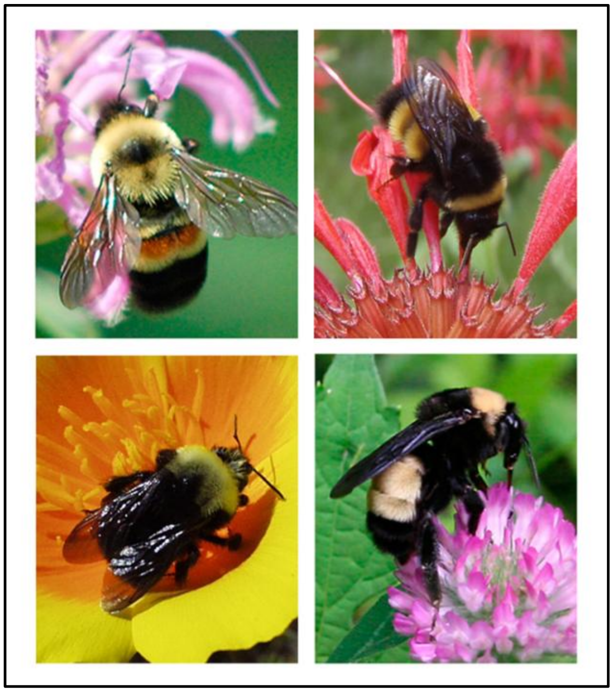
NORTH AMERICAN BUMBLE BEE
SPECIES CONSERVATION PLANNING WORKSHOP



Final Report
9-12 November 2010
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SAINT LOUIS ZOO
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CONSERVATION BREEDING SPECIALIST GROUP

THE XERCES SOCIETY FOR INVERTEBRATE CONSERVATION

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A contribution of the IUCN/SSC Conservation Breeding Specialist Group.

Cameron, S., S. Jepsen, E. Spevak, J. Strange, M. Vaughan, J. Engler, and O. Byers (eds.). 2011. *North American Bumble Bee Species Conservation Planning Workshop Final Report*. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

An electronic version of this report can be downloaded at www.cbsg.org.

TABLE OF CONTENTS

Executive Summary

Background
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 in North America. Several local (McFrederick and LeBuhn 2006; Grixti et al. 2009) and regional (Colla and Packer 2008) studies have documented bumble bee decline in North America in the last decade. A recently completed nationwide study of bumble bee decline in the U.S. is published in the *Proceedings of the National Academy of Sciences* (Cameron et al. 2011) verifying that certain bumble bee species are declining across the U.S. and that the decline of these species relative to healthy species is associated with decreased genetic diversity and higher prevalence of the fungal pathogen *Nosema bombi*. While the genetic diversity and pathogen prevalence data remain correlative, significant declines in the abundance and distribution of four species was documented. This study followed upon the work of Robbin Thorp, who has documented the decline and possible extinction of Franklin's bumble bee (*B. franklini*) within the past decade.

Bumble bee declines have also been noted in Europe, and have been largely attributed to habitat loss and climatic factors (reviewed in Goulson et al. 2008). 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 9th-12th. 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). Principal funding was provided by the U.S. Department of Agriculture National Institute of Food and Agriculture (NIFA) through the University of Illinois, with additional funding from the Saint Louis Zoo, the Xerces Society for Invertebrate Conservation, the CS Fund, the U.S. Forest Service, Pollinator Partnership/North American Pollinator Protection Campaign, and the Regina Bauer Frankenberg Foundation. Koppert Biological Systems and Biobest N.V. contributed donations to the workshop.

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 Agricultural Research Service, Animal and Plant Health Inspection Service, Forest Service, Natural Resource Conservation Service, U.S. Fish & 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.

Process
CBSG-facilitated workshops are designed to bring together the full range of groups with a common strong interest in the conservation of a species and its habitat. CBSG uses processes that promote sharing of information and ideas. Structured analysis of problems is used to develop creative and inclusive solutions. Most of the workshop is spent working in small working groups, with occasional reports back to all participants in plenary sessions for comments and revision. Small group work allows for effective and efficient use of time while plenary sessions allow all participants to have input on all workshop recommendations.

The *North American Bumble Bee Species Conservation Planning Workshop* was designed to help participants achieve the following agreed upon goals:

- To bring together and create a sense of community and engagement among a broad coalition of stakeholders involved in bumble bee conservation in North America, including researchers, conservation organizations, individuals with expertise in conservation planning for insects, commercial bumble bee producers, and government agencies.
- To share information about bumble bee status, threats, production and policy.
- To identify the full breadth of issues of concern that may impact the success of bumble bee conservation.
- To provide general direction for bumble bee conservation in North America.
- To develop a strategy that contains clear goals and identifies future research and conservation needs for the protection of the most imperiled North American bumble bee species.
- To serve as a first step in a long-term collaborative effort to work toward bumble bee conservation.

