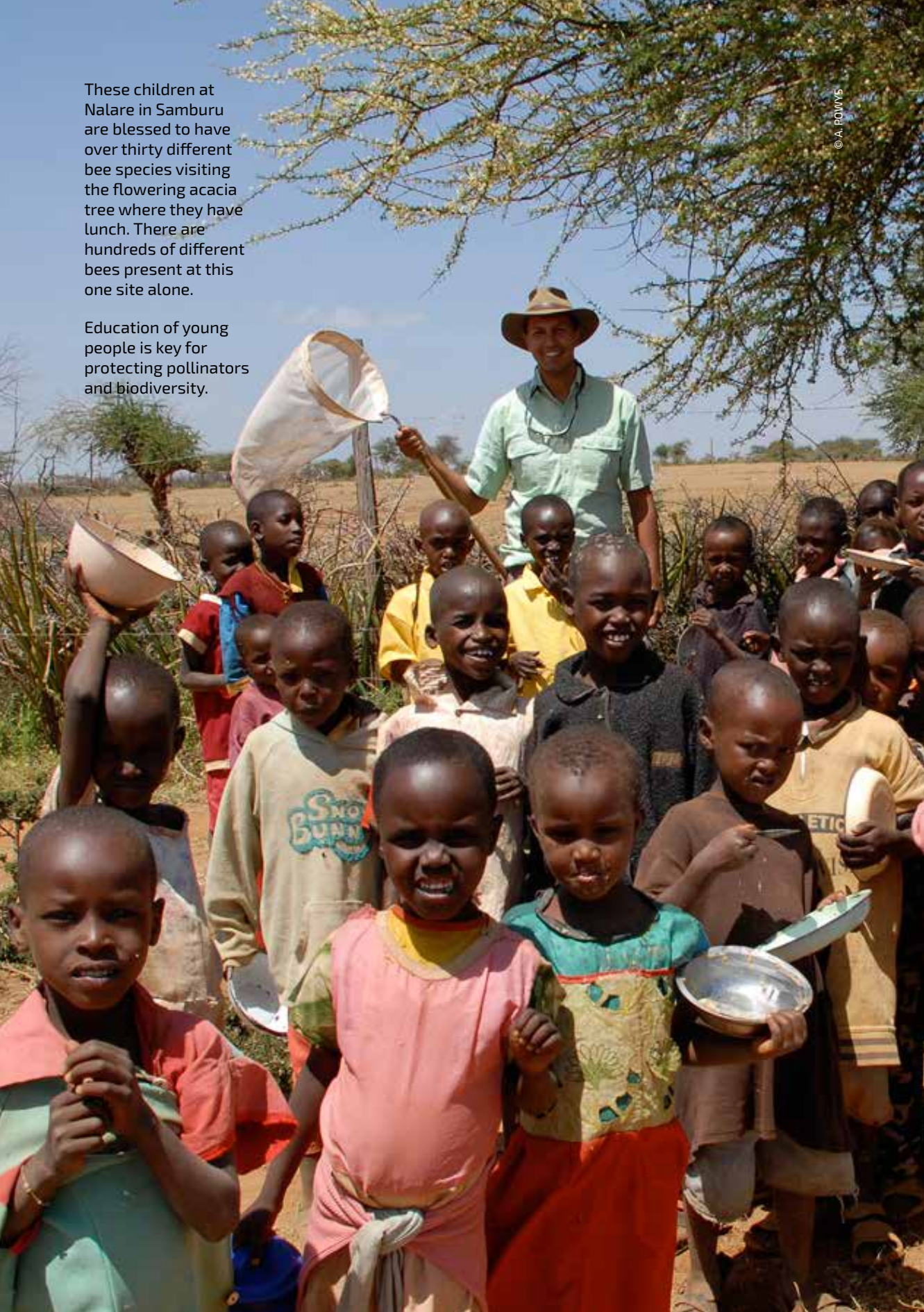
Some crops are 100% dependent on pollinators, without whose pollination services there are simply no yields, as with watermelon, and passionfruit. In other cases as with coffee, and runner beans, pollinators contribute to the volume and improved quality of yields.

