CHAPTER ONE: MONITORING THE STATUS AND TRENDS OF POLLINATORS

1.1 POLLINATORS AND POLLINATION SERVICES

The efforts in many parts of the world to conserve and better manage pollinators are proposing innovative concepts in the conservation of biodiversity. Thinking beyond the confines of species conservation and a focus on rare and endangered species, the conservation of pollination is concerned with relationships between species. It is the loss of this that was noted years ago by an eminent ecologist: “What escapes the eye is the most insidious kind of extinction – the extinction of interactions.” 1 Pollination, of course, is a key interaction with implications for both wild ecosystems and human livelihoods. It enables both plant reproduction, and food production for humans and animals of fruits and seeds, including many crops essential to food security and sound nutrition.

Pollinators such as bees, birds and bats affect 35 percent of the world’s crop production. Animal pollinators increase the outputs of 87 of the leading food crops worldwide2. In the continents of Latin America, Africa and Asia, an average of 40% of the land area of crops is planted to crops with some dependence on animal pollinators. These are low estimates, as they do not include secondary crops, medicinal plants or wild-harvested crops, but they do provide an indication of the extent to which pollinators are essential for many “diversities”: diversity in diet, biological diversity including its agricultural dimension and the maintenance of a diverse and resilient natural resource base.
With focused efforts to conserve and manage pollination services, biodiversity conservation enters a new and innovative phase. Ecosystem services, including climate regulation, soil production, water purification, pest control and pollination, are critical to human survival. Nonetheless, few natural areas are managed or valued for the services they provide, although many are managed to produce ecosystem goods such as wood, wildlife, or fish. Pollination services, supplying direct production inputs to agriculture from wild biodiversity, provides one of the strongest cases for valuing and managing natural habitats and resources for the services they provide to livelihoods. No other natural phenomenon illustrates more vividly the principle that conservation measures must be directed at ecological processes, and not just individual species.

One of the most potent indicators of the health of pollinator interactions may be the incidence of plants suffering pollen limitation: receiving insufficient quantities of pollen to produce seed or fruit at what would be considered optimal levels. Recent research has shown pollen-limited fecundity is widespread amongst natural populations; in natural communities up to 62% of plants may be experiencing pollen deficits\(^3\). Pollen limitations are more severe in areas of high plant diversity, and may be due to a shortage of pollinators\(^4\).

**1.2 GLOBAL STATUS OF POLLINATORS**

Worldwide, the number of flower-visiting species is estimated to be around 150,000\(^5\). Bees account for 25,000 to 30,000 species and together with flies, butterflies, moths, wasps, beetles and some other insect orders encompass the majority of pollinating species\(^6\). Vertebrate pollinators include bats, non-flying mammals (several species of monkey, lemur, rodents, tree squirrel, coati, olingo and kinkajou) and birds (hummingbirds, sunbirds, honeycreepers and some parrot species).

Though pollinators are known to provide essential services to critical ecosystem functions, changes in the distributions of most pollinator groups remain poorly described. The challenges of identifying declines in pollinators are considerable given the high rarity found in some taxonomic groups (e.g. bees), the lack of baseline data collected and high spatial and temporal variation in pollinator populations\(^7\). While there is a need for more data, there are however two sources of information available: (1) direct evidence in the form of case studies recording declines of specific
As they have for generations, Nepalese men gather at the base of cliffs twice a year and carry out a semi-annual harvest of honey from the world’s largest honeybee, *Apis laboriosa*, the Himalayan cliff bee - with prayers and a sacrifice of flowers, fruit and rice. Descending the cliff by a rope ladder, honey hunters use smoke to subdue bees before cutting chunks of honey from the combs. For hundreds of years, the skills required to perform this treacherous task have been passed down through the generations. But recent surveys show that over the last 20 years, the number of bee nests and bee cliffs substantially decreased. The cliff bee is extraordinarily well-adapted to the harsh, oxygen-poor conditions of the high Himalayan altitudes, and serve as the prime pollinator for the eco-region. Its decline is thought to have devastating consequences for the native, high-altitude plants that rely on the honeybee for their reproduction.

A key threat to the cliff bees and traditional Nepalese honey hunters may be the growing recognition of the honey’s value for use in Japanese, Chinese, and Korean traditional medicines. In the past few decades, demand for *A. laboriosa* honey, which is produced during the spring when the rhododendrons bloom, has soared. A kilogram (2.2 pounds) fetches upwards of US$15 on the open market. Traditional honey hunting techniques and rituals that ensured a sustainable harvest and maintained bee populations have given way to non-traditional techniques that denude cliffs of nests in an effort by contractors to maximize profits. Forest destruction and habitat loss also impact *A. laboriosa* populations with dwindling forage resources, as pristine forests are cleared and replanted with non-native commercial crops or fast-growing plantation trees that are of no use to the bees.

*BOX 1-A PRECIPITOUS DECLINE IN THE STATUS OF HIMALAYAN CLIFF BEES*

from Ahmad et al. (2003)
taxa in a particular region; and (2) indirect evidence from studies focusing on the
distribution of known drivers of pollinator loss as a surrogate for declines.

1.3 DIRECT EVIDENCE FOR POLLINATOR DECLINES

Pollinator declines have been noted in many regions of the world. Every continent,
extcept for Antarctica, has reports of pollinator declines in at least one region or
country. Evidence is generally in the form of case studies and fragmentated in nature,
making it difficult to identify general trends across taxa and across regions. However,
a recent large-scale assessment and analysis of long-term data in the Netherlands
and the United Kingdom has shown parallel declines in pollinating species and the
plants they pollinate.

Honeybee (Apis mellifera) colonies, both managed and wild, have undergone
marked declines in the US and some European countries. The number of managed
honeybee colonies in the US dropped from 5.9 million in the 1940’s to 1.9 million in
1996, and most feral colonies have also been lost. Numbers of honeybee colonies
are reported to have declined from 15 to 30% between 1985 and 2005 from locations
in Italy, Austria, France, Germany, Netherlands, Sweden and Hungary. The related
Himalayan cliff bee (Apis laboriosa) has experienced significant declines (see Box
1-A). In a regional study, all but one censused cliff showed declines in number of
colonies or total loss across a 15 year period.

Studies have described marked declines of bumblebees (Bombus spp.) in Britain,
Belgium and eastern Germany and native solitary bee species in Germany and in
Britain. Changes have been attributed to habitat loss resulting from agricultural
intensification.

