FOOD AND AGRICULTURE OF THE UNITED NATIONS
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GLOBAL ACTION ON POLLINATION SERVICES FOR SUSTAINABLE AGRICULTURE

*INFORMATION DOCUMENT PREPARED BY THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO)*

# PROGRESS ON THE INTERNATIONAL INITIATIVE FOR THE CONSERVATION AND SUSTAINABLE USE OF POLLINATORS

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Items 5.2 and 13.5 of the provisional agenda*

# PROGRESS REPORT OF FAO ON THE IMPLEMENTATION OF THE INTERNATIONAL POLLINATORS INITIATIVE

*Note by the Executive Secretary*

1. Attached is the report of the Food and Agriculture Organization of the United Nations (FAO) on the implementation of the International Initiative for the Conservation and Sustainable Use of Pollinators, also known as the International Pollinators Initiative (IPI). This information note is referenced in paragraph 38 of document UNEP/CBD/COP/11/17.

2. The International Pollinators Initiative was formally established in decision VI/5 (annex II) of the Conference of the Parties, in 2002. It is a cross-cutting initiative under the programme of work on agricultural biodiversity and the lead partner for the initiative is the FAO. The FAO is hereby reporting in further detail on progress with the initiative as part of the reporting to the eleventh meeting of the Conference of the Parties to the Convention on Biological Diversity under agenda item 5.2 (cooperation) and the topic is also relevant to agenda item 13.5 (agricultural biodiversity).

3. This document is circulated in the form and language in which it was received by the Secretariat of the Convention on Biological Diversity.

* UNEP/CBD/COP/11/1.



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## I. INTRODUCTION

Animal pollinators such as bees affect 35 percent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide, or 75 percent of all crops. The total economic value of crop pollination worldwide has been estimated at €153 billion annually (Gallai et al. 2009). The leading pollinator-dependent crops are vegetables and fruits, representing about €50 billion each, followed by edible oil crops, stimulants (coffee, cocoa, etc.), nuts and spices; most of these are critically important for nutrient security and healthy diets. The global population of managed honey bee hives has increased by 45 percent during the last half century. But with the much more rapid (>300percent) increase in the fraction of agriculture that depends on animal pollination during the last half century, the global capacity to provide sufficient pollination services may be stressed, and more pronouncedly in the developing world than in the developed world (Aizen and Harder 2009).

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. As managed pollinators such as honeybees face a suite of debilitating threats, the services provided by wild pollinators become even more essential. Concerns about the loss of pollinators - wild as well as managed - and the services they provide have continued to mount over the last decades.

Considering the urgent need to address the issue of the worldwide decline in pollinator diversity, in 2000 the Fifth Conference of the Parties to the Convention Biological Diversity established an International Initiative for the Conservation and Sustainable Use of Pollinators (also known as the International Pollinators Initiative-IPI) (COP decision V/5, section II). The CBD Executive Secretary was requested to "invite the Food and Agriculture Organization of the United Nations to facilitate and co-ordinate the Initiative in close co-operation with other relevant organizations." In particular, the development of a plan of action was requested. In November 2000, FAO organized a meeting with the participation of key experts to discuss how to elaborate the International Pollinators Initiative. Subsequently, a Plan of Action was prepared by FAO and the CBD Secretariat (COP decision VI/5, in 2002) with four elements: assessment, adaptive management, capacity building and mainstreaming.

The aim of the International Initiative for the Conservation and Sustainable Use of Pollinators (IPI), as outlined in the Plan of Action, is to promote coordinated action worldwide to:

- Monitor pollinator decline, its causes and its impact on pollination services;
- Address the lack of taxonomic information on pollinators;
- Assess the economic value of pollination and the economic impact of the decline of pollination services; and
- Promote the conservation, restoration and sustainable use of pollinator diversity in agriculture and related ecosystems.

In 2008, FAO published a document entitled "Rapid Assessment of Pollinators' Status: a Contribution to the International Initiative for the Conservation and Sustainable Use of Pollinators", as a first report back to the Convention on Biological Diversity on progress in implementing the Plan of Action of the IPI. That same year, in Decision IX/1, the Ninth Conference of Parties (COP) welcomed this report and invited "the Food and Agriculture Organization of the United Nations in collaboration with Parties, other Governments and relevant organizations, to continue the implementation of the International Initiative for the Conservation and Sustainable Use of Pollinators (decision VI/5) and, in particular:

- Complete information on pollinator species, populations and their taxonomy, ecology and interactions;
- Establish the framework for monitoring declines and identifying their causes;
- Assess the agricultural production, ecological, and socio-economic consequences of pollinator declines;
- Compile information on best practices and lessons learned;
- Develop response options to promote, and prevent the further loss of, pollination services that sustain human livelihoods; and
- Disseminate openly the results through the CHM and other relevant means.

In 2010 FAO submitted an information document to SBSTTA-14 on Progress on the International Initiative for the Conservation and Sustainable Use of Pollinators.

The current document is similarly a regular update, submitted to COP XI, of the main activities and findings carried out by the global community concerned with the conservation and sustainable use of pollinators. It is organized according to the elements of the Plan of Action of the IPI. The information presented in this paper is based on reports produced during this time that address the objectives of the IPI, and on consultations with participants at the 24 September, 2011 meeting held during the 42nd Apimondia Conference in Buenos Aires, Argentina.

## II. ASSESSMENT

Previously there has not been an accurate published calculation of the proportion of the ca 352 000 species of flowering plants that depend on animal pollinators to reproduce. Widely cited figures range from 67 percent to 96 percent but these have not been based on firm data. Ollerton et al. (2011) estimated the number and proportion of flowering plants that are pollinated by animals using published and unpublished community-level surveys of plant pollination systems that recorded whether each species present was pollinated by animals or wind. The findings showed that the proportion of animal-pollinated species rises from a mean of 78 percent in temperate-zone communities to 94 percent in tropical communities. By correcting for the latitudinal diversity trend in flowering plants, the global number and proportion of animal pollinated angiosperms was estimated at 308 006, which is 87.5 percent of the estimated species-level diversity of flowering plants.

### Importance of diversity

Increasingly, the essential importance of conserving the diversity of pollinators has been recognized. As reported by the Platform for Agrobiodiversity Research and FAO in 2011 there are many crops which are not satisfactorily pollinated by managed and domesticated honey bees (PAR and FAO 2011). Currently, over one million colonies of bumble bees are raised worldwide to pollinate mainly tomatoes and other greenhouse crops. Similarly, passion fruit is pollinated mainly by wild carpenter bees (*Xylocopa* spp.). Modern methods of plant breeding and the use of hybrid seeds in a growing number of crop species require access to a growing panel of pollinators. For example, recurrent selection of beans *Phaseolus vulgaris* is undertaken using bumble bees (as is the production of true seeds in potatoes *Solanum tuberosum*. One of the obstacles to the development of hybrid seed production in lettuce is the availability of an effective pollinator as its flowers are visited neither by honey bees nor bumble bees.

