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Review article

Bee conservation in Sub-Saharan Africa and Madagascar: diversity, status and threats*

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Abstract – Sub-Saharan Africa and Madagascar contain a wealth of bee diversity, with particularly high levels of endemicity in Madagascar. Although Africa contains seven biodiversity hotspots, the bee fauna appears rather moderate given the size of the continent. This could be due to various factors, an important one being the dearth of bee taxonomists working in Africa and difficulties in carrying out research in many regions. Anecdotal observations suggest a very large number of undescribed bee species. A number of serious threats to this diversity exist, especially habitat destruction and degradation. Bee diversity in these regions is likely to be important for both agriculture and indigenous ecosystems, but is under-appreciated. Reliance on conserved areas such as National Parks will not be sufficient to preserve bee diversity in Africa and Madagascar; changes to land use practices and development of industries that facilitate conservation, such as ecotourism, will be essential. There is also a strong need to build regional expertise and infrastructure that can be used for documenting bee diversity, identifying the most urgent conservation issues, and implementing conservation strategies. Support from developed countries and international funding agencies is needed for this.

bees / conservation / biodiversity / Africa / Madagascar / Apoidea

1. INTRODUCTION

Trying to understand the issues surrounding bee conservation in sub-Saharan Africa and Madagascar is complex. It requires consideration of both the history of bee research in these regions, as well as the prevailing socio-economic and cultural circumstances. These are vastly different from North America and Europe, and the strategies that are needed to conserve bee diversity are similarly very different (cf. Byrne and Fitzpatrick, 2009).

African and Malagasy people appreciate the aspects of biodiversity that tangibly affect their daily lives. These include beneficial species, such as those used for medicine, food, building materials, the beetle larvae that San people used for poison arrows (Koch, 1958; Shaw et al., 1963) and harmful species like agricultural pests. They have names for all of these species. Food and medicinal uses for honey from stingless bees are known (Macharia, unpubl. data), but today these are better known to rural communities than urban people.

While honey bees and sometimes stingless bees are widely regarded for their pollination services, the benefits from other bees are largely overlooked by farmers – to what extent they were recognised in the past is not known. Increased crop production has been mainly based on the use of agronomic inputs, such as quality seeds, fertilizers and pesticides, with little regard to non-*Apis* pollination as an agricultural eco-service that may require protection.

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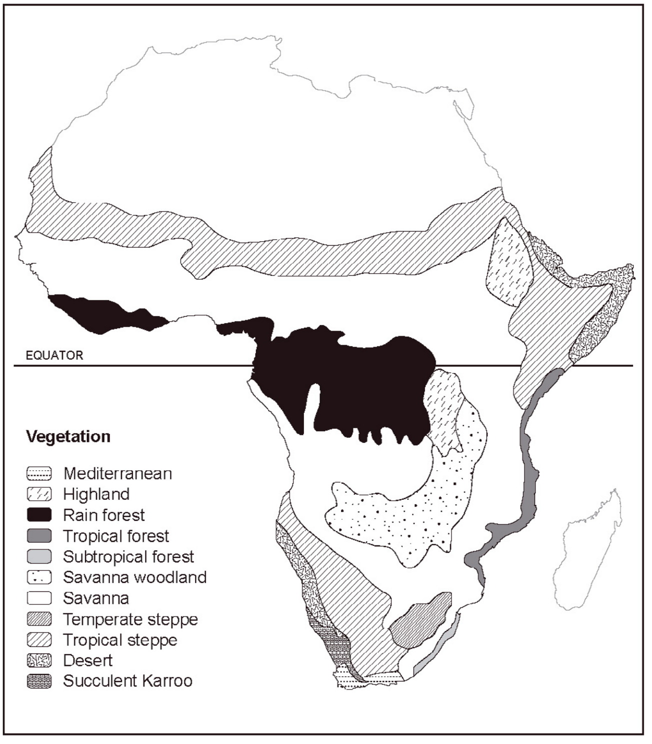

Figure 1. Map of Sub-Saharan Africa showing broad distribution of vegetation types. Adapted from the NASA Scientific Visualization Studio maps (http://svs.gsfc.nasa.gov/vis/) and the University of Chicago Fathom Archive African map series (http://fathom.lib.uchicago.edu/).

