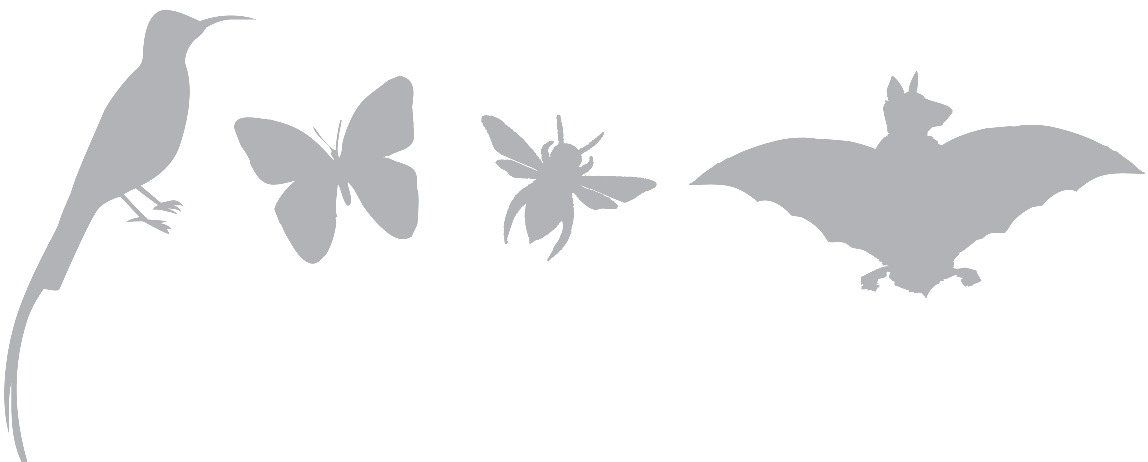
Pollinators and pollination:

A resource book for policy and practice



Pollinators and pollination:

A resource book for policy and practice

Editors: Connal Eardley, Dana Roth, Julie Clarke,
Stephen Buchmann and Barbara Gemmill

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Foreword

The workshop on pollinators and pollination held in Mabula, South Africa, in May 2003, was organised to address major questions in the area of animal pollination. Plants and animals have coevolved over millions of years, since the Cretaceous period. Plant fertilisation depends on the behaviour of many species of animals, from insects to birds to mammals, which transport pollen from stamens to pistils, a key step in the reproduction of most flowering plants. Nature is rapidly disappearing all over the planet, and we have reached, on a geological time scale, the last minute where we have a chance to avert a huge biological disaster – the large-scale loss of pollinator services. All this is well known to biologists, ecologists, agronomists and other nature experts from many fields. Most people around the world, however, including decision makers, are poorly informed about the enormous biological disaster we may soon face, owing to a serious shortage of pollinators.

As this book shows, we are planetary citizens who have to act quickly in many fields. We will most definitely have to increase the number of protected nature reserves. In Brazil, in accordance with Brazilian Federal laws, we have seven different types of nature reserves, which are increasing rapidly in both number and extent. However, we are still losing many areas through conversion to pasture or crop plantations. In the tropics this is still a general trend. It means we are losing some pollinators even before they can be studied by scientists.

This book deals with many different subjects related to pollination that are seldom put side by side. It considers issues such as the assessment of pollinators and pollination services, adaptive management of crop plants and wildlife, capacity building and how pollination can be mainstreamed into policy decisions. The economic and agricultural aspects of pollinators are discussed, as well as their biological role in nature. All these matters are explained at the level of detail that is needed to fully understand the importance of the work on animal pollination.

The Mabula workshop has the support of the FAO and of many countries and important NGOs. This book shows this clearly and presents other valuable data on the feasibility of pollination programmes. Recognition of the importance of pollinators and pollination services will be a vital part of the world's ethical and practical drive to eliminate extreme poverty in Brazil and other countries.

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Mabula Workshop participants. Back row: Gabriela Chavarria, Rodrigo Medellin, Caroline Gross, Connal Eardley, Breno Freitas, Ros Urban, Farooq Ahmad, Simon Potts, Michael Ruggiero, Barbara Gemmill, Elize Lundall-Magnuson and Terry Griswold. Front row: Peter Kwapong, Linda Collette, Marina Castro, Vera Fonseca, Julie Clarke, Sidwell Banne, Uma Partap and Dana Roth. *(Photgraph by C Eardley)*

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Introduction

Pollinators provide an essential ecosystem service that results in the out-crossing and sexual reproduction of many plants. They benefit society by increasing food security and improving livelihoods and by the role they play in conserving biological diversity in agricultural and natural ecosystems. Reduced agricultural yields and deformed fruit often result from insufficient pollination rather than from a deficiency of other agricultural inputs, such as agrochemicals. In natural ecosystems, the visual clues of insufficient pollination are more subtle than in agriculture, but the consequences can be as severe as the local extinction of a plant species, a noticeable decline in fruit and seed eating animals, the loss of vegetation cover and ultimately, if keystone species are involved, the demise of healthy ecosystems and their services.

Natural ecosystems and many agricultural ones depend on pollinator diversity to maintain overall biological diversity. A variety of materials, including dry wood (especially wood with empty beetle burrows), bare ground, vegetation-free embankments, mud, resins, sand (for some bees), carrion (for certain flies), host plants (for bees, moths and beetles) and caves (for certain bats) contribute to the diverse environment needed to maintain pollinator diversity.

Pollinator diversity is immense. There are more than 20,000 pollinating bee species in the world, as well as numerous other insect and vertebrate pollinators. Pollinators differ from many other providers of essential ecosystem services because they are often part of highly specific pollinator–plant relationships. Where there are very specific niche requirements for the plants and their pollinators, loss of the pollinator can have cascading effects across the ecosystem. For example, some bees that pollinate small herbaceous plants depend on holes in dry wood to nest, and when the wood is removed plant fecundity is reduced.

The importance of pollination in agriculture has been recognised for millennia (Kevan & Phillips, 2001). Ancient Assyrian temple carvings depict winged deities pollinating female date palms with male flowers to ensure that dates would form on their trees (Buchmann & Nabhan, 1996). Old Mayan screenfold books (e.g. the Madrid Codex, now housed in a Madrid museum) indicate that the ancient Maya of Mesoamerica kept stingless bees (*Melipona beecheii*), indicating that they knew how to manage and propagate captive colonies in log hives. Much of this ancient knowledge was lost until essentially modern times, with the rediscovery of sexuality in tulips by Arthur Dobbs in 1750 and other early floral biologists. The irony, however, is that although the importance, and fragility, of pollination for agriculture and nature conservation has been known for a long time, there appears to have also been a popular belief that flowering plants always somehow seem to get pollinated and bear fruits and seeds and carry on into the next generation. Thus the science of pollination ecology has not advanced adequately, and this makes ample room for new and established researchers to contribute to knowledge about pollinators and the plants they pollinate, whether in natural or agroecosystems. Surprisingly, even the identities of major and minor pollinators for many major crops plants worldwide remain unknown.

The science of pollination ecology and floral biology has, however, now been mainstreamed in biodiversity conservation. In the mid-1990s, scientists and agriculturists around the world were concerned that a worldwide decline of pollinator diversity was occurring, and this prompted policymakers at the Fifth Meeting of the Conference of Parties (COP) of the Convention on Biological Diversity (CBD) to establish an International Initiative for the Conservation and Sustainable Use of Pollinators (also referred to as the International Pollinators Initiative, or IPI) in 2000 (www.biodiv.org/decisions/). COP V/5 considered this to be a cross-cutting initiative within the Programme of Work on Agricultural Biodiversity to promote coordinated action worldwide, and so requested the development of a Plan of Action for the IPI. Subsequently, the Executive Secretary of the CBD requested the Food and Agriculture Organization of the United Nations (FAO), in collaboration with key experts, to develop a Plan of Action for the IPI. This Plan of Action, which built on recommendations from the São Paulo Declaration on Pollinators, was adopted at COP 6 (decision VI/5) in 2002.

The African Pollinator Initiative (API), one of the first regional networks, was formed to facilitate Africa's implementation of the IPI. The priority activity identified for API's Plan of Action was awareness and education, particularly targeted at policymakers. On a global scale, however, conservationists, farmers, foresters, horticulturists, soil conservationists, landscape architects, town planners and other stakeholders need to work with policymakers on the economic and ecological importance of pollinator biodiversity conservation. One of the purposes of this book is to help address this need.

How to use this resource book

Because pollinator diversity conservation and the sustainable use of pollinators is specifically addressed in the CBD, this book is designed to reflect the CBD IPI Plan of Action. It thus includes chapters on Assessment (Chapter 1), Adaptive management (Chapter 2), Capacity building (Chapter 3) and Mainstreaming (Chapter 4). Figure 1 shows how these areas fit together.

Activities in pollinator conservation should focus on making pollinator conservation and sustainable use an integral part of farm and natural ecosystem management (Figure 1.b). In some agricultural systems pollinator management, such as beekeeping, increases production (Figure 1.c); in others naturally occurring pollinators, maintained by resources from nearby remnant vegetation that provides nesting sites, nesting materials, and alternative forage when crops are not in bloom, sustain agricultural production (Figure 1.d).

This book provides guidance for improving and/or developing policies and practices to enhance pollinator conservation and habitat restoration, including the reintroduction of lost pollinators. It provides case examples of best practices, makes recommendations, lists up-to-date references and summarises the recommendations (the case examples and recommendations are named, numbered, and indexed at the back of the book for easy reference). The format mostly follows the key elements in the IPI Plan of Action, but is not restricted to addressing only these. It should provide policymakers and practitioners with tools to start addressing pollinator conservation and incorporating it into their action plans.

A quick preview of this book’s content can be obtained from each chapter’s ‘Introduction’ and concluding ‘Summary of recommendations’.

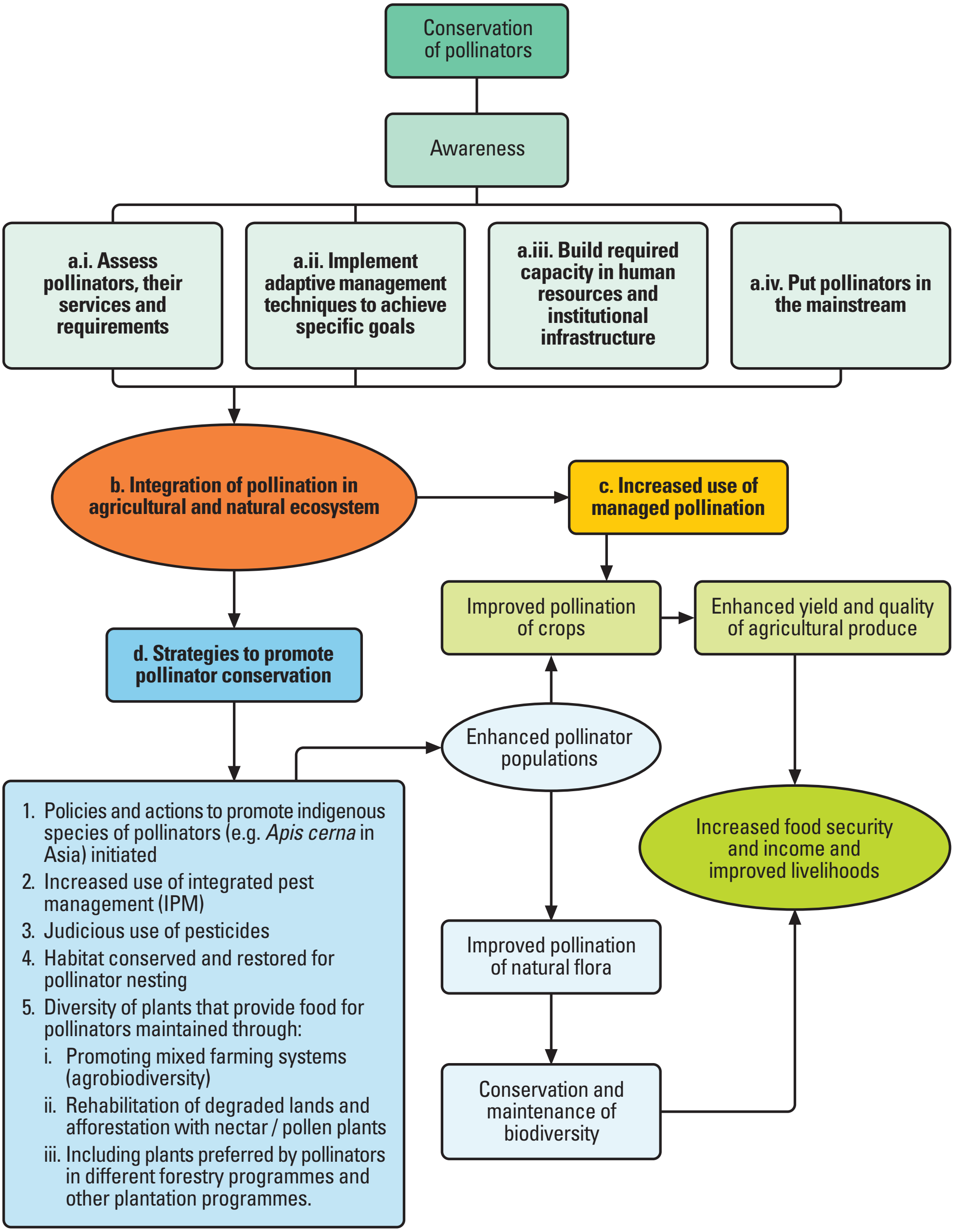


Figure 1. **Diagram showing where policy and/or activities are needed for an ecosystem approach to the conservation of pollinator biodiversity. A greater understanding of the multiple goods and services provided through pollinator diversity, and the factors that influence pollinator decline, is clearly needed (i.e. assessment and adaptive management). Capacity building and mainstreaming should lead to appropriate activities to ensure food security and improved livelihoods and long-term conservation of natural ecosystems. Measures on the ground that help conserve pollination, as an ecosystem service in both managed and natural systems, contribute to the protection of other ecosystem services, including water and soil conservation.** *(Diagram by U Partap)*

1 Assessment of pollinators and pollination services

Assessing both pollinator declines and pollen deposition deficits, which may result in diminished seed and fruit sets, is one of the principal priorities identified by international pollination experts, and is therefore one of the elements in the IPI Plan of Action. Such an assessment is needed to provide a comprehensive analysis of the status and trends of pollinator diversity and distribution and to provide information useful for enhancing pollinator conservation and sustainable use.

Assessing pollinator status and trends is complicated. Scientific data on the status of pollinators and the state of pollination services are inadequate. Observations suggest that a decline in pollinator abundance is occurring, but often these observations are considered anecdotal. Documenting a decline reliably can help identify specific areas of concern. Measurement and assessment of pollination services therefore need to be properly planned and designed to produce verifiable results.

To accurately assess the extent of pollinator declines, standardised methodologies should be applied globally. There are several approaches to measuring the current status of pollinators, identifying trends in pollinator diversity and abundance, and assessing the adequacy of pollination services. There are also several methodologies for documenting pollinator occurrence across time and/or across environmental gradients, directly and/or indirectly. Pilot methods exist to collect information for assessing the monetary value of pollination services for commercial crops, but more collaborative studies between agricultural economists, natural resource and environmental economists, agronomists and pollination biologists should be fostered.

Assessment also includes evaluation of resources, such as human capacity, infrastructure and funding, and determining research needs. A few economic assessments of the monetary contributions of pollinators to crops have been made, for example Johannsmeier et al. (2001), Morse & Calderone (2000), Robinson et al. (1989), Southwick & Southwick (1992), and Kevan & Phillips (2001). These are largely based on the honey bee (*Apis mellifera*), which is an introduced species in many agroecosystems, and do not take into consideration other insect pollinators, often present and actively pollinating unnoticed on the same crops. They also do not address associated ecosystem services provided by maintaining habitat for pollinators, for example the spatial heterogeneity in ecosystems, including vegetation cover on the ground associated with soil nutrient cycling, clean water and carbon sequestration.

Accurate assessment depends on the correct taxonomic identification of pollinators and the plants they visit, and on basic scientific and technical information on pollinators and pollinator–plant relationships. Taxonomic capacity is currently insufficient and building it must form a priority pillar in pollinator conservation (see Chapter 3). The Global Taxonomic Initiative under the CBD provides a forum for addressing this problem. All these issues were highlighted by policymakers when they made a global commitment through adopting the IPI at COP 6 in 2002 (www.biodiv.org/decisions/).

1.1 Assessing the state of pollination services

Though answering particular questions may require specific protocols, a core methodology that would permit comparison of results globally is needed. Tools for assessing pollination services should therefore ideally be simple, standardised and applicable in a variety of habitats worldwide and universally used by researchers assessing pollination.

Case example 1 – protocols for monitoring and assessment

A recent review of bee studies (Williams et al., 2001) found existing approaches to be of limited use in differentiating between natural population fluctuations and human-induced changes, and recommended approaches that would optimise our ability to detect change. There are similar concerns about pollinating flies (Kearns, 2001). Such protocols exist for several other groups, such as ants (Agosti et al., 2000). Standardised sampling methods and field trials are under development for native bees (using pan traps, glycol traps, malaise traps, trap nests and netting at flowers, etc.) and field tests are under way in North America (http://online.sfsu.edu/~beeplot/) and Europe (ALARM: Assessing Large Scale Risks to Biodiversity with Tested Methods; www.alarmproject.net).