A number of recent studies indicate that the essential question may not be: “are wild pollinators or managed honey bees more effective in providing pollination services?” In several instances, the interaction between different species of pollinators can enhance pollination efficiency and be an essential element for achieving optimal pollination. In studies of sunflower pollination, the pollination efficiency of honey bee foragers was enhanced up to 5 times by the presence of wild bees.

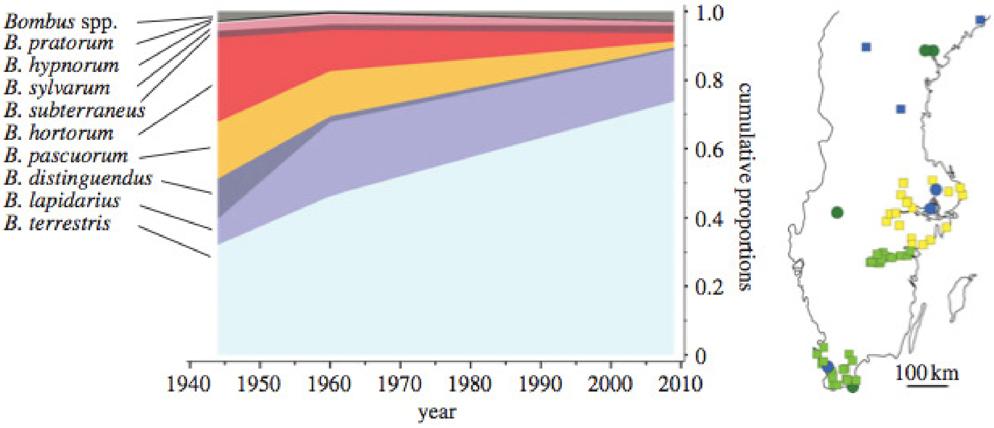
The PAR and FAO report notes that in some instances pollinator diversity may be even more important than the number of pollinators; this holds true for crops such as almond, coffee pumpkin, and sunflower grown for hybrid seed production.

**Pollination in Rangelands**

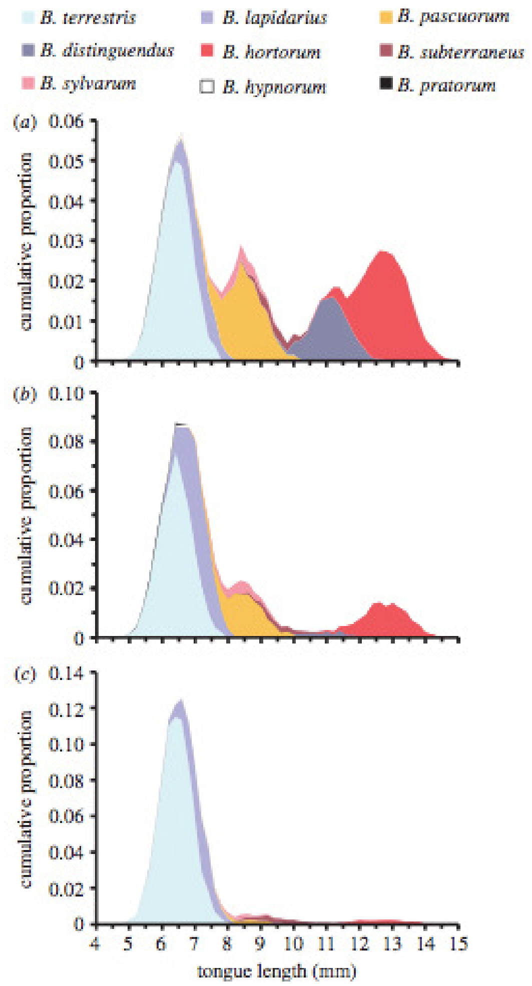
While the contribution of pollinators to agricultural productivity is receiving increased attention, the role of pollination in sustaining rangelands and pastoralist production systems is relatively unrecognized. A special issue of the journal *Rangelands* was produced in 2011, providing those working in rangeland ecosystems with information about why pollination is important to rangelands, why rangelands are important to pollinators, and how these relationships are being threatened (Ganguli and Harmon 2011). Pollinators in rangelands enable plant reproduction and fitness, providing resources for livestock and wildlife, and provide pollination services to adjacent agricultural areas. Large-scale efforts to restore degraded rangelands often require the production of dryland herbs and shrubs that depend upon pollinators; thus new seed enterprises are being pioneered in farming wildflower seed, including measures to encourage pollination by native bees (Cane 2011).

**Importance of Evenness**

The species richness of flower-visiting insects has declined in past decades, raising concerns that the ecosystem service they provide by pollinating crops and wild plants is threatened. It is conceivable that the relative commonness of different species with shared ecological traits could provide resilience through redundancy, thus sustaining ecosystem functioning. But there is little information on changes in abundances of pollinators over time. Researchers in Sweden gathered data on abundances of bumble bee species in Swedish red clover fields during three periods in the last 70 years (1940s, 1960s and present), and on clover seed yields since 1921 (Bommarco et al. 2011). They found substantial decreases in bumble bee community evenness. The relative abundances of two short-tongued bumble-bees increased from 40 percent in the 1940s to entirely dominate present communities with 89 percent. Average seed yield declined in recent years and variation in yield doubled, suggesting that the current dependence on few species for pollination has been especially detrimental to stability in seed yield. These results also suggest that management schemes are needed that that promote not only species-rich but also more evenly composed communities of service-providing organisms (Figures 1a and b).




Map of visited sites and detected proportional shifts in bumble-bee community composition in red clover seed fields in the last 70 years. Blue circles, all three periods; green circles, 1940s and present; blue squares, 1940s; yellow squares, 1960s; green squares, present. Proportion of bumble-bee abundance for the different species is presented as cumulative proportions for the communities averaged among sites and years within each period.




Relative frequencies of bumble-bee tongue lengths in red clover fields across Sweden in the (*a*) 1940s, (*b*) 1960s and (*c*) present.

Figures 1a and 1b. (from Bommarco et al. 2011)

**Pollinator Declines**

Recent declines in pollinators have been associated with the concern over loss of pollination services, although specific evidence of pollination loss has been difficult to document. In research in South Africa, a new method was devised to analyze present and historical plant-pollinator relationships using the oil-collecting bee *Rediviva peringueyi* and the oil-secreting orchid *Pterygodium catholicum* as study species (Pauw and Hawkins 2011). When historical pollination rates were compared to present rates, a decline in the pollination and abundance of this orchid was found.

