



Concept note

Risk governance of pollination services

Abbreviations used in the text:

ALARM	Assessing Large-scale environmental Risks for biodiversity with tested Method (EU)
CAP	Common Agricultural Policy
CCD	Colony Collapse Disorder
CSREES	Cooperative State Research, Education, and Extension Service (US)
EIA	Environmental Impact Assessment
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
INRA	National Institute for Agricultural Research (France)
IUCN	International Union for the Conservation of Nature
MEA	Millennium Ecosystem Assessment
PES	Payment for Environmental Services
UNEP	United Nations Environment Programme
US	United States of America

Preface

IRGC is an independent organisation whose purpose is to help the understanding and management of emerging global risks that have impacts on human health and safety, the environment, the economy and society at large. IRGC's work includes developing concepts of risk governance, anticipating major risk issues and providing risk governance policy recommendations for key decision makers.

Every IRGC project commences with the writing of a "concept note" to describe the particular risk issue being addressed. This is the objective of the following document, which is not intended to be a complete and in-depth description of the risk of the loss of pollination services but, rather, provides a brief summary of the most relevant and urgent issues in the field and a preliminary identification of risk governance deficits. The document thus seeks to inform and guide any future work by IRGC on the subject.

More information on this document can be obtained from Malin Samuelsson, at malin.samuelsson@irgc.org.

Contents

Introduction	6
Why has IRGC decided to address risks related to pollination issues?	7
1. Background/definitions	8
What are ecosystem services?.....	8
What is pollination?.....	9
Observed pollinator declines	10
2. Risks related to the loss of pollination services	11
Risks posed to pollination.....	11
Risks posed by the failure of pollination services.....	13
3. Current regulatory and governance context	16
At the international level	16
European Union.....	17
United States of America	18
Mexico	19
France.....	19
Problems with current regulations	19
4. Risk governance deficits	20
Uncertainty of the science	20
Lack of adequate economic schemes to internalise environmental costs	20
Absent or inadequate land-use policies.....	21
Inadequate stakeholder participation and consultation	21
Difficulty of medium- to long-term planning	22
5. Recommendations.....	22
Conclusions	24
Appendix.....	25
References and bibliography	26
Acknowledgements	30
About IRGC.....	31

Introduction

Ecosystem services are benefits that people obtain from nature. The services include provisioning services (such as food, air and water), regulating services (such as air quality, climate and water regulation), cultural services (including cultural identity, spiritual values and recreation and tourism) and supporting services (for example, soil formation and photosynthesis). Ecosystem services are being put at increasing risk from pressures exerted by both population growth and increasing per capita consumption [Sachs, 2008]. Urbanisation, deforestation, climate change, non-native invasive species, unsustainable agricultural practices and over-fishing, among other factors, are modifying the structure of ecosystems and disrupting their proper functioning.

One important ecosystem service is pollination (classified by the Millennium Ecosystem Assessment (MEA) as a regulating service), which is fundamental to the reproduction of flowering plants and essential for the production of about one-third of the human diet [Klein et al., 2007]. It is one of the 15 ecosystem services identified by the MEA as currently being under threat. Commonly thought of as a free service, pollination nevertheless needs resources for its proper functioning. Whilst some plants can reproduce asexually or rely on wind or self-pollination, the majority of flowering plants require animal pollinators in order to produce fruit and seeds.

There is mounting evidence of a global decline in pollinators that threatens the reproductive cycle of many plants and may reduce the quality and quantity of fruit and seeds, many of which are of nutritional and medicinal importance to humans. Such evidence includes the finding that those plant species requiring external pollination and reliant on declining pollinators have, themselves, declined relative to other plant species. Such findings “strongly suggest a causal connection between local extinctions of functionally linked plant and pollinator species” [Biesmeijer et al., 2006].

Pollinators are at risk from numerous threats and this, in turn, threatens the many benefits people and ecosystems derive from pollination services. The quality and quantity of pollination has multiple implications for food security, species and ecosystem conservation as well as nature and society’s resilience to environmental changes such as climate change. As the UN Food and Agriculture Organization (FAO) notes: “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” [FAO, 2008a]. Identification of appropriate actions is needed, especially given the uncertainty posed by gaps in both scientific knowledge and effective policy interventions.

This concept note will provide background on pollination services, evaluate the risks related to the loss of these services, and identify the relevant governance deficits in this field.

Why has IRGC decided to address risks related to pollination issues?

IRGC is concerned that, in comparison with other ecosystem services such as fresh water supplies, fishery provisioning services, and climate regulation services, insufficient attention is being given to the risks associated with the loss of pollination.

IRGC considers that, although pollination is a critical issue that is well acknowledged within the scientific community, it appears to be neglected and insufficiently appreciated by policymakers, industry (particularly the agricultural sector) and the general public. As a result, IRGC believes that the threats to pollination services and related risks are not adequately taken into account, directly or indirectly, in policies and regulations that may affect pollinators and their habitats.

1. Background/definitions

What are ecosystem services?

An ecosystem is defined as a “dynamic set of living organisms (plants, animals and micro-organisms) all interacting among themselves and with the environment in which they live (soil, climate, water and light)” [Natural Resources Canada, 2007]. Ecosystems vary dramatically in size. Thus, a dead tree, just like a lake, can simultaneously be, and take part in, an ecosystem. Each living component is interdependent upon numerous other species and abiotic components of the system. “Due to complex relationships and feedbacks among people, ecosystems, and the biosphere, human well-being is inextricably linked to the optimal use and management of ecosystems. Humans are an integral part of almost every ecosystem – not only as agents of change, but as consumers of ecosystem goods and services that range from the provisioning of food, fuel, fibre, and fresh water, to the regulation of processes that affect air quality, climate, erosion control, and human diseases” [USDA, 2007a]. In this sense, ecosystem services can be considered as the benefits that humans derive from ecosystems. These services are usually organised into four distinct groups:

- Provisioning services: the products obtained from ecosystems such as food, fibre, fuel, genetic resources, pharmaceutical resources and fresh water;
- Regulating services: the benefits obtained from the regulation of ecosystem processes that control climate, water and air quality, disease, pests, natural hazards, and pollination;
- Cultural services: the non-material benefits obtained from ecosystems through spiritual enrichment, development of knowledge, reflection, recreation, and aesthetic experience; and
- Supporting services: the underlying processes that support all other ecosystem services, such as soil formation, photosynthesis, nutrient cycling, and water cycling [MEA, 2005].

Ecosystems and their services provide the foundations for human life on Earth, yet our activities are modifying and disturbing ecosystems, which are not always capable of responding successfully to the demands we place upon them. The speed at which natural ecosystems have been converted into cultivated ones is accelerating rapidly: “more land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850” [MEA, 2005].

Of the 24 ecosystem services assessed by the MEA, 15 are considered to be seriously degraded [MEA, 2005]. The degradation of ecosystem services is defined as “the persistent decrease in the capacity of an ecosystem to deliver services” [MEA, 2005]. For instance, some ecosystems are losing some of their capacity to absorb greenhouse gases or to recycle water. Thus, because humans depend on ecosystem services to create a hospitable environment, and because many ecosystem services are being degraded and are irreplaceable, the quality of human life on Earth is itself threatened [Costanza et al., 1987].

What is pollination?

Pollination is the transfer of pollen grains from the male anther to the female stigma of flowering plants and is critical to fruit and seed production [Ingram et al., 1996]. The vast majority of plants rely on external vectors for pollination, such as the wind or animal pollinators. As a key process in sexual reproduction of flowering plants, pollination is crucial both to plant reproduction and to the continued evolution of flowering plants. The role of insects in the reproduction of plants was first formally discovered in the 18th century by Joseph Kölreuter (1733-1806), a professor of natural history at the University of Karlsruhe, Germany [National Research Council, 2007]. This knowledge was then popularised by Charles Darwin half a century later, and the use of managed pollinators to improve seed and fruit production has developed progressively since then.

Most conifers, such as pine trees, and about 12% of the world's flowering plants are pollinated by the wind transporting their pollen [US Forest Service, 2008b]. Some of these wind-pollinated plants are major agricultural crops, such as rice, wheat and maize [Ghazoul, 2007]. Other crops, however, especially fruits and nuts, are reliant to differing degrees upon pollination by animals. Some mammals, birds and reptiles act as pollinators, but the majority of pollination is provided by insects such as flies, moths, butterflies, beetles and, especially, bees. Wild bees can be extremely effective pollinators [Ricketts et al., 2008] but agriculture increasingly relies upon managed colonies of domesticated bees to ensure the pollination of many agricultural crops [National Research Council, 2007]. The most common domesticated bee species is the Eurasian Honeybee – *Apis mellifera*.

Over one-third of global food production comes from animal-pollinated crops such as almond, melon, pumpkin, kiwifruit, cherimoya, papaya, sapodilla, passion fruit, rowanberry, brazil nut, macadamia, cocoa, coffee and vanilla, and is therefore dependent on pollinators [Klein et al., 2007].

Pollination is also essential for the production of many medicinal plants, such as goldenseal (used for respiratory, immune system and gastrointestinal diseases), sage (used for its astringent and antiseptic properties) and dandelion (used for heartburn). Thus, pollination not only underpins many traditional medicines but is also crucial to many modern pharmaceuticals since up to 25% are derived from plant-based compounds [US Forest Service, 2008a].