Bee research in sub-Saharan Africa has included extensive research on the honey bee, *Apis mellifera* L., especially in South Africa (Hepburn and Guye, 1993; Johannsmeier, 2001), limited work on stingless bees, haphazard descriptions of new species, revisional taxonomic studies for two-thirds of the known genera, a host of distributional records, and a relatively small number of studies on ecology and social biology. Eardley and Urban (in preparation) provide complete references to the non-*Apis* studies in a species catalogue. Research on Malagasy bees has been similar, except that all previous studies have been brought together with a full revision of the bee fauna by Pauly et al. (2001).

Prospects for bee research in sub-Saharan Africa are improving, and there is a growing awareness of the need to conserve pollinator diversity. This is largely driven by an interest in agricultural pollination management. However, the potential importance of all bees, as part of an ecosystem approach to conservation, is recognized in a number of projects. One such project is BIOTA East Africa, which deals with the protection of Kakamega Forest in Kenya.

Although Africa and Madagascar are geographical neighbours, they are in many respects very different. They are therefore mostly treated separately in the discussions that follow.

2. BEE DIVERSITY

2.1. Sub-Saharan Africa

Sub-Saharan Africa is an enormous and diverse continent with a host of different ecosystems, from rain forest to desert. A broad vegetation map for regions south of the Sahara is given in Figure 1. A large proportion of the continent is savannah, with many different bee pollinated plants, and with biotypes ranging from dry to relatively wet. The continent has seven biodiversity hotspots, as identified by Conservation International (CI). (http://www.biodiversityhotspots.org), making it second to Asia and the Pacific Islands in biologically rich areas. The highest temperate plant biodiversity in the world occurs in the winter rainfall areas in the south-western region of Africa (Koekemoor, unpubl. data). All this should suggest a rich bee fauna.

The described bee fauna in sub-Saharan Africa can, however, at best be described as moderately diverse. Six of the seven bee families recognized by Michener (2007) occur in Sub-Saharan Africa, with the Stenotritidae being confined to Australia. About 21% of the World's bee genera occur in Sub-Saharan Africa (102 from a total of about 476; Michener, 2007), and about half of these are either cosmopolitan or Old World endemics. At a generic level, this suggests reasonably high diversity. However, at a species level diversity is less rich. The 2600 described Sub-Saharan species comprise only about 13% of the global fauna of around 19400 species (http://www.itis.gov./ and Eardley, unpubl. data). Some highly speciose genera, like *Perdita* and *Centris*, do not occur in Africa, whilst *Andrena*, which is diverse in the Holarctic (about 1500 species), has only nine African species. The most speciose genera in Africa are *Lasioglossum* (about 260 species, no revision available) and *Megachile* (about 322 species, Pasteels, 1965), and these are fairly small proportions of their global species numbers.

It is possible that low species diversity in Africa is more apparent than real. Schwarz and Bull (unpublished) found that in extensive nest collections of allodapines in South Africa, about one third of species encountered did not fit current species descriptions, and less-intensive allodapine collections from Uganda indicate a great many undescribed species and possibly new genera (McLeish and Schwarz, unpubl. data). For allodapines at least, this suggests a wealth of unrecorded diversity, despite the Herculean efforts of Michener (1975) in revising the African allodapines. The problem appears to be one of a mismatch between the sheer size of sub-Saharan Africa and the number of African bee taxonomists. Even with the involvement of taxonomists from other regions, political and infrastructural circumstances make biodiversity research very difficult in many important regions.

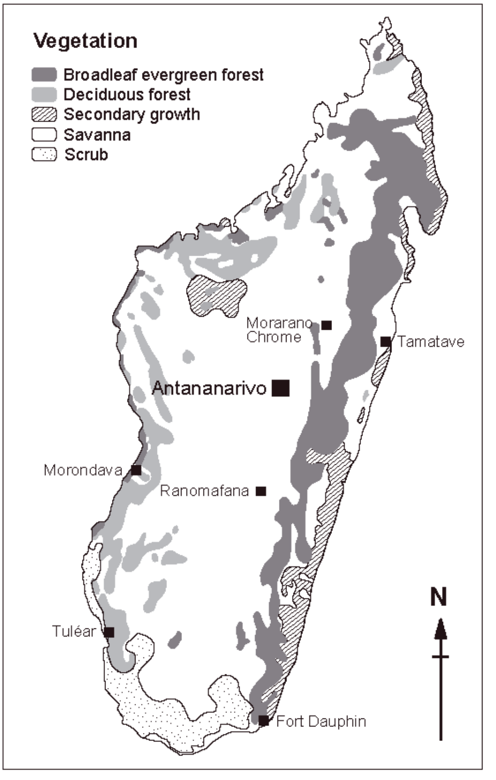

Figure 2. Map of Madagascar showing broad vegetation types (excluding marshlands). Adapted from the Food and Agriculture Organization (United Nations) (http://www.fao.org/ag/AGP/agpc/doc/Counprof/Madagascar/madagascareng.htm) and the University of Texas Perry-Castañeda Map Collection (www.lib.utexas.edu/maps/madagascar.html).