***Causes of Bee Declines***

Colony losses witnessed throughout the Northern hemisphere continue to be worrying, especially because no single driver has yet emerged as the definitive cause. Interactions between viruses, ectoparasitic mites and microsporidian endoparasites are most likely key factors, but the underlying mechanisms are not well understood. In sum, these losses clearly expose the vulnerability of relying solely on honey bees to pollinate field crops. In the Northern hemisphere, beekeepers are being regularly confronted with severe inexplicable and sudden colony losses, with colonies exhibiting diverse symptoms, incl. CCD (= Colony Collapse Disorder). Efforts by individual countries are hampered the lack of standards for both monitoring and research. The COLOSS Network was set up to coordinate research efforts and importantly to facilitate the transfer of information on CCD. It has led to unprecedented cooperation between bee researchers throughout the world, and a number of methods for the dissemination of information have been used. As the first phase of the network reaches its conclusion, the major output will be the COLOSS "BEEBOOK: standard methodologies for *Apis mellifera* research", to be published at the end of 2012.

***Pollinators Share Pathogens***

Pathogens are clearly implicated as one of the factors contributing to honey bee declines in North America. Thus it has been a worrying finding to learn that pollinators may share pathogens, both with wild populations, and across species. Researchers at the University of Toronto presented compelling evidence that commercially produced bumble bees used in greenhouses are infecting their wild cousins, and that this is likely contributing to reductions in the natural pollinating bee population (Otterstatter and Thomson 2008). In 2010, a study from Penn State University involving apiaries in Illinois, New York and Pennsylvania, researchers confirmed that pathogens can be transmitted from honey bees to wild pollinators when both use the same pollen source. Eleven wild pollinators studied, including the sweat bee (Halictidae) and a bumble bee species (Bombus), contracted all five of the viruses used in the study (Singh et al. 2010)

***Patterns of widespread decline in North American bumble bees***

Bumble bees (*Bombus*) are vitally important pollinators of wild plants and agricultural crops worldwide. Fragmentary observations have suggested population declines in several North American species. Scientists in North America carried out an interdisciplinary study of changing distributions, population genetic structure, and levels of pathogen infection in bumble bee populations across the United States (Cameron et al. 2011). They compared current and historical distributions of eight species, compiling a database of >73,000 museum records for comparison with data from intensive nationwide surveys of >16,000 specimens. They were able to show that the relative abundances of four species have declined by up to 96 percent and that their surveyed geographic ranges have contracted by 23– 87 percent, some within the last 20 years. They also found that declining populations have significantly higher infection levels of the microsporidian pathogen *Nosemabombi* and lower genetic diversity compared with co-occurring populations of the stable (nondeclining) species. Higher pathogen prevalence and reduced genetic diversity may thus be realistic predictors of patterns of decline in North America, although cause and effect remain uncertain.

***Pollinators and pesticides***

Linkages between pesticide use and pollinator declines has for some time been a concern, but to date, knowledge is limited. Historically, pesticide risk assessment for pollinators has been based on information related to only one species, the Western honey bee (*Apis mellifera mellifera*). However, there are more than 20,000 species of wild bees, and for many plants, those bees are more important pollinators than honey bees.

Regulatory procedures for pollinator risk assessment have hitherto focused entirely on Western honey bees, as in – Europe (EPPO 2010b), the USA (EPA 2011) and Australia (EPHC 2009). In most cases these methods cannot easily be adapted to wild bees. Bees are a diverse group, and many are solitary and seasonal, not social and perennial.

In response to growing international concern about risk factors that may cause declines in many bee species, initiatives are underway to refine and elaborate pesticide risk assessment practices to include wild bee species. The OECD carried out a survey of “Pollinator Testing, Research, Mitigation and Information Management” in 2009. Its objective was to gather information related to pollinator declines, with a specific focus on possible relationships with pesticides. The survey, with responses from 17 OECD member countries, indicated concerns about bee and other pollinator declines. It also revealed commitments on the part of almost half of all countries to expand toxicity tests and make risk assessment for pollinators more effective (OECD 2010).

In January 2011, the Society of Environmental Toxicology and Chemistry (SETAC) held a workshop to explore the state of science concerning pesticide risk assessment for pollinators (Fisher and Moriarty 2011). One of the workshop goals was to explore the applicability of testing protocols used for *Apis* to measure effects of pesticides and pesticide risk on native (non-*Apis*) bee species. The workshop report has noted that the biology and ecology of non-*Apis* bees differs from honey bees in a number of aspects that may be important in risk assessment for pesticides.

Recent work under the EU ALARM project has also contributed to comparative risk assessment for wild bees (Barmaz et al. 2010), but needs further development aimed at regulatory decision-making. An investigation into the effects of the insecticide fenitrothion in vine fields in Italy, for its effect on wild pollinators suggested that wild bees, as compared to bumblebees or butterflies, showed particular sensitivity to the effects of this insecticide (Brittain et al, 2012).

In 2011 and 2012, work was undertaken by FAO and partners in the Netherlands on understanding the context of pesticide exposure of key crop pollinators - honey bees, but also wild bee species - through the development of risk profiles for cropping systems in Brazil, Kenya and the Netherlands. This has resulted in a study of factors that may determine the risk of pesticides to wild bees, on three continents, has shown that large data gaps still exist on biology, life-history and population dynamics of bees among various pollinated crops (Van der Valk et al. 2012.). This greatly complicates proper risk assessment, i.e. making reliable inferences about the magnitude and duration of adverse pesticide effects on wild bees. As an alternative, the authors of the study propose to initially use a more qualitative approach of establishing “risk profiles” describing the likelihood of pesticide impact on bees in specific cropping systems. The data collected through such risk profiling should increase knowledge of pesticide risks for different groups of wild bees under different circumstances, and may contribute to the development of more specific risk assessment procedures.

**Climate Change and Pollination Services**

FAO's Global Action on Pollination Services for Sustainable Agriculture commissioned a review of the potential effects of climate change on crop pollination (Kjøhl et al 2011). The review concluded that climate change may have a significant impact on the provisioning of pollination services in the future. The global capacity to provide sufficient pollination services may come under significant stress from climate change, and more pronouncedly in the developing world than in the developed world. The most likely effect of climate change on pollinators will result from an increase in temperature (Figure 2). This may have particularly damaging consequences in the tropics, where most pollinators are already occurring close to their optimal range of temperature tolerance. While it is always possible to shift the cultivation of crops to more suitable areas under changing climates, are few species of managed pollinators and wild pollinators may not be able to follow the movement of crops. There could be mismatches between the adaptive capacities of plants and of pollinators, including wild pollinators – for example, crops can be bred, relatively quickly, to incorporate traits such as drought hardiness, but pollinators have no such mechanism to introduce new traits that can help with their adaptation, and hence also to synchronize with the plant. The review identifies information that is needed to make a more comprehensive assessment; in the absence of such information, a format for a rapid assessment of the potential vulnerability of national pollinator loss to climate change is provided.