Beekeepers of the stingless bee Melipona beecheii, traditionally kept in log hives
in the Maya zone in Quintana Roo state, southeastern Mexico, testify to a sharp drop
during the last twelve years in the already declining managed bee populations. Im-
portant reasons for that decline include deforestation, competition from introduced
feral African Apis mellifera, hurricane damage, a lack of economic incentives for
traditional stingless beekeeping, and the failure to properly instruct new stingless
beekeepers. Since 1980, the numbers of bee hives have decreased by over 90%. For
the tropics, this scenario, sampled from 20% of the largest traditional beekeeping
group in the Americas, shows how pollinators are threatened both by environmental
RAPID ASSESSMENT OF POLLINATORS’ STATUS

Population characteristics of bees may show changes before actual declines may be detected: bees that appear common may in fact be in jeopardy. For genetic reasons alone, bees are more extinction prone than other taxa as single locus sex determination makes them particularly sensitive to the effects of small population size through the production of sterile diploid males. An example of this is the most abundant orchid bee in lowland forest in Panama, Euglossa imperialis, which frequently has high levels of sterile males resulting in low effective population sizes subject to extinction.

The widespread declines of invertebrate pollinators in North America highlighted in the “Forgotten Pollinators” campaign have been critically evaluated in a series of papers which concluded that an inability to find direct evidence reflects more a lack of appropriate data rather than an absence of any broad-scale declines. Information on the status of pollinator populations is unfortunately limited by the

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**BOX 1-B: ENDANGERED MUTUALISMS**

The beautiful black and white ruffed lemurs are found in the eastern rain forest of Madagascar where both habitat destruction and hunting for food has resulted in this species being classified as Endangered on the IUCN Red List. These striking primates primarily eat fruit, but also feed on nectar, leaves and seed, as well as occasional small birds and rodents. Black and white ruffed lemurs are associated with the traveller’s palm, a familiar Madagascan plant that has large flowers, up to 25 cm long. Black and white lemurs have been seen using the stems of leaves and flower bracts as ladders to help them reach up into the flowers for nectar. The pollen is then transferred as they move from one bloom to another. This makes them one of the largest, and most unique of all pollinators.

(from Kress et al. (1994).

© Steve Hart

Traveller’s Palm

Black and white ruffed lemur

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intensity of data gathering. For example, no bee species are listed as threatened or endangered in the Mediterranean region, although this is a recognised centre for bee speciation, which experiences considerable human impacts. The lack of listed species probably reflects the absence of active specialists to compile Red Data Lists for this region, as well as others\textsuperscript{18}. Variable impacts from one species to another are evident in monitoring information from Belgium and France, highlighting the difficulty of characterising whole communities by simple statements of trends\textsuperscript{19}.

The European Pollinator Initiative is currently seeking to document and quantify distribution shifts in key pollinator taxa across Europe. Amongst the innovative approaches they are using is an exercise to survey all possible sources of data. Across the EU and beyond, there are many sources of information relating to pollinator distributions, but these resources are in diverse and incompatible formats, highly fragmented, spread across continents and institutions and employing a number of different languages. By carrying out an inventory of the resources and prioritising their value, an efficient system of searching for and accessing the richest historical resources is being developed\textsuperscript{20}. The potential for amateur naturalists to record present distribution records with a high standard of accuracy is evident in the activities of the Bees, Wasp and Ants Recording Society\textsuperscript{21}.

Additional pollinator taxa besides bees are the focus of monitoring concerns: there are several local and national-level butterfly (Lepidoptera) recording schemes in Europe, notably those in Great Britain, the Netherlands and Germany. Comparison with historical records (1970-1982) showed that half of British resident butterflies have disappeared from over 20% of their range, and a quarter have declined by more than 50%. Many European butterflies are under serious threat because of changing land-use and agriculture intensification\textsuperscript{22}. Again, the concentration of data is more a reflection of the location of specialists to gather it, than a reflection of zones of greatest concern.

Strong evidence is available for declines in mammalian and bird pollinators-which, being larger and more visible, more often are included in monitoring schemes. At least 45 species of bats, 36 species on non-flying mammals, 26 species of hummingbirds, 7 species of sunbirds and 70 species of passerine birds - all of which are known to pollinate plants - are of global conservation concern\textsuperscript{23}.
BOX 1-C: POLLINATORS SPRING OPEN “POP-TOP” FLOWERS

Bright red mistletoe flowers are a feature of the New Zealand temperate rainforests, but something may be amiss with this floral display. Whereas most flowers prominently display their assets—pollen, or nectar, or both, to floral visitors, these mistletoe flowers keep their pollen receiving structures sealed firmly within the flower.

Only “specialist” pollinators—a native honeyeater bird, and some native bees—know how to twist the bud and make it pop open. In the case of the tui, a nectar-loving honeyeater bird, pollen falls onto the bird’s head as it sips the nectar that is now available. The native bees, being quite small, must work quite some time to “trip” the flower, but they too succeed and gather pollen, often carrying pollen to the next flower they may pry open. With both the honeyeaters and the bees, only native species seem to have had time to learn how to unlock the mistletoe blossoms.

At the turn of the last century, botanists reported forests ablaze with the scarlet blooms of native mistletoes, but today few areas of New Zealand support profuse growth. In most places, unpollinated dead blooms littering the ground are more common than flowers twisted open by birds and bees. Experiments have shown that at several sites in the central Southern Alps of South Island, mistletoe plants produce no more fruits than plants that have been placed inside cages to keep out pollinators. This means that birds and bees are visiting flowers so infrequently—or that the birds are becoming so scarce—that essentially there is no increase at all in pollination over the low rate of self pollination.

from Sessions (2000).
1.4 INDIRECT EVIDENCE FOR POLLINATOR DECLINES

Multiple drivers of pollinator loss have been identified in case studies, and given that these drivers are widespread and are perceived to be increasing around the world\textsuperscript{24}, then it follows that declines in pollinators may also be widespread.

Habitats required by many pollinators are being lost through changing land-use patterns such as increasing agricultural intensification\textsuperscript{25}. Pollinators require a range of resources from their environment for foraging, nesting, reproduction and shelter. The loss of any one of these requirements can cause pollinators to become locally extinct\textsuperscript{26}. Temporal datasets documenting pollinator declines are few, but additional evidence in support of such declines comes from snapshot studies across gradients of human disturbance. On melon farm sites in the western United States, wild bee communities become less diverse and abundant as the proportion of natural habitat surrounding farms declines. The most important species for crop pollination became locally extinct throughout large parts of the landscape. All species declined along this gradient, however, so that more resistant species could not compensate for the loss of more sensitive species. The implications for pollinator function are evident: only farms located near natural habitat were able to sustain communities of pollinators sufficient to provide the necessary levels of pollination services\textsuperscript{27}. Distance from natural habitat affected pollinator communities and services in a similar way on coffee farms in Costa Rica\textsuperscript{28}.

Similar effects have been shown for bat pollinated plants and butterfly populations. For example, lower visitation rates by bats and reduced fruit set occurred on a dry forest tree species, \textit{Ceiba grandiflora}, in disturbed habitats in Mexico and Costa Rica\textsuperscript{29}. The ‘Red Data Book of European Butterflies’ reports that many European butterflies are under serious threat because of changing land-use and agriculture intensification\textsuperscript{30}.