2.2. Madagascar

Madagascar is the World's 4th largest island. It exhibits a much wider range of ecosystems and biodiversity than most other large islands. This is probably due to its physical geography, the times since it rifted from other major land masses, and its distance from sources for cross-ocean dispersal (Yoder and Nowak, 2006). The eastern mountain range also leads to very different climatic regimes across the island. There is lowland rainforest in the east, montane and dry deciduous forest in the west and high elevation thicket in the central highlands (Fig. 2). The south-west is arid with spiny forests and scrub. All regions have suffered from prolonged slash and burn agriculture, leading to extensive grassland and areas dominated by exotic weeds such as *Eucalyptus* and *Grevillea*.

Madagascar has played an important role in our understanding of historical biogeography (Yoder and Novak, 2006). However, for many groups of organisms it is still not clear whether affinities with African taxa represent vicariant origins, dating back to the rifting of Madagascar+India from Africa, or whether this is due to dispersal across the Mozambique Channel. The combined land mass of Madagascar and India began rifting from Africa about 165–155 my before present (BP) and Madagascar reached its current position relative to Africa about 130–118 my BP. It is generally thought that bees first evolved in the early-mid Cretaceous, perhaps 120 my BP (Engel, 2001), so a vicariant origin for any endemic Malagasy bee clades is unlikely. It has been hypothesized that a land bridge, or island 'stepping stones', connected Madagascar to Africa from the mid-Eocene to the late Miocene (McCall, 1997), though such a dispersal corridor is contentious (Rogers et al., 2003).

The likelihood that Madagascar contains relictual elements from the earliest radiations of the bees seems low. There are no Malagasy species in the most basal bee family Dasypodaidae (Danforth et al., 2006) and in the next-most basal clade, Meganomiidae + Mellitidae s. s., there are only two Malagasy species, both meganomiids (Pauly et al., 2001). The only stingless bee genus in Madagascar, Liotrigona, is not basally situated in the Meliponini (Rasmussen and Cameron, 2007), and all the Malagasy allodapine and ceratinine lineages originated from dispersals from Africa, beginning about 30 Mya and continuing up until a couple of million years ago (Fuller et al., 2005; Schwarz et al., 2006; Smith et al. 2007; Rehan and Schwarz, unpubl. data).

Some elements of the Malagasy bee fauna show evidence for high levels of vagility among the Mascarene islands and the Indian Ocean Rim. Three of the six Malagasy Xylocopa species also occur in Africa, and a fourth occurs in India (Pauly et al., 2001). It is possible that these African-Malagasy connections represent dispersal via vegetation rafts arising from tsunamis or extreme floods in eastern Africa, since several large rivers flow into the Mozambique Channel separating Africa from Madagascar. On the other hand, another wood nesting bee, Lithurgus pullatus, occurs in Madagascar, East Africa, India, Mauritius, the Seychelles and the Maldives (Pauly et al., 2001), and it is unlikely this could be explained by vegetation rafting. The possible role of anthropogenic dispersal for some bees in Madagascar is something that needs study. The only ceratinine recorded from Mauritius is identical to Ceratina dentipes from Malaysia and is likely to represent a dispersal via ocean trading routes (Rehan and Schwarz, unpubl. data).

3. BEE DISTRIBUTION AND ENDEMICITY

3.1. Sub-Saharan Africa

Sub-Saharan Africa's bee diversity is greatest in the winter rainfall area of South Africa. This area is species-rich for all families except Andrenidae, and this fits with global patterns showing high bee diversity in Mediterranean climates (Michener, 2007). However, a number of taxa are most diverse in the tropics, with decreasing diversity at higher latitudes. The large carpenter bees (*Xylocopa*) are one example of this phenomenon, with many species are confined to the tropics, and other species' ranges extending southwards to varying extents. Some extend down the mountain ranges, like *Xylocopa somalica* Magretti, and others extend to different degrees along the coast, with the range of *Xylocopa nigrita* (Fabricius) extending to northern Kwazulu-Natal and with *Xylocopa flavorufa* (DeGeer) reaching the southern Cape. The South Western Cape has several unique, endemic species, like *Xylocopa albifrons* Lepeletier and *Xylocopa capitata* Smith.