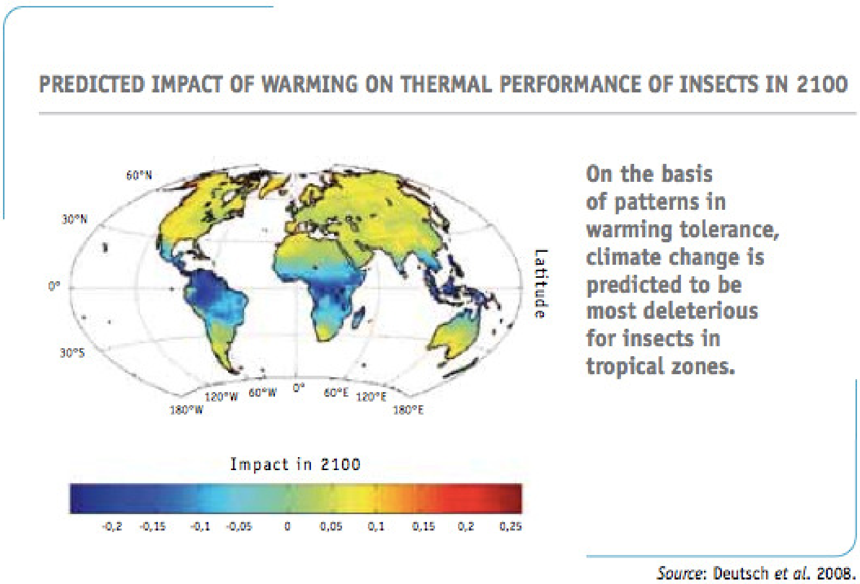



Figure 2. Predicted impacts of warming on insects, 2100 (Deutsch et al 2008)

FAO has advised that "climate-smart" agriculture can help pollinators – as well as farmers - adapt to climate change. Providing more biodiversity on-farm, such as in cover crops, strip-crops, agroforestry and hedgerows, can contribute to the stability of pollinator populations. Ensuring connectivity of natural habitats in farm landscapes can help pollinators move about more easily in response to changing climates. The more diversified the landscape, the more diversified the pollinators, providing insurance and resilience under erratic weather conditions.

### *Historical Trends*

An analysis of bee collection data over the past 130 years has shown that warmer spring weather arrives about 10 days earlier than in the 1880s in northeastern North America, and bees and flowering plants have kept pace by also emerging or flowering earlier. The study also found that most of this shift has occurred since 1970, when the change in mean annual temperature has increased most rapidly (Bartomeus *et al.* 2011), Although the triggers for most bee spring emergence are unknown, it is likely that bees are cued to emerge when temperatures rise above a threshold over a number of days. The authors of this study note that while it is encouraging to see that both plants and pollinators are maintaining their synchrony, if climate change accelerates the way it is expected to, it is not clear that bees and plants will be able to adapt quickly enough (Figure 3). The study is an example of the value of natural history collections, and the analyses of bee distributions, phenology and host-plant preferences that they can provide.

Figure 3. Plants and pollinators need to maintain synchrony in their life cycles.

## Economic Importance of Pollination Services

### *Demands for pollination services*

Although many species are known to provide pollination services, honeybees (*Apis mellifera*) are often assumed to provide the majority of these services to agriculture. Using data from a range of secondary sources, researchers in the UK assessed the importance of insect pollinated crops at regional and national scales and investigated the capacity of honeybees to provide optimal pollination services to UK agriculture (Breeze et al. 2011). The findings indicate that insect pollinated crops have become increasingly important in UK crop agriculture and, as of 2007, accounted for 20 percent of UK cropland and 19 percent of total farmgate crop value. Analysis of honeybee hive numbers indicates that current UK populations are only capable of supplying 34 percent of pollination service demands even under favorable assumptions, falling from 70 percent in 1984. In spite of this decline, insect pollinated crop yields have risen by an average of 54 percent since 1984, suggesting that wild pollinators provide a significant portion of pollination services. Many of the UK's most valuable crops, including apples, strawberries, runner beans, and, increasingly oilseed rape, are pollinated by other insects. The total monetary value of pollinators to crop production in the UK has been estimated at £430 million per year. This research suggests that a substantial portion of this value is derived from wild pollinators.

*Tools to Assess Value of Pollination Services on National Levels*

In 2009 FAO's Plant Production and Protection Division, in collaboration with INRA (Institut National de la Recherche Agronomique, a national government agency) developed a tool for assessing the value of pollination services and national vulnerabilities to pollinator declines. Guidelines explaining the use of the tool, and a downloadable spreadsheet for applying the assessment, are available on the "Documents" page of AGP's Global Action on Pollination Services for Sustainable Agriculture website:

http://www.internationalpollinatorsinitiative.org/jsp/documents/documents.jsp.

The tool was initially used to analyze of the vulnerability of the national economies of Ghana and Nepal. The economic value of pollinators in Ghana - with a high dependence of its economy on cocoa production which in turn is 90 percent dependent on insect pollinators for yields - was estimated at US$ 788 million dollars; the economic value of pollinators to the Nepal economy in 2005 was US$ 81 million. Subsequently, it has been applied in China by the Chinese Academy of Agricultural Science, in Nigeria (assisted by Bees for Development (E. McLeod pers. comm.), in India (Basu *et al.* 2011) and in Vietnam and the Philippines (Ngo et al*. in preparation*). In a comparison of several of these studies (Figure 4) the contribution of pollinator-dependent crops to global and national GDP is variable: very high in a country such as Ghana with its cocoa trade; relatively small but still notable in an advanced economy such as the US; and quite important in countries with an important horticultural market.

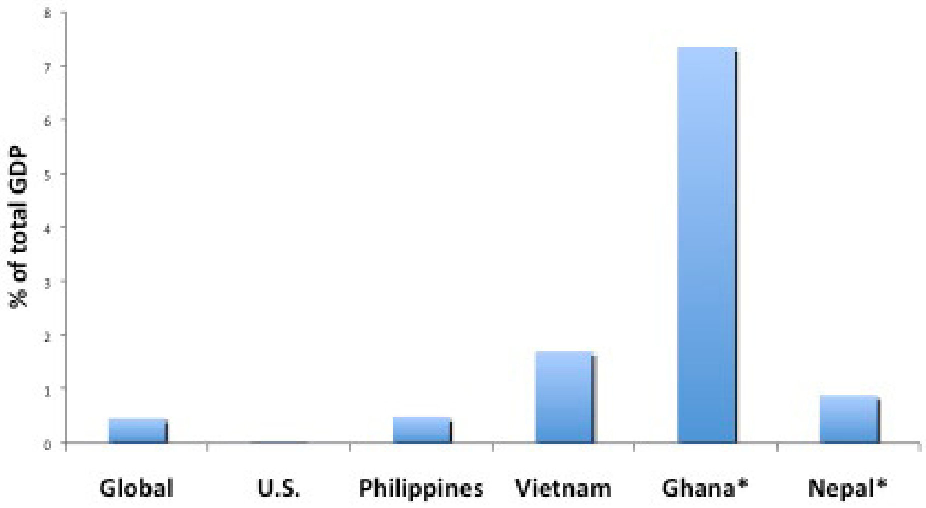



Figure 4. Contribution of pollinator-dependent crops to global and national GDP (from Ngo et al. in prep.)

