first Rapid Assessment of Pollinator Status
coordinated by United Nations Food and Agriculture Organization

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 pioneering with efforts quite innovative 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 essentially to food security and sound nutrition.

Pollinators such as bees, birds and bats affect 35 percent of the world's crop production. This increased the outputs of 87 of the leading food crops worldwide[2], 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, providing direct production inputs into agriculture from wild biodiversity, provides one of the strongest cases for valuating 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 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 close to 300,000[5]. Bees account for 25,000 to 30,000 species and together with flies, butterflies and moths, wasps, beetles, and other 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 remains poorly described. The challenges of identifying declines in pollinators are considerable given the high rarity found in some taxa (e.g. bees), the lack of baseline data collected and high spatial and temporal variation in pollinator populations[7]. It is therefore not surprising that relatively few studies provide clear evidence for declines, and those available are of two types: (1) direct evidence in the form of case studies recording declines of specific taxa in a particular regions, and (2) indirect evidence from studies focussing 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, except for Antarctica, has reports of pollinator declines in at least one region/country. Evidence is generally in the form of case studies and fragmented 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[8].

Honeybees (*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 has dropped from 5.9 million in the 1940's to 1.9 million in 1996, and most feral colonies have also been lost.[9] In the EU, honeybee colonies are reported to have declined by 16% between 1985 and 1991 and losses thereon were expected to be great.[10] Two major causes of honeybee declines are parasitic mites (*Varroa jacobsoni* and *Acarapsis woodi*) and the expansion of the range of Africanized honeybees in the US[11]. The related Himalayan cliff bee (*Apis laboriosa*) has experienced significant declines (see box A). In a regional study, all but one censused cliff showed declines in number of colonies or total loss across a 15 year period.[12]

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[13]. 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. Important 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 events and inappropriate conservation efforts[14].

Population characteristics of bees may show changes before actual declines may be detected: bees that appear common may 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[15]. 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[16.]

The widespread declines of invertebrate pollinators in North America highlighted in a "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[17]. Information on the status of pollinator populations is unfortunately limited by the 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, and at the same time 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[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[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 a "data-mining" exercise. Across the EU, and beyond, there are a large number of resources with 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 inventorying the resources and prioritising their value, an efficient system of "mining" the richest historical resources is being developed[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[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[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. 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*** are of global conservation concern[23].

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[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[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[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 near to natural habitat sustained communities of pollinators sufficient to provide needed levels of pollination services[27]. Distance from natural habitat affected pollinator communities and services in a similar way on coffee farms in Costa Rica[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, *Ceiba grandiflora*, in disturbed habitats in Mexico and Costa Rica[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[30].

Excessive use or inappropriate application of ***pesticides*** and other agro-chemicals is known to have negative impacts on a range of pollinators[31].

Climate change may potentially be one of the most severe threats to pollinator biodiversity[32]. Substantial distribution changes are predicted for groups such as butterflies[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 Africanized honeybees in the US[34]. Introduced *Apis mellifera* has had strongly deleterious impacts on indigenous honeybees (the cliffs bees and Asian hive bees) in the Hindu-Kush region[35].

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 specialized pollinators. Examples are populations of a snapdragon relative in South Africa[36] and bird-pollinated vines in Hawaii[37]. 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[38].

However, most pollination systems can be characterized as "somewhat generalized"[39]. 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 a wealth of specific observations on pollinator declines have been documented, it has proven extremely difficult to determine if whole pollinator communities in different regions of the world 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 D). In many sites, "normal" bee populations commonly halve or double in one-year intervals, in response to environmental conditions[40].

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 statistically the results that are derived. 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[41]. Sorting out this natural variability and diversity over time, in itself, could require sampling schemes and resource commitments that might swamp many national budgets for biodiversity monitoring. To distinguish natural long-term trends from those that are caused by human activity, is even more challenging.

There are two effective antidotes to dealing with the diversity, variability, and "unruliness" of pollination population monitoring: narrowing the focus, and standardisation of methods:

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, replicated over space, rather than trying to sample entire faunas.
2. Regardless of the purpose of the study, standardized 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.

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 below.

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) have surveyed cultivated squashes and pumpkins at 20 sites in 11 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 $25,000 annually to rent honey bees for what is probably superfluous pollination service[42].

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[43].

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 Ceara, Brazil, a working group discussed surveying and monitoring methods for pollinators in natural and cultivated landscapes. Recognising that results with different methods has 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 initiative 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[44].

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 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 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[45].

ALARM: Assessment of Large Scale Environmental Risks with Tested Methods, a project of the European Pollinator Initiative. The project will build a knowledge base to underpin 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 standardised monitoring methods to quantify pollinator diversity and abundance in agricultural and natural habitats[46].

1.7 Monitoring trends in pollinator populations: other pollinator taxa

Flies. The natural population fluctuations in fly populations are equally as difficult to differentiate from fluctuations caused by human-induced changes. Data on flies is even more limited than that on bees, but case studies showing the impacts of urbanisation on fly populations indicate severe impacts on the biodiversity of flies in human-dominated landscapes[47].

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 institutions[48].

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 genera (Vogel 1969). 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 Threatened (Hutson, Mickleburgh and Racey 2001). 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 Conservacíon de Murciélagos Migratorios (PCMM, Program for the Conservation of Migratory Bats) monitors over 20 caves in 14 states of Mexico[49] 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 Mexico[50].

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 polliination 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, 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.

Recommendations

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. Thus may only be feasible by focusing on manageable indicator groups.

3. Synergies between different initiatives to document trends in pollinator status should be strengthened.

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

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[3] Burd 1994; Ashman et al. 2004.

4 Vamosi et al. 2006

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[6] O'Toole & Raw 1991; Buchmann and Nabhan 1996.

[7] Williams et al. 2001.

[8] Biesmeijer et al. 2006

[9] Ingram et al. 1996; USDA National Agricultural Statistics Service 1997; Kearns et al. 1998.

[10] Williams et al. 1991.

[11] Allen-Wardell et al. 1998.

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[20] 1stRAPS Case study contribution: 1-001CS.EPI data mining.

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