A bee few genera, like *Dactylurina* Cockerell, are exclusively tropical, but several are endemic to southern Africa. Some of these are desert bees, like *Mermiglossa* Friese, which is confined by the tropics and savannah to the north and the east of its range. Southern Africa has a few endemic genera that occur in both the dry, winter rainfall areas in the west and the wetter, summer rainfall areas in the east, like *Rediviva* Friese. A few genera are diverse in the Palaearctic and recorded in southern Africa from only one or a few rare species, such as *Aglaoapis* Cameron. *Fidelia* Friese, on the other hand, has its centre of diversity in southern Africa with a relic species in Morocco. Neither of these genera have any known species in the tropical regions of Africa. *Meliturgula* Friese has its maximum diversities in southern Africa and the Sahara Desert, yet one species, *Meliturgula scriptifrons* (Walker), occurs in East Africa. The Anthidiini and Osmiini, which are largely cosmopolitan, have their centres of diversity in the south-western region of Africa.

Very little is known about the bee fauna of north-east Africa, but it is likely to be an interesting region for endemism. For example, six of the ten species of *Nomada* Scopoli occur in Ethiopia, with only three species in South Africa. The region between tropical Africa and the Sahara Desert is narrow and does not appear to have the diverse ecosystems that occur south of the tropics. However, this area is very poorly sampled and political situations in the Horn of Africa mean this situation is unlikely to be rectified soon.

Both at generic and species levels there appears to be higher diversity and endemicity in the CI hotspots. *Rediviva* and *Colletes* have distinct south-western Cape (Cape Floristic Region and Succulant Karoo, Fig. 1) and south-eastern Cape centres of diversity (Whitehead and Steiner, 2001; Whitehead et al., 2008; Kuhlmann, 2005). East Africa has several unique melittid genera (Michener, 1981) and given the basal nature of this group among bees (Danforth et al., 2006) this is likely to become a critical biodiversity resource for inferring early stages in bee evolution.

Overall, coming to terms with bee diversity and endemicity in sub-Saharan Africa is problematic because the continent is largely under-collected and is likely to remain so, particularly in the north east, for some time. Political and infrastructural barriers to research are major impediments to assessing even basic elements of bee diversity in much of tropical Africa and the Horn of Africa.

3.2. Madagascar

Madagascar has a very high level of bee endemicity compared to the rest of the world, with about 90% of species being endemic and with ten endemic genera (out of 86 genera on the island) and another five endemic subgenera. There are about 240 described species from six families. Of the 18 bee tribes recorded from Madagascar (Michener, 2007), all are found in Africa, so the Malagasy bee endemism does not extend to taxa higher than genera. Given that India rifted from Madagascar well after Madagascar separated from Africa, it is interesting that there are no genera or tribes in Madagascar that occur in Asia but not Africa.

The Malagasy bee fauna is dominated by the Halictidae (123 species) and the Apidae (82 species) and nine of the ten endemic genera belong to these two families (the other endemic genus is a megachilid). Three families have very minimal representation: there are only three colletid species (all in the Hylaeinae), one andrenid (a *Meliturgula* species closely related to *M. scriptifrons* [Pauly et al., 2001]) and two meganomiids (Pauly et al., 2001).

The only comprehensive treatment of the Malagasy bee fauna is Pauly et al. (2001). This study is remarkable for the extent of its coverage, the number of new taxa described, and the extensive provision of biogeographical records. More recently, the phylogenetic relationships of Malagasy species to elements from other regions have been explored for two tribes using molecular data. Danforth et al. (2008) showed that in the Halictini, the Malagasy species of *Patellapis* were all nested within an African clade, and that one Asian species had a well-supported sister-clade relationship to a Malagasy group. For the allodapine bees, Fuller et al. (2005) found that there were two colonisation events of Madagascar by the genus *Braunsapis* Michener, one about 2.6 my BP and another one about 12.8 my BP.