The majority of flowering plants are pollinated by several pollinator species, but some depend on a single species for pollination. For example, the Yucca plant (a member of the *Agavaceae* group of plants) relies exclusively on a single species of the yucca moth (*Tegeticula maculate*) for pollination. Such cases are called obligate mutualisms.

Box 1 - Endangered Pollinators

The International Union for the Conservation of Nature (IUCN) Red List of Threatened Species includes 41,415 species and 1,238 animal species are listed under the United States Endangered Species Act [US Fish and Wildlife Service, 2008c]. At least two bats and 13 bird species on the US list are pollinators, but the number of listed pollinator insects remains unknown [NAPPC, 2002-2005]. However, a list of pollinator insects prepared by the American Xerces Society includes 59 endangered species of moths and butterflies and 58 species of bees [Xerces Society, 2005]. In many countries, up to a quarter of their known bee species may be listed on their endangered species lists [FAO, 2008a].

Observed pollinator declines

There is evidence of a sizeable decrease in the population and range of many pollinators such as bees, butterflies, moths, hummingbirds and bats. Some farmers have already noticed significant declines in pollinator activity. Californian almond growers are accustomed to paying beekeepers from all over the US to place managed honeybee colonies in their orchards during the spring blossom to guarantee effective pollination. However, in 2005, almond growers in California were compelled to import domesticated bee colonies from Australia to ensure that they met their production targets, because of the devastation of the US bee colonies by the mite *Varroa destructor* [Holden, 2006]. The current global population of honeybees, which pollinate the majority of pollinator-dependent crops, is suffering dramatic losses [Kluser et al., 2007]. The disappearance of many *Apis mellifera* honeybee colonies initially occurred in the US, with 29% of 577 surveyed beekeepers across the country losing up to three-quarters of their colonies in 2006 and 2007 [Stokstad, 2007]. In these extreme cases, bees simply left their hives and never returned. This still-unexplained phenomenon, known as Colony Collapse Disorder (see Box 2) is also occurring in Asia and Europe [Cornell University, 2007]. A report by the French government [science.gouv.fr, 2008] quoted losses of 25% of hives in Taiwan, Germany, Portugal, Switzerland and Greece. Significant declines are also being observed in other bee species, such as the Himalayan cliff bee (*Apis laboriosa*) and bumblebees (*Bombus* spp.).

Box 2 - Colony Collapse Disorder

Colony Collapse Disorder (CCD) is the name given to a phenomenon involving the sudden disappearance of worker bees from honeybee colonies. There is still significant uncertainty surrounding the likely factors that cause CCD but most scientists agree that it is probably attributable to a mix of biotic and abiotic factors.

Pathogens such as *Varroa destructor* mites, *Nosema apis* microsporidians and Israel Acute Paralysis Virus all weaken bees, disrupt their immune systems and are thought to be a major contributory factor of CCD. Pesticides have also been linked to CCD, especially neonicotinoids such as imadacloprid, which has been found in affected colonies.

Stress is likely to be a factor and can be exacerbated by managed migration of colonies, poor nutritional intake (perhaps through the feeding of sugar and high-fructose corn syrup to overwintering colonies), and extreme weather such as drought and heatwaves [USDA, 2007d]. There are also concerns about possible links with genetically modified crops and electro-magnetic radiation, although these are still considered to be speculative until further research can produce scientific evidence.

Given the level of uncertainty of the causes of CCD and thus the difficulty of developing appropriate mitigation practices, current governance approaches are focusing on funding further research to clarify causal factors and possible treatments.

Many mammal and bird pollinators are also declining. On a global scale “at least 45 species of bats, 36 species of 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 endangered [FAO, 2008a]. The lesser long-nosed bat, which lives in the desert scrub region of Mexico and the South-Western US, is one example of an endangered mammal pollinator; these bats act as important pollinators for night-blooming plants such as agave cacti [US Fish and Wildlife Service, 2008].

2. Risks related to the loss of pollination services

Risks posed to pollination

- Environmental risks: human activities threatening pollination services

Pollinators are facing a multitude of threats, many of which derive from urbanisation and agriculture.

Loss of habitat: Urbanisation, agricultural intensification and a shift to large-scale monocultures reduce nesting sites and food resources for pollinators, and lead to fragmentation and the loss of natural habitats. A consequence of habitat destruction and fragmentation is the isolation of pollinators, which has the effect of reducing population sizes and eroding their genetic pools, as well as increasing genetic drift between isolated populations [Zayed and Packer, 2005]. Wild pollinator diversity and crop visitation rates diminish with increasing isolation from their natural habitats [Ricketts et al., 2008].

Fragmentation also threatens migratory species, as is the case with the Rufous Hummingbird (*Selasphorus rufus*). This hummingbird migrates from Mexico to Alaska and facilitates plant gene flows over considerable distances [Center for Sonoran Desert Studies, 2007]. Its population is steadily declining and the bird is now on the Red List of Threatened Species of the IUCN. At smaller scales, fragmentation has been shown to reduce the abundance of pollinators as well as the seed set in many species of flowering plants [Donaldson et al., 2002].

Agricultural chemicals: The use of pesticides reduces pollinator populations directly through poisoning, and also contaminates their principal food supplies resulting in early death, behavioural changes and reduced mobility [Boulter et al., 2006]. Herbicides affect pollinators indirectly by eliminating non-crop flora, which support pollinators. Whilst many monoculture crops are wind-pollinated, such as grasses, others require insect pollination for seed production, such as rapeseed and alfalfa. Monocultures that are not wind-pollinated often require the provision of managed insect pollinators [Bradbear, 2003].

Invasive species: Another threat to pollinators comes from the deliberate or accidental introduction of non-native pollinator species [Enserink, 1999]. The introduction of new species can induce competition for food and nesting sites with native species. For instance, European honeybees have been imported from Eurasia into almost every other continent and have reduced the populations of many native pollinators [Buchmann, S. L. 1996]. In Latin America, African honeybees were accidentally released in 1957 and have hybridised with feral European honeybees. The new “africanized” subspecies is aggressive and is spreading north into the US. In New Zealand, introduced *Apis mellifera* are the primary pollinators of introduced invasive weeds and so reinforce the process of colonisation by invasive plants [Goulson, 2003]. Moreover, imported pollinators are often vectors for parasites and diseases that can then spread to native populations of pollinators which may lack any resistance to introduced pathogens. For example, bumblebees imported in 1998 to the US for greenhouse pollination brought with them parasites which quickly infected native wild bees, such as *Bombus occidentalis*, driving some colonies into decline [Thorp and Shepherd, 2005].

The global spread and introduction into the US of the varroa mite in the 1980s is also known to have increased the mortality of honeybees [Cox-Foster et al., 2007].

- **Climate risks: disruption of pollination timing**

The timing of pollination is determined by climatic cues such as temperature and water availability [Cleland, E. E. et al., 2007]. Many pollinators also synchronise their life cycles with climatic cues, and this phenological response of plants and pollinators needs to remain broadly synchronised for many plant-pollinator relationships to remain viable.

Climate change is altering the phenological response of plants and some pollinators may be unable to alter their life cycles in synchronisation with altered pollination timing. Kudo et al. (2004) show that, since 1998, plants have been flowering much earlier in alpine environments whilst the time of emergence of pollinators has not necessarily changed, thereby disrupting pollination.

Climate change also shifts the latitudinal and altitudinal climate ‘envelope’ of species. Some species are more mobile or adaptable to change and so the composition of plant and pollinator assemblages is likely to change in many locations. For example, species in the tropics appear to be living at or near their thermal optimum and further warming may cause some species to migrate to cooler areas, or die out [Deutsch et al., 2008].

- **Conclusion**

Whilst there has been a documented decline in the population and range of numerous species of pollinators, controversy remains over the level of concomitant threat to pollination services. In some plant-pollinator relationships, loss of specific pollinators will result in local extinction of mutualistic plants. However, most plants are pollinated by a diverse community of pollinators, and assessing the risk to pollination services from declines in individual species remains extremely complex, and in most cases, inadequately understood. Most of the recent declines in pollinators are part of a global pattern of loss of biodiversity that is being observed at local, national and regional scales, the main drivers of which are loss of natural habitat, disruption from invasive species and pollution.

Some scientists argue that pollination services are relatively robust and resilient in many ecosystems and agricultural scenarios, and that investments in the conservation of pollinator habitats for some agricultural crops may be misplaced, especially where pollination is highly managed and thus decoupled from wild pollinators [Ghazoul, 2005]. Others argue that current declines of pollinators threaten crop productivity, biodiversity and rural livelihoods [Steffan-Dewenter et al., 2005].

What is clear is that as an ecosystem service, pollination is extremely difficult to replace. Bernard Vaissière, a specialist on pollination at the French National Institute for Agricultural Research (INRA), believes that attempts to develop substitute solutions through technological methods are not, to date, satisfactory [Contre Info, 2007]. Some crops, for instance tomatoes and courgettes (zucchini, squash), can produce fruit with hormone spraying. However, these techniques cannot be used for every plant species and results can be inefficient in terms of both quantity and quality, not to mention economics.