*Valuation of Pollination Services- and Ecosystem Services in general- as an Agricultural Input*

Appreciating and assessing the value of biodiversity and ecosystem services provided by agricultural ecosystems is central to their conservation and sustained use. Until recently these services and their contribution to food production and security were little understood, in part because they were perceived as being “free”: provided by nature at no explicit cost to people.

New paradigms of sustainable production intensification recognize an increased reliance on biological inputs, as generated by ecosystem services operating on the scale of a farm production unit: natural pest control, natural weed control, soil fertility and structure, pollination and nutrient cycling. These ecosystem services, provided by biodiversity, underlie the principles of sustainability, permitting the agroecosystem itself to sustain its production functions.

The monetary valuation of ecosystem services is important, in order to place a figure value on “free” ecosystem services. In agricultural ecosystems, placing monetary value serves various purposes. For example, it can affect decisions taken at the policy level (to reverse perverse policies in different sectors, or support policies that consider ecosystem services), or it can affect farmers’ decisions regarding the management of ecosystem services (e.g. reducing purchase of pesticides and using integrated pest management strategies, crop diversification strategies, maintaining wild habitat areas).

Finding the ways to assess the value of a service as an input – similar to conventional inputs of water and fertilizer, but different in that the ecosystem has to be managed to supply the service - has challenges. A global team of researchers, using pollination as an example have shown how the mean and stability of the service is quite variable; where crops are more dependent on pollinators, the stability of the service is more variable (Garibaldi et al. 2011). Recognizing this, the design of agricultural systems for sustaining yields of pollinator-dependent crops may need to pay greater attention to policies, measures and practices that sustain levels of pollination service.

To further document and develop tools on the economic valuation of pollination services, as part of the global contribution to the FAO/UNEP/GEF project on the “Conservation and management of pollinators for sustainable agriculture, through an ecosystem approach”, and in collaboration with partners in Brazil, an international workshop (Brasilia, Brazil, March 2012) was held to address this issue. An International Workshop was held in March 2012, in Brasilia, Brazil to address the economic valuation of pollination services in commercial agriculture. Presentations were made by experts, illustrating different approaches to economic valuation (e.g. direct use, indirect use, contingent valuation, dependency approach, etc); a workshop report will be forthcoming.

Amongst the approaches has been a model for understanding the dynamic contribution of ecosystem services to production (Garibaldi et al. 2012). This model indicates that:

- The marginal contribution of a unit of change in ecosystem services increases as ecosystem services are being degraded;  For example, the marginal contribution of pollination by wild insects to yield is greater when the pollination service is lower, such as when abundance and diversity of wild flower visitors has been degraded.
- As with agricultural inputs in general, there is a threshold above which increases in ecosystem services are no longer beneficial.
- The marginal contribution of costly agricultural inputs to crop yield is lower when the delivery of “free” ecosystem service, provided by wild biodiversity, is greater.

Pending the availability of resources, work will continue on the valuation of pollination services, and expand to other ecosystem services important for agriculture, with considerable scope for synergies. For example, several management practices that promote the services of (wild) pollinators also promote other ecosystem services (e.g. pest control).

**Pollinator Information Management**

In several countries, support is being given to consolidating such data from geographically dispersed collection into searchable, publicly available online database; one which has served the bee community in this respect is Discover Life (http://www.discoverlife.org).

There have been many initiatives to make information on pollinator fauna and its interactions accessible and available over the internet. One such effort in Australia has succeeded in creating species pages for more than 75 percent of the Australian bees, which can be found at the Australian Pollinators website (http://www.padil.gov.au/pollinators/). This site includes, among other resources, some excellent live bee videos that portray fascinating aspects of bee behavior and natural history. (http://australianmuseum.net.au/Bee-Scene1) (Figure 5). In Brazil, information on native bee species have been available on line for almost a decade now, at the Webbee portal (http://www.webbee.org.br). It includes images of the bees (several views of workers, queens, drones), videos, and information on interactions with plants. The Pollinator Thematic Network, one of the networks of the Inter American Biodiversity Network (IABIN-PTN) has developed a set of tools to help digitize data on pollinators and their interaction with plants. They are available at a webportal (http://pollinators.iabin.net/portal) where an online roster of people involved with pollination and pollinators can also be found.


Figure 5. Video clips of bee behavior and natural history, available on the Australian Museum website.

**III. ADAPTIVE MANAGEMENT**

Increasingly it is recognized that pollination has multiple aspects (PAR and FAO 2011): it is a service provided by biodiversity to crops and natural and at the same it may be an explicit practice applied by farmers in their overall production scheme. It is an ecosystem service in that wild pollinators – especially wild bees (Apiformes) of which there are 20,000 species in the world – contribute to the pollination of many crops. It is also a production practice in that farmers commonly bring colonies of honey bees (*Apis mellifera*) or purchase colonies of bumble bees (e.g., *Bombus terrestris* in Europe) to ensure the pollination of their crops. Farmers may also apply practices in the management of their farms to increase the occurrence, health and visitation of pollinators, whether these are wild or managed. Identifying the suite of practices, appropriate and effective in a particular site, is where adaptive management of pollination becomes key. Here, new work is highlighted to identify such effective practices.

**Diet Diversity for Pollinators**

The maintenance of the immune system can be costly, and a lack of dietary protein, or lack of diversity of food can increase the susceptibility of organisms to disease. Indeed, nutrition and diet diversity has been shown to play a role in bee immunity from disease: studies have shown that diverse (polyfloral) diets for honey bees (*Apis mellifera*) improve individual immunocompetence (haemocyte concentration, fat body content and phenoloxidase activity) and social immunocompetence (glucose oxidase activity, which enables bees to sterilize colony and brood food, as a parameter of social immunity.) Diet diversity was actually more important in increasing social immunity than was protein-rich diets. Bees fed with monofloral pollen (even that containing the highest protein levels) produced fewer antiseptics (secreted in the food for larvae and in honey) than those fed with multiflower pollen. As a result, the colony became more susceptible to disease. These results suggest a link between protein nutrition and immunity in honeybees and underscore the critical role of resource availability on pollinator health; in particular they highlight the fact that bees may suffer when the diversity of their food is low, such as provided with large monocrops. Hedgerows, pollen-rich cover crops and even weeds are likely to have an important role in maintaining pollinator health in agroecosystems (Alaux *et al.* 2010).