Other examples of protocols can be found in Silveira & Godínez (1996), Herrera (1988), Minckley et al. (1999), Leong & Thorp (1999), Frankie et al. (1993) and Frankie et al. (1998).

Potts et al. (2005) discuss the intricacies and problems of sampling pollinators in the field.

Recommendation 1 – protocols for monitoring and assessment

Standardised protocols for monitoring pollinators are an immediate need. Researchers have been brought together to collaborate in developing such protocols, but refinement and testing are still needed. The use of these protocols in Long Term Ecological Research (LTER) sites and biosphere reserves for the development of long-term baseline data should be considered.

Case example 2 – US standardised protocols and sampling methodologies

A working group in the US (led by G LeBuhn and S Droege) has formulated standardised protocols and sampling methodologies (e.g. netting at flowers in standardised grids and use of colorful plastic pan traps filled with soapy water) for repeatable, multi-year sampling of native bees. This group meets annually to discuss and review their results. A website has been created to help disseminate this information (http://online.sfsu.edu/~beeplot/). A comparative analysis of netting bees at flowers vs pan-trapping, and caveats for each, has been presented by Cane et al. (2000).

1.1.1 Monitoring pollination services through time (direct monitoring)

The IPI, the World Conservation Union (IUCN, www.uoguelph.ca/~iucn/) and many other bodies recognise the critical importance of global monitoring systems for understanding the status and sustainability of pollinating animals worldwide. Detection of human-induced changes in plant–pollinator mutualisms presumes knowledge of the natural fluctuations in the abundance of both pollinators and flowers, against which human-induced changes can be assessed. Such baseline knowledge for monitoring programmes is scarce.

The natural abundance of many invertebrates, including pollinators, varies greatly between seasons (Cane et al., 2005; Minckley et al., in press; Williams et al., 2001; Kearns, 2001; Roubik, 2001), complicating and delaying efforts to detect trends. Hilton and Miller (2003) demonstrated the importance of long-term surveys and stressed the need to broaden them. (Monitoring for vertebrate pollinators may be easier than for invertebrates, because their population densities normally vary less between seasons.) Policy and management decisions, however, need to be made quickly and should be based on the best available information. Therefore monitoring needs to be undertaken in anticipation of policy/management needs.

Case example 3 – target flowers

Standardised protocols for monitoring bee fauna are addressed in a recent issue of *Conservation Ecology* (www.ecologyandsociety.org/vol5/iss1/). These include comparisons of bees sampled at individual plant families vs the entire flora in the Carpathian Mountains (Osychnyuk, 1967). Although no single plant family could be considered a typical example for the bees for this area, the Asteraceae provided a reasonable estimate of patterns of bee diversity and abundance. Asteraceae was not a good surrogate for bees in Pinnacles National Monument, a Mediterranean-type community in California (O Messinger and T Griswold, unpublished data). Alternatively, sampling a single magnet flowering plant may provide sufficient information for monitoring trends (Frankie et al., 1997, Frankie & Vinson, 2004; Minckley et al., 1999), but as the bees that visit a single plant species cannot represent the entire fauna, sub-sampling from other plants is needed to capture the essence of the variation or changes in entire bee communities over space and time (Cane et al., 2005; Minckley et al., in press).

Case example 4 – monitoring bees in urban habitats

Native bees have been observed and monitored by netting at flowers within urban landscapes in two cities in California (Frankie et al., 2005). These studies demonstrated that diverse assemblages of solitary and social bees exist in cityscapes when nesting sites and flowering plants (often exotic horticultural varieties) are available throughout the year. Surprisingly, formerly common large bees (e.g. several bumblebees, *Bombus* spp.) are declining and are no longer commonly encountered. These authors have also designed experiments to examine the potential for interference competition between honey bees and native bees on a wide variety of flowering host plants. Results from both California and Costa Rica indicate that resource overlap is considerably less than originally expected. Where competition appears likely, close examination reveals several mechanisms used by native bees to avoid or reduce competition. Two of the mechanisms are spatial and temporal sorting of the bees at flowers. Another mechanism may be induced by the plant through apparently different quantity/quality of floral rewards among conspecific individuals of the population. A brief history of the Urban Bee Project at UC Berkeley can be found online (http://nature.berkeley.edu/urbanbeegardens/research_history.html).

Male Scarlet-chested Sunbird (*Nectarinia senegalensis*) on *Aloe lateritia.* *(Photograph by C Eardley)*

Case example 5 – monitoring pollinators of cultivated cucurbits

In 2004 an international pollinator monitoring effort on cultivated and wild squash, gourds, pumpkins and other cucurbits was undertaken and coordinated by James Cane (USDA, Logan, US). A website (www.loganbeelab.usu.edu/squashbee/) containing information and sampling methods can be accessed. This group exchanges information on various bees (e.g. the genera *Apis*, *Bombus*, *Peponapis* and *Xenoglossa*) that pollinate cultivated and wild cucurbits (*Cucurbita* and *Cucumis*) and on their abundance and diversity on agricultural and adjacent lands.

Case example 6 – fruit and seed monitoring

Monitoring pollen deficits, or declines in pollen deposition, and subsequent decline in plant reproduction, may be an effective measurement of pollinator abundance and diversity. It has many of the same limitations as monitoring pollinator populations, and trends can only be detected if the effects of other influences, such as internal resource limitations, climate and floral herbivory, can be removed. An international working group is developing approaches to accurately assess pollen limitations (www.nceas.ucsb.edu/fmt/doc?/frames.html).

Hummingbirds in the western hemisphere and sunbirds in the Old World are key pollinators of a number of native plant species and may contribute to crop pollination of some fruit such as papaya and okra. Many hummingbirds, in the same way as bats and butterflies, migrate long distances, breeding in one site and overwintering in another. Their conservation requirements are therefore often complex and efforts in one place may be counteracted by a loss of habitat far away. Hence monitoring populations of these animals in their different habitats is important for their protection.

Case example 7 – hummingbirds

There have been binational efforts to monitor hummingbirds across the Mexico–US border (www.hummingbirds.net/surveys.html). The US Geological Survey (USGS), as part of the Breeding Bird Survey, has the longest continuous hummingbird population data (Sauer et al., 2005). The development of a centralised database for banding and recapture of hummingbirds and other avian pollinators is in progress (Allen-Wardell et al., 1998). A major hurdle at present is coordination and data standardisation. Given the large number of plants that rely on avian pollinators across the Americas and the fact that many hummingbirds are of conservation concern, these surveys should be a priority for governments, conservation organisations and agricultural institutions within the range of hummingbirds.

Hummingbird. *(Photograph by D Inouye)*

1.1.2 Monitoring pollinator services over space (indirect monitoring) and across disturbance regimes in the landscape

Bees are generally very sensitive to insecticides. Efforts to control plant pests can have severe unintended consequences for pollination. The impact of insecticide application on pollination services and the resulting crop yields depends on the kind of pesticide, dosage, formulation and timing of application. Herbicides are not usually directly toxic to bees and other pollinators, but can have important impacts through eliminating larval host plants (weeds) for Lepidoptera or reducing nectar and pollen for bees (SL Buchmann, personal communication to C Eardley). Malathion is very toxic, especially in its micro-encapsulated form where it mimics and travels like pollen grains, and is collected by bees (SL Buchmann, personal communication to C Eardley; Johansen & Mayer, 1990).

Case example 8 – low bush blueberry in North America

Low bush blueberries in northeastern North America are naturally pollinated by a large assemblage of insects, mostly native bees. The threat of spruce budworm, a native forest pest, to forestry resulted in the widespread use of insecticides in attempts to curtail outbreaks. DDT was used at first, but was replaced in the early 1970s by fenitrothion, which is known to be far more toxic to bees. Blueberry fields are often enclaves within, or adjacent to, tracts of forest. In south central New Brunswick, Canada, when fenitrothion was used, the bee pollinators of the blueberries were reduced in abundance and diversity to the extent that a significant decline in blueberry yields resulted. Bee diversity and abundance in fields to the west and east of the affected area, where no pesticides were applied, remained high and blueberry yields were good. After precedent-setting litigation, the use of fenitrothion in the vicinity of blueberry fields was banned and over the ensuing few years patterns of bee diversity and abundance became more uniform across southern New Brunswick and blueberry crops increased provincially to the expected levels (Kevan, 1975; Kevan & Plowright, 1995).

Sharp declines and habitat destruction have prompted close monitoring of the migratory nectarivorous Mexican long-nosed bat (*Leptonycteris nivalis*) and lesser long-nosed bat (*Leptonycteris curasoae*) (other Mexico and US endangered and threatened bats are listed – SEMARNAT, 2002). However, methods to estimate population sizes continue to be debated; recent technological advances may contribute to increased survey accuracy (TH Kunz, personal communication to RA Medellín), and results suggest that the lesser long-nosed bat, for example, might be more abundant than was previously thought (Cockrum & Petryszyn, 1991).

Case example 9 – Mexico bat survey

The *Programa Para la Conservacíon de Murciélagos Migratorios* (PCMM, Program for the Conservation of Migratory Bats) monitors bats in over 20 caves in 14 states of Mexico (Medellín, 2003). The survey involves visiting each cave at least once every season, estimating population sizes and sex ratios, and obtaining blood, fecal and stable carbon isotope samples for subsequent dietary analysis. Although specific, cross-cave comparisons cannot be conducted owing to methodological hurdles and lack of standardisation, the data are useful to identify the waves of migrating bats and document migratory patterns, seasonal changes in diet, reproductive cycle and approximate departure and arrival dates for specific regions. This information is being used to establish additional protected areas in Mexico (Medellín et al., 2004).

Monitoring requires significant time periods to detect population trends. In some situations this may take too long for effective actions to reverse pollinator declines. An alternative approach is to simultaneously measure pollinators along gradients of concern, such as fragmentation, pesticides, invasive species and varying levels of habitat disturbance.

Osmia ribifloris. *(Photograph by T Griswold)*

Case example 10 – response of pollinators to fire

The effects of perturbations may be complex. A simultaneous study of a mosaic of different age burns in a Mediterranean ecosystem showed a peak in bee and plant diversity two years after a fire (Potts et al., 2003). Fire effects were not equivalent for all bee pollinators; pollinator composition showed significant change through time. Studies on pollinators in longleaf pine habitats in Florida (Pitts-Singer et al., 2002) suggest that fire timing is important to ensure that flowering occurs when pollinators are available. Thus it is necessary to understand the life cycle of important pollinators and, further, whether fire has an effect on the availability of food and nesting materials.

Case example 11 – habitat loss in Argentina

Interesting insights can be found in habitat fragmentation studies with regard to the prominent influence of different nesting attributes of bee species (Cane, 2001). In Argentina's subtropical dry forest, two bee taxa, *Dialictus* and *Augochlora*, were detected in three continuous forest samples (Aizen & Feinsinger, 1994). Both genera comprise floral generalists, but *Dialictus*, which are ground nesters, were found in all forest fragments and in the agricultural matrix. Some *Augochlora*, which nest in rotting tree stumps and logs, fared poorly in small forest fragments and farmers' fields. The contrasting response to deforestation in these two bee genera is explained by differences in their nesting biologies, not their floral preferences; small fragments and the agricultural matrix contain soils that are suitable for *Dialictus*, but no longer contain the logs required for nesting by *Augochlora*.

Recommendation 2 – habitat fragments

Better knowledge of the specific resource needs of key pollinators will enable better management of the habitat characteristics that help maintain their populations. Studies on fragments as reserves may generate data and practical insights of critical importance for pollinator conservation. In many regions of the world, the opportunities to set aside massive reserves are limited, impractical or already past, requiring us to think small. There is growing evidence that substantial fractions of native bee communities can persist in habitats that have been modestly altered, or are even drastically changed, by human activities (Minckley et al., in press).

Although conservation of pollinators can occur in a landscape mosaic, large-scale conversion of natural areas to croplands can cause marked changes in pollinator faunas. Since native resident pollinators can play a large role in crop pollination under certain conditions, changes in their populations can significantly diminish crop production. Concern for pollination services might never have arisen if farms had remained small and highly diverse, but since the rise of large-scale intensive agriculture several crops grown under such conditions have shown severe pollination deficits. Below are some examples where monitoring helped identify the effects of pollinator declines on crop production.

Case example 12 – passion fruit in Kenya

A large commercial grower uprooted passion fruit plantations when yields were much lower than those achieved by smallholders, whose pollinator population had remained intact because of their diverse farming practices (Kakazi Farm staff, personal communications to B Gemmill).

Case example 13 – pollination of passion fruit in central America and Asia

Passiflora edulis, passion fruit, is the most successful commercially grown species of 500 species within that genus. It is largely self-sterile and requires pollen to be moved between flowers or from plant to plant. The large flowers are visited by bees, other insects, some hummingbirds and birds called bananaquits. Larger bees (e.g. *Ptiloglossa* and *Xylocopa*) are the most efficient pollinators (increasing out-crossing, fruit set, size and yields) in both north and the south countries. Carpenter bees (*Xylocopa*) are the predominant pollinators in Asia. Mardan created a novel and versatile observation and nesting domicile (a kind of 'multiple comb' nest box) for carpenter bees, for use in passion fruit orchards in peninsular Malaysia (Roubik, 1995).

Case example 14 – melons in the US

On melon farms in the western US, wild bee communities become less diverse and abundant as the proportion of natural habitat surrounding farms declines. The most important species for crop pollination tend to become locally extinct throughout large parts of the landscape. More resistant species do not compensate for the loss of more sensitive species (Kremen et al, 2004). Only farms near natural habitats sustain communities of pollinators sufficient to provide the required pollination services (Kremen et al., 2002).

Distance from natural habitats affected pollinator communities and services in a similar way on coffee in Costa Rica (Ricketts et al., 2004, Ricketts, 2004).

Specialised pollinators, imported from a crop's centre of origin, may be required for some crops, as a natural service harnessed through agricultural research.

Case example 15 – oil palm weevil – Africa/Malaysia

The oil palm is native to West Africa and is pollinated by wind. The high commercial value of its oil has led to its introduction into many regions of the world. Malaysia was the first country (1917) to embark on large-scale planting and processing of oil palms. Twenty-five years ago newly established oil palm estates in SE Asia were not producing fruit. Failure was blamed on heavy rains in the region. To make the plantations productive hundreds of local people were employed to pollinate the palms by hand. This costly process was required to obtain a crop, but yields were still far smaller than in Africa. Studies in West Africa revealed that a specialised beetle, *Elaeidobius kamerunicus*, was responsible for pollination through disturbing the anthers so that the pollen could become wind-borne. Following intensive screening tests and clearance to import the beetles into Malaysia, a captive-breeding programme began. Within a year of its release in Malaysia, the weevils had spread throughout the entire Peninsula and impressive increases in yields ensued. Malaysia and Indonesia are now the world's leading producers of palm oil. Malaysian palm oil output in 1982 alone increased by 400,000 tonnes and palm kernels by 300,000 tonnes, with a total value of US$370 million (www.bionet-intl.org/case_studies/case14.htm). Management practices can play a key role in maintaining biodiversity of native pollinators who in turn provide 'free' services (Kremen et al., 2002; Mayfield, 1999).

Chinese woman pollinating apple blossoms by hand. *(Photograph by U Partap)*

Several pollinators can become invasive alien species. There are numerous documented introductions of bees (Snelling, 2003; Cane, 2003). The best known is the honey bee, which is indigenous to Europe and Africa (several other honey bee species occur in Asia) and has been introduced to many other regions of the world for honey production and pollination. Bumblebees, which are mostly endemic to the northern hemisphere, have been introduced to several countries, often for greenhouse pollination. The effects of invasive bees are variable. In California, the tendency of honey bees to forage on introduced weeds and crop plants may limit their impact on generalist native bees (Thorp, 1996). In other situations, honey bees are adequate pollinators of obligate out-crossing native plants and they displace native bees (Gross, 2001; Paton, 1996; Roubik, 1996). Naturalised leafcutter bees (*Megachile* spp.) are more specialised in pollen collection and nest site requirements, and overlap significantly with native bees in both resources.

Case example 16 – invasive carder bee

The spread of invasive bees can be rapid. A European carder bee (*Anthidium oblongatum*), first detected in the 1990s along the east coast of North America, crossed the Appalachian Mountains and moved into the interior of the US by the year 2000 (Miller et al., 2003).

1.2 Assessing the economic value of pollinators

There is a critical need to obtain better estimates of the economic value of pollinator services to convince policymakers of the importance of conserving them. Currently no reliable estimates are available.

1.2.1 Assessing monetary value of pollination services in agro-ecosystems

For crops, economic valuation of pollination services would appear simple, but estimates often do not consider the benefits also gleaned from maintaining refuges for native pollinators. Such refuges may also harbour biological control organisms and structurally support biological diversity that may contribute to preventing soil erosion and maintaining watersheds. The common commercially available pollinator, the honey bee, is often given credit, or assumed to be the only pollinator of many commercial crops. This is often incorrect. It is difficult or impossible to assign values for pollination services when mixed honey bee and other pollinator species contribute different amounts to the ecosystem service. Certain crops, such as those with poricidal dehiscence (i.e. buzz pollinated – e.g. tomato, cranberry, blueberry, chili peppers, kiwi fruit) must be sonicated to release their pollen. Honey bees are incapable of pollinating such crops (Buchmann, 1983).