Risks posed by the failure of pollination services

- **Environmental risks: depletion of biodiversity**

Any decline in pollination services could lead to cascading effects on ecosystems and an overall loss of biodiversity and ecosystem services (such as agricultural production). Mutualistic relationships are most directly affected since the loss of individual pollinator species will lead to the extinction of any co-dependent plant species (and vice-versa). A research study conducted in Britain and the Netherlands, under the European project *Assessing Large-scale environmental Risks for biodiversity with tested Method (ALARM)*, has shown that specialist pollinators and the obligate outcrossed plants that they pollinate decline in tandem [Biesmeijer et al., 2006].

Ecosystems possess some robustness to the loss of individual species since multiple pollinators can pollinate most plants, each with somewhat different effectiveness or responses to environmental change. However, the loss of particular pollinator species and the impoverishment of pollinator diversity diminish the resilience of ecosystems to change, which are subsequently less able to provide services to humans [FAO, 2008a]. Many pollinators are also important food sources for higher animals, so their loss may threaten birds, bats and other small mammals. As individual species are lost from an

ecosystem, the functional redundancy that diverse ecosystems generally display is reduced and resilience to change also tends to decline.

This loss of functional redundancy of ecosystems is complex, but ecosystems seem to be resilient to major disruptions up to certain thresholds, beyond which irreversible vegetation “phase-shifts” can occur. To date, most research has focused on fire and deforestation as major driving factors [Barlow & Peres, 2008]. Major gaps remain in our understanding of how the loss of pollinators might precipitate a similar shift in vegetation communities. Natural hazard protection is also put at risk as altered vegetation cover may change river flow regimes, alter vulnerability to fire and reduce natural flood protection.

- **Climate risks: disrupting the CO₂ and water cycles**

The interaction between climate and vegetative cover is an important element of carbon and water cycles [Denman et al., 2007]. Thus, a modification in density or diversity of the vegetative cover could have an impact on climate change, especially in regions such as the Amazonian interior, where rainfall is generated in large part by vegetation cover.

Loss of the pollination process could also have an impact on climate change through the disruption of the water cycle. Since tropical forests mitigate warming through evaporative cooling [Bonan, 2008], a diminishing vegetative cover could mean less evaporative cooling, which could, in turn, modify surface temperatures.

However, studies have not yet been conducted to measure the extent to which ecosystem services provided by plants are increased by animal-mediated pollination [Kremen et al., 2007] and the interactions between ecosystems and the atmosphere are complex. The impact of climate change on pollination services therefore remains highly speculative, but seems likely to vary across ecosystems.

- **Social and economic risks: threats to food security, rural development and industry**

Food Security: Large-scale loss of pollination services would affect important components of food security since 80% of the world’s crop plants rely on animal pollination [Klein et al., 2007]. In addition to fruit and vegetable production, the supply of meat and milk may also suffer from the lack of pollinators, since many fodder crops such as alfalfa and clover are largely reliant on insect pollination [Voeller et al., 2007]. Oil seeds such as canola are important inputs for animal feeds and have been found to be less productive when numbers of honeybees decline [Klein et al., 2007].

Currently, the loss of pollination services is not perceived to be a major threat to global food security. The main cereal crops, such as rice, maize and wheat, are not directly affected by loss of pollinators [Ghazoul, 2007]. However, failures in the pollination process may ultimately threaten food security in regions where cereals are not a significant part of the human diet. Food diversity may decline considerably and any switch in human diet, especially if certain fruits and vegetables become scarcer, may have repercussions on health. For instance, foods pollinated by animals supply a large proportion of essential micronutrients such as vitamin C [National Research Council, 2007].

Rural Livelihoods: Any deterioration of pollination services will also have an impact on the livelihoods of many rural communities. For instance, in the event of drought, some poor communities of northern Mexico rely on the bat-pollinated fruit of columnar cacti, an important source of water, sugar and other nutrients [Medellin, 2004]. Quite simply, “poor people, with restricted access to resources, and lower integration into the cash economy, are less able to substitute human and physical capital, and have less purchasing power, and are therefore particularly, and most directly, dependent on ecosystem services” [Ash et al., 2007, p.11]. Such reliance upon ecosystem services makes the poorest more vulnerable to any change in those services. Thus, a functioning pollination process is life-threateningly important to the rural poor, who rely on animal-pollinated food crops and medicines for their subsistence.

The economic value of pollination services is difficult to assess with precision because the contribution of wild pollinators is often poorly understood and extremely difficult to quantify. The total economic value of pollination worldwide has recently been estimated at US\$ 224 billion, representing 9.5% of the value of world agricultural food production in 2005 [Gallai et al., 2008]. Pollinator-dependent crops – fruits, vegetables, edible oils, nuts and spices – are generally "high-value" crops: a ton of the crop categories that do not depend on insect pollination averages US\$ 221 in value while those that are pollinator-dependent are worth US\$ 1,112 per ton. These high-value horticultural crops are serving as important sources of income for many poor farmers in developing countries, and allow smallholders to maintain profitable livelihoods on smaller farms typical of developing countries. Thus, a decline in pollination services could have an adverse impact on both the food industry and the rural poor. Additionally, for 75% of food crops, a deficit in pollination services reduces fruit quality and/or quantity [Klein et al., 2007]. The majority of agriculture is, therefore, potentially affected by pollinator scarcity. Beekeepers are already experiencing losses of 30 to 90% of their hives in the US [USDA, 2008]. For consumers, commodities that are affected by a pollinator deficit may suffer because the commodity becomes less available and therefore costs more [Kevan et al., 2001].

Industry: A decline in pollination services would be detrimental to the pharmaceutical industry, as about 25% of modern medicines were developed from plants [Ngandwe, 2006]. Other industries, such as the floral and perfume industries, would also be affected. The perfume industry, for example, uses spices or flowers, such as vanilla orchids and cardamom, that depend on pollination [McGregor, 1976]. Both the availability and market prices of such spices would be affected by the loss of pollination services.

The bioenergy sector is also at risk since bees help pollinate crops such as sunflower, soy, rapeseed and safflower [Klein et al., 2007] which are all used in biofuel production.

Yet, perhaps even more importantly, loss of pollinators is likely to contribute to loss of some plant species, and accompanying losses of potentially valuable compounds for future biochemical advances for pharmaceuticals and a host of other industrial applications. With fewer than 2% of plants having been thoroughly tested for potential medicinal compounds, there is huge untapped potential resource that is at risk before it is even discovered. The loss of this “option value” is a significant risk.

3. Current regulatory and governance context

Governmental regulations relevant to pollination exist at different levels: international, national, and local. Some refer specifically to pollination; others do not.

At the international level

The International Initiative for the Conservation and Sustainable Use of Pollinators was established in 2002 at the fifth meeting of the Conference of the Parties to the United Nations Convention on Biological Diversity. This Initiative is built around four distinct goals:

- “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 and the restoration and sustainable use of pollinator diversity in agriculture and related ecosystems” [Convention on Biological Diversity, 2008].

The Initiative is facilitated and coordinated by the FAO.

The Conservation and Management of Pollinators for Sustainable Agriculture through an Ecosystem Approach is a five-year project launched by the Global Environment Facility (GEF) in 2008 and implemented through the United Nations Environment Programme (UNEP) and coordinated by the FAO. The project aims to show how pollination services can be conserved and sustainably used in agriculture, through a set of targeted cropping systems in seven countries with a wide diversity of ecological zones and farming patterns. Through the development and testing of good agricultural practices, built on an extended knowledge base, capacities will be built and awareness raised to promote wise management of animal pollinators. A set of tools, methodologies, strategies and best management practices will be created, which can then be applied to pollinator conservation efforts in relevant agroecosystems globally. Project outcomes will be:

- “An integrated and accessible knowledge base for the management of wild pollination services, for farmers, land managers and policy makers;
- Enhanced conservation and sustainable use of pollinators for sustainable agriculture;
- Increased capacity for conservation and sustainable use of pollinators by farmers and land managers; and
- Mainstreaming of pollinator conservation and sustainable use” [Global Environment Facility, 2007].

The Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) was adopted in 1991 and came into force in 1997 [UNECE, 1991]. The Convention provides an international framework (limited in its geographical scope mostly to European countries, Russia, Canada and the US) for the use of environmental impact assessments, particularly when an activity under the jurisdiction of one Party may have effects on the environment in the jurisdiction of another Party [UNECE, 1991]. The Kiev Protocol to the Espoo Convention establishes procedures for a strategic environmental assessment of a programme of projects [UNECE, 2003]. However, neither the

Espoo Convention nor the Kiev Protocol refers specifically to pollination or pollinators.

European Union

The *Environmental Impact Assessment (EIA) Directive* was introduced in 1985 [Europa, 2008c]. This Directive aims to avoid pollution by identifying and assessing the possible environmental impacts of a public or private project before authorising its implementation. Construction work and other interventions in the natural surroundings are considered as projects that fall within the scope of the Directive [EUR-Lex, 1985]. More specifically, the EIA Directive identifies the need to assess the effects of a project on:

- “Human beings, fauna and flora;
- Soil, water, air, climate and the landscape;
- The interaction between the factors mentioned in the first and second indents; and
- Material assets and the cultural heritage.”