Excessive use or inappropriate application of pesticides and other agro-chemicals is known to have negative impacts on a range of pollinators\textsuperscript{31}.

Climate change may potentially be one of the most severe threats to pollinator biodiversity\textsuperscript{32}. Substantial distribution changes are predicted for groups such as butterflies\textsuperscript{33}.

Invasive species are globally recognised to have major negative impacts across
a wide range of taxa. Two major causes of honeybee declines are parasitic mites (*Varroa jacobsoni* and *Acarapsis woodi*) and the expansion of the range of African-ized honeybees in the US. Introduced honeybees (*Apis mellifera*) has had strongly deleterious impacts on indigenous honeybees (the cliffs bees and Asian hive bees) in the Hindu-Kush Himalaya region.

**BOX 1-D. UNRULY BEES.**

Surveys of pollinator populations are difficult to design, largely due to the very wide variation in pollinator populations. This merits some explanation, as it impacts the ability of scientists to deliver clear assessments of pollinator trends to policymakers. Bees and insects that comprise most pollinator populations are “vagile”, meaning that they quickly change or adapt to new situations by moving their location. If conditions at a site are poor with stormy or cold weather that may prevent pollinators from flying, their apparent numbers in a survey may be low. But as conditions improve, they may equally quickly return. It is quite normal for bee populations to double, or to halve, from one year to the next. It is thus difficult to sort out long term trends when short term variation, or “unruliness” in the data may be very high.

An example of a very long term study of Orchid bees (Euglossini) in tropical moist forest in Panaman helps to illustrate this. Over 21 years, no aggregate trend could be detected, although four individual species declined, and nine increased. The most common set of bee species gradually declined over time, which probably bodes poorly for the pollination services of the forest, although biodiversity (taken in simple terms of species numbers) increased! There were up to fourfold differences in bee abundance among years, and 14-fold changes in species abundance. El-Niño climatic events led to brief increases in bee abundance.

A close examination of this data suggests that minimum series of four years (i.e., three intervals) of several counts during the active season may demonstrate genuine trends. Longer term, continuous studies are still needed for meaningful insights on pollinator population shifts in nature.

*from Roubik (2004).*
1.5 ENDANGERED MUTUALISMS: WHAT HAPPENS WHEN A PLANT LOSES ITS POLLINATOR?

Poor reproduction observed in several rare plants has been linked to the loss of their specialized pollinators. Examples are populations of a snapdragon relative in South Africa\(^3\) and bird-pollinated vines in Hawaii\(^4\). Highly specialized relationships occur between fig tree species and their pollinator, fig wasps, which can have dramatic effects on ecosystems when “keystone” species such as figs lose their specialized pollinators\(^5\).

However, most pollination systems can be characterized as “somewhat generalized”\(^6\). In exploiting each other's resources, it is in the interest of both pollinators and plants needing pollination services to remain at least somewhat flexible. Pollination systems are thus reasonably “robust”—most flowers attract and can be pollinated by a range of pollinators that often vary under different climatic conditions. Throughout the range of pollinators, however, some will be much more effective than others. Thus flowers usually will continue to experience visitation even if the most effective pollinators are for some reason eliminated. Pollinators will still visit flowers, but less quantities of pollen may be deposited, or may be deposited at the wrong place on the plant, or the visits may occur at times when the flower is less receptive to receiving pollen.

1.6 MONITORING TRENDS IN POLLINATOR POPULATIONS: BEES

While numerous specific observations of pollinator declines have been documented, it has proven extremely difficult to determine if whole pollinator communities globally, or across entire regions are already widely diminished and threatened by human activities. Even more difficult is to determine which activities of human populations may be responsible for pollinator declines. The inherent difficulty is the “unruliness” of pollinators: as largely composed of vagile insects, their population numbers vary naturally, and tremendously, in time and space (see Box 1-D). In many sites, “normal” bee populations commonly halve or double in one-year intervals, in response to environmental conditions\(^7\).

If a group of organisms have large variability in their population sizes, the effort required to sample that population increases proportionally, to be able to confirm
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that the results are statistically valid. Bee populations are not only highly variable, but have many locally rare species: “singletons” that may be collected only occasionally in one locality, and do not occur there in large numbers or regularly over considerable time. Characterising this natural variability and diversity in itself could require sampling schemes and resource commitments that could be extremely costly. To distinguish natural long-term trends from those that are caused by human activity is even more challenging.

Effective antidotes to dealing with the diversity, variability, and “unruliness” of pollination population monitoring include the following:

1. Given the limits on time and funding for monitoring pollinators, approaches that maximize information for effort must be sought for future studies. Reliable information on status and trends of pollinators may be documented in a few focused plant-pollinator systems, rather than trying to sample entire faunas.

2. If broad trends across multiple taxa are needed, means of increasing sample sizes (for example by using large numbers of volunteers) will be essential.

3. Regardless of the purpose of the study, standardized unbiased sampling protocols using replicated designs will increase the value of data. Standardization permits statistical testing of changes in bee populations and communities, and allows for rigorous comparison between studies.

4. The significant information resources on species populations and trends that do exist are labour intensive and expensive to access. Since monitoring is a long term effort it is critical that steps are taken to make current information more accessible for future investigations. Proposals for biodiversity research should include a plan for the maintenance and sharing of the digital biodiversity data generated in projects. Species and specimen level data and associated metadata that are generated in funded projects can be made publicly available, for example, through mechanisms cooperating with the Global Biodiversity Information Facility (GBIF).

The fairly daunting challenges of sampling design, combined with the taxonomic impediment that can make monitoring results less meaningful when identifications are uncertain, must be overcome if the objective is to reliably monitor invertebrate
pollinator populations and respond to their declines with effective conservation measures.

Several improved monitoring methodologies are under development in multiple regions of the world. A few of these are highlighted here.

**Squash Pollinators of the Americas Survey (SPAS).** Given the methodological problems of sampling whole pollinator communities, an alternative methodology has been developed and is being tested for a distinctive, but widespread pollination system in the Americas, involving squashes and squash bees. The design is guided by several considerations and principles, including ease of data interpretability (maximum data return for modest effort); strict uniformity and consistency across all sites in methods; data maintenance through easily-available Excel spreadsheets; minimal time commitment; and decentralised data analysis (collaborators own and analyse their own data). In 2004, SPAS (Squash Pollinators of the Americas Survey) surveyed cultivated squashes and pumpkins at 20 sites in 11 US states and Mexico. Wild squash bee populations have been found to be present at all but one site, and providing a much-undervalued natural ecosystem service. In one farm with about 90,000 squash flowers, an estimated 1 million specialist squash bees were effectively visiting and pollinating the squash crop. Yet the grower currently spends US$25,000 annually to rent honey bees for what is probably superfluous pollination service.