For many crops where we consume the vegetative leaves or roots (such as kales, terere, carrots), we still require pollinators for the production of seed. ■

Common name	**Latin name**	**Pollinator**
Alfalfa	*Medicago sativa*	Leafcutter bees, halictid bees, honeybees
Apple	*Malus domestica*	Honeybees, solitary bees, hover flies
Avocado	*Persea americana*	Honeybees, stingless bees, solitary bees, flies, wasps
Beet	*Beta vulgaris*	Honeybees, hover flies, solitary bees
Blackbean (Njahe)	*Lablab niger*	Carpenter bees, leafcutter bees
Broad bean	*Vicia faba*	Honeybees, carpenter bees, solitary bees
Broccoli	*Brassica oleracea*	Honeybees, solitary bees
Brussels sprouts	*Brassica oleracea*	Honeybees, solitary bees
Cabbage	*Brassica oleracea*	Honeybees, solitary bees
Prickly pear	*Opuntia* spp.	Carpenter bees, solitary bees, honeybees
Cantaloupe (Melon)	*Cucumis melo*	Honeybees, carpenter bees, solitary bees
Caraway	*Carum carvi*	Honeybees, solitary bees, flies
Cardamom	*Elettaria cardamomum*	Honeybees, solitary bees
Carrot	*Daucus carota*	Flies, solitary bees, honeybees
Cashew	*Anacardium occidentale*	Honeybees, stingless bees, carpenter bees, solitary bees
Cauliflower	*Brassica oleracea*	Honeybees, solitary bees
Celery	*Apium graveolens*	Honeybees, solitary bees, flies
Chilli pepper, Green pepper	*Capsicum annuum, Capsicum frutescens*	Honeybees, stingless bees, carpenter bees, leafcutter bees, hover flies

Chinese cabbage	*Brassica rapa*	Honeybees, solitary bees
Clover	*Trifolium* spp.	Honeybees, carpenter bees, solitary bees
Cocoa	*Theobroma cacao*	Midges
Coconut	*Cocos nucifera*	Honeybees, stingless bees
Coffee	*Coffea* spp.	Honeybees, stingless bees, solitary bees
Coriander	*Coriandrum sativum*	Honeybees, solitary bees
Cotton	*Gossypium* spp.	Honeybees, carpenter bees, solitary bees
Cowpea (Black-eyed pea)	*Vigna unguiculata*	Honeybees, carpenter bees, solitary bees
Cucumber	*Cucumis sativus*	Honeybees, carpenter bees, solitary bees
Eggplant	*Solanum melongena*	Carpenter bees, solitary bees – especially halictid bees
Fennel	*Foeniculum vulgare*	Honeybees, solitary bees, flies
Fig	*Ficus* spp.	Fig wasps
Guava	*Psidium guajava*	Honeybees, stingless bees, carpenter bees, solitary bees
Lemon, Lime	*Citrus* sp.	Honeybees
Kidney bean, Green bean	*Phaseolus* spp.	Honeybees, solitary bees
Loquat	*Eriobotrya japonica*	Honeybees, carpenter bees
Lupine	*Lupinus angustifolius*	Honeybees, carpenter bees, solitary bees
Lychee	*Litchi chinensis*	Honeybees, flies
Macadamia	*Macadamia ternifolia*	Honeybees, stingless bees, solitary bees, wasps, butterflies
Mango	*Mangifera indica*	Honeybees, stingless bees, flies, ants, wasps
Mitoo (Crotolaria)	*Crotolaria brevidens*	Leafcutter bees, carpenter bees
Mustard	*Brassica alba, Brassica hirta, Brassica nigra*	Honeybees, solitary bees
Oil palm	*Elaeis guineensis*	Weevils, thrips
Okra	*Abelmoschus esculentus*	Honeybees, solitary bees
Onion	*Allium cepa*	Honeybees, solitary bees
Papaya	*Carica papaya*	Large hawkmoths, butterflies
Passionfruit	*Passiflora edulis*	Carpenter bees, solitary bees, honeybees
Peach	*Prunus persica*	Honeybees, carpenter bees, solitary bees, flies