The *Environmental Liability Directive*, based on the “polluter pays principle”, was adopted on 30 April 2004 and came into force on 30 April 2007 [Europa, 2006]. It seeks to ensure that, in the future, environmental damage in the European Union (EU) is prevented or remedied and that those who cause it are held responsible. Environmental damage includes damage to natural habitats, animals and plants, water resources, as well as contamination of land that causes significant harm to human health [FSN, 2007].

The EU-funded *ALARM project* aims to assess the changes of biodiversity and the impact of its loss in Europe. Among other risks posed to biodiversity, it considers the loss of pollinators. The four main goals of the project’s Pollinator Module are to:

- “Quantify distribution shifts in key pollinator groups across Europe;
- Measure the biodiversity and economic risks associated with the loss of pollination services in agricultural and natural systems through the development of standardised tools and protocols;
- Determine the relative individual and combined importance of drivers of pollinator loss (land use, climate change, environmental chemicals, invasive and socio-economic factors); and
- Develop predictive models for pollinator loss and consequent risks” [ALARM, 2003].

The *Habitats Directive* establishes a European ecological network of protected sites: Natura 2000. The purpose of the Directive is to protect biodiversity by conserving natural habitats and wild flora and fauna at suitable scales. Other activities include “monitoring and surveillance, reintroduction of native species, introduction of non-native species, research and education” [Europa, 2008b]. The Directive establishes clear targets for nature and biodiversity protection, and is implemented within the framework of the UN Convention on Biological Diversity [EuropaWorld, 2006].

The *Wild Birds Directive* was launched in 1979 and aims to protect and conserve wild bird species living within the European territory of member states, in the long-term [Europa, 2008a]. European Member States must conserve, maintain and restore the biotopes and habitats of wild birds by:

- “Creating protection zones;

- Maintaining the habitats;
- Restoring destroyed biotopes; (and)
- Creating biotopes” [Europa, 2008a].

The *Plant Protection Products Directive* of 15 July 1991 regulates the sale of pesticides and herbicides by implementing “uniform rules on the evaluation, authorization, placing on the market and control within the EU of plant protection products and the active substances they contain” [Europa, 2007]. The Directive aims to ensure that marketed products do not pose a threat to human, animal and environmental health.

The *Common Agricultural Policy (CAP)* was launched in 1962 and now has two pillars: the market and income policy and the sustainable development of rural areas. Some of the agri-environmental measures of the CAP are:

- “Environmentally favourable extensification of farming;
- Management of low-intensity pasture systems;
- Integrated farm management and organic agriculture;
- Preservation of landscape and historical features such as hedgerows, ditches and woods; (and)
- Conservation of high-value habitats and their associated biodiversity” [European Commission, 2003].

United States of America

The *CCD Action Plan* (July 2007) has been established by the United States Department for Agriculture (USDA) to deal with Colony Collapse Disorder (CCD) of honeybees [USDA, 2007d]. The action plan has four main components:

- “Survey and data collection needs;
- Analysis of samples to determine the prevalence of various pests and pathogens, exposure to pesticides, or other unusual factors;
- Controlled experiments to carefully analyze the potential causes of CCD; and
- Developing new methods to improve the general health of bees to reduce their susceptibility to CCD and other disorders” [USDA, 2007c].

The *Ecological Goods and Services Working Group* is made up of Cooperative State Research, Education, and Extension Service (CSREES) national program staff [USDA, 2007a]. Its goals are to:

- “Identify a research, education, and extension agenda for ecological goods and services within CSREES;
- Coordinate agency efforts in the development and implementation of government-wide initiatives to incorporate ecological goods and services into science and policy; (and)
- Form a partnership with land managers, stakeholders and policymakers to improve the sustainability and stewardship of working lands” [USDA, 2007a].

National Research Initiative – Managed Ecosystems

The several objectives of the Managed Ecosystems Program are to:

- “Protect and enhance the natural resource base and environment through the appropriate use and management of ecological systems;

- Enhance economic opportunities by increasing productivity and ecosystem services; and
- Improve the quality of life in rural America through improved environmental quality” [USDA, 2007b].

Mexico

The Mexican government has amended its federal wildlife laws in order to support the preservation of bats. Bats are essential for the pollination of agaves, used for the production of alcoholic beverages such as tequila and pulque [FAO, 2008a]. Caves and crevices, which are the bats’ natural habitats, are now considered as protected areas.

France

The French initiative *Charte “L’abeille, sentinelle de l’environnement”* was launched by the Union Nationale de l’Apiculture Française in 2005. The charter alerts, informs and sensitises territorial communities, corporations and the public. The goals are:

- To fight against the use of pesticides with unknown effects;
- To preserve honey bees in France and in other parts of the world;
- To protect plant biodiversity;
- To promote a sustainable agriculture;
- To preserve the link between human and nature; and
- To inform the public [UNAF, 2007].

Problems with current regulations

Current regulations reveal several deficits on how the risks posed to pollination services are addressed. The main deficit is that most regulations are not specific to pollination. In the opinion of IRGC, pollination and pollination services are insufficiently understood or recognised as important, so they cannot be fully taken into account by implication alone.

More specifically, the EU Habitats Directive has some deficits. It lacks a clearly-defined target for how much land needs to be included in the Natura 2000 network to protect key species and ecosystem services. Moreover, it does not effectively use the opportunity provided by Natura 2000 to build an ecologically representative network at the continental scale through collaboration between European countries. Thus, site coverage and selection often represent social, political and economic factors, to some detriment for ecological concerns.

The 1991 Plant Protection Products Directive concerning the placing of pesticides and herbicides on the market does not contain norms for the chemical industry that might be relevant to pollinators [Moreigne, 2006]. Assessment of pesticides before approval seems to be insufficient, as illustrated by the controversy surrounding neonicotinoids (systemic pesticides) suspected of having increased the mortality of honeybees in France in the 1990s through their assimilation into plant pollen and nectar [Dupont, 2005; Quiret, 2008]. The use of pesticides seems to receive insufficient guidance and

regulation, so they are often overused or applied carelessly, and may reach unintended areas that harm pollinators [Kevan et al., 1997].

Because pollinators easily cross national boundaries, their management and protection need to be reflected in an international approach to governance. In this respect, the US is not a Party to the UN Convention on Biological Diversity although it has publicly stated its commitment to the Convention's objectives [Burnam, 2002]. Also, most countries currently implement their own invasive species mitigation policies but, due to the mobility of such species, a more coherent and integrated approach is required.

Furthermore, few economic incentives reward positive contributions, particularly by groups such as farmers whose husbandry techniques are so influential on the biodiversity of rural agricultural landscapes [FAO, 2008a]. Also, IRGC is concerned that most policy initiatives seem to be directed more towards research and sensitisation rather than encouraging specific actions.

4. Risk governance deficits

Several elements impede the effective governance of risks related to the loss of pollination services.

Uncertainty of the science

Current understanding of pollinators, plant-pollinator relationships and threats to pollinators is beset by a number of knowledge deficits, including:

- The relationship between plants, pollinators and ecosystems;
- The capacity and importance of wild pollinators;
- The impacts of pollination disruptions on plant reproduction;
- The knock-on effects induced by species extinctions;
- The requirements of wild pollinators;
- The trends in pollinator populations;
- The impacts on pollinators of climate change;
- The causes of Colony Collapse Disorder; and
- The effects of pesticides and other chemicals on pollinators.

Lack of adequate economic schemes to internalise environmental costs

Evaluating the benefits that are provided by most ecosystem services, such as pollination, is a difficult task because such benefits are often perceived as public goods that are not captured by conventional, market-based economic instruments [Balmford et al., 2002]. The most obvious value is from provisioning services, such as the production of timber or the collection of plants and animals for food [Edwards et al., 1998]. However, the most challenging ecosystem services to incorporate into the marketplace are regulating, cultural and supporting services. This is because they "clearly underpin human welfare and a range of economic activities, but they can also

be extremely difficult to measure and link to specific providers or beneficiaries and are highly variable across sites” [Hanson et al., 2008].

Pollination, which is often regarded as a free public good, represents only indirect uses for people and does not draw immediate attention [Edwards et al., 1998]. Pollination services are also difficult to measure because fruit and seed production varies dramatically in response to many biotic and abiotic factors such as weather, water, or soil [National Research Council, 2007]. Thus, the economic value of pollination often becomes apparent only after the services are lost. Current efforts to internalise environmental costs are centred on setting up economic incentives broadly called Payments for Environmental Services (PES). PES is a mechanism whereby landowners receive compensation for the ecosystem services their land provides to the general public [Redondo-Brenes et al., 2006]. Examples of successful PES projects at local and regional scales include the Nestlé Waters project to mitigate the risk of nitrate contamination of mineral water aquifers caused by agricultural intensification in the Vosges mountains of France [Perrot-Maître, 2006], and, in Costa Rica, a project whereby downstream customers of water utilities subsidise re-vegetation and good watershed management practices carried out by upstream land owners [Redondo-Brenes et al., 2006].

Absent or inadequate land-use policies

Land-use policies that allocate suitable habitat for pollinators and protect pollinator habitats such as woodland, hedgerows and windbreaks (used as foraging and nesting sites) may be insufficient or inadequate.