The conservation community has made several attempts to estimate global valuations of ecosystem services (Costanza et al.,1997), but their attempts have met with various degrees of criticism. Nevertheless there is a growing interest in ecosystem service valuation and payment for ecosystem services. Pollinators move between human-dominated ecosystems and wild ecosystems, bringing direct and indirect benefits to agricultural systems while foraging to rear their progeny. Rather than global estimates, what are needed are small focused estimates on a farm, regional or watershed scale which consider the balance between the value of maintaining pollinator habitat and more conventional farm management. This will require simple economic assessments that can be used by extension agents and land managers themselves to weigh options in pollinator conservation.

Case example 17 – economic value of pollination in the US

In the US alone, the annual value of honey bee pollination on the 100 most significant agricultural crops is estimated at US$1.6–9.0 billion (Robinson et al., 1989, Southwick & Southwick, 1992). Estimates of the global annual monetary value of pollination range from $120 billion for all pollination ecosystem services (Costanza et al., 1997), to $200 billion for the role of pollination in global agriculture (Richards, 1993). The wide variation in these figures is a reflection of the different ways of valuing pollination services and does not differentiate between pollination services provided by native and non-native species on the same crop. Estimates of the value of pollination exist for many countries; e.g. Carreck & Williams (1998) for the UK, and Johannsmeier et al. (2001) for South Africa.

Case example 18 – coffee in Costa Rica

An economic evaluation of pollination services from tropical forests demonstrated that 7% of coffee production, $62,000, came directly from the pollination services provided by adjacent forests (Ricketts et al., 2004). The pollination value of tropical forests is likely greater than other land uses for which forests are often destroyed. Cattle pasture, for example, yields about $24,000 a year, less than half the value of pollination services for coffee.

Recommendation 3 – how to value pollination

For many agricultural crops, there have been no rigorous assessments of how much production depends on pollinators, which ones are self-compatible, or the relative contributions of various pollinators. Research on ways to increase production through improved pollinator management and on varieties of crops that benefit from pollination are needed to ascertain the added value due to pollinators.

Case example 19 – pollination as a vocation in Canada

The value of pollination for alfalfa seed growers in the Canadian prairies is 35% of the crop. Generally, seed growers and pollinator providers (Megachile culturalists) share the cost and benefit risks. In Saskatchewan, Manitoba, and Alberta, about 30,000ha of alfalfa seed was grown annually in 1999 and 2000, with yields of about 200–800kg/ha worth Can.$0.50–0.75/kg. Therefore the annual value of alfalfa pollination services in these provinces was Can.$2 million (Blawat & Fingler, 1994).

The value of pollination by honeybees to agriculture has been estimated to exceed the value of hive products by about eight- to ten-fold. The value of pollination to the sustainability of natural terrestrial ecosystems cannot be estimated because without pollination many ecosystems would change drastically. In agriculture, published valuations of pollination do not include economic analyses that embrace market forces, supply and demand, and trade. Kevan and Phillips (2001) attempt to provide a simple model of the economic effects of declines (or increases) in pollination services. In short, market forces tend to keep farm gate prices somewhat stable on average because if a crop is in short supply the price increases, but if it is abundant the price declines. These price changes are passed on to consumers. The profits to merchants tend to remain stable. Major stresses to farmers occur in regions that suffer poor crops while other regions have a bumper crop, and again if bumper crops cause a glut on the market, prices often fall below costs of production. The latter situation may be adversely affecting coffee production (S Buchmann, personal communication to C Eardley).

1.2.2 Assessing plant dependence on pollinators in natural ecosystems

It is difficult to put a value on environmental health. Just as pollination is pivotal to agriculture for quantity, quality and diversity of foods, fibres and medicines, it is also essential for the functioning and long-term maintenance of natural ecosystems, and for maintaining biological diversity. Some ecosystems have a greater proportion of animal-pollinated plants than wind-pollinated. On the other hand, the great boreal Carolinian forests of Canada, which encompass a significant part of Canada's land surface, comprise mostly wind-pollinated trees. The African savannah, although predominantly grassland (grasses are wind-pollinated), has many animal-pollinated flowering plants. Although the monetary value of pollinators in natural ecosystems cannot be accurately measured, their importance in maintaining wild plant abundance and diversity should be appreciated by land managers and policy makers alike.

Case example 20 – rare plants

Pollination services may be critical for conserving rare and endangered species. Of 35 rare plants in the western US, only two do not require pollinators to reproduce. This suggests that pollinators are vital to the reproductive success of most rare plants (V Tepedino, personal communication to T Griswold). For rare and endangered rangeland plants of the southwestern US, pollination and fruit set may be impacted by insecticidal spraying for grasshoppers, or by focusing only on protecting plants with little or no concern for their pollinators that may live or nest some distance away (Tepedino et al., 1997).

Case example 21 – rare Hawaiian lobelias

The native forests of Hawaii used to contain many species of rare and unusual plants. Some of the most bizarre flowers included the lobelioids (genera including *Lobelia*, *Clermontia* and *Cyanea*), which were pollinated by native birds whose beaks matched the length and curvature of the floral corollas. Deforestation, habitat alternation and avian malaria have caused many bird populations to decline and some to go extinct. As a result, many Hawaiian lobelioids are now without their primary and most dependable avian pollinators (Carlquist, 1980).

Case example 22 – durian

In the Old World tropics, flying foxes (bat family Pteropodidae) are important pollinators of fruit trees, including durian, petai and jambu, which are economically valuable in Malaysia, Thailand and Indonesia. An important tree species in the mangroves is beremban (*Sonneratia* species), which flowers at night throughout the year and provides food for three different bat species. The mangroves also provide roosting sites for these bats. Durian only flowers once or twice a year, but because the bats feed upon beremban year round they are available to pollinate the durian crop. With vast areas of mangroves being deforested, and bats being killed for sport or food or because they are believed to be agricultural pests, the durian industry is threatened (www.batcon.org/batsmag/v6n1-2.html).

1.3 Assessing capacity, resource and research needs

Pollinator assessment requires basic knowledge of pollinator biology, floral biology and the correct identification of pollinators and their floral hosts.

Case example 23 – African literature review

Literature on pollination is scattered in speciality journals and reports, and therefore is often not readily available. A central updated repository, or linked repositories, would greatly facilitate pollination research and economic analyses. Rodger, Balkwill and Gemmill (www.elci.org/api) have provided a literature review of the publications on pollination biology in Africa, with thematic and geographic analyses.

1.3.1 Taxonomy

Accurate genus and species identifications are essential for understanding pollination (Cane, 2001). Identifications of principal pollinators are severely hampered by a shortage, in all countries, of taxonomists (O'Toole, 1996, analysis for Europe) and a dearth of modern identification keys, catalogues, automated identification technology and revisionary studies. (Revisions are comparative studies of all the species in a group and include identification tools. They prevent duplicate naming of the same species and facilitate species identifications.) The taxonomic impediment is greater for invertebrate animals than for vertebrates because of their greater diversity. O'Toole (1996) discusses the need for taxonomic research in the bees. Michener (2000), a recent comprehensive revision of the genera and subgenera of bees of the world, is an excellent reference for this large and important group of pollinators, summarising the state of knowledge on bee systematics. It provides a common taxonomic framework worldwide and a platform for catalogues and species level revisions needed for conservation-related studies of bees. Similar references are needed for other insect pollinator groups.

Case example 24 – species-rich bee genera in need of taxonomic revisions

In the US, 81% of the bee genera have been revised, in Mexico 58% and in Costa Rica 27% (Ayala et al.,1993). These figures suggest that the taxonomy of Nearctic bees, one of the better studied bee faunas, is in good shape. However, the vast majority of US bee diversity (80%) is concentrated in 20 of the 119 genera; two genera account for 30% of the fauna. Eleven of the 20 genera need revision.

Many insect pollinators are known from one sex or from a very few specimens. It is also difficult to know whether species are threatened or naturally rare. Distributions, yearly abundances, population fluctuations and true rarity should be more thoroughly studied.

Case example 25 – species known from only one sex

The tribe Anthidiini, carder bees, is a diverse, cosmopolitan group, particularly diverse in sub-Saharan Africa. A recent comprehensive study for sub-Saharan Africa (Pasteels, 1984) might suggest a well-known fauna, but a closer inspection reveals a bleak picture. Of 162 sub-Saharan species, 31% are known from a single specimen and 57% are known from one sex; the other sex awaits discovery. Knowledge of their taxonomy, distribution and biology is therefore rudimentary and far from complete.

Catalogues of pollinators have the potential to provide ready access to knowledge on the biology, distribution, and taxonomy of constituent species. Current coverage is very incomplete. For example, the only worldwide catalogue of bees is over a century old (Dalla Torre, 1896). Recent regional catalogues are available for Australia (Cardale, 1993) and central Europe (Schwarz et al., 1996).

Recommendation 4 – electronic catalogues

Printed catalogues quickly become outdated. The catalogue of bees for America north of Mexico (Hurd, 1979) is now 26 years old. A solution is electronic catalogues, which can be hosted on internet servers and rapidly updated. Such bee catalogues are being developed for most of the world. Significant progress has been made in interchangeability, standardised formats and electronic dissemination. Global and regional checklists of pollinator species are becoming available as authoritative references (ITIS, HymenopteraBase, Species 2000 and ITIS Catalogue of Life). These efforts should be expanded to include all pollinator taxa and all geographic regions. Electronic systems enable species names to be linked to other electronic data, such as bibliographies, spatial (GIS) data and specimen databases. At some museums (e.g. University of Kansas, Lawrence; US National Pollinating Insects Collection, Logan) specimen databasing is well under way.

Computer-aided systems using image-processing techniques and non-linear classification procedures show promise for providing rapid results to diverse users at remote locations without the need for extensive training in taxonomy, extensive museum reference collections or expensive equipment. Initiatives exist for creating ‘virtual type specimens’ (so-called e-types: high resolution images of type specimens at different angles and magnifications – type specimens are single specimens set aside as the ‘blueprint’ for a species) and can be found at the American Museum of Natural History, Harvard University (for insects: http://mcz-28168.oeb.harvard.edu/mcztypedb.htm), California Academy of Sciences (for ants: www.antweb.org/) the Missouri Botanical Gardens (for plants and herbarium sheets: www.mobot.org, and http://mobot.mobot.org/W3T/Search/image/imagefr.html), and others. These reduce the need to mail precious and irreplaceable specimens.

Case example 26 – semi-automated identification systems

Software exists (e.g. Discover Life, Lucid, Expert Centre for Taxonomic Identification – ETI) for generating illustrated, interactive electronic keys (these are called semi-automated identification tools; image analysis and DNA bar coding are automated identification tools). These techniques have advantages over traditional identification methods (e.g. hardcopy dichotomous keys). First, they are multi-entry, enabling users to select what they consider to be distinct features. Second, illustrations are easily associated with character states. Third, they are easily updated. Few such keys exist for pollinators, but one has been developed for North American bumblebees and some eastern US bees by Droege and Pickering (www.discoverlife.org/nh/tx/Insecta/Hymenoptera/Apoidea/).

Some automated identification tools have been developed. Notably, the Automated Bee Identification System (ABIS), developed by workers at Bonn University in Germany, recognises wing venation patterns from digital images of bee wings. Another pattern-matching software for bee wings is DAISY (Digital Automated Identification System – The Bee Works, Tucson, AZ). Molecular biology is also offering solutions for automated identification. The Barcode-of-Life project (www.barcodinglife.org/) uses DNA nucleotide sequences to distinguish species of many organisms, including insects. Indeed, C Sheffield, P Hebert and P Kevan have demonstrated that each species of bee from Nova Scotia has a unique genetic bar code (P Hebert, personal communication to C Eardley).

Recommendation 5 – image identification

Image recognition has been demonstrated to be reliable for bee identification, using digitised images of forewings (www.informatik.uni-bonn.de/projects/ABIS/). Such systems are needed, and it is hoped that the software will soon be available to researchers.

1.3.2 Faunal studies

Properly designed faunal studies are needed that include comprehensive sampling of pollinator communities, provide detailed information on spatial and temporal pollinator distribution and abundance, and elucidate plant–pollinator relationships. Communities of pollinators are dynamic in time and space, with some being active as adults for only a few days or weeks. Although numerous faunal surveys have been conducted, few have used standardised or statistically comparable methodologies and thus may be of limited value for long-term monitoring (Michener 1979; Williams et al., 2001). Exceptions are long-term studies of orchid bees (euglossines) in Panamanian tropical forests (Roubik, 2001) censused at chemical baits, and nocturnal tropical bees at light traps on Barro Colorado Island (Roubik & Wolda, 2001; Wolda, 1992). In Europe and the US, groups of scientists have formed ad hoc groups to standardise evaluation protocols and sampling methods for native bees (www.alarmproject.net & http://online.sfsu.edu/~beeplot/).

Case example 27 – faunal studies

Williams et al. (2001) analysed 48 bee faunas. They found that local bee faunas are mostly diverse, highly variable spatially and temporally, and frequently rich in rare species.

For most areas of the world there simply are no baseline data for pollinator populations, or studies conducted over enough years to reveal true declines.

Recommendation 6 – faunal surveys

Pollinator censuses should be continued for periods of at least four years and ideally more, with standardised sampling effort.

Recommendation 7 – faunal studies and monitoring

Well designed faunal studies or assessments could serve as a form of monitoring. This might require concentrating on components of a fauna with characteristics that make them conducive to long-term monitoring. Such attributes will include species that are abundant, easily monitored (e.g. wood-nesting bees that use trap-nests) or floral specialists, since focused monitoring on the pollen plants minimises sampling effort (J Cane, personal communications to B Gemmill).

Recommendation 8 – ecosystem faunal surveys

Faunal surveys of representative habitats in major ecosystems of the world should be conducted. They should be designed to supply regional pollinator patterns of abundance and diversity; baseline data for long-term monitoring; material of known species and new species for taxonomic studies; plant relationships and basic information for selecting crop pollinators; and details on species abundance through time and across space. Data should be collected and recorded in a way that enables retrieval by other researchers.

1.3.3 Pollinator–plant relationships

Asymmetry in plant–pollinator relationships appears to be typical (Vázquez & Aizen, 2004). Seldom do pollinator species visit a single plant species. Similarly, few plant species are visited by just one pollinator. The predominant pollinator may change between seasons and between sites. Further, pollinators differ in their efficacy. Sometimes the most abundant flower visitor provides fewer pollination services than a less common visitor. Therefore the whole pollinator guild for each plant species, and similarly the whole plant guild for the pollinators, needs to be understood for the conservation and sustainable use of biological diversity, including agricultural biodiversity.

Causes of knowledge gaps in pollinator–plant relationships are insufficient sampling intervals across the entire flowering season, poor coverage of different habitats and geographical areas and inadequate survey durations. Faunal and plant–pollinator studies are concentrated in a few regions, while there is little knowledge about major parts of the world.

Recommendation 9 – pollinator–plant relationships

Further observation and targeted research into a deeper understanding of pollinator–plant relationships are desperately needed.

1.3.4 Pollinator life histories and nesting habits

Knowledge of pollinator life history is often essential for conserving pollinators and managing pollination. Basic information needs for bee conservation include nesting sites, substrate (dead wood, stems, soil, etc.), building materials (mud, leaves, resin, fibre) and food plants. Some specialist pollinators have very short active seasons and these may be finely timed to coincide with their host plants' flowering time. Generally, bees that nest in hollow sticks or bore holes in wood are easier to manage. For many bats, access to caves with appropriate characteristics, such as cave entrances, ceiling height and internal topography, is limited.

Summary of recommendations for assessment of pollinators and pollination services

Assessing the state of pollination services

- Develop protocols for monitoring and assessment. Existing initiatives need to be refined and tested. Their use in Long Term Ecological Research sites and biosphere reserves for the development of long-term baseline data should be considered.
- Improve knowledge of the specific resource needs of key pollinators to enable better management of the habitat characteristics that help maintain their populations. Studies on fragments, as reserves, may generate data and practical insights of critical importance for pollinator conservation.

Assessing the economic value of pollinators

- Undertake rigorous assessments of agricultural crop pollinators – how much production depends on pollinators, which ones are self-compatible, and what are the relative contributions of different pollinators.
- Research ways to increase production through improved pollinator management of varieties of crops that benefit from pollination. This can be used to ascertain the added value due to pollination.

Assessing capacity, resource and research needs

- Produce electronic catalogues, hosted on internet servers, and regularly update. Use interchangeable, standardised formats designed for electronic dissemination. Build onto existing global and regional checklists of pollinator species and expand these to include all pollinator taxa and all geographic regions.
- Develop semi- and fully automated specimen identifications systems and make software available to researchers.
- Conduct pollinator censuses, at regular intervals, lasting at least four years, and standardise sampling.
- Conduct formal surveys of representative habitats in major ecosystems of the world. They should be designed to supply regional pollinator patterns of abundance and diversity; baseline data for long-term monitoring; material of known species and new species for taxonomic studies; plant relationships and

basic information for selecting crop pollinators; and details on species abundance through time and across space. Data should be collected and recorded in a way that enables retrieval by other researchers.
- Undertake further observation and targeted research into a deeper understanding of pollinator–plant relationships.