**Beeplot: Monitoring methods for solitary bee species using bee bowls in North America.** A group of researchers associated with the North American Pollinator Protection Campaign (NAPPC) have been working on standardized protocols for sampling bees that are applicable to a global monitoring program. Two protocols have been developed: one for sampling over a uniform one-hectare area of habitat over an eight hour period, repeated at least four times a year, and another to sample large landscapes such as protected area, districts or counties, states or provinces, and large physiographic regions, to be repeated at 5 to 20 year intervals. The methods are simple and inexpensive, and have been selected for their accuracy and replicability. The protocols have been implemented at over one hundred sites across the United States and Canada.

**Sao Paulo+5 Forum Workshop on Survey Methods for bees:** assessing status and suggesting best practices. In October 2003 in Sao Paulo, Brazil, with a follow-up session at the 2004 Solitary Bees Workshop in Ceará, Brazil, a working group dis-
cussed surveying and monitoring methods for pollinators in natural and cultivated landscapes. Recognizing that results with different methods have been quite variable throughout the world, specific recommendations were made for designing rapid assessment, surveys and monitoring programs for bees. At the follow-up workshop, it was proposed that the different regional pollinator initiatives undertake pilot programmes of comparing the results from different methodologies, deployed simultaneously at sites around the world, to be better able to agree on common standardized approaches.

**Project Ape Miele Ambiente (Bee-Honey-Environment), Italy:** Italy is one of the few countries to have undertaken a countrywide, multi-year monitoring program of its wild bees in agricultural and semi-natural landscapes, from the years 1997-2000. The diversity of the Italian bee fauna was investigated at 52 sites in 8 Italian regions using a transect method. Even at this sampling intensity, just over a third of the historically known Italian bee fauna were collected and recorded. Three species collected were new records for Italy, and 45 species showed an enlarged distribution. 75% of the bees collected were found in agricultural habitats; 81% were found in semi-natural habitats, indicating the large overlap in these communities.

**ALARM: Assessment of Large Scale Environmental Risks with Tested Methods:** a project of the European Pollinator Initiative. The project works to build a knowledge base to support the sustainable conservation and management of pollinators throughout Europe. Researchers in a network across Europe are quantifying distribution shifts in key pollinator groups across Europe, measuring the economic and biodiversity risks associated with the loss of pollination services in agricultural and natural habitats, determining the relative importance of drivers of pollinator loss, developing predictive models for pollinator loss and consequent risks. The project includes standardized monitoring methods to quantify pollinator diversity and abundance in agricultural and natural habitats.

### 1.7 Monitoring Trends in Pollinator Populations: Other Pollinator Taxa

Other groups of animals that are known to pollinate have been the focus of some monitoring programs:

- **Flies.** The natural population fluctuations in pollinating fly populations are
difficult to differentiate from fluctuations caused by human-induced changes. Data on flies is even more limited than that on bees but case studies for example showing the impacts of urbanization on fly populations indicate severe impacts on the biodiversity of flies in human-dominated landscapes48.

- **Birds.** 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. Hummingbirds, like bats and some butterflies, migrate long distances. With breeding places in one site and over wintering sites in another, their conservation requirements are often complex; efforts in one place may be counteracted by a loss of habitat far away. For hummingbirds, the Arizona-Sonora Desert Museum has established a monitoring system based on collaboration between USA and Mexican institutions49. Additionally, many hummingbird species in North America are monitored by the North American Breeding Bird Survey which has data from over 4000 transects run each year across the US, Canada, and Mexico since 1966, largely carried out by volunteers.

- **Bats.** Bats can play important roles in pollination. Where estimates of their importance have been made, the diversity of plants that may be pollinated by bats is impressive. For example, it has been estimated that bats play some part in the pollination of at least 500 Neotropical species of 96 genera50. Bats as a group seem to be particularly vulnerable to human impacts on biodiversity; approximately 22% of bat species are considered Threatened and a further 23% as Near Threatened51. The long migratory ranges of pollinating bats require conservation monitoring and planning on large, often multiple-country scale. In one case, the sharp declines and habitat destruction have prompted closer monitoring of the migratory nectarivorous Mexican long-nosed bat (*Leptonycteris nivalis*) and lesser long-nosed bat (*Leptonycteris curasoae*). The Programa Para la Conservación de Murciélagos Migratorios (PCMM, Program for the Conservation of Migratory Bats) monitors over 20 caves in 14 states of Mexico52 where bat colonies remain stable or growing. The survey involves visiting each cave at least once every season, and estimating population sizes, sex ratios, obtaining blood samples, fecal samples and stable carbon isotope samples for subsequent dietary analysis. Although specific,
cross-cave comparisons cannot be conducted due to methodological hurdles and lack of standardization, 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 Mexico53.

- **Pollen limitation studies.** Since one of the ultimate concerns of the International Pollinators Initiative is that plant reproduction is suffering from declines in pollen deposition, monitoring plant reproductive success or pollen deposition deficits may be among the most effective direct measurements of pollinator declines. It has many of the same caveats as the monitoring of pollinator populations and trends will only be detected if the effects of other influences, such as climate and floral herbivory, can be removed.

**CONCLUSIONS**

Every continent, except for Antarctica, has reports of pollinator declines in at least one region/country. The losses of pollination services have been well documented in many specific instances; what remains lacking is global assessments of changes in the distribution and levels of pollination services. As the recognized drivers of pollinator losses (changing land-use patterns, pesticide use, diseases, invasive species and climate change) are themselves changing in intensity, the global community is justified in taking note and determining the actions that will conserve pollinators. The insidious nature of the loss of ecosystem services—by slow erosion rather than cataclysmic events—demands a careful monitoring system. Several very recent monitoring systems have been initiated on sub-global levels, although their conclusions will be some years away.

**View of experts on the way forward**

1. Disturbing trends and evidence for loss of pollination services have been recorded in multiple locations and ecological systems; the evidence, while fragmented, tells enough of a similar story in many different contexts that the global community is quite justified in taking action.

2. Policy makers need to have concrete, practical information on pollinator declines,
which can only be provided by a broad, collaborative global effort to effectively monitor pollinator trends and status. This may only be feasible by focusing on manageable indicator groups of selected pollinators.

3 Synergies between different initiatives to document trends in pollinator status should be strengthened. Research councils, other funding agencies and private foundations should promote that proposals for funding for biodiversity research include a plan for the maintenance and sharing of the digital biodiversity data generated in proposed projects and that species and specimen level data and associated metadata that are generated in funded projects are made publicly available.