For example, the EU introduced financial incentives for “set aside” in 1992. However, the focus was on reducing agricultural surpluses and compensating farmers for reduced production. Wildlife benefits were clearly secondary in importance and no assistance was provided in planning set aside to maximise benefits to wildlife in general, or pollinators in particular. This is just one example of a wider problem of lack of planning of agricultural landscapes that balance production with biodiversity. Scientific understanding of biodiversity increasingly points to the need for landscape-scale efforts to provide connected habitats to maintain minimum viable populations of species.

Sustainable practices which assure the retention of habitats able to support wild pollinators are needed. Practices such as protecting nesting sites and planting species-rich hedgerows around farms are carried out in order to protect and conserve pollinators [FAO, 2008b], but are still too few and are seldom planned specifically with pollinators in mind. At larger scales, agricultural approaches such as ecoagriculture could offer methodologies for balancing biodiversity conservation, agricultural production and rural livelihoods at landscape scales [Milder et al., 2008].

Inadequate stakeholder participation and consultation

At present, many relevant stakeholders are not adequately involved in decision-making. Beekeepers are rarely consulted for input into decisions on local developments that may affect pollinators, nor is their detailed knowledge sought on what is actually happening to the bee populations. This is especially important where evidence of new or uncertain risks to pollinators is emerging,

as is the case with many of the factors that are suspected of contributing to CCD (see Box 2).

Conflicting views between stakeholders may also hinder efforts to improve the governance of risks related to the loss of pollination services. For example, the chemical and biotechnology industries and beekeepers may have diverging interests. Pesticides and herbicides are suspected of having a negative impact on managed honeybees, potentially causing important financial losses to beekeepers [Boulter et al., 2006].

Farmers have both the local knowledge of pollinator habitats as well as the means to manage those habitats, so their contributions are especially valuable. In addition, there is an important deficit in public knowledge and awareness, in terms of understanding both the pollination process and the importance of pollinators to society. In many cases, diverging views may be the result of poor communication.

Difficulty of medium- to long-term planning

A short time horizon leads to discounting the future [Edwards et al., 1998]. This short-term perspective is widespread, mostly due to market forces, and often takes precedence over the preservation of the environment, which requires a longer-term outlook. More specifically, market forces often give higher incentives to the destruction of natural habitat to maximise production, without taking a holistic view of longer term needs.

The problem is accentuated by poverty, which often compels people to compromise the long-term sustainability of their livelihoods in order to meet short-term basic needs. Also, the agricultural industry does not always recognise the trade-off between increased acreage and reduced biodiversity and this is reinforced by the belief that biodiversity and productivity are increasingly decoupled thanks to the use of energy and resource intensive modern technologies.

5. Recommendations

IRGC recommends that the following measures be considered to address the governance deficits of pollination services:

Reduce knowledge gaps

- Increase funding for research, especially multidisciplinary research, in order to better understand the plant-pollinator relationship, natural and man-made threats to pollinators and pollination services, and the environmental, social and economic consequences of their loss. Such research should have the objective of creating a body of knowledge able to guide policymakers in establishing a regulatory framework that will protect wild pollinators and their habitats. It should also provide the basis for voluntary initiatives by industry and the general public;

- Establish at the earliest opportunity the monetary and non-monetary values of the benefits of pollination services at multiple scales;
- Increase funding for research into pollinator pathogens; and
- Better assessment of agricultural chemicals for their impact on pollinators, before approval for use.

Governance practices

- Provide farmers with advice and incentives to adopt sustainable agricultural practices. This would initially be through implementing more effective and robust land-use policies (set-aside land within and around cultivated areas, such as hedgerows and windbreaks) [Ingram et al., 1996] but should also, in the longer term, be part of an integrated progression towards sustainable agricultural practices that are sufficient to ensure long-term global food security. Such incentives could be based on emerging PES approaches;
- Encourage the restoration and preservation of endangered habitats and species, reintroduce native plants and pollinators where absent, and better manage invasive species such as exotic pollinators imported to support pollination of agricultural crops;
- Establish liability regimes, such as the one established by the EU's Environmental Liability Directive, to penalise those whose actions cause damage to vital habitats; and
- Impose a system of certification for traded pollinators to ensure that they are disease-free, in order to reduce the spread of pathogens.

Improve stakeholder participation and communication

- Initiate a closer level of communication between scientists and policymakers. This could be done through the establishment of national roundtables on pollination that communicate closely with the International Initiative for the Conservation and Sustainable Use of Pollinators;
- Because ecosystems do not follow political boundaries, international collaboration is needed between policymakers to assess the continuity and health of migratory corridors [Ingram et al., 1996];
- Information exchange and collaboration is needed between policymakers and the agricultural and agribusiness sectors, who are best placed to act at the local level to implement protection policies for pollination services;
- Policymakers should work with the agrochemical industry, in order align the needs of this sector with those of pollination services; and
- Raise public awareness by launching campaigns to provide general information about the pollination process and pollinators' role, to promote good practices that are implementable at the local level, such as gardening using native flowering plants, reducing the use of pesticides and herbicides, and leaving parts of gardens untouched and unmown.

Conclusions

This concept note provides a general overview of pollination as an ecosystem service, of the risks to pollination – particularly the risk of the loss of animal pollinators – and of the risks and issues associated with its potential decline. Failure of pollination services can have additional indirect and potentially harmful consequences. The risks of the loss of pollination services are complex, multi-dimensional and uncertain and they involve a wide range of stakeholders.

The loss of pollinators has been scientifically observed but no firm evidence demonstrates a general decline in pollination services. When a decline in pollination has been observed, the link to the loss of pollinators is not always obvious. In the short term, a potential loss of pollination services mainly concerns the agricultural sector and there is a particular need to assess and internalise the economic value of these services in prices paid for agricultural commodities. In the long term, the main risks generated by failures in the pollination process are a wider depletion of biodiversity and the resultant reduction in the resilience of ecosystems; here, the most important questions concern how the current loss of biodiversity is linked to the disruption of pollination services.

The high degree of uncertainty regarding the risks related to pollination services implies the need for continued research to improve the scientific understanding of pollination processes. Additional measures include improving interactions between scientists, policymakers, farmers, industry and the public; designing regulatory frameworks that account for pollination services in the absence of scientific certainty; and encouraging multi-stakeholder participation in the governance process. On this last point, the involvement of industry and of groups such as farmers who are responsible for land-use decisions at the local level is especially important.

Appendix

Organisations working on pollination and related issues

- **Bat Conservation International:** North American Pollinator Protection Campaign partner. www.sdp.gov/sdp/initiative/c22350.htm.
- **BirdLife International:** the BirdLife International partnership forms the leading authority on the status of birds, their habitats and the issues and problems affecting bird life.
- **ESA:** Ecological Society of America have developed a pollination toolkit which provides clear advice on the state of pollination and possible actions to protect pollinators.
- **EU:** European Union.
- **FAO:** Food and Agriculture Organization of the United Nations, the FAO Global Action on Pollination Services for Sustainable Agriculture provides guidance to member countries and relevant tools to use and conserve pollination services that sustain agroecosystem functions.
- **GEF:** Global Environment Facility.
- **INRA:** Institut National de la Recherche Agronomique (France).
- **International Initiative for the Conservation and Sustainable Use of Pollinators:** Established by the 5th Conference of Parties to the Convention on Biological Diversity.
- **IUCN:** International Union for Conservation of Nature.
- **NAPPC:** North American Pollinator Protection Campaign, working to protect the pollinators of the North American Continent.
- **Pennsylvania State University:** Colony Collapse Disorder Working Group.
- **The US National Academies:** Advisers to the Nation on Science, Engineering, and Medicine (USA).
- **UNCBD:** United Nations Convention on Biological Diversity is the major international treaty aimed at preserving the diversity of life on Earth. In 2002, the CDB established the International Initiative for the Conservation and Sustainable Use of Pollinators (facilitated and coordinated by FAO).
- **UNEP:** United Nations Environment Programme.
- **USDA:** United States Department for Agriculture, CCD Action Plan, action plan for dealing with colony collapse disorder of honey bees.
- **WBCSD:** World Business Council for Sustainable Development, "Guidelines for Identifying Business Risks and Opportunities Arising from Ecosystem Change", March 2008.
- **WWF:** World Wild Fund for Nature aims to stop the degradation of the planet's natural environment.
- **Xerces Society:** An environmental organisation which launched a Pollinator Conservation Program.