On the basis of larval morphology and sequence data, Chenoweth et al. (2008) transferred Malagasy *Halterapis* Michener species to a new genus, *Hasinamelissa*. Molecular data suggest that this lineage diverged from an African clade at least 20 my BP (Chenoweth and Schwarz, 2007). Seventeen species of *Hasinamelissa* have been described, and Chenoweth et al. (2008) indicate the existence of another three undescribed species based on DNA sequence data. That study was based on limited collections centred on major provincial towns and it is likely that the actual number of extant species is much larger than currently described. In fact, the number of described allodapines in Madagascar is now larger than for all of Asia (Reyes, 1991), making Madagascar the third most speciose region for allodapines in the world, after Sub-Saharan Africa and Australia.

4. NICHE SPECIFICITY

4.1. Sub-Saharan Africa

In Sub-Saharan Africa some bees are generalists, such as *Xylocopa caffra*, which occurs in winter and summer rainfall areas, deserts, savannah and forests, nesting in a variety of woods and pithy plant stems (Eardley, unpubl. data). *X. sicheli*, on the other hand, nests only in dead *Aloe* inflorescences and is confined to dry savannah and semi-desert areas (Eardley unpubl. data). *Xylocopa scioensis* Gribodo nests only in dead *Phragmites* spp. stems, and therefore only occurs near water courses. *Rediviva* spp. (Mellitidae *s. s.*) collect oil from a range of orchids as well as the genus *Diascia* (Scrophulariaceae) using modified front tarsi. Their front legs are of comparable length to the oil producing spurs of the flowers (Whitehead et al., 1984; Whitehead, unpubl. data). The plants visited by bees in the arid and semi-arid areas of southern Africa have been well documented by Gess and Gess (2003).

Most African bee communities remain poorly understood in terms of pollinator diversity and niche specificity – largely due to lack of extensive sampling. One example of niche specificity in east Africa involves species of *Ctenoplectra* – oil collecting bees with highly modified hind legs characterized by long brush-like hairs on the tibia. They forage mainly on *Mormodica foetida,* an oil-producing plant. *Ctenoplectrina*, which has two cleptoparasitic species, are found in close association with *Ctenoplectra* (Eardley, 2003). Unfortunately little is known about their nesting biology. These two genera are mainly found together in areas rich with oil producing plants such as *Mormodica foetida* and *M. balsamina* (Eardley, 2003; Gikungu, 2006).

4.2. Madagascar

Malagasy bee locality records (Pauly et al., 2001) indicate a wide range in distributional patterns, ranging from near ubiquity to very limited distributions, sometimes comprising single locality collections. More extensive collections are needed to confirm whether the single locality records really do indicate extremely limited distribution. There are few data that allow distributions to be linked with specific resource or climatic requirements, though most genera and subgenera have marked regional distributions. There appear to be diversity hotspots that roughly correspond to some habitat types. Particularly notable areas are the spiny forests and scrub in the far south west, the forests in the Ranomafana region, the remote Morarano-Chrome region in the north east, the coastal area south of Tamatave, and the Morondava region (Fig. 2). However, because of the extensive degradation of native vegetation, it is not clear whether current diversity hotspots reflect original distributions, rather than remnants of indigenous vegetation.

5. CHANGES TO ECOSYSTEMS

5.1. Africa

Africa, as with Europe, is home to the honey bee, *Apis mellifera* Linnaeus and is the birthplace of modern humans (Stringer and Andrews, 2005). Although these factors impact on bee diversity and abundance, they should probably be considered part of the ecological ground plan for Africa. Nevertheless, technologically modern man has contributed to pollinator declines in Africa. This is evident in that bee diversity and abundance is much greater on crops in areas surrounded by natural vegetation than in ecosystems that have been widely transformed by agriculture (Eardley, unpublish. data).

Honey bees are an important pollinator of the African flora and part of the pollinator guilds of natural ecosystems, but they can displace other bees on flowers (Eardley, unpubl. data). Their natural abundance is a moot point. San people paintings in the Drakensberg, South Africa, indicate that honey hunting has taken place for centuries. This was by destructive sampling that could have reduced wild honey bee numbers. However, the honey bee is the only managed pollinator in Africa, and their numbers and distribution have increased with domestication and the introduction of alien plants, like *Eucalyptus* spp. (Wiese, unpubl. data). At the same time the recent movement of the Cape Honey Bee into Gauteng Province, South Africa, and the introduction of honey bee diseases, such as *Varroa*, have reduced honey bee numbers over the past two decades.