4 The impact of pollinator loss on plant reproduction is not yet well addressed in most biodiversity monitoring programs, yet ultimately this impact is the underlying focus of concern for pollinator initiatives.
Chapter One Endnotes

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4. Vamosi et al. 2006
8. Biesmeijer et al. 2006
11. data from the ALARM project; www.alarmproject.net
14. Villanueva et al. 2005
19. 1stRAPS Case study contribution: 1-010CS.WildBeesBelgium.
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47. Kearns et al. 1998.
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51. Medellín 2003
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2.1 GLOBAL ESTIMATES OF THE VALUE OF POLLINATION SERVICES

Estimates of the annual monetary value of pollination vary widely. A value of US$120 billion per year for all pollination ecosystem services was estimated in 1997\(^1\). Specific estimates on a national basis for the role of pollination in the United States, Canada, Europe, New Zealand and Australia have been used as an estimate of more than US$50 billion in values to global agriculture alone\(^2\). Beyond this estimate of pollinator contributions to crop production, other aspects of agriculture also depend upon pollinators. Seed production and grazing resources for livestock and wildlife and soil fertility all benefit from pollination services, as do many functions of natural ecosystems. Pollination valuations have suffered from a lack of comprehensive, site-based assessments to properly identify the contribution of pollination to agricultural yields and human livelihoods - using accepted economic methods to assess values - so these values can be compiled into credible national, regional and global estimates. Nonetheless, existing valuations show that the monetary contribution of pollination to agricultural production is significant.

2.2 FOOD SECURITY AND POLLINATION SERVICES: HOW DEPENDENT ARE WE?

A global study of how much the production of crops that nourish humanity is dependent on animal pollination, based on FAO crop production data,
CHAPTER TWO: ECONOMIC VALUATION OF POLLINATION SERVICES

BOX 2-A: DEPENDENCE OF WORLD CROPS ON POLLINATORS.

Out of the 115 crops whose pollen vectors were determined in a recent global study, over 75% depend to some degree upon animal pollination. Among the leading crops that benefit from animal pollination, 13 are entirely reliant upon animal pollinators, 30 are greatly dependent and 27 are moderately dependent.

A few crops rely entirely on pollinators for reproduction; without pollinators, a crop could only be produced with human help via hand pollination. These include cocoa, one of the most important cash crops in tropical countries, the vitamin-rich and tasty kiwifruit, passion fruit, annona and sapodilla fruits, as well as vanilla, squashes and pumpkins, cantaloupes and watermelons, and Brazil- and macadamia nuts. Most crops showed a production increase between 5 and 50% as a result of pollination by animals (mainly bees).

The authors of this study readily acknowledge, however, that there are multiple gaps in the knowledge of pollination requirements, which may vary between varieties and geographic locations. The understanding of the pollination needs of many crops has recently been revised, as they are grown under increasingly intensive practices where the underappreciated wild pollination service may be impacted. In addition to gaps in knowledge about pollination requirements, there is also a dynamic aspect about knowledge development in this area, as production systems evolve and change. In particular, as production systems intensify, there has been an increase in awareness of the importance (and value) of previously supplied wild pollination services.

from Klein et al. (2007)
reveals that pollinators such as bees, flies, butterflies and moths, and beetles affect 35 percent of the world’s crop production. This increased the outputs of 87 of the leading food crops worldwide. Although 60% of the global food production comes from crops that do not depend on animal pollination – mainly staple crops like cereals such as wheat, maize and rice– the remainder, ensuring nutritional diversity, either comes from crops that depend on pollinators or from a small percentage of crops (5%) for which the dependence upon animal pollination is still unknown.

2.3 METHODS FOR VALUING POLLINATION SERVICES

The International Pollinator Initiative, in its plan of action, states the necessity to: “Assess the economic value of pollinators, including evaluation, in economic terms, of different crop-pollinator-pollination systems for optimal use of pollinators in sustainable agricultural systems, through economic analysis of data from various crop-pollinator-pollination systems”. Such an assessment could be central to convincing farmers and policy-makers of the value of conserving pollinators. However, several questions arise: how to do this? And, is there a valid methodology that can be applied to the valuation of pollination services?

Over the last decade, there have been several efforts to place a value on biodiversity to human livelihoods, including pollination as a contributing element. The 1997 study mentioned in Section 2.2 presented a global estimate of the value of biodiversity, showing that the value of ecosystem services is large and relatively important compared to the size of the human economic system. The numbers used in this study- estimating the value of pollination services globally at US$120 billion annually- should not be considered precise, but rather indicate orders of magnitude. More recent attempts have addressed some of the earlier imprecisions, but not specifically with respect to pollination valuation.

Given these impressive global estimates of pollination’s value to humans, it may well be asked why is it so unrecognized in the market place? Many different types of “failure” (market, institutional and global) explain why those values are not recognised or taken into account by markets. Mechanisms to capture values and channel support towards the conservation of the natural resources and ecosystem services that generate those values are discussed below, both from consumer and producer perspectives.
Global efforts to value biodiversity are applied at a macroeconomic level, whereas farmers and local and national decision makers focusing on particular crops need tools to balance the impacts on production of pro-pollinator practices against the impacts of other production practices that negatively affect pollinators - such as use of pesticides. Consumers are also part of the equation, and their values and demands need to be considered.

Methods that have been used to value pollination services, have considered, *inter alia*, the market value of all or some of the insect pollinated crops grown; or the value only of the proportion attributable to honey bees. Some have included the value of crops grown from seed derived bee-pollinated plants the legume crops and livestock products dependent on them, or even those legumes that fix nitrogen and thereby reduce nitrate fertiliser requirements. A relatively more sophisticated consumer surplus approach (i.e. one that measures changes in gains to consumers resulting from pollination induced price changes and thereby accounting for the effect of the existence of potential substitute crops- see also next section) was developed by Southwick and Southwick.

FAO has recently reviewed and identified methods for the valuation of pollination services for application in farming systems around the world. The methods are being applied in pilot projects assessing the benefits and costs of pollinator-friendly practices in chilli pepper farms in Ghana, and buckwheat, mustard and kitchen gardens in Nepal.

Recent research in coffee agroecosystems in Costa Rica has shown that the pollination services provided by pollinators nesting in forest patches adjacent to coffee plantations may contribute to substantially greater yields of coffee. The economic value of pollination services provided by intact forests was found to be similar to the expected annual earnings from the forested lands if they were cut down and converted to common agricultural uses for the area (see Box 2-B).

### 2.4 CONSUMER PERSPECTIVES

While pollination is generally conceived as being of value primarily to farmers, the consumer perspective should not be left out. Any comprehensive economic analysis
will need to take not only production (yield) changes into account but also price changes. The degree to which a change in pollination translates into a change in yields and production quantities is a first step in the analysis. How this translates into price changes at the farm gate and for consumers is a second and vital step of the analysis and will depend on the relative price elasticities of supply of demand of individual commodities, as well as that of their substitutes (i.e. cross elasticities)\(^1\). A good example of this type of analysis was carried out by Southwick and Southwick\(^2\). The overall impact on society’s welfare is determined by the change in consumer and producer surplus in the presence of different degrees of pollination. A model of the economics of pollinator deficits\(^15\) concluded that consumers of a commodity affected by a pollinator deficit may suffer because the commodity costs more and becomes less available. Consumers may thus have to pay more for traded commodities because of pollinator declines.