Pear	*Pyrus communis*	Honeybees, carpenter bees, solitary bees, hover flies
Pigeon pea	*Cajanus cajan*	Honeybees, solitary bees, leafcutter bees, carpenter bees
Plum	*Prunus domestica, Prunus spinosa*	Honeybees, carpenter bees, solitary bees, flies
Pomegranate	*Punica granatum*	Honeybees, solitary bees, beetles
Rapeseed	*Brassica napus*	Honeybees, solitary bees
Raspberry	*Rubus idaeus*	Honeybees, carpenter bees, solitary bees, hover flies
Runner bean	*Phaseolus coccineus*	Carpenter bees, honeybees, solitary bees, thrips
Sesame	*Sesamum indicum*	Honeybees, solitary bees, wasps, flies
Spiderplant (Mchicha)	*Gynandropsis gynandra*	Honeybees, amegilla bees, hawkmoths
Squash, Pumpkin, Gourd, Marrow, Zucchini	*Cucurbita* spp.	Honeybees, squash bees, carpenter bees, solitary bees
Strawberry	*Fragaria* spp.	Honeybees, stingless bees, carpenter bees, solitary bees, hover flies
Sunflower	*Helianthus annuus*	Honeybees, carpenter bees, solitary bees
Tamarind	*Tamarindus indica*	Honeybees
Tangerine	*Citrus tangerina*	Honeybees, carpenter bees
Tomato	*Solanum lycopersicum*	Carpenter bees, solitary bees
Turnip (Canola)	*Brassica rapa*	Honeybees, solitary bees, flies
Vanilla	*Vanilla planifolia*	Solitary bees, stingless bees
Vetch	*Vicia* spp.	Honeybees, carpenter bees, solitary bees
Watermelon	*Citrullus lanatus*	Honeybees, carpenter bees, solitary bees



These children at Nalare in Samburu are blessed to have over thirty different bee species visiting the flowering acacia tree where they have lunch. There are hundreds of different bees present at this one site alone.

Education of young people is key for protecting pollinators and biodiversity.

'Connecting nature and people'

About the East Africa Natural History Society, popularly known as 'Nature Kenya'

The East Africa Natural History Society is a national organization that in 2009 celebrated it's 100 anniversary. The Society has had exceptional achievements in the study of natural history, and nature conservation. It is supported by volunteers, naturalists, scientists, and grassroot community members.

The Insect Committee works to promote the conservation and understanding of insects. Its pollination projects aim to:

- Study, document, and describe bees and other pollinators from across East Africa.
- Raise public awareness about insects and pollination.
- Plant and promote pollinator gardens at community and public sites.
- Produce leaflets, booklets, and make accessible to farmers and schools, information on insects and their importance.
- Undertake research on the impact of different farming practices on biodiversity.
- Document the benefits of pollinators to rural subsistence farmers.
- Show the links between the productivity of farms, and wild pollinator species.
- Improve food security, and reduce rural poverty through better management of shared natural resources, such as pollinators.
- Work with schools immediately adjacent to the most biodiversity-rich areas in the region.
- Run education activities like insect walks, with follow-up activities for students to try.
- Have students and teachers plant pollinator gardens in their schools. ■

Some of the work of the Society is carried out by its committees and projects, including the Insect Committee, which was formed in 2001.

We need your help –what can you do?

There are many different ways you can help save wild pollinators. From making a donation, and joining Nature Kenya, to participating in activities like monitoring surveys.

For more information contact us by email:
insects@naturekenya.org or
insects.eanhs@gmail.com

Visit our blogs: dududiaries.wildlifedirect.org/ and bit.ly/1bX3kAe

Visit our websites:
discoverpollinators.org and
naturekenya.org

or write to us at:

Insect Committee of
Nature Kenya
The East Africa
Natural History Society
P. O. Box 44486 GPO
00100 Nairobi
Kenya

About the author

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Dr. Dino J. Martins studies ants, bees, and other insects, and their interactions with plants. He holds a research fellowship with the Turkana Basin Institute-Stony Brook University (USA), and lives and teaches in his home country, Kenya. Dino is a scientist, naturalist, artist, prolific writer, and shares his love for insects on his blogs, in numerous articles, and in the talks he gives, and dudu* walks he leads.

He currently teaches for the Turkana Basin Field School, and is a Research Associate of the Museum of Comparative Zoology at Harvard, the National Museums of Kenya, and the Smithsonian Institution.

Dino's research has been in East Africa where he has studied bee evolution and ecology, hawkmoth and butterfly pollination, co-evolution, the biology of vectors, and the links between biodiversity and landscape-level processes.

He is currently looking at what drives cooperation between flowers and their pollinators, as well as between ants and plants. He works with farmers to improve awareness and conservation of bees, and other pollinators, and tries to help mitigate the threat of pesticides.

Dino's work has been recognised with many awards including the Whitley Award for Conservation (2009). More recently he was selected as one of National Geographic's 'Emerging Explorers' (2011), elected a Fellow of the Linnean Society (2013), and an Honorary Member of the Kenya Horticultural Society (2014).

Dino earned his PhD in Organismic and Evolutionary Biology at Harvard University in 2011. ■

**dudu is the word for insect in Kiswahili*

OUR FRIENDS the Pollinators

A Handbook of Pollinator Diversity and Conservation in East Africa

Dino J Martins

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