The most comprehensive work on bee conservation in Africa is that of Gess and Gess (1993). They outline factors that affect the abundance and diversity of bees in semi-arid areas, but their findings are likely to be more widely applicable. Transformation of the landscape by replacement of natural vegetation with crops and other exotics, along with removal of natural vegetation through urbanization, are major problems. These problems are greatest in the higher rainfall regions, primarily the tropical, subtropical, and montane areas, along with the Mediterranean ecosystems of South Africa where extensive cropping has occurred. More subtle threats arise from selective grazing, removal of bush to expand grasslands, trampling by stock, removal of wood and charcoal production, and the use of insecticides to control diseases like sleeping sickness. These problems are important in savannah and semi-arid areas. Slash and burn agriculture is also a common practice in arid and semi-parts of eastern Kenya and has reduced the population of both arboreal and ground nesting bees (Gikungu and Njoroge, 2007).

There have been no studies that examine whether loss of bee diversity impacts on horticultural yields. However, a few studies in east Africa (Gikungu et al., 2008) have shown that agricultural ecosystems may support higher levels of bee diversity and abundance than forested areas. This is because disturbed habitats in low-intensity farming systems may provide more suitable resources for many bee species. This calls for further holistic approaches in regard to management of disturbed and undisturbed habitats given that bees are both coarse and fine-grained organisms.

5.2. Madagascar

Madagascar has suffered some of the worst destruction of natural ecosystems in the world. This began approximately 2000 years ago with human colonisation from southern Asia and Polynesia, and a major problem derives from extensive slash and burn agriculture. The continuing threat from this is still evident to anyone flying over Madagascar, where the telltale signs of fire and smoke forming thin lines at the edges of forests are depressingly common. This has left most of the central *hauts plateaux* comprising a mixture of anthropogenic grasslands and eucalyptus plantations that are cropped to provide small timber for local construction and charcoal. The result is also evident in wide-scale erosion, evident from red plumes extending tens of kilometres into the sea from the major estuaries.

The effects of land clearing on bee diversity is suggested by a comparison by Pauly et al. (2001) of bee species between coastal and montane forests with a coastal urban and montane cultivated area. The former habitats had 49 and 69 species respectively while the latter two regions had 25 and 20 species. That study did not provide a firm quantitative basis where seasonal and other proximate effects were controlled for, but is nevertheless alarming. There is a strong need for further studies, including studies that examine the effects of exotic weeds which, in some large areas, have almost entirely replaced native vegetation.

6. THREATS

The same general suite of threats to pollinator decline affect both Africa and Madagascar: namely, spread of exotic weeds, pesticide use and, most importantly, habitat destruction and degradation. Perhaps the main driver of these threats comes from population growth and the imperative to improve living standards, combined with economic circumstances that make the implementation of conservation strategies very difficult.

In Madagascar there has been a massive increase in the number of national parks since the 1980's, but in both Madagascar and Africa there is a need for smaller-scale conservation strategies that have the support of local communities. Conservation measures imposed by central governments may lack effectiveness if the benefits to local communities are not evident to those communities, and if the measures cannot be policed. To this extent, there need to be clear links between conservation and the well-being of local communities. Ecotourism and development of sustainable agriculture are two ways in which these links can be encouraged, but we should not underestimate the size of the challenge. It seems unlikely that conservation measures will be effective if they ignore social issues.

7. CURRENT CONSERVATION STATUS AND LONG-TERM OUTLOOKS

7.1. Africa

For Africa there is an urgent need to identify areas with a high bee diversity and endemicity, and conservation strategies for these areas need to be specifically designed and prioritised. Nothing like this exists in Africa and it will not be easy to develop. With the recent awareness of the importance of pollination services, Africa has come up with a plan of action, through the African Pollinator Initiative (API, Martins et al., 2003), for a pollinator conservation consortium. The main goal of API is to promote pollination as an essential ecosystem service for sustainable livelihoods and the conservation of pollinator biological diversity (Martins et al., 2003). However, the only strategies specifically regarding bee conservation that have been implemented to date are designed to protect agriculture and not bee diversity per se. One impediment to bee conservation is that while honey bees are perceived to be important pollinators, this does not seem to extend to other bee groups. In a continent where government finances are often very limited and socio-economic and health challenges are very large, establishing a priority for bee conservation will be difficult. Outside of protected areas like national parks, making agricultural practices more bee-friendly will be important, but there is a need for studies to show that such measures will actually benefit communities if they are to be widely adopted.