**The Contribution of Hedgerows in the Landscape**

In countries such as the UK where up to 90 percent of the country's flowering meadows may be gone because of intensive agriculture, only isolated fragments of land may offer nectar-rich flowers to sustain pollinators. Bees and other pollinating insects use hedgerows as places to feed. But researchers have also found that bees use hedgerows as motorways, to navigate between patches of resources. The nearer bees and butterflies get to hedgerows, the straighter they have been observed to fly alongside them. Such findings could guide the way highly managed landscapes are planned in the future. If agroecosystems, intensively managed, have only fragments of flower-rich land, managing land in a way that connects these fragments up may be increasingly important. Strategic planting of hedgerows could be one approach (Cramner et al. 2011).

**Creating on-farm habitat**

Several programs are working across the globe to support on-farm habitat for pollinators in a manner that is compatible with current farming systems. Programs such as Operation Bumblebee in the United Kingdom and Operation Pollinator across Europe are providing practical solutions to help growers create valuable on-farm habitats to encourage natural pollinators. Agricultural companies are also becoming involved; private sector companies have supported Operation Pollinator based on scientific research. The experience of selected farmers has been to experience a dramatic recovery in pollinating insect populations.

In the US, changes to the Food, Conservation and Energy Act of 2008 (aka US Farm Bill), made pollinators and their habitat objects of special consideration for determining financial allocation to a variety cost share programs for farmers. Thus, a significant investment in pollinator habitat for farmland has been supported by the Natural Resources Conservation Service of the United States Department of Agriculture. The Xerces Society's Pollinator Conservation Program works closely with the US Department of Agriculture's Natural Resources Conservation Service (NRCS) to develop technical guidance and demonstration projects on how to create on-farm habitat for bees. Print and web guidelines on habitat creation are available for most of the US. Technicians from Xerces are working with NRCS conservation specialists to help design on-farm habitat in many states. As a result, many statue-supported conservation programs now have formal language that allows farmers to include wildflowers for supporting pollinators in the seed mixes used to establish non-farmed habitat, and for hedgerows that can be enhanced to support bees using the appropriate plants.

National and state-specific programs provide between 50-90% of the costs for pollinator plantings and this is encouraging greater adoption of these practices. Research underway in different regions is also aiming to assess the ability of such plantings to increase pollinator populations locally as well as increase the delivery of pollination services to crops. Early results are encouraging, suggesting measurable benefits to crop yield and farmer profit. These policy incentive measures, along with persistent outreach efforts by NGO's, such as the Xerces Society for Invertebrate Conservation, and others have increased dramatically increased the land area allocated to pollinator habitat and the numbers of participating growers nationally. These efforts have been supported by parallel scientific investigation over many regions supported to a great extent by the NRCS Conservation Innovation Grants Program. Such programs as well as those mentioned above have provided practical information on habitat establishment, maintenance and most recently function of pollinator habitats to support native pollinator biodiversity and increase crop yield (see Operation Pollinator above).

**Evidence for the effects of interventions**

A recent volume (Dicks et al. 2010) brings together scientific evidence and experience relevant to the practical conservation of wild bees. The authors worked with an international group of bee experts and conservationists to develop a global list of interventions that could benefit wild bees. They range from protecting natural habitat to controlling disease in commercial bumblebee colonies. For each intervention, the book summarizes studies captured by the Conservation Evidence project (http://www.conservationevidence.com/), where that intervention has been tested and its effects on bees quantified. The result is a guide to what is known, or not known, about the effectiveness of bee conservation actions throughout the world. Bee Conservation is the first in a series of synopses arising from the Conservation Evidence project that will cover different species groups and habitats, gradually building into a comprehensive summary of evidence on the effects of conservation interventions for all biodiversity throughout the world. By making evidence accessible in this way, it is hoped to enable a change in the practice of conservation, so it can become more evidence-based and gaps in knowledge can be highlighted. Evidence from all around the world is included. Conservation interventions are grouped primarily according to the relevant direct threats, as defined in the International Union for the Conservation of Nature (IUCN)'s Unified Classification of Direct Threats (www.iucnredlist.org/technical-documents/classification-schemes).

The basic tenets guiding the synopsis are described in the table below:

| **The Bee Conservation Evidence synopsis does:** | **The Bee Conservation Evidence synopsis does not:** |
|---|---|
| Bring together scientific evidence captured by the Conservation Evidence project (over 2,000 studies so far) on the effects of interventions to conserve wildlife | Include evidence on the basic ecology of species or habitats, or threats to them |
| List all realistic interventions for the species group or habitat in question, regardless of how much evidence for their effects is available | Make any attempt to weight or prioritize interventions according to their importance or the size of their effects |
| Describe each piece of evidence, including methods, as clearly as possible, allowing readers to assess the quality of evidence | Weight or numerically evaluate the evidence according to its quality |
| Work in partnership with conservation practitioners, policymakers and scientists to develop the list of interventions and ensure the most important literature is covered | Provide answers to conservation problems. Rather, scientific information is provided to help with decision-making |

## IV. CAPACITY BUILDING

### Development of tools and manuals

As a contribution to the International Pollinators Initiative, in 2011 FAO and its partners developed a protocol for assessing and detecting pollination deficits in crops (Vaissière et al. 2011):

http://www.internationalpollinatorsinitiative.org/uploads/Protocol_PolDef_FINAL.pdf

The aim of the protocol is to detect and assess pollination deficit in crops to be applied to focal crops at the farm scale level to (i) detect and assess pollination deficits in field situations in a standard and statistically testable way; and (ii) draw management conclusions from the proposed experiment for possible action to reduce or eliminate these deficits. This protocol has been applied in Brazil, Ghana, Kenya, India, Nepal, Pakistan and South Africa; it has also been picked up and applied by other research groups in India and France.

In 2012, FAO and IIED developed a 5-step guide to help farmers evaluate the benefits, and costs of applying pollinator-friendly practices, "Handbook for participatory socioeconomic evaluation of pollinator-friendly practices" (Grieg Gran and Gemmill-Herren 2012):

http://www.internationalpollinatorsinitiative.org/uploads/SocioEconomicEvalPollinatorFriendlyPractice.pdf.

The handbook focuses on socioeconomic evaluation of pollinator-friendly practices, and addresses the impact of these practices on the inputs and outputs of crop production systems, and to a lesser extent suggests ways in which farmers could take into account some less tangible impacts of these practices, such as health. The handbook was presented at the international workshop on the economic valuation of pollination services (Brazil, 2012), and is currently being used in several countries.