References and bibliography

- [ALARM, 2003] ALARM, Research Modules - Pollinators loss, online at www.alarmproject.net.ufz.de/index.php?pid=4140.
- [Akratanakul, 1990] Akratanakul P., Honeybees of the Genus apis, In: Beekeeping in Asia, Roma, Food and Agriculture Organisation of the United Nations, online at www.fao.org/docrep/x0083e/X0083E00.HTM.
- [APMN, 2000] Asia Pacific Mountain Network, Conserving Himalayan Honeybees, *Asia Pacific Mountain Network Bulletin*, 5 (2), online at <http://apmn.icimod.org/publications/Chapter10.pdf>.
- [Ash et al., 2007] Ash N., Jenkins M., Biodiversity and Poverty Reduction; The Importance of Biodiversity for Ecosystem Services, Cambridge, UNEP, WCMC, online at www.unep-wcmc.org/latenews/Biodiversity%20and%20Poverty%20Reduction%20UNEP-WCMC.pdf.
- [Balmford et al., 2002] Balmford A., Bruner A., Cooper P., Costanza R., Farber S., Green R.E., Jenkins M., Jefferiss P., Jessamy V., Madden J., Munro K., Myers N., Naeem S., Paavola J., Rayment M., Rosendo S., Roughgarden J., Trumper K., Turner R.K., Economic Reasons for conserving Wild Nature, *Science*, 297, 950-953.
- [Barlow & Peres, 2008] Barlow, J. & Peres, C. A., 2008. Fire-mediated dieback and compositional cascade in an Amazonian forest. *Philos Trans R Soc Lond B Biol Sci*, 363(1498), 1787-1794
- [BBC News, 2008] BBC News, Tropics insects face extinction, online at <http://news.bbc.co.uk/2/hi/science/nature/7384807.stm>.
- [Berenbaum, 2007] Berenbaum M.R., 2007, The Birds and the Bees: How Pollinators Help Maintain Healthy Ecosystems, online at http://www7.nationalacademies.org/ocga/testimony/How_Pollinators_Help_Maintain_Healthy_Ecosystems.asp.
- [Berendse et al., 2004] Berendse F., Chamberlain D., Kleijn D., Schekkerman H., Declining Biodiversity in Agricultural Landscapes and the Effectiveness of Agri-environment Schemes, *Ambio*, 33 (8).
- [Biesmeijer et al., 2006] Biesmeijer, Roberts S.P.M., Reemer M., Ohlemüller R., Edwards M., Peeters T., Schaffers A.P., Potts S.G., Kleukers R., Thomas C.D., Settele J., Kunin W.E., Parallel Declines in Pollinators and Insect-Pollinated Plants in Britain and the Netherlands, *Science*, 313, 351-354.
- [Bonan, 2008] Bonan G.B., Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests, *Science*, 320, 1444-1449.
- [Boulter et al., 2006] Boulter S.L., Kitching R.L., Zalucki J.M., Goodall K.L., Threats to Pollination Systems, In: Reproductive Biology and Pollination in Rainforest Trees: Techniques for a Community-level Approach, Cairn, Australia, Cooperative Research Centre for Tropical Rainforest Ecology and Management Rainforest CRC, 53-56.
- [Bradbear, 2003] Bradbear N., Bees are diligent pollinators of fruit and seed crops, In: Beekeeping and sustainable livelihoods, Roma, Food and Agriculture Organisation of the United Nations, online at www.fao.org/docrep/006/y5110e/y5110e03.htm#bm03.6.
- [Buchmann, S. L. 1996]. Competition between honey bees and native bees in the Sonoran desert and global bee conservation issues. In: Matheson, A., C. O'Toole, S. Buchmann, P. Westrick, and I. Williams (Eds). The Conservation of Bees. New York: Academic Press
- [Burnam, 2002] Statement to the Ministerial Roundtable, Sixth Conference of the Parties to the Convention on Biological Diversity, Jeffrey Burnam, Deputy Assistant Secretary of State for Environment, 17 April 2002, <http://www.state.gov/g/oes/rls/rm/2002/9577.htm>.
- [Center for Biological Biodiversity, 2003] Center for Biological Diversity, Lesser Long-nosed Bat, online at www.biologicaldiversity.org/swcbd/SPECIES/bats/ll_bat.html
- [Center for Sonoran Desert Studies, 2007] Center for Sonoran Desert Studies, Migratory Pollinators Program: Rufous Hummingbirds, online at www.desertmuseum.org/pollination/hummingbirds.php.
- [Cleland, E. E. et al., 2007] Cleland, E. E., Chuine, I., Menzel, A., Mooney, H. A. & Schwartz, M. D. Shifting plant phenology in response to global change. *Trends in ecology and evolution*, 22, 7, 357-365
- [Commission Interministérielle pour les Véhicules Propres et Economes, 2006] Commission Interministérielle pour les Véhicules Propres et Economes, Recommandations pour un développement durable des biocarburants en France : Rapport du groupe de travail sur les biocarburants, online at www.industrie.gouv.fr/energie/renou/biomasse/rap-douaud-civepe.pdf.
- [Convention on Biological Diversity, 2008] Convention on Biological Diversity, Pollinators Introduction, online at www.cbd.int/agro/pollinator.shtml.
- [Contre Info, 2007] Contre Info, Un monde sans abeilles serait un monde sans fruits ni fleurs, online at http://contreinfo.info/article.php?id_article=1333.
- [Cornell University, 2007] Cornell University (2007, May 12). Bee Colony Collapse Disorder: Could It Be Parasites, Pathogens Or Pesticides?. ScienceDaily. Retrieved March 13, 2009, from <http://www.sciencedaily.com/releases/2007/05/070511210207.htm>
- [Costanza et al., 1987] Costanza R., d'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., Raskin R.G., Sutton P., van den Belt M., The Value of the World's Ecosystem Services and Natural Capital, *Nature*, 387, 253-260.
- [Cox-Foster et al., 2007] Cox-Foster D.L., Conlan S., Holmes E.C., Palacios G., Evans J.D., Moran N.A., Quan P-L., Briese T., Horning M., Geiser D.M., Martinson V., vanEngelsdorp D., Kalkstein A.L., Drysdale A., Hui J., Zhai J., Cui L., Hutchison S., Simons J.F., Egholm M., Pettis J.S., Lipkin W.I., A Metagenomic Survey of Microbes in Honey Bee Colony Collapse Disorder, *Science*, 318, 283-287.
- [David Suzuki Foundation, 2007] David Suzuki Foundation, Pollinators...what's the Buzz?, online at www.davidsuzuki.org/files/swag/species/pollinators_fact_sheet.pdf.
- [DEFRA, 2008], DEFRA, Environmental Impact Assessment (EIA), online at www.defra.gov.uk/farm/environment/land-use/eia.
- [Denman et al., 2007] Denman K.L., Brasseur G., Chidthaisong A., Ciais P., Cox P.M., Dickinson R.E., Hauglustaine D., Heinze C., Holland E., Jacob D., Lohmann U., Ramachandran S., da Silva Dias P.L., Wofsy S.C., Zhang X., Couplings Between Changes in the Climate System and Biogeochemistry, In: Climate Change 2007: The Physical

Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds), United Kingdom and New York, NY, USA. Cambridge University Press, Cambridge.

[Deutsch et al., 2008] Deutsch, C. A., et al. 2008. Impacts of climate warming on terrestrial ectotherms across latitude, *Proceedings of the National Academy of Sciences*, 105, 18, 6668-6672

[Donaldson et al., 2002] Donaldson, J., Nanni, I., Zachariades, C. & Kemper, J. 2002. Effects of Habitat Fragmentation on Pollinator Diversity and Plant Reproductive Success in Renosterveld Shrublands of South Africa. *Conservation Biology*, 16, 5, 1267-1276.

[Dupont, 2005] Dupont G., Un moratoire interdit l'usage de Gaucho (Bayer) et du Régent (BASF), *Le Monde*, October 9, 2005, online at www.cbgnetwork.org/1192.html.

[Earthwatch Institute, 2006], Earthwatch Institute, Climate Change Threatens Pollination Timing, online at www.newswisw.com/p/articles/view/522516.

[Edwards et al., 1998] Edwards P. J., Abivardi C., The Value of Biodiversity: Where Ecology and Economy blend, *Biological Conservation*, 83 (3), 239-246.

[Enserink, 1999] Enserink M., Predicting Invasions: Biological Invaders Sweep In, *Science*, 285 (5435), 1834-1836.

[Environmental News Service, 2008] Environmental News Service, Mysterious Honey Bee Disorder Buzzes into Court, online at www.ens-newswire.com/ens/aug2008/2008-08-19-092.asp.

[ESA] Ecological Society of America, Pollination Tool Kit, online at www.esa.org/ecoservices.

[EUR-Lex, 1985] EUR-Lex, Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment, online at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31985L0337:EN:NOT>.

[Europa, 2008a] Europa, Summaries of legislation: Conservation of wild birds, online at <http://europa.eu/scadplus/leg/en/lvb/l28046.htm>.

[Europa, 2008b] Europa, Summaries of legislation: Natura Habitats (Natura 2000), online at <http://europa.eu/scadplus/leg/en/lvb/l28076.htm>.

[Europa, 2008c] Europa, Environmental Impact Assessment, online at <http://ec.europa.eu/environment/eia/eia-legalcontext.htm>.

[Europa, 2007] Europa, Summaries of legislation: The placing of plant protection products on the market, online at <http://europa.eu/scadplus/leg/en/lvb/l13002a.htm>.

[Europa, 2006] Europa, Summaries of legislation: Environmental liability – Directive, online at <http://europa.eu/scadplus/leg/en/lvb/l28120.htm>.

[EuropaWorld, 2006] EuropaWorld, Questions and Answers about EU policy for protecting the most important habitats and species, online at [www.europaworld.org/week261/questions24306.html](http://europaworld.org/week261/questions24306.html).