2 Adaptive management of pollinators for crop plants and wildlife

This chapter is primarily focused on key issues related to adaptive management of pollinators and ecoystems. It deals with conservation measures, rehabilitation of landscapes, targeted research programmes and finally animal husbandry. These form part of a total reiterative management cycle of assessment (Chapter 1), policy and planning, implementation, capacity building (Chapter 3), mainstreaming (Chapter 4) and monitoring and review.

The expanding awareness, understanding and value of the multiple goods and services provided by pollinators can help make forest and agriculture more sustainable and improve productivity in agroecosystems. The technologies that promote the positive and mitigate the negative impacts of humans on pollinator diversity need to be identified and conveyed to the agricultural and forestry communities.

Pollinator-friendly agriculture and natural ecosystem management requires

- identification of interactions between pollinators and plants that support effective pollinator functioning.
- conservation of natural areas needed to optimise pollinator services.
- development of active pollination management technology, such as megachileculture (raising leafcutter bees), bombiculture (rearing bumblebees) and meliponiculture (managing stingless bees).
- development of plant lists for nectar and pollen (food plants) for various regions, including larval host plants for butterflies and moths.

2.1 Conservation measures

Agroecosystems and wild lands may be losing the pollinator communities that are critical to their productivity. There are well-documented losses of pollinators (Buchmann

& Nabhan, 1996). It is evident that there are losses of vertebrate pollinators but it is also suspected that invertebrate pollinators are being lost. Loss of native pollinators can result from habitat loss, a shortage of bare ground for nesting caused by alien plants, and the insidious effects of invasive alien pollinators.

Case example 28 – habitat loss in Asia

The International Centre for Integrated Mountain Development (ICIMOD) has carried out research on pollination and associated productivity of mountain crops over the past decade. The project has identified loss of habitat and the associated decrease in food and nesting sites for pollinators, resulting from the expansion of farming into forests and grassland areas, as a major cause of decreased mountain crop productivity. As a result of their findings, the project is making efforts towards conservation of pollinators through raising awareness among farmers and policy makers (Partap & Partap, 2002; Ahmad et al., 2002).

Case example 29 – indicator species in Brazil

Central and South American native bee populations are declining in several disturbed habitats, including fragmented natural ecosystems. Lima-Verde and Freitas (2002) identified *Melipona quinquefasciata* as an indicator of stingless bee habitat loss. They mapped its distribution in fragmented ecosystems on the northeastern Brazilian plateaus. Knowledge about the bee species and its habitat now enables conservation measures to prevent this stingless bee species from going extinct. These measures include reducing firewood gathering and agricultural expansion, which destroy the ecosystem needed for ground-nesting bees and their floral host plants.

Case example 30 – persistence in a farming system

Marlin and LaBerge (2001) demonstrated that although land uses and land cover in Macoupin County, Illinois (US) have changed during the past two centuries, the bee community in the early 1970s resembled that found at the turn of the century. The diversity persisted probably because diverse habitats within the heterogeneously used agricultural matrix contained the variety of host plants and nesting sites required by the bees. On the other hand, farming began in Illinois long before the first survey and the modern fauna may reflect the survivors of an already depauperate bee fauna, as there is no baseline data for Illinois bees pre-settlement. Advice given for land management was maintenance of diversity in land use, including the retention of natural areas, hedgerows etc.

Loss of pollinators can also result from the spread of disease, or invasive alien species.

Case example 31 – honey bee regulations in New Zealand

New Zealand has strict quarantine measures to prevent the introduction of undesirable organisms. The movement of hive bees between North and South Island is strictly prohibited to halt the spread of *Varroa* mites. Although the honey bee is exotic to New Zealand, it is an important agricultural pollinator.

A quarantine sign at the Port of Wellington, New Zealand, where vehicles queue to board the ferry service to the South Island. *(Photograph by CL Gross)*

Case example 32 – invasive bumblebees around the world

Recent concern about invasive alien pollinators has focused on planned introductions of *Bombus terrestris*, a European bumblebee widely used for pollinating greenhouse crops, such as tomatoes, in other areas. Colonies have been exported to Japan, Israel and Chile (*Bombus ruderatus* in this example), and have subsequently naturalised in these regions. In Israel, feral *Bombus terrestris* colonies are a significant ecological threat, with populations of several native bees, including native *Apis mellifera*, showing significant declines (Dafni, 1998). Bumblebees forage widely (5km from nests), are more efficient at exploiting limited nectar resources, and cause significant reduction in seed production of their nectar plants. The result of this lowered reproductive output of indigenous flora is reduced post-fire regeneration (Dafni & Schmida, 1996). More recently *Bombus terrestris* has been deliberately introduced into Mexico, and accidentally introduced into Tasmania, which poses a threat to Australia. If it becomes established in North America, it is plausible that it will expand to include the range of closely related native *Bombus*. Possible negative outcomes include introduction of diseases (e.g. *Nosema* and *Crithidia*), parasites and competition for floral resources with native bumblebees (Imhoof & Schmid-Hempel, 1998). For example, in Tasmania, *Bombus terrestris* has invaded most of the island (Hingston et al., 2002) and is associated with increases in seed production in weeds (Stout et al., 2002). To avoid the introduction of a species that can become invasive, efforts are under way in Colombia to breed native *Bombus* species for greenhouse pollination (D Wittman, personal communication to T Griswold).

Recommendation 10 – avoid importation of exotic pollinators

The importation of exotic species should be a last resort. First try to manage indigenous species and never import species that are known to become invasive. Before any exotic species are imported ensure that appropriate risk analysis and cost/benefit studies are undertaken, as in the case of oil palm pollinators (Martins et al., 2003).

2.2 Rehabilitation of landscapes

Loss of habitat through land use changes, e.g. due to conversion of natural areas to agriculture, mining or urban development, has been identified as the principal cause of pollinator decline. Farmers can be encouraged to restore some of their farmland to forest or grasslands, road planners can ensure roadsides and infrastructure servitudes are reseeded with pollinator-friendly plant species, and urban planners can be encouraged to consider native floral diversity in parks.

Case example 33 – bees prefer gardens in North America

In urban areas in the US, cavity-nesting large carpenter and leaf cutter bees were more ubiquitous at flowers of *Larrea tridentata* (creosote bush), growing within Tucson, Arizona, than at flowers in the outlying desert. This is probably because older residential neighbourhoods offer more woody nesting substrates than the scrub desert (Cane, 2005, Cane et al., in press).

Case example 34 – floral diversity in Japanese gardens

Sakagami and Fukuda (1973) sampled two sites in Japan, one in the city's Botanical Garden and the other on the University of Hokkaido campus. The nine-hectare Botanical Garden contained a mixture of natural and exotic plant species. The University site was 150ha and contained primarily native vegetation. Both were isolated from continuous tracts of natural vegetation by the city. Despite its smaller size, the Botanical Garden yielded one-third more native bee species, perhaps a response to increased floral diversity.

Recommendation 11 – maximise floral diversity

Abundance and diversity of pollinators can improve pollination (Steffan-Dewenter et al., 2003). Because crops generally have limited flowering periods, maximising the floral diversity in the ecosystem will help maintain the abundance and diversity of pollinators for adequate pollination of crops – and wild plants. The assemblage of flowering plants that will maintain pollinators should include those with a variety of floral structures and long, overlapping blooming periods. Modern hybrids should be introduced with caution because they often have inadequate pollen and/or nectar since plant breeders do not select for these.

Increased productivity and sustainable land use should be sufficient incentive for sustaining pollinator species and numbers, but government incentives should encourage this process. Although not necessarily targeting pollination per se, such incentives are increasingly becoming part of national policies (e.g. the Conservation Reserve Program of the US Department of Agriculture and the Agri-Environmental Scheme in Europe – see next case example). The use of pesticides or other agrochemicals may cause pollinator declines. Here rehabilitation strategies should focus on using other methods of pest control, such as biological control and integrated pest management (Case example 62). Farmer knowledge can be increased through educational organisations such as farmer field schools, agricultural extension agents and agricultural colleges.

Pollinator restoration and the management of native pollinators are in their infancy. It may be necessary to reintroduce native pollinators. This is not easy, and procedures for doing so are largely unexplored.

Case example 35 – European Union (EU) Agri-Environmental schemes

The EU Agri-Environmental schemes are to encourage farmers to carry out environmentally beneficial activities on their land and to enhance biological diversity, including pollinators. The cost to the farmer of supplying these environmental services is compensated through payments. The types of land management activities encouraged include

- conversion of intensively used land to biologically diverse, yet commercially profitable, lands.
- reduction in the use of synthetic fertilisers.
- reduction or cessation of pesticide use (organic farming and no-till agriculture).
- creation of nature zones not used for production. Planting of wildflower mixes or use of blooming cover crops that can later be ploughed under as green manure.
- continuation of traditional land management in areas likely to be neglected.
- maintenance of landscape features that are no longer used for agriculture.

The EU applies agri-environmental measures that support farming practices specifically designed to help protect the environment and maintain the countryside. Farmers commit themselves, for a five-year minimum period, to adopt environmentally-friendly farming techniques that go beyond the usual good agricultural practice. In return they receive payments that compensate for additional costs and loss of income that arise as a result of altered farming practices. Examples of commitments covered by national/regional agri-environmental schemes are

- extending environmentally favourable farming.
- management of low-intensity pasture systems.
- integrated farm management and organic agriculture.
- preservation of landscape and historical features such as hedgerows, ditches and woods.
- conservation of high-value habitats and their associated biodiversity.

Agri-environment measures have become the principal instrument for achieving environmental objectives within the Common Agricultural Policy. In 2003, 15 EU member states were participating in the EU Agri-Environmental Schemes, including 900,000 farms encompassing 27 million hectares, or 20% of EU farmland (http://europa.eu.int/comm/agriculture/envir/index_en.htm#measures).

Case example 36 – conversion of crop lands in Asia

In a few mountain areas of China since 1999 the government has initiated programmes encouraging the conversion of croplands by farmers to forests and grasslands (L Shilei, personal communication to C Gross). Such programmes may help restore pollinator populations and improve natural ecosystems.

Case example 37 – cacao in tropical America

Diminished biodiversity in agroforestry cropping systems has reduced effective pollination of cacao (*Theobroma cacao*) in Central and South America (especially Costa Rica and Brazil). Overly fastidious management ('cleanliness') of plantations included the removal of rotting vegetation, the substrate in which the pollinating midges undergo larval development (Winder & Silva, 1972), and yield reductions ensued. Purposeful replacement of appropriate plant materials such as palm trunks (Ismail & Ibrahim, 1986) will restore adequate pollination by fly pollinators – various midges.

Case example 38 – soursop in Brazil

Soursop (*Annona muricata*) is a tropical fruit crop pollinated by beetles that use its flowers for food, protection and finding mates (Webber, 1996). In Brazil, the number of pollinating beetles in commercial orchards is usually inadequate and growers need to hand-pollinate flowers to ensure adequate fruit set and reduce malformation in fruit. Currently, the highest quality fruits result from the labour intensive and costly practice of hand-pollination. The shortage of pollinators is due to ploughing and herbicide use, which eliminate the short grass in orchards, the roots of which are the only source of food for the pollinator's larvae. Stopping the use of herbicides and ploughing, and introducing mowing to control the grass, increased and maintained pollinator numbers to satisfactory levels (Aguiar et al., 2000).

Case example 39 – butterfly adult and larvae plants

Vegetation for butterflies and moths must include nectar plants and foliage planted for their larvae. No caterpillars feeding on foliage results in no adult butterflies and moths later in the season. The concept of 'partial habitats' (Westrich, 1996, Tepedino et al., 1997) is broadly applicable to insect pollinators. Immature stages of invertebrate pollinators are difficult to locate and impractical to sample, but their requirements must be understood and met when classifying habitat diversity, mapping habitat fragments, evaluating habitat change or restoring degraded lands.

Recommendation 12 – reversal of pollinator depletion

Because many pollinators are highly mobile, in areas where they have been depleted their losses are usually reversible in carefully planned rehabilitation programmes. This is easier when they are adjacent to natural habitats with intact pollinator populations. Restoration of vegetation must include the correct nectar and pollen host plants for the pollinators under consideration. Nesting materials, which may include *inter alia* plant resins, leaves, mud, sand and dead trees (containing beetle burrows) may have to be provided.

In healthy natural ecosystems and diverse, low intensity, agroecosystems pollination is usually considered to be a 'free service' – the cost of this 'free' service being the maintenance of a diverse ecosystem. Where pollination services are inadequate, pollination management may be required. There are a number of potential approaches, and targeted research may be needed to identify the correct one. These approaches are discussed in Matheson (1994).

2.3 Targeted research programmes

Targeted research is research designed to address specific concerns. For pollinator biodiversity conservation, it should address issues such as the diversity of pollinators in an ecosystem, their nest and host plant requirements, and their roles as pollinators.

Case example 40 – apple pollination in India

In the Himachal Pradesh Province, in the Indian Himalayas, apple productivity declined continuously for several years because of inadequate pollination. Farmers now use honey bees (*Apis mellifera* or *Apis cerana*) to pollinate the apples. Some farmers keep their own honey bees, while others rent them from the Department of Horticulture or from private beekeepers. At present only Himachal Pradesh, in the entire Hindu Kush–Himalayan region, has a well-organised pollination system. This large-scale use of honey bees has led to a new vocation. The success of this enterprise resulted from targeted research into apple pollination by honey bees.

Case example 41 – managing indigenous pollinators

Australian government agencies have a long history of investigating the use of honey bees for pollinating crops. Recently, the use of native stingless bees (*Trigona* spp.) for macadamia and cucurbits, and the blue-banded bee, *Amegilla* spp., for pollinating tomatoes in glasshouses, has been instigated (Hoogendorn, Gross, Sedgely & Keller, in review). The latter is likely to overcome the need to introduce exotic bumblebees into Australia.

Case example 42 – passion fruit in Brazil

Passion fruit (*Passiflora edulis*) growers, especially on smaller farms in Ceará, Brazil, hand-pollinate their crops because the only efficient pollinator of its large flowers, the carpenter bee (*Xylocopa* spp), is rare in commercial orchards. Because the family work force is needed for other farm activities, many farmers have discontinued passion fruit production. Researchers at the Federal University of Ceará (Freitas & Oliveira-Filho, 2001) have developed efficient nesting boxes for large carpenter bees, and this has increased yield by 92.3% and made hand-pollination unnecessary. Similar technology has been developed in Mardan, Malaysia (reported in Roubik, 1995).

Case example 43 – alfalfa fields in North America

Although alfalfa is not native to North America, it is pollinated by a wide array of bees, especially solitary, leaf-cutting bees (*Megachile* spp.), of which the alfalfa leafcutting bee is a non-native cultivated species. Many leafcutting bees make their nests in tunnels left by wood-boring insects. In the 1940s, in parts of western Canada, farmers cleared land to join together parcels of small fields for alfalfa seed production. This practice reduced brush and wood piles, and the edge:area ratio of the fields. As a result, nesting habitat for native pollinators was diminished and alfalfa growing in the centre of large fields remained unpollinated. Seed yields overall per acre declined. In Manitoba, Stephen (1955) recorded yields of 1000 kg/ha from small fields, but only 15 kg/ha from large fields. The pioneering work of Bohart (1972) and Hobbs (1967) gave rise to the multimillion-dollar industry of 'megachileculture', whose huge economic benefits are described by Olmstead & Woolen (1987). Today, the problem of alfalfa seed production is largely solved by management of domesticated alfalfa leafcutting bees (*Megachile rotundata*).

Case example 44 – reducing pesticide use in Canada

The adverse effects of some pesticides on pollinators are well understood (Johansen & Mayer 1990). The effects of the organophosphorous pesticide fenitrothion on blueberry pollinators in New Brunswick, Canada, were a massive demise of the pollinators and an annual harvest loss of about 75% in the blueberry crop in the affected regions (Kevan, 1975, 1977; Kevan & LaBerge, 1979; Kevan & Oppermann, 1980; Kevan & Plowright, 1995; Kevan & Baker, 1999). This resulted in research into 'bee-safer' insecticides, and blueberry lands received a buffer where only these insecticides could be used (see also Case example 8).

Recommendation 13 – pesticide use

In assessing the impact of agro-chemicals on pollinators, the type, timing and methods of application of the pesticides should be considered. When applying any pesticide, or other agrochemical, strict adherence to safety (operator and pollinator) guidelines should be followed. Often less toxic alternative insecticides could be used. Honey bee colonies can be covered to keep foragers in their nests during spraying, or spraying can be done at night.

2.4 Promoting pollinator husbandry

Pollinator husbandry is the use of technology for keeping pollinators, mostly through the provision of nests and nesting material. The practices should include adequate nectar, pollen and/or larval host plants, and ensuring that nesting sites and nest-making materials are available. Flowering plants in the vicinity should be diverse, and have long and overlapping blooming periods. Care should be taken to avoid the use of toxic agrochemicals.

Case example 45 – indigenous honey bees in Asia

ICIMOD has an ongoing programme promoting the use of indigenous honey bees for pollination in India, Nepal and Pakistan. It includes training for farmers in managing honey bees for crop pollination.

Case example 46 – honey bees in Australia

A key objective of the Australian Government's Rural Industries Research and Development Corporation is to improve the productivity and profitability of the Australian beekeeping industry. While they do not directly train and educate apiarists, they provide key research results from targeted research and husbandry information via their web site (www.rirdc.gov.au/programs/hb.html). Their publications provide information on disease management and nutrition for bees. The mission statement of the Australian Honey Bee Industry Council is 'To maximize the efficient use of industry resources and funds to ensure the long-term economic viability, security and prosperity of the Australian honey bee industry' (www.zeta.org.au/~anbrc/index.html).