Where commodities are grown in places that exclude their natural pollinators, new markets may be created around pollination services. For example, a considerable business is built around providing bumblebee pollinators to greenhouse-grown tomatoes; without the services provided by bumblebees, tomatoes in the off-season would be far more costly.

**Consumer incentives**

To create markets that provide incentives for pollinator conservation, consumers would need to be willing to pay more for commodities that have been produced in a manner that does not negatively impact pollinators, or that have been noticeably well-pollinated. Such market incentives may exist in the certification of organic production, since inorganic pesticides are not used. Well-pollinated crops can be of noticeably better quality, and markets are sensitive to quality considerations: in Canada, good pollination in apple orchards resulted in about one extra seed per apple, which produced larger and better formed apples. These improved apples were estimated to provide marginal returns of about 5–6%, or about Can. US$250/ha, compared to orchards with insufficient pollination\(^16\).
A recent study of the value of wild pollinators to coffee crops in Costa Rica was unique in being conducted at the scale at which land use decisions are made. Dr. Taylor Ricketts and a group of scientists from Stanford University and World Wildlife Fund looked at the value of pollination services from forest-dwelling bees to surrounding coffee farms. They found that coffee fields near tropical forest fragments received more pollinator visits by a more diverse community of bees, higher rates of pollen deposition on flowers, and higher productivity than coffee fields more distant from forest.

Ricketts and his colleagues conducted their study in the Valle General in Costa Rica, near the city of San Isidro. They observed bee visits to coffee bushes at different distances from forest—ranging from within 100m to over 1.5 km away. The team found that pollinator diversity near to the forest was much higher than further away. In the nearest sites, visitors to coffee included feral honeybees (Apis mellifera) and 10 species of stingless bees (Meliponinae), while far from these forests honeybees were almost the only visitors. The more diverse bee community in sites near forest also visited coffee flowers at twice the rate—and deposited twice the pollen on flowers—as the more depauperate communities occurring far from forest. Pollinators near forest also seemed to provide more stable pollination services over time. Mid-way through the study, honeybee populations crashed. In sites far from forest, pollination services declined significantly.

Optimal pollination results in a good harvest of coffee berries.
from forest, where honeybees were almost the only visitors, overall visitation rates declined sharply. In near sites, however, other species increased in abundance, so that overall visitation dropped only slightly. The diversity of available pollinators thus provided a stabilizing form of insurance against declines in any one species.

The team also found that these patterns in pollinator diversity had important consequences on coffee yields in the landscape. Using pollination experiments along the same distance gradient, the team showed that the diverse pollinator community near forest was providing adequate pollination services to coffee. Beyond roughly 1 km from forest, however, pollination services were insufficient, and coffee produced yields approximately 20% lower as a result. Therefore, coffee farmers beyond 1 km from forest suffered 20% lower yields due to inadequate pollination services. Using these results, the team estimated the economic value of the two largest forest patches in the landscape. For a single, large farm, pollination services from these two forest patches represented approximately US$60,000 of additional income per year. This estimate is similar to the expected annual earnings from the forested lands if they were cut down and converted to common agricultural uses for the area.

This study shows that pollination services from wild pollinators can have significant economic value. As agricultural landscapes continue to be intensified and lose their forested components, these pollination services and the productivity of crops may suffer. Forest conservation, therefore, can be in the best interest of both biodiversity and local farmers.

*from Ricketts (2004).*

### 2.5 Producer Perspectives

Pollination services have both market and non-market values.

**Market values, private goods and market failures**

In countries where commercial pollination services are provided, pollination can be treated as a private good (though not a pure one), which can directly be traded in the marketplace. In this case, the delivery and consumption of pollination services are based on human needs and preferences. But the ability of humans to misperceive pollination needs may be considerable. In many agricultural systems, producers may be paying for pollination services by domesticated honeybees, yet pollination by wild
bees may be supplementing or even surpassing managed pollination. In a large farm with over 90,000 squash plants, a grower paid an annual fee of US$25,000 to rent honey bees, yet the squash crop was being adequately pollinated by an estimated one million wild *Peponapis* bees\textsuperscript{17}. In no agricultural systems are payments being made to secure wild services, yet pollination clearly has such values if farmers are willing to pay at levels such as these.

Farmers (along with extension workers) may underestimate and undervalue the role of pollination. In a survey carried out in the United Kingdom in 2000, grower’s perception of the value of pollination services to their crops was about half the value attributed by the scientific literature. As the survey authors mention, “with crops requiring early pollination, for example apple, the prevalence of natural pollinators is affected by the harshness of the weather in the preceding winter. A survey taken after a run of mild winters may lead to growers underestimating the average impact of honeybee pollination”\textsuperscript{18}.

Market failures to capture the value of pollination is undoubtedly linked to the fact that animal-mediated pollination is a subtle, almost unnoticed interaction between plants and small insects. As such, it is not easily understood or manipulated by farmers in the same way as fertilizer application or pest control. The standard economic model of a perfect market assumes perfect information, that is, all agents in the market have full information about product characteristics and prices. This is clearly not the case in pollination markets, where there is a large gap of information on the contribution of pollinators, both for buyers (farmers) and sellers (domesticated honey beekeepers, or managers of land with bee nesting sites and habitat- which may be farmers themselves). Education and public awareness for farmers, extension agents and others in the agricultural sector are critically needed before pollination benefits are recognized by markets.

**Non-market and social values**

Pollination services may be “produced” by forest owners or land owners and bee keepers. Thus farmers who benefit from pollination services may also be the producers of the same since they may be the *de facto* owners and managers of many forest ecosystems, and of areas of wild habitat on their own farms. Other owners of land
within an agricultural landscape that may be “providing” pollination services may be local governments, protected area managers, and even departments of transportation, as floral resources for pollinators are often quite rich on road shoulders, where water runs off from the road surface. Pollination services from wild ecosystems are socially desirable, but are not market-based. In such cases, as is argued in the study by the British Department of Food, Environment and Rural Affairs\textsuperscript{19}, public intervention can assist to assure that pollination services are maintained at an optimal level, for maximum social benefit.

When pollinator habitat is found solely on the farmer’s own land, there is no “externality” in the words of economists. This means that the farmer alone benefits. In this case, a well-informed farmer could choose between having more agricultural land with less pollinator habitat and lower yields vs. less agricultural land with higher yields, if he or she was aware of such alternatives.

But it is rarely if never the case that pollinators forage according to farm boundaries, meaning that positive externalities (public goods) occur from farmers having pollinators making use of their farmland. Owners of the land supporting pollinators cannot restrict the neighbouring farmers from benefiting from the pollination services. Such positive externalities and the potential to “free ride” could provide a justification for public intervention in order to ensure a socially optimal provision of pollination services. Valuation could play a role in determining what degree of intervention is justified. However, it should be recognized that it will be very challenging to separate the pollination service values from the other ecosystem services provided by adjacent “wild” lands (e.g. water catchment, provision of pest control services, wildlife habitat, carbon sequestration, aesthetic and cultural values, etc.).