7.2. Madagascar

For Madagascar the only comprehensive stock-take of indigenous bee was by Pauly et al. (2001), remarkable for its scope and highlighting of biodiversity issues. That study could form the basis for a more focussed examination of conservation risks and strategies. Regional maps of species records provided by Pauly et al. (2001) could be used to identify areas where diversity is high, and this synthesis is needed. Ideally, regional maps of species could be used in a conservation phylogenetics approach to identify which regions contain the most critical species for conservation. There are no current initiatives to assess the conservation status of Malagasy bee species. However, because of the extent to which ecosystem degradation has occurred, all areas containing remnant biota require protection – such areas are now very limited and rapidly disappearing. Our field work (Schwarz, unpubl. data) found that even small pockets of remnant vegetation can still support high bee diversity, but many of these are still being destroyed by slash-burn incursions. Expanding such remnants and linking them via habitat corridors is sorely needed, but the most immediate challenge is to simply prevent the existing pockets from disappearing altogether.

In summary we do not have enough data to thoroughly document bee diversity in Africa and Madagascar, let alone develop prioritised conservation strategies. Furthermore, at the governmental and funding-agency levels, bee conservation will have to compete with more 'glamorous' taxa, such as mammals, reptiles and birds, where conservation measures will hold greater cachet with the public. If strategies for conserving bee diversity in Africa and Madagascar are to be developed and implemented by governments, they will require persuasive arguments that bees are important for broad ecosystem health and conservation. If conservation strategies are to be implemented at a local level, then those people who decide how their land is managed will need to be convinced that bee-specific measures will be to their advantage.

At a broad level, we require bee diversity surveys across the continent, documenting of food plants and pollinated plants, knowing the identity and phylogenetic relationships between bee taxa, understanding their biology and their interaction with other organisms. This calls for increased capacity building at all levels. Taxonomic impediments and a dearth of well-curated local collections are major barriers to pollination ecology and pollinator conservation in Africa. In sub-Saharan Africa, there are only a few countries, such as South Africa, Kenya and Ghana, that have substantial capacity and enthusiasm for pollinator conservation. There are many more countries without a single bee taxonomist or pollination ecologist. In order to overcome these challenges, there is a need for local bee inventories, regional courses and increased collaboration between countries.

8. WHERE TO NOW?

The challenges that face bee biodiversity conservation in Africa are not insurmountable, but the pace of development is far too slow. Much of what is now required involves building local knowledge infrastructure, which is needed to promote and engage communities and government in conservation. We suggest the following as some important initial steps:

- Public awareness needs to be increased. Campaigns, such as the North American Pollinator Protection Campaign (NAPPC – http://www.nappc.org) could be developed and used to engage farmers, conservationists, gardeners and other land users. A number of these are given in Eardley et al. (2006), but additional case examples are needed and different media should be used for publication. Land users should be made aware of comparable situations to theirs where pollinators have been protected and encouraged to implement similar measures.
- Networks, such as API, should be expanded to create an active community that will enable people interested in bees to communicate with one another. These can also be used to coordinate wider participation in surveys and research projects.
- Much effective research results from the effect of 'champions' who promote their subjects. But many potential champions do not develop due to a lack of training and mentorship. Support networks are needed to develop emerging champions in different institutes and countries.
- Many Northern Hemisphere-based scientists work in Africa and mentor developing scientists. Local mentors, however, are needed and overseas researchers can help them develop.
- Taxonomists need collections and catalogued literature. The latter should soon be available in Eardley and Urban (in preparation), but developing collections is a long, slow process. The problem could be alleviated through databases of African material in overseas collections and virtual museums (good quality photographs on the Internet) of type material. But the development of local collections is also essential.
- Existing politically stable regions are best placed to spearhead conservation initiatives and these could involve the

establishment of research sites and associated stations, with local institutes taking a lead to attract researchers to such sites. Research and conservation agencies could also 'adopt' such research centres.
- There is a strong need for research into the effect of non-*Apis* bees on local agriculture and how bee diversity can be encouraged in areas outside of conservation parks. Adoption of bee-friendly practices will be highest when communities and governments are aware of the benefits to them. Studies such as those of Kremen et al. (2002, 2004) are invaluable in understanding the principles that need to be investigated in Africa and Madagascar.