[European Commission, 2007] European Commission, Content of the common agricultural policy, online at <http://europa.eu/bulletin/en/200709/p118002.htm>.

[European Commission, 2003] European Commission, Agriculture and the environment: Introduction, online at http://ec.europa.eu/agriculture/envir/index_en.htm.

[FAO, 2008a] Food and Agriculture Organization of the United Nations. Rapid Assessment of Pollinators' Status. FAO, Rome, Italy.

[FAO, 2008b] Food and Agriculture Organization of the United Nations. Initial Survey of Good Pollination Practices. FAO, Rome, Italy.

[FAO, 2005] Food and Agriculture Organization of the United Nations, Protecting the pollinators, *Spotlight / 2005*, online at <http://www.fao.org/ag/magazine/0512sp1.htm>.

[FSN, 2007] FSN – Business Systems News for Finance and IT Professionals, EU Environmental Liability Directive will enshrine "polluter pays" principle as Public Liability insurance fails to cover for clearing up pollution, online at www.fsn.co.uk/channel_kpi_environment/eu_environmental_liability_directive_will_enshrine_polluter_pays_principle.htm.

[Gallai et al., 2008] Gallai N., Salles J-M., Settele J., Vaissière B.E., Economic valuation of the vulnerability of world agriculture confronted with pollinator decline, *Ecological Economics*, doi:10.1016/j.ecolecon.2008.06.014.

[Ghazoul, 2005] Ghazoul J., 2005, Buzziness as usual? Questioning the global pollination crisis, *Trends in Ecology and Evolution*, 20 (7), 367-373.

[Ghazoul, 2007] Ghazoul J., 2007, Recognising the Complexities of Ecosystem Management and the Ecosystem Service Concept, *Gaia*, 16 (3), 215-221.

[Global Environment Facility, 2007] Global Environment Facility, Work Program Submitted for Council Approval, 14 May 2007, online at [http://www.gefweb.org/uploadedFiles/Documents/Council_Documents_\(PDF_DOC\)/GEF_31/C.31.8%20Work%20Program%20Cover%20Note.pdf](http://www.gefweb.org/uploadedFiles/Documents/Council_Documents_(PDF_DOC)/GEF_31/C.31.8%20Work%20Program%20Cover%20Note.pdf).

[Goulson, 2003] Goulson, D. Effects of Introduced Bees on Native Ecosystems. *Annual Review of Ecology, Evolution and Systematics*, 34, 1-26

[Greenfacts, 2007] Greenfacts: Facts on Health and the Environment, Scientific Facts on Biodiversity, online at www.greenfacts.org/en/global-biodiversity-outlook/index.htm.

[Hanson et al., 2008] Hanson C., Ranganathan J., Iceland C., Finisdore J., The corporate ecosystem services review, guidelines for identifying business risks and opportunities arising from ecosystem changes, USA, WRI, Meridian Institute, WBCSD, online at http://www.wbcsd.org/DocRoot/iP9DI/XxqFFOG2khPfbUR/Corporate_Ecosystem_Services_Review.pdf.

[Holden, 2006] Holden C., Report Warns of Looming Pollination Crisis in North America, *Science*, 314, 397.

[Ingram et al., 1996] Ingram M., Nabhan G., Buchmann S., Our Forgotten Pollinators: Protecting the Birds and Bees, *Global Pesticide Campaigner*, 6 (4), online at www.pmac.net/birdbee.htm.

[INRA, 2006] Pollinators' impact on crop production, press release of 24 October 2006, online at http://www.international.inra.fr/research/some_examples/pollinators_impact_on_crop_production

[ITIS, 2008] Integrated Taxonomic Information System, World Bee Checklist, online at www.itis.gov/beechecklist.html.

- [IUCN] International Union for Conservation of Nature, IUCN Red List of Threatened Species, online at www.iucnredlist.org.
- [Kevan et al., 2001] Kevan P.G., Phillips T.P., The Economic Impacts of Pollinator Declines: An Approach to Assessing the Consequences, *Conservation Ecology*, 5 (1).
- [Kevan et al., 1997] Kevan, P.G., C.F. Greco, and S. Belaussoff. 1997. Log-normality of biodiversity and abundance in diagnosis and measuring of ecosystemic health: pesticide stress on pollinators on blueberry heaths. *Journal of Applied Ecology* 34: 1122 – 1136.
- [King and Brooks, 1947] King J.R. and Brooks R.M., The Terminology of Pollination, *Science* volume 105 pages 379-380, 1947
- [Kleijn et al., 2001] Kleijn D., Berendse F., Smit R., Gilissen N., Agri-environment schemes do not effectively protect biodiversity in Dutch agricultural landscapes, *Nature*, 413.
- [Klein et al., 2007] Klein A-M., Vaissière B., Cane J.H., Steffan-Dewenter I., Cunningham S.A., Kremen C., Tscharntke T., Importance of pollinators in changing landscapes for world crops, *Proceedings of the Royal Society B*, 274, 303-313.
- [Klein et al., 2003] Klein A-M., Steffan-Dewenter I., Tscharntke T., Fruit set of highland coffee increases with the diversity of pollinating bees, *Proceedings of the Royal Society London B*, 270, 955-961.
- [Kluser et al., 2007] Kluser S., Peduzzi P., Global Pollinator Decline: A Literature Review, UNEP/GRID-Europe.
- [Kremen et al., 2007] Kremen C., Williams N.M., Aizen M.A., Gemmill-Herren B., LeBuhn G., Minckley R., Packer L., Potts S.G., Roulston T., Steffan-Dewenter I., Vázquez P., Winfree R., Adams L., Crone E.E., Greenleaf S.S., Keitt T.H., Klein A-M., Regetz J., Ricketts T.H., Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change, *Ecology Letters*, 10, 299-314.
- [Kudo et al., 2004] Kudo G., Nishikawa Y., Kasagi T., Kosuge S., Does seed production of spring ephemerals decrease when spring comes early?, *Ecological Research*, 19, 255-259.
- [McGregor, 1976] McGregor S.E., Insect Pollination of Cultivated Crop Plants, USDA, online at <http://qears.tucson.ars.ag.gov/book/>.
- [MEA, 2005] Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Synthesis, Island Press, Washington, DC.
- [Medellin, 2004] Medellin R., Lesser long-nosed bat, RAPS Case study contribution, online at www.fao.org/ag/AGP/AGPS/C-CAB/Caselist.htm.
- [Milder et al., 2008] Milder, J. C., McNeely, J. A., Shames, S. A. & Scherr, S. J. 2008. Biofuels and ecoagriculture: can bioenergy production enhance landscape-scale ecosystem conservation and rural livelihoods? *International Journal of Agricultural Sustainability*, 6, 2, 105-121.
- [Moreigne, 2006] Moreigne H., 2006, Alerte sur la pollinisation, online at www.agoravox.fr/article.php3?id_article=11835.
- [National Research Council, 2007] National Research Council, Status of Pollinators in North America, Washington, National Academies Press, online at www.nap.edu/catalog.php?record_id=11761.
- [Natural Resources Canada, 2007] Natural Resources Canada, Ecosystem definition, online at <http://ecosys.cfl.scf.rncan.gc.ca/definition-eng.asp>.
- [Ngandwe, 2006] Ngandwe T., Pollinator loss threatens crops and medicinal plants, *Science and Development Network*, online at www.scidev.net/en/news/pollinator-loss-threatens-crops-and-medicinal-plan.html.
- [NAPPC, 2002-2005] North American Pollinator Protection Campaign, Pollinators, online at www.napcc.org/pollinatorEn.html.
- [Perrot-Maitre, 2006] Perrot-Maitre D., The Vittel payments for ecosystem services: a "perfect" PES case?, IIED, DFID, London.
- [Pollinator Partnership] Pollinator Partnership, *What is pollination?*, online at www.pollinator.org/pollination.htm.
- [Quiret, 2008] Quiret M., *Les interactions entre les abeilles et l'agriculture*, online at www.lesechos.fr/info/metiers/4687892.htm.
- [Redondo-Brenes et al., 2006] Redondo-Brenes A., Welsh K., Payment for Hydrological Environmental Services in Costa Rica: The Procuencas Case Study, *Tropical Resources Bulletin*, 25, 19-25.
- [Ricketts et al., 2008] Ricketts T.H., Regetz J., Steffan-Dewenter I., Cunningham S.A., Kremen C., Bogdanski A., Gemmill-Herren B., Greenleaf S.S., Klein A.M., Mayfield M.M., Morandin L.A., Ochieng A., Viana B.F., Landscape effects on crop pollination services: are there general patterns?, *Ecology Letters*, 11, 499-515.
- [Sachs, 2008] Sachs J., *Common Wealth: Economics for a Crowded Planet*, London, Allen Lane.
- [science.gouv.fr, 2008] La disparation des abeilles, French Ministry for Higher Education and Research, 16 May 2008 <http://www.science.gouv.fr/index.php?qcms=dossier.view.28.56.archives.154>
- [Stokstad, 2007] Stokstad E., The Case of the Empty Hives, *Science*, 316, 970-972.
- [Steffan-Dewenter et al., 2005] Steffan-Dewenter, I., Potts, S. G. & Packer, L. Pollinator diversity and crop pollination services are at risk. *Trends in Ecology and Evolution*, 20, 12, 651-652.
- [Thorp and Shepherd, 2005] Thorp R.W., Shepherd M.D., Profile: Subgenus *Bombus*, In : Red List of Pollinator Insects of North America, Shepherd M.D., Vaughan D.M., Black S.H. (Eds).
- [UNAF, 2007] Union Nationale de l'Apiculture Française, Charte "L'abeille, sentinelle de l'environnement", online at www.unaf-apiculture.info.
- [UNECE, 2003] Protocol On Strategic Environmental Assessment To The Convention on Environmental Impact Assessment In A Transboundary Context, United Nations Economic Commission for Europe, 2003, online at http://www.unece.org/env/eia/documents/legaltexts/protocole_nqlish.pdf.
- [UNECE, 1991] UNECE, Convention On Environmental Impact Assessment In A Transboundary Context, online at http://www.unece.org/env/eia/documents/legaltexts/convention_text_english.pdf.
- [UNEP, 2008] UNEP, New \$27 million project will protect key pollinators for food security and biodiversity, online at www.unep.org/Documents.Multilingual/Default.asp?DocumentID=543&ArticleID=5893&I=en.