Case example 47 – native bees in Australia

Australian native bee ecology and husbandry received little attention until the advent of the Australian Native Bee Research Centre, a privately funded NGO. This organisation shares information on blue-banded bees (*Amegilla* spp.) and stingless bees (*Trigona* species) (www.zeta.org.au/~anbrc/index .html), among others.

Case example 48 – eastern honey bee for pollination

The Asian hive bee (Apis cerana), a cavity nesting species in the genus Apis, contains seven species (Engel, 1999). This Asian honey bee has been managed for centuries in Japan and China for honey and wax production. It pollinates *Cymbidium* orchids and has recently been managed for the pollination of other crops (Kevan 1995).

Recommendation 14 – pollinator husbandry

Pollinator husbandry is a mechanism for managing pollination. Where properly researched and implemented, it is highly effective and a form of job creation.

Summary of recommendations for adaptive management of pollinators for crop plants and wildlife

Conservation measures

- Avoid importation of exotic pollinators. First try to manage indigenous species. Never import species that are known to become invasive and, before importing, ensure that appropriate risk analysis and cost/benefit studies are done.
- Maximise diversity and abundance of pollinators to improve pollination, including floral diversity in the ecosystem. The flowering plants that will maintain pollinators should include those with different floral structures and long, overlapping blooming periods. Modern hybrids often have inadequate pollen and/or nectar.

Rehabilitation of landscapes

- Reverse pollinator depletion through carefully planned programmes. This is more successful in areas adjacent to natural habitats with intact pollinator populations. Vegetation must include the correct nectar and pollen plants and nesting materials.

Targeted research programmes

- The type, timing and methods of application of the pesticides are all-important for pollinator conservation. When applying any pesticide, or other agrochemical, follow safely guidelines. Often, less toxic alternative insecticides could be used.

Promoting pollinator husbandry

- Pollinator husbandry programmes can improve pollination and create employment.

3 Capacity building

Capacity building includes building human knowledge, skills and institutional capabilities, and it all begins with awareness. Human capacity building involves both formal and informal education, and scientific and technical training. Institutional capacity building involves developing networks and infrastructure and providing literature on how pollination as an ecosystem service contributes to ecological and economic well-being.

3.1 Pollinator and pollination awareness

In 1996, two independent events greatly stimulated awareness of the importance of conserving pollinator diversity: the Forgotten Pollinators Campaign, and the COP decision III/11 of the CBD, which established the multi-year Programme of Work on Agricultural Biodiversity, and placed pollination in its initial list of thematic areas. Subsequently, in 1998, an international workshop in Saõ Paulo, Brazil, was held, resulting in the Saõ Paulo Declaration on Pollinators. This Declaration was considered by the CBD’s scientific body (the Subsidiary Body on Scientific, Technical and Technological Advice, known as SBSTTA, in recommendation V/9), and subsequently the International Pollinators Initiative (IPI) was established by parties to the CBD (Decision V/5) (as explained in the Introduction). An element of the Plan of Action of the IPI is to raise public awareness about the value of pollinator diversity and the multiple goods and services pollinators provide. Awareness is needed to help citizens and policy makers recognise the economic and ecological value of pollinating animals, and the potential impacts of the loss of pollinator-related ecosystem services and functions.

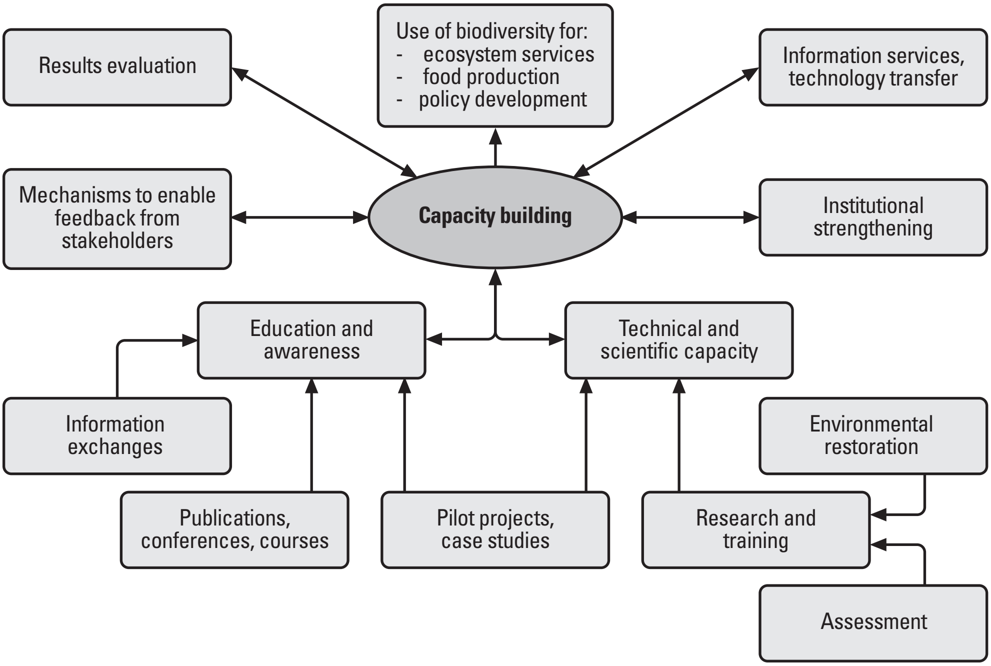


***Figure 2*. Diagrammatic illustration of the pivotal role of capacity building in pollinator biodiversity conservation.** *(Diagram by V Fonseca)*

Case example 49 – agave and tequila

Tequila is produced from agave, a bat-pollinated plant. Scientists have helped increase awareness of the importance of pollination to the tequila industry – hoping that such awareness will lead to improved management. Agaves are New World plants that typically die after sexual reproduction. They are very important plants for local and national economies. Leaf fibre is widely used for utility ropes, rugs, textiles, and many other domestic and industrial uses. When the plant starts to produce the blooming stalk, the centre of the plant increases its sugar content, and many cultural groups use this resource; in Mexico agaves have been used to produce alcoholic beverages, such as tequila and mezcal, for at least 700 years (Ramírez & López, 1985). In Mexico about 55,000 hectares are cultivated with agave (Valenzuela, 2003). To make tequila, the flowering stalk is cut off, thus preventing flowering and thwarting pollination. Agaves can also reproduce asexually, through vegetative bulbils that grow at the base of the main flower stalks after the plants have flowered, and only in the absence of pollinators. The presence of bulbils therefore indicates pollinator scarcity. Human-induced vegetative reproduction, poor varietal selection and a government requirement for a single commercial variety have resulted in little genetic variation in the agave used for tequila (Gil-Vega et al., 2001) and fibre (Colunga et al., 1999). The current varieties have suffered from infections from the fungus *Fusarium* and a root rot bacteria, *Erwinia carotovora*, which together have killed over 30% of the plants. The resultant shortage has increased the price of tequila. The limited genetic diversity of the agaves may have played a role in their susceptibility to infection. Sexual reproduction, via pollinators, is needed to increase the genetic diversity of commercially used agave plants. This may prove to be very important for the tequila industry, and points to the need for increased awareness and increased collaboration to address the maintenance of the genetic diversity of an important economic commodity (R Medellin, personal communication to C Eardley).

Several international networks for coordinating regional pollinator biodiversity conservation awareness and activities have been formed in response to the establishment of the IPI. These include the North American Pollinator Protection Campaign (NAPPC), the African Pollinator Initiative (API) and the European Pollinator Initiative (EPI). The following actions are suggested to help promote global awareness of pollinators and pollination and build capacity in pollinator conservation and restoration efforts:

- Disseminate high-quality and easy-to-understand information about pollinators and their conservation to a wide variety of audiences and users through a variety of media such as books, magazines, newspapers, pamphlets, electronic media, television and radio. (Children's books about pollinating animals can help inspire the next generation and influence future policies.)
- Establish educational outreach and training programmes, including programmes for indigenous communities. This is being done for stingless bees in Central and South America.
- Define criteria and use indicators to evaluate the status of, and threats to, agricultural production from potential, or actual, pollinator losses.
- Create and disseminate manuals for farmers, translated into their native languages, on pollinator conservation and restoration practices.
- Approach International Standards Organisations for certification of 'pollination friendly' products, for example 'bee smart' labels. Bees (honey bees and bumblebees) have already been used to good advantage on produce packaging in several countries.
- Ensure that pesticide labels address important pollinator safety issues to be observed during application and post-application.
- Develop business incentives (and remove disincentives) for pollinator conservation, as has been done in the EU Agri-Environmental Schemes (see Case example 35).
- Encourage national or international entertainment and scientific celebrities to lend their voices to pollinator conservation.

Case example 50 – the Forgotten Pollinators Campaign and book

In 1994 S Buchmann and G Nabhan founded and directed the Forgotten Pollinators Campaign, which ran until 1999, from the Arizona-Sonora Desert Museum (ASDM) in Tucson, US. An integral part of this highly effective tri-national campaign (US, Canada and Mexico) was on-site educational exhibits (outdoor pollinator gardens and signage) about Sonoran Desert pollinators (bees, birds, bats, butterflies, flies, moths and wasps). Individual pollinator gardens were created, and they continue to inspire and educate people on pollination. (The site receives over 400,000 visitors annually.) The Campaign hosted symposia and workshops, published newsletters and academic books, and set up a website. The Forgotten Pollinators Campaign helped stimulate the Migratory Pollinators Campaign, which examined pollinator issues in the US/Mexico border area, as well as the North American Pollinator Protection Campaign (NAPPC) and the book *The Forgotten Pollinators* (Buchmann & Nabhan, 1996).

3.2 Education and training

Widespread awareness about pollinator declines is relatively recent. Pollinator conservation has become a dynamic and engaging new area for research and development. There are, however, very few institutions in developing and developed countries with explicit mandates, and expertise, in research and extension in this area of biological endeavour. Most scientific and government institutions work solely with honey bees, promoting honey bee husbandry as a cottage industry to increase family income through the sale of honey, beeswax and other honey bee products. While research on conserving pollinators and their food plants exists, it is generally limited to a few interested individual scientists and is not institutionally mandated or adequately funded. Research and funding for long-term ecological studies and pollinator identification are especially under-appreciated and relatively poorly funded. Promoting pollinator conservation and sustainable use for fruit and vegetable seed crops production, and for overall biodiversity maintenance, requires special efforts to strengthen research, training and extension systems.

Insufficient knowledge among farmers and pest control operators about the importance of pollinators and pollination processes hinders the conservation and sustainable use of natural pollinators. Addressing this constraint requires building capacity through informational networks among farmers, extension workers, development agencies and researchers. Beekeepers need to manage honey bees for crop pollination as well as honey production. The types of training needed include

- introductory courses in pollination and pollinators for agriculture in primary and secondary school programmes, using an ecosystem approach.
- introductory courses in pollinator identification, biology and conservation, using an ecosystem approach, in agricultural colleges.
- hands-on training for farmers and extension workers in the conservation and sustainable use of pollinators in agricultural landscapes.
- technical skills in determining the economic value of pollinators and the detrimental effects of pesticide use on pollinators. The outcome should focus on improving the economic and social benefits through increasing yield and improving produce quality and management practices.
- teaching the causes and effects of insufficient pollinator biodiversity on seed and fruit production, and the importance of maintaining refuges for beneficial organisms, which also help maintain water tables and reduce soil erosion. Many threatened animals depend on fruit or seeds as their main energy source, including fruit-eating seed-dispersing bats and birds.

In addition, institutional infrastructure must be created for regional and national identification centres (along with new tools for identification), and for training parataxonomists. The global taxonomic impediment is exacerbated by an aging guild of taxonomists, few new ones entering the field and a backlog of undetermined pollinator vouchers in museums.

Case example 51 – training in pollinator identification

Training in conducting faunal studies is needed. For the past seven years an international course, 'The Bee Course', (http://research.amnh.org/invertzoo/beecourse) has been taught at the Southwestern Research Station of the American Museum of Natural History, in Portal, Arizona. This innovative course has taught over 150 students from around the world how to identify bees to family and genus levels.

Scientific cooperation among the various pollinator initiatives, campaigns and organisations can help improve the transfer of scientific knowledge and training in taxonomy, management techniques and standard sampling methodologies and protocols for rapid assessment. Strengthening scientific institutions, through scientific publications, seminars, conferences, courses, workshops, catalogues, evaluation guidelines, mechanisms for stakeholder feedback, and information exchange through personal, institutional and electronic networks, is also valuable for building capacity.

One way to build taxonomic capacity may be through training parataxonomists, whose work includes

- collecting specimens, especially for monitoring and faunistic studies.
- preparing specimens: curation, mounting, labelling, identification and databasing.
- sorting into taxonomic groups (subfamily, tribe, and genus).
- photographing, such as creating electronic types from primary types.
- maintaining collections (e.g. fumigation against museum pests).

It has been suggested that taxonomists and taxonomic service-providing institutions should provide training for parataxonomists in accordance with a generally agreed curriculum, and certification on a national or regional basis, either as individual training or in training courses. Parataxonomists should be eligible for academic upgrading in their profession after a satisfactory period of activity (Dias et al., 1999).

Case example 52 – parataxonomists in Costa Rica

The training of parataxonomists in developing countries was pioneered by INBIO (Instituto Nacional de Biodiversidad) in Costa Rica. This was an innovative government sponsored programme. It was one of the first organisations to train and use technicians as parataxonomists working alongside mentor taxonomists. As a result, in its 15-year history, INBIO staff have documented and discovered over 2,000 species of plants and animals native to Costa Rica (www.inbio.ac.cr/es/default2.html).

Traditionally taxonomists have provided free-of-charge identification services for invertebrates because of the large number of species and because they are difficult to separate. This is not ideal. Pollination biologists, ecologists, extension officers and farmers need to be able to identify pollinators. This can be achieved with modern electronic tools, as discussed in Chapter 1, Section 1.3.1. It is important for pollination ecologists and conservation biologists to include funding for identification services in their grant proposals. Through the intelligent deployment of parataxonomists, interactive keys, automated pattern recognition and genetic barcodes, easy identification services can be accomplished, leaving time for taxonomists to describe species, undertake generic revisions and analyse phylogeny (the evolutionary relatedness between species).

Many taxonomic resources needed by entomologists working in developing countries are located in museums in the developed world and inaccessible to scientists in their countries of origin. This information needs to be shared (images of types and specimen databases will contribute). The Global Biodiversity Information Facility (GBIF) (www.gbif.org) is concerned with developing specimen databases for all collections and has made calls for proposals for seed money. Pollinators have been listed as a priority category for funding during 2005/2006. Partnerships between institutions in developed and developing countries can help reduce the taxonomic impediment.

Case example 53 – overcoming the taxonomic impediment in Mexico

The Programa Cooperativo sobre la Apifauna Mexicana (PCAM) is a partnership between bee taxonomists from several institutes in the US and Mexico. This programme has produced one major, highly illustrated work, which facilitates the identification of all bees from North and Central America to genera (Michener et al., 1994). Databases have been created giving distributional and taxonomic information for the species. Thousands of bee specimens collected during five PCAM expeditions in northern Mexico have been deposited in the SNOW museum at the University of Kansas, Lawrence, US. An ongoing specimen-level databasing effort (at the University of Kansas) has captured this PCAM bee information, but the database is not yet online or accessible to the public. The original PCAM bee data (coordinated by D Yanega at the University of California, Riverside) can be found online (www.inhs.uiuc.edu/cbd/collections/insect/mexicanbees.html).

Recommendation 15 – training

Education programmes should be adapted for specific groups of people, and should address their unique needs. (Case example 46 – honey bees in Australia – describes the use of a specific medium, the Internet, for a unique purpose.)

3.3 Information dissemination

For awareness, education and training to be successful, information must be disseminated beyond those immediately involved. Libraries, museums, multimedia and popular media outlets are the vehicles for this (see Case example 46 – honey bees in Australia).

Case example 54 – the International Pollinator Initiative (IPI)

The IPI Plan of Action suggested

- a web site with databases of pollinator type materials.
- a web site with specimen data.
- exchange and transfer of information, especially literature.

Case example 55 – sharing information in Africa

The African Pollinator Initiative (API) has as one of its objectives the sharing of information and expertise between bee taxonomists, pollination researchers, farmers, conservationists and policy makers. In Kenya, the pollinators for several crops and their alternate forage resources were documented. Eggplant blossoms, for example, are buzz-pollinated (i.e. anthers must be sonicated to release pollen) by large carpenter bees (*Xylocopa caffra*) and nomiine bees (*Nomia* sp.). A colourful educational poster on this has been created, printed and distributed to local farmers.

Case example 56 – using communication technology in Brazil

Communication technology can benefit capacity building through enabling the pollinator biodiversity conservation initiatives, including the International Pollinator Initiative (IPI) and several regional initiatives (Appendix 1), to achieve their goals, and to permit cooperation between groups. For this purpose Brazil has developed Webbee (www.webbee.org.br/bpi/bees_rural_development.htm), which provides information, case studies and recommendations (see Figure 3).

Recommendation 16 – sharing information

Target audiences must be identified and information must be packaged (using an appropriate communication medium and language) and disseminated to them.