9. CONCLUSIONS

Africa and Madagascar together contain a wealth of biodiversity. These regions are especially important for bees, given a likely origin of bees in Africa (Danforth et al., 2006). The loss of bee species in these regions will permanently erode this window into a key part of evolutionary history. Yet the centres of gravity for bee research in these regions have long been in North America and Europe. Continuation of these research efforts is needed, but effective conservation of bees in Africa and Madagascar will only happen with local engagement, and this requires building local expertise and local initiatives. The first steps have been taken with initiatives like the API, but these must be strengthened and extended. This will require an international effort, but it can not be at arms length. The solutions must ultimately come 'Out of Africa' (and Madagascar).

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Conservation des abeilles en Afrique subsaharienne et à Madagascar : diversité, statut et menaces.

abeille / Apoidea / protection / biodiversité / Afrique / Madagascar

Zusammenfassung – Erhaltung der Bienen in Afrika südlich der Sahara und in Madagaskar: Diversität, Status und Bedrohungen. Das südlich der Sahara gelegene Afrika und Madagaskar beherbergen einen hohen Reichtum an Bienendiversität. Diese Diversität ist aus mehreren Gründen unabdingbar. Bienen sind wichtige Bestäuber sowohl für landwirtschaftliche Nutzpflanzen als auch in natürlichen Ökosystemen, und sie ermöglichen Einsichten in verschiedenste Aspekte der evolutionären Biologie. Neuere Untersuchungen legen nahe, dass Bienen zunächst in der afrikanischen Region entstanden sind, hierdurch ist ihre Erhaltung für zukünftige Studien über die frühe Evolution der Bienen unabdingbar. Allerdings stehen das Verständnis dieser Diversität und die Entwicklung von Strategien für ihre Erhaltung vor einigen ernsthaften Herausforderungen. Die erste Herausforderung ist die vollständige Dokumentation der Bienendiversität in diesen Regionen. Derzeitige systematische Studien belegen eine eher mittelmäßige Artenvielfalt im Afrika südlich der Sahara. Dies könnte aber, insbesondere in den ärmeren Gegenden, auf unzureichende taxonomische Untersuchungen zurückzuführen sein. Obwohl eine neuere Übersichtsstudie über die gesamte Fauna von Madagaskar durchgeführt wurde, gibt es Gründe zu der Annahme, dass noch viele weitere Arten beschrieben werden müssen.

Es ist generell anerkannt, dass Bienen für die Bestäubung von herausragender Bedeutung sind. Dies erstreckt sich aber im wesentlichen auf die Honigbienen und die Stachellosen Bienen, während die anderen Bienengruppen kaum beachtet werden. Wenn gegenüber Regierungen und lokalen Kommunen ein überzeugendes Argument für ihre Erhaltung vorgebracht werden soll, ist es notwendig die von den nicht-*Apis* Bienen erbrachten ökologischen Leistungen zu dokumentieren. Die Diversität der Bienen ist einer Anzahl ernster Bedrohungen ausgesetzt, insbesondere der Verschlechterung oder Zerstörung ihrer Habitate. Während es in einigen Ländern ausgedehnte Schutzgebiete wie zum Beispiel Nationalparks gibt und diese auch extrem wichtig sind, ist es für große Teile von Afrika oder Madagaskar unangemessen sich auf Erhaltungsgebiete zu stützen, in denen die Landwirtschaft ausgeschlossen wird. Stattdessen sind für die Erhaltung der Bienendiversität in Gegenden außerhalb von Erhaltungsgebieten die öffentliche Erziehung und die Entwicklung landwirtschaftlicher Arbeitsverfahren sowie Unternehmungen wie Ökotourismus zu fördern.

Die Dokumentation der Bienendiversität in Afrika und Madagaskar wird durch den Mangel an Bienenbiologen in diesen Gegenden sowie durch schlechte Infrastruktur und begrenzte Zugangsmöglichkeiten zu wissenschaftlichen Arbeitsmitteln wir etwa

Büchereien erschwert. Trotz der Einschränkungen ist die Entwicklung lokaler Bienensachkenntnis und die Ausbildung lokaler Forschungs- 'Champions', die jüngere Biologen führen und anleiten können, sehr wichtig. Hierbei können die entwickelten Länder helfen. Obwohl Finanzierungsagenturen und Wissenschaftler aus entwickelten Ländern generell bei der Erhaltung der Bienen helfen können, ist es letztendlich am wichtigsteng, lokale Möglichkeiten wie Museumssammlungen, Zugang zu Informationsquellen und eine Grundlage an fähigen Forschern aufzubauen.

Bienen / Erhaltung / Biodiversität / Afrika / Madagaskar / Apoidea

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