[USDA, 2008] United States Department of Agriculture, Questions and Answers: Colony Collapse Disorder, online at www.ars.usda.gov/News/docs.htm?docid=15572&pf=1&cg_id=0.

[USDA, 2007a] United States Department of Agriculture, Ecosystems: Ecological Goods and Services Working Group, online at www.csrees.usda.gov/nea/nre/in_focus/ecosystems_if_wrkgp.html.

[USDA, 2007b] United States Department of Agriculture, National Research Initiative – Managed Ecosystems, online at www.csrees.usda.gov/fo/managedecosystemsnri.cfm.

[USDA, 2007c] United States Department of Agriculture, USDA Announces Colony Collapse Disorder Research Action Plan, online at www.csrees.usda.gov/newsroom/news/2007news/ccd.html.

[USDA, 2007d] United States Department of Agriculture, Colony Collapse Disorder Action Plan, online at ars.usda.gov/is/br/ccd

[US Forest Service, 2008a], US Forest Service, Celebrating Wildflowers – Cultural Importance of Pollination, online at www.fs.fed.us/wildflowers/pollinators/cultural.shtml.

[US Forest Service, 2008b] US Forest Service, Wind and Water Pollination, online at www.fs.fed.us/wildflowers/pollinators/wind.shtml.

[US Fish and Wildlife Service, 2008c] US Forest Service, Threatened and Endangered Species Database System, online at www.fws.gov/Endangered/wildlife.html.

[Voeller et al., 2007] Voeller D., Nieh J., UC San Diego, Why are bees ecologically important?, online at http://www-biology.ucsd.edu/labs/nieh/TeachingBee/eds_importance.htm.

[Wang et al., 2004] Wang Y., Zhang D., Renner S.S., Chen Z., A new self-pollination mechanism", *Nature*, 431, 39-40.

[Weaver, 1935] Weaver J.E, Kramer J., Relative Efficiency of Roots and Tops of Plants in Protecting the Soil from Erosion, *Science*, 82 (2128), 354-355.

[WRI, 2007] World Resource Institute, *Biodiversity Loss: cascade effects*, online at http://archive.wri.org/item_detail.cfm?id=575§ion=pubs&page=pubs_content_text&z.

[Xerces Society, 2005] Xerces Society, Red List of Pollinators Insects of North America, online at www.xerces.org/Pollinator_Red_List/index.htm.

[Zayed and Packer, 2005] Zayed A., Packer L., Complementary sex determination substantially increases extinction proneness of haplodiploid populations, *Proceedings of the National Academy of Sciences*, 102 (30), 10742-10746, online at www.pnas.org/content/102/30/10742.full.pdf+html.

Acknowledgements

This concept note has been researched and written by Laura Alberte, Sam Keam and the IRGC Secretariat. IRGC and the authors are grateful to the experts who contributed to it as well, and in particular to Jeff McNeely (IUCN), Claire Kremen (UC Berkeley), Bernard Vaissière (INRA), Barbara Herren and Linda Collette (International Initiative for the Conservation and Sustainable Use of Pollinators, established by UNCBD, facilitated and coordinated by FAO), whose comments have led to a number of substantial improvements to this concept note.

About IRGC

The International Risk Governance Council (IRGC) is an independent organisation based in Switzerland whose purpose is to identify and propose recommendations for the governance of emerging global risks. To ensure the objectivity of its governance recommendations, the IRGC draws upon international scientific knowledge and expertise from both the public and private sectors in order to develop fact-based risk governance recommendations for policymakers, untainted by vested interests or political considerations.

The International Risk Governance Council is headed by:

Members of the Foundation Board

Donald J. Johnston (Chairman), formerly Secretary-General, OECD (1996-2006); **Christian Mumenthaler** (Vice-Chairman), Member of the Group Executive Board, Life & Health, Swiss Reinsurance Company, Switzerland; **Pierre Bérout**, Senior Vice-President, Risk Group Controller, Electricité de France, France; **John Drzik**, President and CEO, Oliver Wyman, USA; **Walter Fust**, Chief Executive Officer, Global Humanitarian Forum, Switzerland; **José Mariano Gago**, Minister for Science, Technology and Higher Education, Portugal; **C. Boyden Gray**, Boyden Gray & Associates, USA; **Charles Kleiber**, Former State Secretary for Education and Research, Swiss Federal Department of Home Affairs, Switzerland; **Wolfgang Kröger**, Director, Laboratory for Safety Analysis, Swiss Federal Institute of Technology Zurich, Switzerland; **Liu Yanhua**, Vice-Minister for Science and Technology, People's Republic of China; **L. Manning Muntzing**, Energy Strategists Consultancy Ltd, USA; **Rajendra Pachauri**, Chairman, Intergovernmental Panel on Climate Change (IPCC) and Director-General, The Energy and Resources Institute, India; **Björn Stigson**, President, World Business Council for Sustainable Development, Switzerland. The OECD has observer status and is represented by **Michael Osborne**, Director of the OECD's International Futures Programme.

Members of the Scientific and Technical Council

Prof. Dr M. Granger Morgan (Chairman), Head, Department of Engineering and Public Policy, Carnegie Mellon University, USA; **Dr Lutz Cleemann**, Senior Adviser Group Social Opportunities, Allianz4Good, Allianz SE, Munich, Germany; **Dr Anna Gergely**, Principal Scientific and Regulatory Adviser, Mayer Brown, Brussels; **Dr John D. Graham**, Dean, Indiana University School of Public and Environmental Affairs, Indianapolis, USA; **Prof. Dr Manuel Heitor**, Secretary of State for Science, Technology and Higher Education, Portugal; **Prof. Carlo C. Jaeger**, Head, Social Systems Department, Potsdam Institute for Climate Impact Research (PIK), Germany; **Prof. Ola M. Johannessen**, Director, Nansen Environmental and Remote Sensing Center, Bergen, Norway; **Prof. Dr Wolfgang Kröger**, Director, Laboratory for Safety Analysis, Swiss Federal Institute of Technology Zurich, Switzerland; **Dr Patrick Lagadec**, Director of Research, Ecole Polytechnique, Paris, France; **Prof. Ragnar E. Lofstedt**, Professor of Risk Management, Director of King's Centre of Risk Management, King's College, London, UK; **Jeffrey McNeely**, Chief Scientist, IUCN - The International Union for Conservation of Nature, Switzerland; **Dr Stefan Michalowski**, Head of the Secretariat, Global Science Forum, OECD; **Dr Warner North**, President, NorthWorks Inc., and Consulting Professor, Department of Management Science and Engineering, Stanford University, USA; **Prof. Dr Norio Okada**, Disaster Prevention Research Institute, Kyoto University, Japan; **Prof. Dr Ortwin Renn**, Professor for Environmental Sociology, University of Stuttgart, Germany; **Dr Mihail Roco**, Chairman, Subcommittee on Nanoscale Science, Engineering and Technology, National Science and Technology Council, and Senior Advisor for Nanotechnology, National Science Foundation, USA; **Prof. Dr Joyce Tait**, Innogen Scientific Advisor, ESRC Centre for Social and Economic Research on Innovation in Genomics, UK; **Prof. Shi Peijun**, Professor and Vice-President, Beijing Normal University, and Vice-Dean, Chinese Academy of Disaster Reduction and Emergency Management, Ministry of Civil Affairs and Ministry of Education, Beijing, People's Republic of China; **Dr Hebe Vessuri**, Head, Department of Science Studies, Venezuelan Institute of Scientific Research, Venezuela; **Dr Timothy Walker**, Chair, Accounting and Actuarial Discipline Board, Financial Reporting Council, London, UK.

International Risk Governance Council

Chemin de Balexert 9
1219 Châtelaine
Geneva – Switzerland

info@irgc.org
www.irgc.org

Tel +41 (0)22 795 17 30
Fax +41 (0)22 795 17 39

© All rights reserved, International Risk Governance Council, Geneva, 2009
ISBN 978-2-9700631-7-9