**Producer incentives**

Incentives that could promote pollinator conservation can be provided on the producer side through \textit{inter alia}:

- Land use restrictions and obligations to maintain natural habitats within agroecosystems. Such goals could also be achieved through market-based instruments e.g. tradeable permits.
Reduced subsidies provided to intensive farming systems (e.g. agrochemical and fuel subsidies, cheap loans for farm machinery purchase, etc.).
Payments for environmentally-friendly practices that generate positive externalities (e.g. habitat and wildlife conservation, watershed management, reforestation, bee-keeping, land set-asides).

CONCLUSION
Pollinators provide essential services to humans, providing improved agricultural yield and hence economic returns. In several instances, impressive documentation of the market and non-market values derived from pollination services has been made. Despite this, the economic valuation of pollination services is in a relatively undeveloped stage, and has a number of challenges to overcome, many stemming from the gaps in knowledge and producer understanding of the actual contribution of pollination to crop production. The non-market values of pollination services have not been well defined in an economic sense.

View of experts on the way forward
Pollination services provide a key local benefit arising from biodiversity conservation. The design of mechanisms to capture such values could play an important role in providing local incentives for biodiversity conservation, yet the technical means to quantify such values and inform such a process is still in its early stages of development.

1. More precise and accurate assessments of the agronomic value of pollination management in crop production are urgently needed for herbaceous crops as well as perennial ones (and in this case, it requires that the study be conducted over several years). This should include the impact of pollinator management on the stability of the pollination system.

2. More precise and accurate assessments of the economic valuation of pollination services for all stakeholders, including consumers, are critically needed (this includes, for example, the potential benefits of abundant fruit and vegetables for general well-being of citizens as well as health costs that derive from poor diets lacking in vitamins and minerals).
3. Valuation of pollination services for natural ecosystems- in both their production and consumption functions- is also needed.

4. Farmers, extensions workers, land managers and policy makers need to be better informed of these values, so that they can appropriately account for and address pollination services in their decision-making processes. The development of decision-support tools appropriate for different types of stakeholders would facilitate this process. The scope of agricultural education should include pollination in a more thorough-going manner, including the role of wild pollinators and the management actions, costs and benefits needed to promote their services.

Chapter Two Endnotes

1  Costanza et al. 1997.
2  United States:  Morse and Calderone (2000); Canada: Winston and Scott (1984); EU: Borneck and Merle (1989); New Zealand Matheson and Schrader (1987); Australia: Gordon and Davis (2003). Values were updated to 2007 at 3% rate of inflation, and the sum of agricultural production by these countries was taken as 60% of global production.
3  Klein et al. 2007
5  Balmford et al. 2002.
6  as reviewed by Drucker 2004
7  Matheson and Schrader 1987
8  O’Grady 1987
9  Borneck and Merle 1989
10  Martin, 1975
11  Levin 1984 and 1983
12  Southwick and Southwick 1992 1989
13  Mburu et al. 2006
14  1stRAPS Case study contribution: 2-001CS.CoffeeRickets
16  Kevan 1997.
17  stRAPS Case study contribution: 1-002CS.squash bees
18  http://statistics.defra.gov.uk/esg/evaluation/beehealth/
19  http://statistics.defra.gov.uk/esg/evaluation/beehealth/
CHAPTER THREE: THE TAXONOMIC IMPEDIMENT TO POLLINATOR CONSERVATION

3.1 THE IMPORTANCE OF TAXONOMY IN POLLINATOR CONSERVATION

Pollinator faunas and their life-sustaining relationships with flowering plants occupy crucial positions in both natural and agricultural ecosystems. As with all natural resources, inventories of their diversity and distribution are needed in order to conserve and sustainably manage them to the best advantage. Unfortunately, the current state of bee taxonomy imposes severe restraints on the realization of these goals, as it does for other pollinator groups like flies, wasps and beetles. This “Taxonomic Impediment” derives from serious shortfalls in investment in training, research and collections management and some reluctance within the taxonomic community to take advantage of modern approaches to information management so that essential information related to pollinators is accessible to a broad audience. It seriously limits the global capacity to assess and monitor pollinator decline, to conserve pollinator diversity and to manage it sustainably1.

The International Pollinator Initiative Plan of Action highlighted the urgent need for universities to raise the academic status of taxonomic research by investing in new post-graduate programs with an increased emphasis on training in data management and data sharing. Taxonomy is a field in which it is often difficult to attract new students, yet this is important as taxonomic capacity is essential to pollinator identification, conservation and management. There are a number of dimensions to the challenges that need to be addressed in a targeted
effort to surmount the taxonomic impediment: the adequacy and accessibility of identification services, the status of taxonomic knowledge, the provision of tools to assist non-experts in identification.

This report focuses on the taxonomic impediments in relation to bees, the superfamily Apoidea, which are uniformly central to pollination services in every ecosystem of the world. It should not be forgotten, however, that a vast suite of other organisms play important roles in pollination, and the taxonomic impediment of each of these should be reviewed and addressed as well (Box 3-A). Few of these other groups, in fact, have the benefit of such a well-organised and collaborative network of taxonomists as does the Apoidea.

3.2 POLLINATOR DIVERSITY AND HUMAN CAPACITY IN IDENTIFICATION SERVICES

The first taxonomic impediment to face pollination conservation efforts is the correct identification of pollinators; as is often repeated, one cannot begin to save what is not known. At the present time, to identify the pollinators associated with a plant, the services of an expert who can identify pollinators to genus, if not to species level, is needed. Some indication of the variation of diversity in bee groups is illustrated in the equal-area grid map of bumble bees produced by the Natural History Museum (see Box 3-B). Accessibility and support for identification services is another issue. Many if not most museums and taxonomic services charge fees for identification services. There is increasing recognition that support for taxonomy and identification services are legitimate and critical components of biodiversity conservation projects. Nonetheless, field biologists often neglect to consider the time, effort and resources required for insect identification, and often where funds have been set aside for taxonomic support, these are inadequate.