## IV. Mainstreaming

### Public Awareness

#### *Social media*

With their great charisma, pollinators can feature readily in different ways of raising public awareness around pollination issues and declines. One example of this is "Dudu Diaries"- blog on maintained on WildlifeDirect at the address: http://dududiaries.wildlifedirect.org/, by Dino Martins, who won the Whitley Fund for Nature award in both 2009 and 2011, for his work on *"**People, plants and pollinators: Uniting conservation of insects and sustainable agriculture",*** an award that includes support for increasing public awareness of pollinators. This "insect diary" includes many posts on pollination and pollinators, mostly from Kenya, with vibrant pictures of pollinators and text describing observations of their behavior (Figure 6a). Over 18,000 visitors linked to the site over the last year, from all over the world, showing that there is very broad interest in pollinators (Figure 6b). Many questions are posted to the blog from people around the world: questions about pollinators from farmers, gardeners, school children, researchers and the general public. A single post on mango pollination in 2011 was discussed by blog visitors from Ghana, India, Pakistan, the USA and Rome. Some of the blog posts are re-posted on the National Geographic NewsWatch Blog, and many other sites ping, share, tweet and disseminate information from the blog.

Figure 6a. Blue-eyed carpenter bee in Turkana, Kenya, featured in a blog post: "*The most striking bee we found was this Carpenter Bee (Xylocopa sp.) that had the most incredible bright blue eyes! It flew around quite aggressively occasionally chasing off other Carpenter Bees that ventured too close to its patch of flowers."*

Figure 6b. Map of visitors to Dudu Diaries, a blog about insects mostly in Kenya.

***Bee-pollinated Tomatoes Taste Better!***

Pollination issues may interest people particularly when it connects to their food quality. It has long been known that good pollination may contribute to quality of fruit formation, but new evidence now brings in the aspect of taste: tomato flowers (*Solanum lycopersicum* L.) in greenhouses require assisted pollination. The results of pollination using a vibration wand were compared with pollination by buzz pollinating bees in Australia. The tomatoes pollinated by bees had a higher fruit weight. In addition, the tomatoes were presented to a taste panel, which significantly preferred bee-pollinated over wand-pollinated tomatoes and classified bee-pollinated tomatoes as having more depth of flavor than wand-pollinated tomatoes (Hogendoorn et al 2011).

**Policy Development: Agricultural yields and pollinator dependence**

As noted under economic valuation, pollination has rarely been considered an agricultural input, alongside the conventional inputs of fertilizers and water. Yet increasingly, it is recognized as such. Its provisioning may depend on the presence of semi-natural areas of habitat in an agricultural landscape, implying that some land may need to be conserved or withdrawn from production to sustain the service. Hence, the question arises: "can yields on the productive land offset taking some land out of production?" The international group of researchers - using FAO global statistics - found that crops with greater pollinator dependence had lower mean and stability in relative yield and yield growth, despite global yield increases for most crops (Garibaldi *et al.* 2011). Lower yield growth was compensated by increased land cultivation to enhance production of pollinator-dependent crops. They suggest that these results reveal that pollen limitation may hinder yield growth of pollinator-dependent crops, decreasing temporal stability of global agricultural production, while promoting compensatory land conversion to agriculture. Recognizing this, the design of agricultural systems for sustaining yields of pollinator-dependent crops may need to pay greater attention to policies, measures and practices that sustain levels of pollination service.

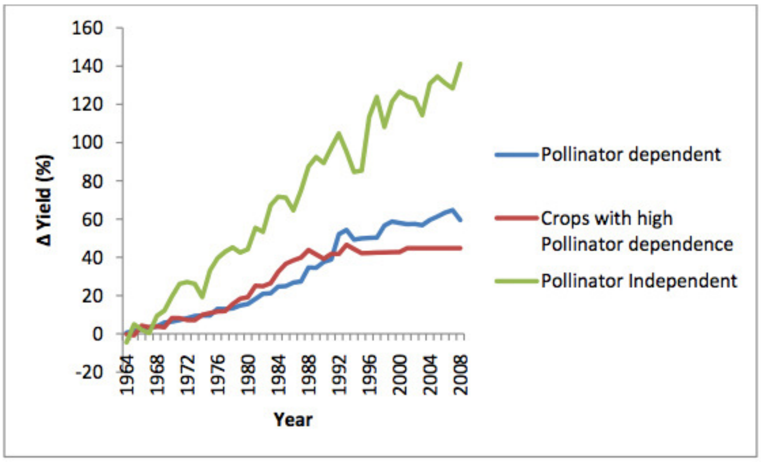
***The disappearing Mexican mango: climate and pollination work against good yields***

In the Chiapas region of Mexico in 2011, a combination of heavy rains and extreme temperatures caused mango flowers to bud too early and experience insufficient pollination, resulting in small seedless mangoes that are essentially worthless. A properly formed mango fetches up to US$ 2 in U.S. markets, while the tiny ones cannot be sold. Over the past two years, the crop of Ataulfo mangoes (the gold-colored variety sold as "champagne" mangoes in the U.S.) has fallen 60 percent (Figure 7). A 2008 study by agricultural researchers at the U.S. Agency for International Development backed up that assessment, finding that mango production per hectare in the Soconusco region had dropped from about 15 tons in 1995 to two or three tons in 2008. As a result, many growers are pulling out mango plantations and instead planting sugar cane or palm, fast-growing crops that give a more regular harvest but require more costly fertilizers and pesticides. Farmers in the region also suggest that overuse of pesticides on cotton crops grown nearby may have killed off many of the insect pollinators.

Figure 7. Mango production in Mexico is experiencing uncertainty.

***'Pollination crisis' hitting India's vegetable farmers***

Each year, India produces about 7.5 million tonnes of vegetables. This accounts for about 14 percent of the global total, making the nation second only to China in the world's vegetable production league table. Many vegetables - such as pumpkin, squash, cucumber and gherkin - were reliant on insects, such as bees. A suspected decline in pollinating insects in India is resulting in reduced vegetable yields and could limit people's access to a nutritional diet, (Basu et al. 2011). Indian researchers at the University of Calcutta's Ecology Research Unit said there was a "clear indication" that pollinator abundance was linked to productivity. They added that the loss of the natural service could have a long-term impact on the farming sector, which accounts for almost a fifth of the nation's GDP. Despite the concern, no study yet has been done to directly assess the scale of the decline in natural pollinators. While ideally it would be best to compare the overall pollinator abundance over the years, that data is not yet available. However, the research unit has compared the yields of pollinator-dependent crops with pollinator-independent crops. The yields of pollinator-independent crops have continued to increase while pollinator-dependent crops have leveled off (Figure 8). This fall in yield per hectare was against the backdrop of a greater area being turned over to production of pollinator-dependent crops each year, such that production levels continue to increase.