Summary of recommendations for capacity building

Pollinator and pollination awareness

The following actions will to help promote global awareness of pollinators and pollination, and build capacity in pollinator conservation and restoration:

- Disseminate high-quality and easy-to-understand information about pollinators and their conservation to a wide variety of audiences and users.
- Establish educational outreach and training programmes for all communities.
- Define criteria and use indicators to evaluate the status of, and threats to, agricultural production from pollinator losses.
- Use international standards organisations to certify ‘pollinator-friendly’ products.
- Ensure that pesticide labels address important pollinator safety issues.
- Develop business incentives (and remove disincentives) for pollinator conservation.
- Encourage celebrities to build awareness for pollinator conservation.

Education and training

- Adapt education programmes for specific groups of people.

Information dissemination

- Identify target audiences and package and disseminate information in the appropriate communication medium and language.

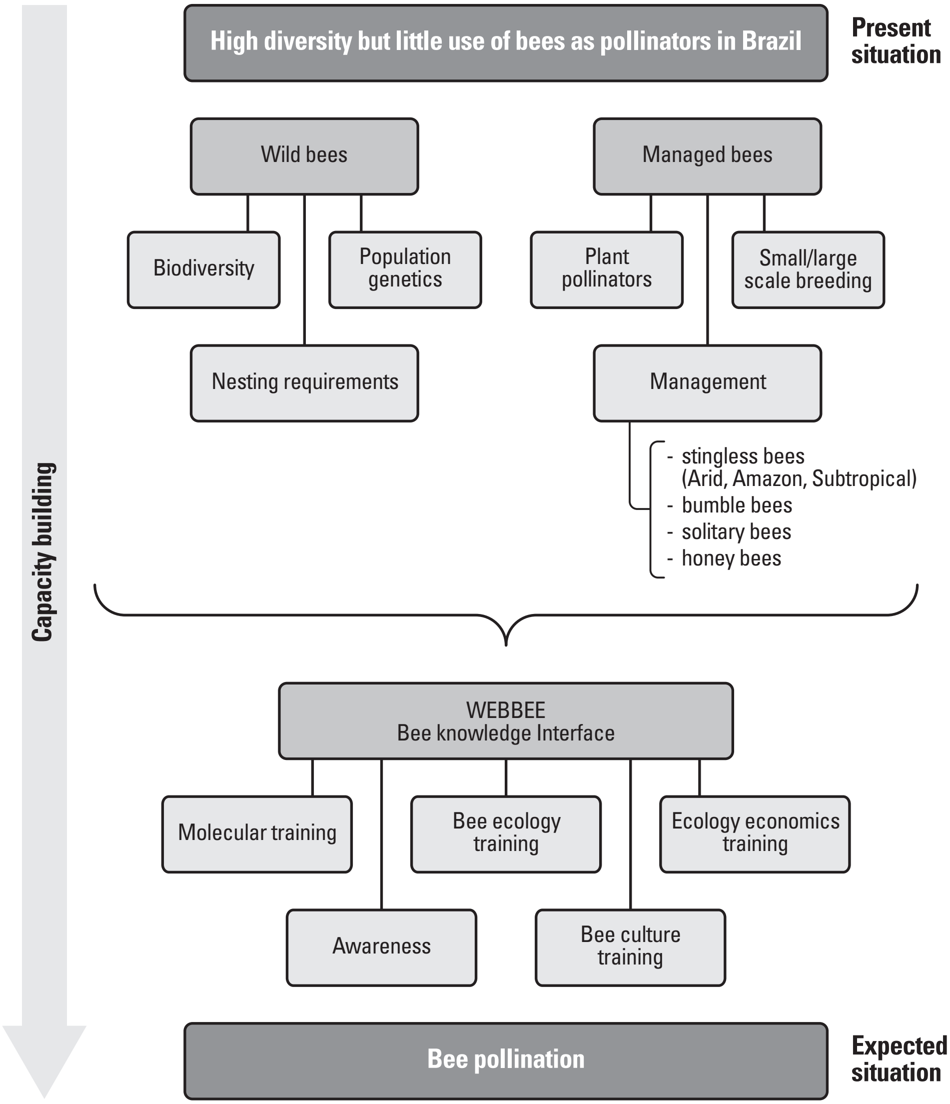


Figure 3. **Knowledge integration of pollination by bees.** *(Diagram by V Fonseca)*

4 Mainstreaming pollinators into policy decisions

Truly innovative concepts for understanding societal dependence on the natural world are emerging in global policy arenas. Among the more compelling of these is the realisation of the value of ecosystem services, including pollination, and the attempt to put a price tag on them. The concept of ecosystem services suggests that it is not on specific organisms that we have our strongest dependencies, but rather on systems and processes of nature. This relationship underlies sustainable livelihoods. Pollination is certainly an important ecosystem service, because it is linked to food production and ecosystem regeneration through plant reproduction. Pollination, fruit set and seed set are integrally linked to biodiversity conservation because many plants have unique pollinators. Although this concept has strong resonance and logic, the global community has yet to develop an enabling policy framework to ensure the continuity and conservation of pollination services. The general lack of awareness about ecosystem services and their value and why pollination is important both to conservation and sustainable agriculture needs to be conveyed more effectively by scientists to broader audiences in the policy arena.

Pollinators are small animals that rarely appear on policymakers' agendas. Yet the challenge to protect them and to ensure stable and lasting pollinator–plant relationships is important to the survival of human beings and the ecosystems on which we depend. A policy environment that recognises the fundamental role pollination plays in food security, safety and biodiversity conservation is needed. The reality that pollinators are essential to agriculture husbandry and biodiversity conservation is only beginning to be recognised by policy makers, planners, development workers and farmers. In the agricultural sector alone, pollination has been essentially overlooked in rural development strategies and is not included as a technological input in most agricultural development packages. High value agriculture (cash crops) is usually promoted. Thus farmers have little opportunity to discover how important successful pollination is for crop yields. Introducing substantive changes in agricultural development first requires changes in agricultural research directives and development investment policies

The present rates of extinction of the Earth's biota are unprecedented and catastrophic, and accelerating daily. It is somewhat surprising then that the role of pollination deficits, and pollinator decline, contributing to regional and complete species extinctions, have only recently attracted widespread scientific attention and research (Washitani, 1996; Bond, 1994). On a practical and policy-making level, conservationists and wilderness land managers have few specific guidelines or criteria in their management plans to ensure that pollinator services are maintained, and they are not compelled by existing policies to include them.

An enabling policy environment for pollination alone is unlikely. However, policy makers may be more likely to be successful in strategically introducing pollination concerns into existing sectoral and governmental policies. This chapter suggests ways in which conservation of pollination services can be integrated into different sectors, including environment, agriculture, science and technology, trade and finance. While by no means comprehensive, this chapter provides ideas and some case examples that illustrate ways to incorporate pro-pollinator approaches into policies and practices and into new and existing legislation.

Recommendation 17 – pollinator conservation

At present there exists only a broad concept of what is needed for pollinator conservation. But although additional research is needed to understand the specific details and to bring pollination awareness and management into rural development and land management practices, there is already sufficient general knowledge to initiate activities that conserve and sustainably manage pollinators within agroecosystems. The generally accepted measures include

- conserving and restoring natural habitat.
- growing flowering plants preferred by pollinators.
- promoting mixed farming systems.
- establishing nectar corridors for migratory pollinators.
- providing habitats alongside cropland for pollinator nests and food.
- encouraging integrated pest management.
- discouraging misuse of agrochemicals.

The specific details that are unknown include the food plants, nesting materials and nesting sites and the finer details of how to make a pollinator-friendly habitat (see Chapter 1).

4.1 The environmental sector

Article 6 of the Convention on Biological Diversity (www.biodiv.org) creates an obligation for national biodiversity planning, making the development and adoption of a national biodiversity strategy a cornerstone to the implementation of the CBD. National strategies reflect the way countries intend to fulfill the objectives of the Convention in the light of specific national circumstances, and the related action plans constitute the sequence of steps to be taken to meet these goals.

More specifically, Article 6 states that 'Each Contracting Party shall, in accordance with its particular conditions and capabilities:

(a) Develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes that shall reflect, *inter alia*, the measures set out in this Convention relevant to the Contracting Party concerned; and
(b) Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies.'

Article 6 (b) requires that biodiversity considerations be mainstreamed into all aspects of national planning and is closely linked to Article 10 (a), which states that each Contracting Party shall, as far as possible and appropriate, 'Integrate consideration of the conservation and sustainable use of biological resources into national decision-making'. The requirement to mainstream the conservation and sustainable use of biological resources across all sectors of the national economy and policy-making framework is the complex challenge at the heart of the Convention.

Hence, National Biodiversity Strategy and Action Plans (NBSAPs) are important national policy tools that address biodiversity specifically, and also its sustainable use. In some cases, pollination per se is not explicitly mentioned in an NBSAP; rather, the issue falls within a larger context, for example when discussing ecosystem services. For example, the Philippines National Biodiversity Assessment and Action Plan (NBAAP) seeks to value and account for direct and indirect goods and services from biodiversity and bioresources. This brings the conservation and management of pollinators within the scope of their action plans. NBSAPs are ideal places to introduce mainstreaming activities for pollinators into national policy.

Case example 57 – legislation that protects pollinators in Canada

Existing legislation has been applied to protect pollinators in Canada. This legislation embraces such concepts as ecosystem function and sustainability, even though it does not recognise pollination per se. Other legislation that affords protection for honey bees and beekeepers, and sometimes alfalfa leafcutting bees, also contains provisions that may help protect other pollinators (P Kevan, personal communication to C Eardley).

Recommendation 18 – National Biodiversity Strategy and Action Plan (NBSAP)

It is important to realise that NBSAPs can only be used as effective tools for managing biodiversity if they are fully integrated into planning systems at local, regional and national levels. Biodiversity regulations and permitting processes can be used for making NBSAPs effective tools for pollinator conservation.

4.2 Clearinghouse mechanisms and public access to information

The CBD uses the term 'clearinghouse' to mean any agency that brings together 'seekers and providers' of goods, services or raw information/data, thus matching demand with supply. Demand for information on biodiversity conservation, or key biodiversity threats, typically exceeds any government or intergovernmental agency's ability to supply such information. The clearinghouse mechanism of the CBD directs users to use information-rich initiatives, such as the Global Taxonomy Initiative (GTI) and the Global Invasive Species Program (GISP). Such decentralised means of managing specialised databases are gaining popularity. Pollinator conservation initiatives, whether national, regional or international, should share their data. The CBD Parties have agreed to develop mechanisms for sharing biodiversity data through a clearinghouse mechanism, internationally (www.biodiv.org/chm/default.aspx) and nationally (www.biodiv.org/chm/stats.asp).

Case example 58 – Namibia's national clearinghouse

Namibia has a tradition of scientific inquiry into biodiversity, but did not make the information accessible (digitised and online) to the public, nor was it analysed and summarised for policy makers until it signed the CBD and fulfilled its commitments to information management and dissemination. For the databases, the National Museum is constructing a national clearinghouse website for a biodiversity inventory of priority insect groups (www.dea.met.gov.na/programmes/biodiversity/biodiversity.htm).

Recommendation 19 – biodiversity information clearinghouses

Countries should establish national and international clearinghouses for sharing information, as sharing enables otherwise unavailable capacity to contribute to biodiversity conservation. These clearinghouses should include pollinators. Modest beginnings, such as inventories of known pollinator species, are often the most practical way to start.

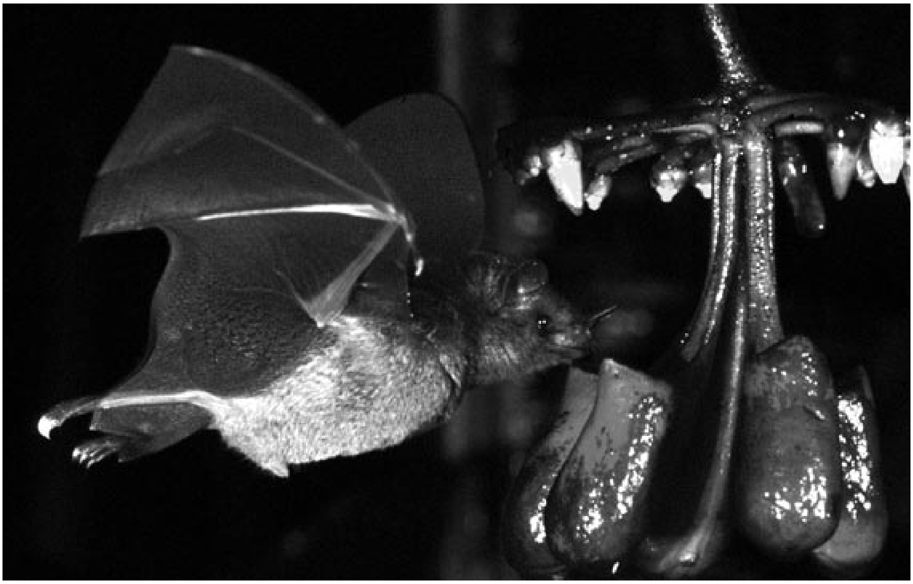
4.3 Protected area networks

Protected areas have figured prominently in biodiversity conservation efforts around the world. Increasingly, it is recognised that protected areas cannot be islands. Their configuration within a landscape, including provision for migratory corridors connecting wilderness areas, is paramount, and can help to extend the concept of protection to migratory species whose ranges span vast areas. This includes and benefits certain pollinators, e.g. giant honey bees (*Apis dorsata*) in Asia, danaid butterflies (*Danaus plexippus*) in North America, and nectar-feeding bats (*Leptonycteris* and *Chironycteris*) in Central America. Even on smaller scales, recent research shows that pollinators benefit greatly from migratory corridors linking, for example, two flowering patches. If such corridors between two protected areas transverse agricultural land, the benefits to agricultural productivity and livelihoods may be increased.

Case example 59 – migratory bats in Mexico

In Mexico, migratory bats are important pollinators and seed dispersers. In 1994, the Programme for Conservation of Migratory Bats was started with the Institute of Ecology at Mexico's National Autonomous University and Bat Conservation International (BCI). The programme focused on research and environmental education to protect bats by conserving habitats along migratory corridors. It involved policy in an amendment to Mexico's Federal Law of Wildlife to encompass all caves and crevices as protected areas (Walker, 2001).

If policy makers wish to include pollination considerations in the design of protected area networks, new criteria may be needed. Protected areas for pollinators may depend on specific, often small, protected sites, such as soft banks where ground-nesting bees congregate to build nests, caves for nectar-feeding bats, or areas with larval host plants for butterflies (such as milkweed plants for monarch butterflies). In the vast areas of the world where agricultural practices are not particularly pollinator-friendly, protected areas can provide key resources and/or habitat refuges for pollinator populations.



Glossophaga soricina **male visiting flower of** ***Marcgravia nepenthoides.*** *(Photograph by R Medellin)*

Case example 60 – migratory butterflies

Monarch butterflies migrate between Canada, the US and Mexico, and they depend on milkweed plants. Absence of sufficient host plants can reduce their populations. Additionally, although monarch butterflies are widespread, they concentrate in small island-like roosting sites in the Mexican highland forests, and deforestation in this region has put the entire species at risk (Buchmann & Nabhan, 1996; Missrie, 2004).

Case example 61 – citrus and pollination from neighbouring forests

Managers of lands adjacent to protected areas recognise the valuable services these protected areas provide. These include watershed maintenance, pest management, pollination and nutrient recycling. In Costa Rica, large orange producers realised that plantations next to wildland reserves had fewer pests, and a year-round secure water supply. Because they needed to use fewer pesticides next to forests, the farmers sanctioned the protection of wildland reserves, and consented to pay US$500,000 over 20 years to the reserve (McNeely & Scherr, 2003). This type of example helps characterise a system under which there can be 'payments for ecosystem services'. Such a system will involve the land owners and governments in financial agreements between urban water utilities and protected areas. It is possible that contracts between farmers and protected area managers for pollinator services could follow.

Case example 62 – integrated pest management in US National Parks

In national parks of the US, pollinators are protected as a natural resource. Because insect pollinators are especially susceptible to pesticides, integrated pest management (IPM) policies have been developed to minimise risks to pollinators and other biota as a result of pesticides. This is accomplished through a nine-step process:

- Building consensus among site occupants, pest managers, and decision makers.
- Identifying the pests.
- Reviewing national park service policies that apply to pest and pesticide management.
- Establishing priorities by pest or by site.
- Determining action thresholds or population levels that trigger management.
- Monitoring pest populations and the environment.
- Applying non-chemical management and obtaining approval for applying pesticides.
- Evaluating results and continuing monitoring.
- Keeping records of activities, both successes and failures. (T Cacek, revised by M Ruggiero, www.nature.nps.gov/facts/fipm.html)

Recommendation 20 – establishment and maintenance of protected areas

National parks play a vital role in pollinator biodiversity conservation. Nevertheless, protected areas near agricultural lands are important for pollinators and agriculture alike. Such areas should be carefully chosen, preferably in such a way that their contribution enhances other such areas through the creation of a protected area network.