3.2 TAXONOMIC INFORMATION FOR A POLLINATOR INFORMATION MANAGEMENT SYSTEM

Fundamental to overcoming the taxonomic impediments, and using taxonomic information to inform management, is a need for an up-to-date, comprehensive catalogue of the scientific names of pollinators, linking pollinators to their ecological
### BOX 3-A. NON-BEE, NON-BUTTERFLY INSECT FLOWER VISITORS (ANTHOPHILES)

<table>
<thead>
<tr>
<th>ORDER</th>
<th>SUB-ORDER</th>
<th>FAMILY</th>
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<tbody>
<tr>
<td><strong>COLEOPTERA</strong></td>
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<td>Polyphaga</td>
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<td>Mordellidae</td>
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<td>Oedemeridae</td>
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<td></td>
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<td>Melyridae</td>
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<td></td>
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<td>Scarabidae</td>
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<td></td>
<td></td>
<td>Curculionidae</td>
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<tr>
<td><strong>DIPTERA</strong></td>
<td>Nematocera (shorter mouthparts)</td>
<td>Sciaridae</td>
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<td></td>
<td></td>
<td>Mycetophilidae</td>
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<tr>
<td></td>
<td></td>
<td>Cecidomyiidae</td>
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<td>Simulidae</td>
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<td>Chironomidae</td>
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<td></td>
<td></td>
<td>Cerataopogonidae</td>
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<td></td>
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<td>Bibionidae</td>
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<td></td>
<td></td>
<td>Scatopsidae</td>
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<td></td>
<td></td>
<td>Tipulidae</td>
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<tr>
<td></td>
<td>Nematocera (longer mouthparts)</td>
<td>Culicidae</td>
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<td></td>
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<td>Bibionidae</td>
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<td></td>
<td></td>
<td>Sciaridae</td>
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<tr>
<td></td>
<td>Brachycera (Orthorrhapha)</td>
<td>Stratiomyidae</td>
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<td></td>
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<td>Dolichopodidae</td>
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<td>Lonchopteridae</td>
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<td>Empididae</td>
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<td></td>
<td>Bombyliidae</td>
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<tr>
<td></td>
<td>Brachycera (Cyclorrhapha)</td>
<td>(Aschiza)</td>
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<td>Syrphidae</td>
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<td>(Schizophora)</td>
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<td>Conopidae</td>
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<td>Drosophilidae</td>
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<td>Sphaeroceridae</td>
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<td>Tachinidae</td>
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<td>Calliphoridae</td>
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<td>Muscidae</td>
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<tr>
<td><strong>HYMENOPTERA, OTHER THAN APOIDEA</strong></td>
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<td>Apocrita, Parasitica</td>
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<td>Braconidae</td>
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<td>Ichneumonidae</td>
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<td>Leucospidae</td>
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<td>Chrysididae</td>
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<td>Agaonidae</td>
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<td>Chrysididae</td>
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<td>Vespidae</td>
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<td>Formicidae</td>
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*from Kevan (2001).*
needs. The Global Biodiversity Information Facility (GBIF) is collaborating with FAO to produce a catalogue of the world’s approximately 17,000 described bee species. The project will develop an electronic catalogue of the bees, cross-referenced to known biological characteristics (including floral relationships, and ecological linkages), so that the knowledge base on pollinator management is consolidated, widely accessible and as broadly useful as possible. The catalogue will provide critical taxonomic and other primary content needed for the Pollination Information Management System which is coordinated by FAO and currently under development.

3.3 PROVISION OF TOOLS TO ASSIST NON-EXPERTS IN IDENTIFICATION

Where taxonomic services are stretched (as they are throughout the world), the provision of tools and guidance to assist non-experts in identification becomes increasingly valuable. Considerable progress has been made in the last decade in
fulfilling the need of pollination biologists, few of whom are taxonomists themselves, to have simplified keys to facilitate the identification of bee genera. A non-exhaustive list of such efforts includes:

- As an initiative to promote the study of Mexican bees, the Programa Cooperativo sobre la Apifauna Mexicana (PCAM) was initiated in 1985, and in 1994 produced “The Bee Genera of North and Central America” in Spanish and English, utilising abundant illustrations to guide users through the decisions of a dichotomous key.

- The Centre for Biological Information Technology (CBIT) at the University of Queensland has developed interactive identification and taxonomic information programs. The suite of programs developed permit experts to develop easy-to-use identification keys that allow users to enter several characteristics of a specimen into a key at one time, and manage photos and images to assist in identification. The ALARM project (Assessing LArge-Scale environmental Risks for biodiversity with tested Methods) in Europe is using this software, along with other image processing software to develop a user-friendly identification key to the 72 genera of European bees.

- The LUCID software has also been used to develop keys to bumblebees worldwide, through the Natural History Museum in the UK. A key to subgenera for both sexes, and a preliminary key to species from female colour patterns are being trialled.

- With support from the Gordon and Betty Moore Foundation, the University of Queensland has established a program to support the development and implementation of these identification tools in developing countries. The Plant Protection Research Institute in South Africa is using the software to develop a user-friendly key to the African genera of bees.

- A user-friendly guide to the Bees of the Eastern United States is under development.
DNA barcoding is a recent development that permits the identification of organisms based upon sequencing a small fragment of their mitochondrial DNA. The long term goal is to produce a DNA database that will permit identification of unknown specimens by comparison to archived sequences. The technology for this work is developing sufficiently rapidly that a hand held identification device may be available within a decade, and extremely useful for enabling greater public participation in monitoring of pollination populations.

Automated systems for bee identification have been developed that will permit parataxonomists and field workers to scan a bee’s wing into a scanner, subject the image to an “artificial intelligence” analysis, and produce an identification down to species level. One of these systems is DAISY, a generic pattern matching system which would allow non specialists to identify organisms within speciose arthropod genera using a combination of both morphology and molecular data. The DAISY system has been tested on a significant number of datasets including British bumblebees and Costa Rican hawkmoths. Another system, limited to insects with membranous wings is ABIS (The Automated Bee Identification System) developed by the University of Bonn.

CONCLUSION
Developing sound management plans for pollinators will hinge on good taxonomic support. Moreover, linked to the taxonomic information about species is other information on biological characteristics (including floral relationships, and ecological linkages) that is important for adaptive management. New approaches to managing pollinator information should help to overcome the taxonomic impediment, although the focus at present has been on bees, and not other key pollinator groups.

View of experts on the way forward
1. Sharing of and open access to publicly funded research data yielding primary species data on pollinators should be encouraged.
2. User-friendly tools to permit more non-specialists to identify pollinators should complement, while they cannot replace, specialist taxonomic services.
3. Taxonomic training and support for taxonomic services merit high respect and support in national and international priorities.
Chapter Three Endnotes

1 1stRAPS Case study contribution: 3-002CS.Manifesto
2 The information supporting this assessment is derived from C. Michener’s “The Bees of the World”, as well as personal communication with Dr. Michener and colleagues
3 http://www.nhm.ac.uk/research-curation/projects/bombus/
4 GEF support to taxonomy: http://www.biodiv.org/doc/ref/gti-gef-support.pdf
5 1stRAPS Case study contribution: 3-002CS.Manifesto
7 www.cbit.uq.edu.au
8 1stRAPS Case study contribution; 3-003CS.Polaszekbeekey
9 1stRAPS Case study contribution: 3-00CS.5ENABee genera; also see www.discoverlife.org -click on nature guides)
10 1stRAPS Case study contribution: 3-001CS.DAIS