Changes in the relative yield (expressed as % change of productivity; Δ yield) of years 1964 – 2008 in comparison with base year (1963) for pollinator dependent, pollinator dependent crops with high DI and pollinator non dependent crops.

Figure 8. Trends in relative yield, India (from Basu et al. 2011)

The exact cause for the decline of pollinators, especially bees, still remains unknown. In an attempt to identify an underlying cause for the pollinator decline, the research team in the Unit is carrying out a series of field experiments, comparing conventional agriculture with "ecological farming". Defined as "a farming system that aims to develop an integrated, humane, environmentally and economically sustainable agricultural production system", ecological farming is almost a hybrid of conventional and organic farming, looking to capitalize on returns from modern farming methods as well as drawing on natural ecological services, such as pollination. They find greater pollination abundance within the ecological farming setting, since this type of farm typically provides the habitats for natural pollinators. However, the researchers estimate that ecological farming is only practiced on about 10-20 percent of the country's arable land.

**Policy Development: Establishment of Species Conservation Plans for Bumble Bees**

Bumble bees are among the most important wild pollinators in both agricultural and natural ecosystems, yet there is growing evidence that some species are suffering precipitous population declines. Several local and regional studies have documented bumble bee decline in North America in the last decade. Bumble bee declines have also been noted in Europe, and have been largely attributed to habitat loss and climatic factors. The patterns of decline observed in North America seem to be different to those observed in Europe, yet both are part of an alarming trend toward the loss of pollinators. The decline that has been noted in several species of formerly common North American bumble bees underscores the need to develop a comprehensive approach to arrest this threat to wild pollinator biodiversity.

In response to this need, the Saint Louis Zoo hosted an IUCN North American Bumble Bee Species Conservation Strategy Workshop from November 9-12, 2010. This meeting was organized by the Saint Louis Zoo, the Xerces Society for Invertebrate Conservation, the University of Illinois, and the USDA-ARS Pollinating Insect Research Unit, and facilitated by the International Union for Conservation of Nature's (IUCN) Conservation Breeding Specialist Group (CBSG). Fifty-two individuals representing a broad coalition of stakeholders concerned with the survival of North American bumble bees were in attendance. Agencies and organizations represented included the U.S. Agricultural Research Service, Animal and Plant Health Inspection Service, Forest Service, Natural

Resource Conservation Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, the Xerces Society for Invertebrate Conservation, the Pollinator Partnership, the two major North American commercial breeders of bumble bees for agricultural production – Biobest N.V. and Koppert Biological Systems – in addition to bumble bee researchers from the U.S., Canada, Mexico, the UK and Japan. Amongst the goals of the meeting was initiate a conservation planning process with clear goals and identified future research and conservation needs for the protection of the most imperiled North American bumble bee species.

This workshop served as an important step in a long-term collaborative effort toward bumble bee conservation in North America as well as globally. The participants shared information about global bumble bee status, threats, production and policy, and helped identify the issues of concern that may impact the success of bumble bee conservation, and provided general direction for bumble bee conservation in North America.

Two immediate products transpired from this meeting. The first was the formation of an IUCN/Species Survival Commission (SSC) Bumblebee Specialist Group that will help to implement and support this and other action plans. A proposal was reviewed by workshop participants to create the IUCN/Species Survival Commission Bumblebee Specialist Group to coordinate the necessary research that will help policy-makers counteract the population loss. The IUCN/SSC has already approved this proposal and confirmed the establishment of this new Specialist Group. In addition, three species with published evidence of decline – *B. occidentalis*, *B. pensylvanicus*, and *B. terricola* – will be submitted for consideration to the IUCN for listing on the Red List of Threatened Species. In 2009, the Xerces Society submitted a proposal to list *B. affinis* on the IUCN Red List.

The second projected outcome from the meeting is a North American Bumble Bee Species Conservation Strategy that can be used to guide future research, conservation actions, funding opportunities, and possible proposed laws and regulations governing bumble bees.

**Policy Development: Growth of National and Regional Pollinators Initiatives**

***ICPA (Iniciativa Colombiana de Polinizadores, con énfasis en Abejas)***

In August 2010, the first Workshop on Action Plan for Colombian Pollinators Initiative Implementation was held in Bogota, Colombia. The National University of Colombia, the Colombia CDB focal point, and the Humboldt Institute joined their capacities to create the Colombia Pollinator Initiative – ICPA (Iniciativa Colombiana de Polinizadores, con énfasis en Abejas), with an emphasis on bees. The event attracted 61 participants from academic institutes (Universidad Nacional, Universidad Militar Nueva Granada, Universidad de los Andes, Universidad Pedagógica y Tecnológica de Tunja), Ministry of the Environment, Ministry of the Agriculture and Rural Development, Humboldt Institute, CORPOICA, and from productive chains (Bees and Apiculture, Horticulture, Aromatic herbs). At the workshop, it was decided that as a first main action ICPA would promote a diagnosis of the scientific and traditional knowledge around the country and the identification of most important crops and pollinators related; verify the present situation of the pollinators populations and the causes of pollinators decline; and identify the strategic actions for ecosystem services conservation. By the end of the workshop a document was developed: the Declaration of the Colombian Pollinator Initiative, and a committee of the Colombian Pollinators Initiative was created to elaborate an Action Plan document to be published by Humboldt Institute.

***International Symposium on Pollinator Conservation; focus on an Asian Pollinator Initiative***

Given urgent issues about global pollinator decline and its possible impact on pollination services for crops and wild plants, an International Symposium on Pollinator Conservation, themed "Conservation and Sustainable Use of Pollinators: towards Global Assessments", was held at Kyushu University, Fukuoka, Japan from 27th to 29th January, 2012. This symposium was one of the first scientific meetings that addressed the importance of conservation and sustainable use of pollinators in Asia. The organizers aimed to develop collaborative networks among researchers from around the world including Asian countries. Eleven overseas researchers (3 from Asian countries) and 5 Japanese researchers were invited to speak at the symposium. Their subjects covered various topics relating to pollinator conservation: the economic impact of pollinator decline, the influence of landscape change on pollinator communities, invasive alien species, practical approaches to pollinator conservation, etc. Approximately 90 people attended and the interactive question and discussion sessions contributed to the success of the meeting. At the end of the symposium, it was concluded that there is an urgent need for the establishment of an Asian Pollinator Initiative, which would enable assessment and the dissemination of proposals for effective conservation and management. Those attending from the regions with established Pollinator Initiatives (e.g. Europe) also expressed their willingness to support an Asian Pollinator Initiative.

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