4.4 Biodiversity regulations

More than ten years after the adoption of the CBD some countries are still in the process of formalising their commitments into national biodiversity regulations. Policies that are in draft form or under review provide opportunities for including pollinator considerations in the formal policy. For example, where biological diversity is not in a protected area, Kenya's Environmental Management and Coordination Act provides for the Minister of Environment and Natural Resources '*to declare any area* *of land … to be a protected natural environment for the purpose of promoting and preserving specific ecological processes, natural environment systems, natural beauty or … the preservation of biological diversity in general*'. In developing the guidelines and regulations to support this Act, a multi-stakeholder biodiversity taskforce first defined 'specific ecological processes' to include soil erosion control, watershed services, soil fertility maintenance, microclimate regulation, pollination services, and wildlife migrations. Second, they recognised that the Ministry of Environment and Natural Resources does not have sufficient resources to identify all the sites of environmental significance that might merit inclusion in the Gazette as protected natural environments. Thus provision has been made in the biodiversity regulations, for: '*other lead agencies, District Environmental Committees, Provincial Environmental Committees, local communities and other members of civil society [to] propose sites for consideration as Environmentally Significant Areas*'. Through such measures, a community of coffee farmers, for example, could ask for the protection of a small forest or riparian zone that provides alternative forage and nesting sites for coffee pollinators.

Recommendation 21 – enhancing biodiversity conservation regulations

Countries are encouraged to include pollinator conservation in national policy and legislation. However, governments mostly do not have the capacity to identify all areas of concern. They are therefore encouraged to develop mechanisms to enable informed society to contribute.

4.5 Environmental impact assessments

Biodiversity regulations can serve to identify sites and ecosystem processes for protection and define constraints for development to ensure that the conservation of habitats and ecological processes is not compromised. Environmental Impact Assessment (EIA) is a tool for ensuring that environmental considerations, such as impacts on biodiversity, are included in decision-making for new land development or conversion from one use to another. If used effectively, the creation and reporting of EIAs should result in development that is designed to be more sensitive to biodiversity conservation needs and multiple land uses by the public.

Impacts of proposed human development projects (housing, agriculture, mining etc.) on birds, mammals and plants, as well as on water and soil quantity and quality, are routinely considered in EIA procedures. But as yet environmental planners and policy makers have little information to guide them on including impacts on ecosystem services, such as pollination services, in EIAs. Unfortunately, species that are large, colourful, easily observed, appealing and easily identified (the 'charismatic megafauna') are more likely to be surveyed and studied for EIAs than species that may actually be better indicators of overall impact. Regrettably, invertebrates, especially insect pollinators, although keystone service providers in many ecosystems, are often not included in EIAs.

Theoretically, EIAs should consider impacts not only at the level of species, but also at the genetic, ecosystem and landscape levels. Pollinator conservation is closely linked with all these levels but, at present, impacts on individual pollinator species and their mutualisms are unlikely to be captured in an EIA. The checklist below presents useful questions to ask when including pollinators in EIAs.

Case example 63 – environmental impact assessments (EIAs)

A recent review of current experience (Treweek, 2003) suggests that EIA analysis most commonly focuses on the species level, despite the fact that the viability of species clearly depends on processes operating at the genetic, ecosystem and landscape levels. The reasons for this are unclear, but lack of adequate data and skills is probably a major factor. If EIA practitioners are recommended to consider gene-flow, pollination services and landscape level conservation of pollinator habitat, then pollinator conservationists will have to provide the data for EIA analyses.

Checklist: questions relating to assessment of impacts on biodiversity in EIAs
(Le Maitre et al., 1997, modified by Treweek, 2003)

Questions on landscape composition

- What is the distribution pattern and richness of patch/habitat types (vegetation types, biomes) in the study area?
- How do these patterns compare with those outside the study area (is the area unique, or rich, or does it comprise types that are poorly conserved elsewhere)?
- What are the development trends in the adjacent area (is any particular habitat type being radically or rapidly transformed)?
- How might distribution patterns of vegetation types/biomes change as a result of the proposed development (reduction in area, change in shape)?

Questions on landscape structure

- How are biodiversity units organised in time and space?
- What are the spatial relationships between the above units and how may these change as a consequence of development?
- What are the structural/habitat requirements of important species?
- Will successional trends be affected?
- Will habitat loss, fragmentation or reorganisation affect overall provision of feeding and breeding requirements?

Questions on landscape function

- What role do biodiversity units play in maintaining processes and dynamics?
- What is the local and regional functional role of each type (catchment cover, retarding storm flow or spread of fire)?
- What is the functional relationship of one type to another (water yield, refuges for species)?

Questions on community composition

- What is the distribution pattern and richness of communities in the study area?

Questions on community structure
• What are the relationships between communities and environment and how do these relate to the proposed development (changes in water table, flooding or fire regime)?
Questions on community function
• What processes maintain community boundaries and structure (herbivory, predation, dispersal)? • What is the functional role of threatened communities? • Will any wetlands or riparian zones be affected?
Questions on population/species composition
• What are the distribution patterns (abundance)? • Are any flagship (popular, charismatic) species present and threatened by development? • Are any vulnerable species (rare, genetically inbred) present and threatened by development and, if so, what category of threatened species is involved? • What is the taxonomic position of threatened species?
Questions on population/species structure
• What controls distribution patterns (environmental gradients)? • What is the population structure of important species? • What variation is there within species/populations?
Questions on population/species function
• What are the demographic processes determining recruitment patterns (what controls age/size/structure)? • Are any keystone species present and threatened? • Are any umbrella species present and, if so, what are the habitat and range requirements of these species?

Case example 64 – citizen monitoring in Australia

In Australia, there is a process whereby citizens who identify perceived threats, such as declining pollinator numbers or the presence of invasive alien pollinators, can report them to their government, as a 'key threatening process' (www.deh.gov.au/biodiversity/threatened/ktp/). As pollination is rarely likely to receive direct attention from government bodies, finding ways like this to involve citizens in conservation policy will benefit both governments and communities.

Recommendation 22 – environmental impact assessments (EIAs)

EIAs generally rely on a sound spatial planning framework with clear biodiversity priorities. Following the establishment of the CBD, many countries develop their biodiversity priorities through the NBSAP process. By incorporating pollination and other ecosystem processes into the NBSAPs, countries may start to better understand environmental impacts on pollinators.

There are several other key environmental management tools that can be applied to pollinator management practices. All these tools have different functions and operate at different levels of decision making and they are all related and need to be applied in an integrated and reiterative manner – below are some examples of various types of environmental management tools used (Sections 4.6–4.9). It is not suggested that each farmer apply all these tools, but they could be useful for national pollinator conservation programmes.

4.6 Cumulative effects assessment

Cumulative Effects Assessment (CEA) involves changes to the environment that are caused by an action in combination with other past, present and future human actions. A CEA is the process of systematically analysing and assessing cumulative environmental change. It ensures that the full range of consequences of actions is considered in order to avoid a 'tyranny of small decisions' and to address the total impact on the environment by highlighting externalities that affect public goods or resources. It is thus a tool that is used to capture and address environmental impacts that cannot easily be dealt with on a particular project or EIA level of assessment.

4.7 Strategic environmental assessment or sustainability assessments

Strategic Environmental Assessment (SEA) helps to determine the environmental implications of policies, plans and programmers. An SEA has an advocacy role, to raise the profile of the environment in developing plans. 'SEA is a systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision making on par with economic and social considerations' (Sadler & Verheem, 1996). An SEA

- is pro-active and informs development proposals.
- is used to assess the effect of the existing environmental and socio-economic conditions on development opportunities and constraints.
- relates to areas, regions or sectors of development.
- enables the development of a framework against which positive and negative impacts can be measured and various scenarios and alternatives can be evaluated.
- is a process aimed at the development of a sustainability framework to inform continuous decision-making over a period of time.
- is focused on maintaining a chosen level of environmental quality and socio-economic conditions, e.g. through the identification of sustainability objectives and limits of acceptable change.
- has a wide perspective and includes a low level of detail to provide a vision and overall framework.

4.8 Environmental management plan

In an Environmental Management Plan (EMP) the owners of a project or farming system are responsible for the environmental consequences over the entire life cycle of the project, from implementation through operation to closure and rehabilitation. This is often called the 'cradle-to-grave or the cradle-to-cradle approach'. Once an EIA has been approved by the authorities, it provides a foundation for the development of the EMP. The complete EMP must cover the implementation phase, the operating phase during the life of the project, the eventual closure of the project, and the final rehabilitation and aftercare of the site. The EIA will normally contain an outline of the EMP and will contain recommendations for the mitigation of identified environmental impacts.

4.9 Environmental management system

An Environmental Management System (EMS) is a management system to help organisations evaluate the processes and procedures they use to manage environmental issues and incorporate strong operational controls and environmental roles and responsibilities into existing job descriptions and work instructions. An EMS sets objectives and targets for managing their environmental issues. They monitor and measure and evaluate their progress in environmental performance in both areas that are regulated and areas that are not (e.g. demand side issues such as water use). The EMS integrates the environment into everyday business operations, and environmental stewardship becomes part of the daily responsibility for employees across the entire organisation. EMSs are part of the organisation's overall management system. They provide a number of benchmarked tools to manage environmental risk effectively and offer great potential for continuous improvement in compliance and other areas of environmental performance.

Recommendation 23 – integrated environmental management tools

It is important that pollinator issues are identified and addressed at various levels of decision making and are incorporated into environmental assessments in all relevant levels of policies, plans and projects.

4.10 Permitting processes

Closely related to environmental assessments are permitting processes. These involve giving permission (permits) for collection, study and/or export of live animals or plants or their products. Honey bee pathogens and honey bees are regulated under the Office Internationale des Epizooties (OIE or World Animal Health Organization) for diseases and International Plant Protection Commission (IPPC) for plant pests. However, there are gaps when addressing biodiversity concerns and the result is often the importation of pollinator species that displace native fauna or spread invasive weeds.

Case example 65 – Biodiversity Act in South Africa

If an activity is regulated by both the Biodiversity Act and other legislation, both authorities may exercise their respective powers jointly and issue a single integrated permit instead of separate permits and authorisation. If, for example, a developer proposes an exotic forest plantation in a biodiverse region, the integrated permit application to the Forest Department and Ministry of Environment could provide a means by which impacts on endangered plants and pollinators from habitat fragmentation could be more holistically monitored and evaluated (www.environment.gov.za).

Recommendation 24 – permits to regulate pollinator movement

The unnatural movement of pollinators may affect more than the immediate human community, and the local pollinator populations. The introduction of alien species may affect neighbouring countries, and the movement of indigenous pollinators may destroy their inherent ability to deal with natural climate variation. Therefore the movement of pollinators should be guided or controlled.

4.11 Biodiversity-friendly agricultural practices

Conservation of pollinators in agroecosystems can have a tremendous impact on the agricultural sector. Here, the opportunity for increasing agricultural productivity (or fruit or seed quality and prices) by conserving pollinators is an undeniable win-win situation. The challenge is to gain recognition of this opportunity, and integrate pollination into policies that will help promote sustainable agriculture.

The evolving concept of good agricultural practices (GAP) may present one opportunity for emphasising the role of pollination services management in sustainable agriculture. Broadly defined, within the FAO Committee on Agriculture (COAG), GAP applies available knowledge to addressing environmental, economic and social sustainability for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products. The concept of GAP offers potentially strong measures for promoting on-farm biodiversity conservation, within the context of sustainable agriculture and rural development (SARD, Chapter 14 – Sustainable Agriculture and Rural Development – of the Agenda 21 (The Earth Summit) www.fao.org/wssd/SARD/index-en.htm). Pollinator needs could be addressed through the agricultural component 'wildlife and landscape' of the framework of good agricultural practices for selected agricultural components (ftp://ftp.fao.org/unfao/bodies/coag/coag17/Y8704e.doc).

The agricultural component 'wildlife and landscape' of the framework of GAP for selected agricultural components merits consideration for the synergies between wild habitat, farmscapes and pollination, which are as follows:

- Agricultural land accommodates a diverse range of animals, birds, insects and plants. Much public concern about modern farming is directed at the loss of some of these species from the countryside because their habitats have been destroyed. The challenge is to manage and enhance wildlife habitats while keeping the farm business economically viable.
- Good practices related to wildlife and landscapes will include those that identify and conserve wildlife habitats and landscape features, such as isolated trees, on the farm; that create, as far as possible, a diverse cropping pattern on the farm; that minimise the impact of operations such as tillage and agrochemical use on wildlife; that manage field margins to reduce noxious weeds and encourage a diverse flora and fauna with beneficial species; that manage water courses and wetlands to encourage wildlife and prevent pollution; and that monitor those species of plants and animals whose presence on the farm is evidence of good environmental practice.

Recommendation 25 – biodiversity-friendly farming

A diversity of pollinators improves agricultural production, often even for single crops, and therefore techniques for pollinator biodiversity conservation should be included in GAP.

4.12 Commodity certification

A potential tool for promoting pollinator conservation is consumer choices in the marketplace. If consumers understand the need for pollinator-friendly natural resource management, and that ecosystem health and cost benefits may accrue from certain agricultural processes, then they may purchase products that have been labelled to indicate that they were produced in a pollinator-friendly environment. Stickers with charismatic pollinator icons could be placed on fruits or agricultural product packaging materials. Such certification could provide market incentives to farmers to conserve pollinators.

Case example 66 – honey bee certification

There is no certification that accommodates pollination concerns, i.e. pollinators are not included in forest certification for sustainable timber, organic certification or fair trade certification (e.g. coffee). Of the present certification systems, organic certification is probably most relevant to pollinator conservation. Current certification standards address agricultural inputs such as soil conservation, water management, alternative pest and weed management strategies and organic plant nutrition, but do not perceive pollination as an agricultural input (B Gemmill, personal communication to C Eardley).

Case example 67 – bird-friendly coffee

A certification system in Latin America has been developed specifically for fostering bird biodiversity on farms, namely 'bird-friendly' coffee (http://nationalzoo.si.edu/ConservationandScience/MigratoryBirds/Coffee/default.cfm). This provides a good model for other biodiversity-friendly commodities: pollinator-friendly production systems have the double benefit of supporting biodiversity while promoting production levels.

Recommendation 26 – pollinator-friendly commodity certification

Awareness preceeds pollinator conservation, and commodity certification is a powerful awareness tool. Therefore a way to give an initial competitive advantage to famers who produce their fruit and seeds in a pollinator-friendly way should be established – the benefits from improved pollination will later sustain pollinator-friendly farming practices.

4.13 Trade in pollinators

Some pollinators, such as the oil palm weevil (see Case example 15), have been exported to other countries and apparently have little effect on natural ecosystems. Others are invasive and detrimental to pollinator biodiversity conservation (see Chapter 1 and Chapter 2). The importation of alien pollinators, such as bumblebees (*Bombus terrestris*) for greenhouse pollination, is cautioned against. Although importation is the decision of one country, the consequences of introducing invasive species are often regional. Since invasive alien species easily cross national borders, regional policies on trade in pollinators are an important consideration for policy makers.

Recommendation 27 – trade in pollinators

International trade in pollinators mostly involves moving living material of exotic species into countries where they do not occur. Such species are mostly easy to proliferate and disperse quickly, and therefore they are predisposed to become invasive – though this does not always happen. Therefore the introduction of pollinators into regions where they do not occur naturally should only be permitted after detailed research to ensure that they have an obligate dependence on their host plant and will not introduce disease or affect native flora and fauna in any significant way.

4.14 Green accounting

A way to help policy makers recognise the importance of pollination services, and thus guide their decisions, is to promote the inclusion of ecosystem services, such as watershed and non-timber forest values, which include pollination services, in national accounting practices. These services could then be given visible economic value for understanding national wealth; for example the gross domestic product (GDP). Developing 'greener' national accounting methods holds the promise of introducing environmental problems into a framework that key economic ministries, governing bodies and heads of state could understand. (For economic value see Chapter 1, Assessing the economic value of pollinators.)

Rarely are ecosystem services included in accounting spreadsheets or economic equations and models. Policy choices that keep a natural resource base intact or encourage 'free' ecosystem services, such as native bee pollination of crops, should make a country wealthier. A good bibliography on green national accounting is available over the Internet (www.gwagner.net/work/green_accounting.html).

Pollination services, if they are to enter into green accounting, should be considered in the first component of the methodology for developing natural resource asset accounts. This requires measuring 'opening stocks' of natural resources at the start of a given year, and 'closing stocks' at the end of the year. If pollination cannot be entered into such 'national stock-taking' by itself, it should be factored in as 'added value' to wild lands and forest 'stock', along with other values such as carbon sequestration and soil fertility. Several countries are at present working on developing national or state-level environmental accounting methods and using them for policy-making. These include the US, many European countries, Botswana, Costa Rica, Chile, Korea, Mexico, Moldova, Namibia, the Philippines and South Africa. This process has been driven in part by international protocols for global climate change that allow tradeoffs between carbon emissions and carbon sinks, involving for example maintenance of large tracts of healthy forests. Countries wanting to participate in 'carbon trading' are obliged to keep accurate, detailed national accounts of their forest (and other vegetation type) assets. An opportunity therefore exists for pollination conservationists to assure that 'pollination values', along with other values, are included in the measurement and accountability of natural resource assets.

Recommendation 28 – green accounting

Providers of essential ecosystem services are a national asset and should be accounted for accordingly. This implies that they should receive their required guardianship, and the contribution of their services should be added to the national GDP.

Summary of recommendations for mainstreaming pollinators into policy decisions

The broad concept of what is needed for pollinator conservation requires additional research to understand the specific details and to bring pollination awareness and management into rural development and land management practices.

It is important to support existing initiatives and general knowledge to conserve and sustainably manage pollinators within agroecosystems. The generally accepted measures include

- conserving and restoring natural habitat.
- growing flowering plants preferred by pollinators.
- promoting mixed farming systems.
- establishing nectar corridors for migratory pollinators.
- providing habitats alongside cropland for pollinator nests and food.
- encouraging integrated pest management.
- discouraging misuse of agrochemicals.
- building knowledge gaps, such as knowing the food plants, nesting materials and nesting sites of pollinators and other finer details of how to make a pollinator-friendly habitat.

The environmental sector

- NBSAPs can only be used as effective tools for managing biodiversity if they are fully integrated into planning systems at local, regional and national levels.

Clearinghouse mechanisms and public access to information

- The establishment of biodiversity clearinghouses, and the inclusion of pollinators therein, should be a national priority.

Protected areas networks

- Protected areas near agricultural lands should be carefully chosen, preferably in a way that creates a protected area network.

Biodiversity regulations

- Pollinators should be included in national conservation and sustainable use policy and legislation, and mechanisms to enable public participation should be used.

Environmental impact assessment

- Undertake EIAs of activities that could potentially have a significant impact on ecoystems and pollinator species.
- Ensure EIAs offer clear biodiversity priorities, such as making use of the CBD NBSAP process.

- Incorporate pollination and other ecosystem processes into NBSAPs to enable better understanding of environmental impacts on pollinators.
- Identify and address pollinator issues at various levels of decision making, and incorporate them into environmental assessments at all relevant levels of policies, plans and projects.

Permitting processes
- The introduction of alien species should be avoided because they may negatively affect neighbouring countries
- The movement of indigenous pollinators should be confined to the area in which the genotype occurs naturally, because mixing genotypes may destroy their inherent ability to deal with natural climate variation.

Biodiversity friendly agricultural practices
- The concept of good agricultural practice (GAP) should enable the inclusion of pollinator biodiversity conservation in agriculture, where it rightfully belongs.

Commodity certification
- Commodity certification should encourage famers to produce their fruit and seeds in a pollinator-friendly way. The benefits from improved pollination will later sustain pollinator-friendly farming practices.

Trade in pollinators
- International trade in pollinators mostly involves moving living material of exotic species into countries where they do not occur. Research should first be undertaken to ensure that they will not affect native flora and fauna in any significant way.

Green accounting
- Countries should consider the providers of essential ecosystem services as a national asset, and account for their services as a contribution to national productivity.

Conclusions

The economic and ecological importance of pollinators and the issue of their declines around the world have not been recognised in most mainstream research and development efforts. Apparently most people, including farmers and policy makers, are generally unaware of the services pollinators provide to natural and agroecosystems. To effectively address this issue it is necessary to bring pollination concerns into the policy, research and development mainstream through promoting their integration into agricultural research policies, extension and outreach activities. There is a dearth of non-technical literature for promoting awareness among planners and policy makers.

The attitude that pollination is something we do not have to think or worry about is changing. The need to conserve pollination as an essential ecosystem service, and therefore the need to do something about losses in pollinator abundance and diversity, is gaining momentum. How to do it, however, is not fully appreciated by the public or most environment conservation organisations and policy makers.

Two important events that helped bring pollinator biodiversity conservation into the mainstream were

- the publication of the popular book '*The Forgotten Pollinators*' (Buchmann & Nabhan, 1996).
- the COP decision III/11 of the CBD (www.biodiv.org), which established the multi-year Programme of Work on Agricultural Biodiversity, considering pollination in its initial list of thematic areas also in 1996.

In spite of the short time that has lapsed since these two events, an amazing amount has been achieved in pollinator awareness at all levels. It therefore appears reasonable to assume that they and their associated outreach campaigns, such as NAPPC, IPI, API, EPI, played a major role in bringing pollinator biodiversity conservation into the mainstream. The question that now arises is 'What next?' The answer is surely 'More on-the-ground activity in pollinator conservation' that will result in the achievement of the ultimate objective, the conservation of pollination biodiversity. This is our goal and it has not yet been accomplished.

This resource book has tried to give ideas on how this goal can be attained. It arose from the questions 'How can we use the awareness we've created to implement mechanisms for pollinator conservation?' and 'How can we use pollinators to make policy makers and practitioners aware of the importance of ecosystem services?' Questions like these stimulated an international group of scientists and policymakers at the workshop at Mabula, South Africa, in May 2003 to attempt to find answers. To the surprise of the workshop organisers, there were large numbers of recent examples that indicate innovative ideas, but there has been room to highlight only a select few in this book. To maintain the momentum gained from the international community, agriculturists, conservationists, scientists and policy makers are encouraged to use the case examples, references, webpages and other information to learn more and develop innovative ways to conserve pollinators and the ecosystem services they provide.

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Appendix Ongoing pollinator initiatives and related institutions

1 African Pollinator Initiative

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Objectives: The African Pollinator Initiative (API) is a regional initiative committed to understanding, protecting and promoting the essential ecosystem service of pollination for sustainable livelihoods and the conservation of biological diversity in Africa. Informed by an increasing world-wide recognition that pollinators play a key role in ecosystem health, both in farmers' fields and in wild landscapes, a group of biologists, extension agents, educators and conservationists met in Kenya in early 2002 to formulate a continent-wide initiative to conserve pollinators in Africa. The meeting endorsed the 'Kasarani Declaration' with the following objectives:

- To promote pollination, as an essential ecosystem service, for sustainable livelihoods and the conservation of biological diversity in Africa.
- To develop a Plan of Action to realise this purpose.
- To commit to working together to carry out the Plan of Action.
- To call upon the United Nations Food and Agriculture Organization (FAO) to support API.

2 Brazilian Pollinators Initiative

Contacts: Vera Fonseca
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vlifonse@ib.usp.br

Dr Braulio Dias
Brazilian Ministry of Environment, Brasilia, Brazil

Objectives: The Brazilian Pollinators Initiative (BPI) aims to strengthen scientific and technological excellence on pollinators by means of an active network with a critical mass of resources and expertise. BPI generates knowledge on pollinators and facilitates the integration of teams, with the mission of spreading excellence beyond the boundaries of its partnership. Training capabilities using standard methodologies and network facilities are its essential components. The initiative will provide the necessary integration by adopting and reinforcing electronic information and communication networks to support interactive working between the teams involved. Activities planned to spread excellence are the following:

- A joint programme for training researchers and other key staff.
- Dissemination and communication activities, including public awareness and understanding of science.
- Promoting the exploitation of the results generated within the network.

3 European Pollinator Initiative (EPI)

Contact: Simon Potts
Centre for Agri-Environmental Research
University of Reading, PO Box 237, Reading, RG6 6AR, UK
s.g.potts@reading.ac.uk.

Objectives: To integrate trans-European expertise relating to pollination into a cohesive network, in accordance with the aims of the International Pollinator Initiative (IPI), in order to overcome the currently fragmented activities of scientists, end-users and stakeholders. EPI has developed two action plans. First, the Assessment of Large-scale Environmental Risks with Tested Methods (ALARM), which focuses on the assessment and risk analysis of pollinator loss; second, the Sustainable Use of Pollinators as a European Resource (SUPER), which focuses on adaptive management, capacity building and mainstreaming of pollinators and pollination services.

ALARM aims to

- quantify distribution shifts in key pollinator groups across Europe.
- measure the biodiversity and economic risks associated with the loss of pollination services in agricultural and natural systems.
- determine the relative individual and combined importance of drivers of pollinator loss.
- develop predictive models for pollinator loss and consequent risks.

SUPER aims to

- identify and promote best land-use and conservation practices to restore and conserve pollinator communities.
- ensure long-term sustainable management of pollinators in agricultural and natural systems.
- maximise the socio-economic benefits of effective pollination services.
- develop of a state-of-the-art understanding of the ecological, behavioural and evolutionary driving forces of plant-pollinator interactions.

4 International Centre for Integrated Mountain Development (ICIMOD)

Contact: Uma Partap
International Centre for Integrated Mountain Development (ICIMOD)
PO Box 3226, Kathmandu, Nepal
upartap@icimod.org.np.

Objectives: To develop and provide integrated and innovative solutions, in cooperation with regional and international partners, to foster action and change for overcoming mountain people's economic, social, and physical vulnerabilities. The goal of the Centre's pollinator programme is to improve the livelihoods of mountain people by enhancing agricultural productivity and biodiversity conservation through promoting conservation of indigenous pollinator species, including beekeeping, to ensure sustainable pollination of agricultural crops and other indigenous plant species of the region. The specific objectives of this programme are as follows:

- To enhance the understanding of the role of pollinators and pollination in maintaining crop productivity.
- To identify problems related to crop pollination management.
- To promote the conservation and sustainable use of pollinators in agricultural and natural ecosystems.
- To promote adoption of managed crop pollination through beekeeping as an immediate solution to ensure pollination of cash crops.
- To develop human resources and build the capacities of collaborating institutions to achieve the above-mentioned objectives.

5 North American Pollinator Protection Campaign (NAPPC)

Contact: Laurie Adams
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NAPPC@coevolution.org
www.nappc.org

Kimberly Winter, Coordinator
North American Pollinator Protection Campaign
NAPPCoordinator@hotmail.com
www.nappc.org
Phone: (301) 405-2666
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University of Maryland
College Park, MD 20742-1026

Objectives: The major goal of this network of pollinator researchers, conservation and environmental groups, private industry, state and federal agencies in Mexico, Canada and the United States, is to develop and implement an action plan to

- coordinate local, national, and international action projects in the areas of pollinator research, education and awareness, conservation and restoration, policies and practices, and special partnership initiatives.
- facilitate communication among stakeholders, build strategic coalitions and leverage existing resources.
- demonstrate a positive measurable impact on the populations and health of pollinating animals within five years.

6 The Bee Works, LLC (TBW)

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www.thebeeworks.com
Phone: (520) 888-7332

Objectives: The major goals of this pollinator company are as follows:

- To conduct research (e.g. bee surveys and GIS maps) on federal, state and

private lands, especially with native bees and their floral host plants.
- To write, publish, create and disseminate free and commercial publications on pollinators, pollination and pollinator conservation themes.
- To conduct customised high resolution scanning and digital photography services (and/or make large-scale prints) of bees and other pollinators for use in educational outreach (e.g. museums, science centres and publications for educational outreach).
- To help reduce the taxonomic impediment by creating composite (all-in-focus) digital photographs of bees and other pollinators that can serve as illustrations in hardcopy field guides and online publications.
- To network with individual pollination scientists, other NGOs, pollinator initiatives and commercial enterprises to help raise awareness about pollination concerns, and to help reverse or slow pollinator declines around the world.

Institutional resources

Region: Africa (AF); Asia (AS); Australasia (AU); Europe (EU); Meso-America (MA); North America (NA); South America (SA).

Type of organisation: Government (GOV); Non-Government Organisation (NGO); Network (NET). Explicitly includes pollinators (*)

Main activities: Conservation (CON); Policy (POL); Research (RES); Commercial Applications (CA); Taxonomy (TAX); Education (EDU); All these above (ALL)

Organisation	Website	Type
African Pollinator Initiative (API)	www.elci.org/api	NGO, AF, *, ALL
Agricultural Research Council of South Africa (ARC)	www.arc.agric.za	GOV, AF, *, ALL
APIMONDIA	www.beekeeping.com/apimondia	NGO, *, CA
Arizona-Sonoran Desert Museum	www.desertmuseum.org/pollination/index.html	NGO, NA, *, EDU
Australasian Pollination Ecologists Society (APES)	www.roseworthy.adelaide.edu.au/APES/welcome.html	NGO, AU, *, RES
Australian Native Bee Research Centre (ANBRC)	www.zeta.org.au/~anbrc	NGO, AU, *, RES
UK Biodiversity Action Plan (UK BAP)	www.ukbap.org.uk/default.htm	GOV, EU, *, ALL
Bat Conservation International	www.batcon.org	NGO, *, CON
Bee Systematics and Biology Unit, Oxford University Museum	www.oum.ox.ac.uk/bees.htm	GOV, EU *, RES, TAX
Bees, Wasps and Ants Recording Society (BWARS)	www.bwars.com	NGO, EU, *, RES
BioNET-International	www.bionet-intl.org	NGO, ALL
Brazilian pollinator Initiative (BPI)	www.webbee.org.br	NGO, SA, *, ALL
British Ecological Society (BES)	www.	NGO, EU, RES

Organisation	Website	Type
Butterfly Conservation (BC)	www.butterfly-conservation.org	NGO, EU, *, CON
Centre for International Forestry Research (CIFOR)	www.cifor.cgiar.org	NGO, RES, CA, POL
Centre for Agri-Environmental Research, UK (CAER)	www.apd.rdg.ac.uk/Agriculture/CAER/index.htm	GOV, EU, *, RES
Consultative Group on International Agricultural Research (CGIAR)	www.cgiar.org	NGO, RES, POL
Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE)	www.catie.ac.cr/catie	NGO, MA, RES, CA
Conservation International	www.conservation.org/xp/CIWEB/home	NGO, CON
Consortium of European Taxonomic Facilities (CETAF)	www.cetaf.org	NGO, EU, TAX
Convention on International Trade in Endangered Species (CITES)	www.cites.org/index.html	NGO, CON, POL
Department for Environment, Food and Rural Affairs (DEFRA), UK	www.defra.gov.uk	GOV, EU, POL
Discover Life	www.discoverlife.org	NGO, NA, *, TAX
Eco-agriculture Partners	www.bionet-intl.org/html/whatsnew/news/EcoAgrPartners.htm	NGO, AF, CA, POL, EDU
Ecological Society of America (ESA)	www.esa.org	NGO, NA, ALL
Ecological Society of Australia	www.ecolsoc.org.au/?esahome.html	NGO, AU. ALL
English Nature (EN)	www.english-nature.org.uk	GOV, EU, *, CON
European Pollinator Initiative (EPI)	www.apd.rdg.ac.uk/Agriculture/CAER	NGO, EU, *, ALL
European Union Agri-Environmental Schemes	www.europa.eu.int/comm/agriculture/envir/index_en.htm	GOV, EU, POL

Organisation	Website	Type
Expert Centre for Taxonomic Identification (ETI)	www.eti.uva.nl	NGO, TAX
Fauna Europaea	www.faunaeur.org	NGO, EU, TAX
Food and Agriculture Organization (FAO)	www.fao.org/biodiversity/pollinat_en.asp	NGO, *, ALL
Farming and Wildlife Advisory Group (FWAG)	www.fwag.org.uk	NGO, EU, ALL
Global Biodiversity Information Facility (GBIF)	www.gbif.org	NGO, NET
Convention on Biological Diversity (CBD)	www.biodiv.org	NGO, *, ALL
Global Taxonomic Initiative (GTI)	www.biodiv.org/programmes/cross-cutting/taxonomy/default.asp	NGO, TAX
Hymenoptera On-line Database	http://iris.biosci.ohio-state.edu/hymenoptera	NGO, NA, TAX
Integrated Taxonomic Information System (ITIS)	www.itis.usda.gov	GOV, NA, TAX
International Bee Research Association (IBRA)	www.ibra.org.uk	NGO, *, ALL
International Centre for Integrated Mountain Development (ICIMOD)	www.icimod.org	NGO, AS, *, ALL
International Centre of Insect Physiology and Ecology (ICIPE)	www.icipe.org	NGO, RES
International Commission for Plant Bee Relationships (ICPBR)	www.lsoft.com/scripts/wl.exe?SL1=ICPBRandH=LISTSERV.UOGUELPH.CA	NGO, *, ALL
International Network of Expertise for Sustainable Pollination (INESP)	www.uoguelph.ca/~inesp	NGO, *, NET
International Pollinator Initiative (IPI)	www.fao.org/waicent/FaoInfo/Agricult/AGP/AGPS/pollinators/pollinators/index.htm	UN
Linking Environment and Farming (LEAF)	www.leafuk.org/LEAF	NGO, EU, CA
National Wildlife Federation	www.nwf.org	NGO, NA, *, ALL

Organisation	Website	Type
North American Pollinator Protection Campaign (NAPPC)	www.nappc.org	NGO, NA, *, ALL
Program for Conservation of Bats of Mexico	www.ecologia.unam.mx/laboratorios/rmedellin/pcmm.htm	NGO, NA, *, CON
Scandinavian Association for Pollination Ecologists (SCAPE)	www.nlh.no/ibn/scape/scape03.htm	NGO, EU, *, RES
Species 2000	www.sp2000.org/index.html	NGO, TAX
Task Force on Declining Pollination of the Species Survival Commission of the World Conservation Union (IUCN)	www.uoguelph.ca/~iucn (www.iucn.org)	NGO, *, NET
United Nations Environment Programme World Conservation Monitoring Centre (WCMC)	www.unep-wcmc.org/index.html	NGO, ALL
USDA-ARS Bee Biology and Systematics Laboratory	www.loganbeelab.usu.edu	GOV, NA, *, RES
US Department of Agriculture – Natural Resource Conservation Service, Conservation Reserve Programs	www.nrcs.usda.gov/programs/crp/	GOV
World Conservation Society (WCS)	www.wcs.org	NGO, CO
World Wide Fund for Nature (WWF)	www.panda.org/index.cfm	NGO, CON
The Xerces Society	www.xerces.org	NGO, NA, *, CON

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