In order to ensure that all participants had a common base of understanding, the first day of the workshop was dedicated to a series of overview presentations on the status of, threats to, and the latest research on bumble bees (http://www.xerces.org/stlouis-iucn-bumblebee-conservation/). This was followed by an issue-generation session to determine working group topics. Participants were asked to identify direct threats to bumble bees in North America. These conservation issues and threats were themed into seven working groups:

- Compilation of IUCN Red List Data Sheet Information
- Habitat Loss and Degradation
- Climate Change and Range Shifts
- Genetic and Demographic Issues in Conservation Strategies
- Diseases and Pests (Parasites and Pathogens)
- Import Issues and Regulations
- *Bombus* Education, Outreach and Citizen Science

Much of day two was spent in working groups. The IUCN Red List Data Sheet Group collected and organized IUCN Red List data sheets that participants had prepared in advance of the workshop. They were tasked with reviewing the data provided for each species, adding any additional data available from workshop participants, and then identifying species of concern along with rationale for each designation. This list was presented to the workshop in plenary sessions and eventually consensus was reached and an IUCN Red List data sheet was prepared for each. In addition, data sheets were prepared for other species for which there was both interest and some amount of data.

The other, topic-based working groups were instructed to review the threats associated with their group's topic, ensuring that there was a common understanding of each. They determined which of these threats are:

- Direct threats (human activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of bumble bees of North America);
- Indirect threats (causes of direct threats; contributing factors, underlying factors, or root causes); and
- Impacts of direct threats

They then constructed system maps by arranging the threats into threats chains:
indirect threats → direct threats → impacts → target (NA bumble bees)

Once these chains were constructed, statements were prepared to define the threat(s) involved, the relationships between the indirect threats and direct threats, and the impact of these threats on the bumble bees of North America. On each threats chain, participants were asked to identify areas where research is needed to test assumptions or fill data gaps, and areas where there is an opportunity for effective intervention. Goals were then developed to address these identified areas of research need and intervention opportunity.

Presentations were made to share each group's progress and to get feedback from members of other groups. This feedback was incorporated into working group reports during the next working group session. In this session, goal development was completed, and goals were prioritized on the basis of both urgency and impact.

As the focus began shifting from threats to solutions, a series of presentations were given that described current conservation measures. This served to inform the group's thinking as the process of developing action steps for each of the high priority goals began. These priority actions form the details of the recommendations from this workshop. The workshop ended with final working group reports and a session to discuss and come to consensus on next steps.

Results

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.

The participants drew up a list of research priorities, such as determining if there is a cause-effect relationship between the pathogen (*N. bombi*) and declining bumble bee species. The pathogen is found in higher prevalence in some declining species and is hypothesized by some to be the cause of the population crashes. However, this hypothesis remains controversial and needs to be tested directly. The researchers suggested organizing efforts to determine the pathogen's mode and rate of transmission and natural disease etiology, and identify other diseases possibly infecting bumble bees.

Several other research priorities were developed. Many working groups, including the habitat loss and degradation working group, emphasized the need for a North American effort to gather and digitize information, such as distribution and population data, from the databases of different agencies, such as the U.S. Forest Service and U.S. Fish and Wildlife Service, in addition to museum and university research databases. In many cases, the data housed in museums is not yet digitized and this impedes research efforts. This information could be used to determine historic range, abundance and population dynamics of species. Additionally, museum collections house information on past disease levels, genetic structure and species diet. One working group concentrated on climate-change impacts that could be exacerbating the decline. For instance, climate change may adversely affect the synchrony of bumble bee-floral interactions, resulting in reduced bumble bee survival and productivity. This group proposed long-term monitoring projects to better understand the effects of changing climate on species distributions. Long term monitoring was suggested by several groups as a useful tool to address other questions as well. The population genetics working group suggested prioritizing the development of standard protocols to be used in evaluating species. Participants also identified a need for basic research into bumble bee genetic diversity. Current evidence (Cameron et al. 2011) suggests that the declining species exhibit low genetic diversity, and tests could determine additional species at risk of a future die-off. The regulatory working group emphasized the need to understand the effects of non-native and commercial bees on native bee populations. They further suggested the need to develop a regulatory structure that considers both the health of wild bees and the needs of the agricultural community.

Several groups suggested that scientific studies could be coordinated and augmented with sightings in gardens made by members of the public. The need for additional citizen science initiatives was identified by the public outreach working group.

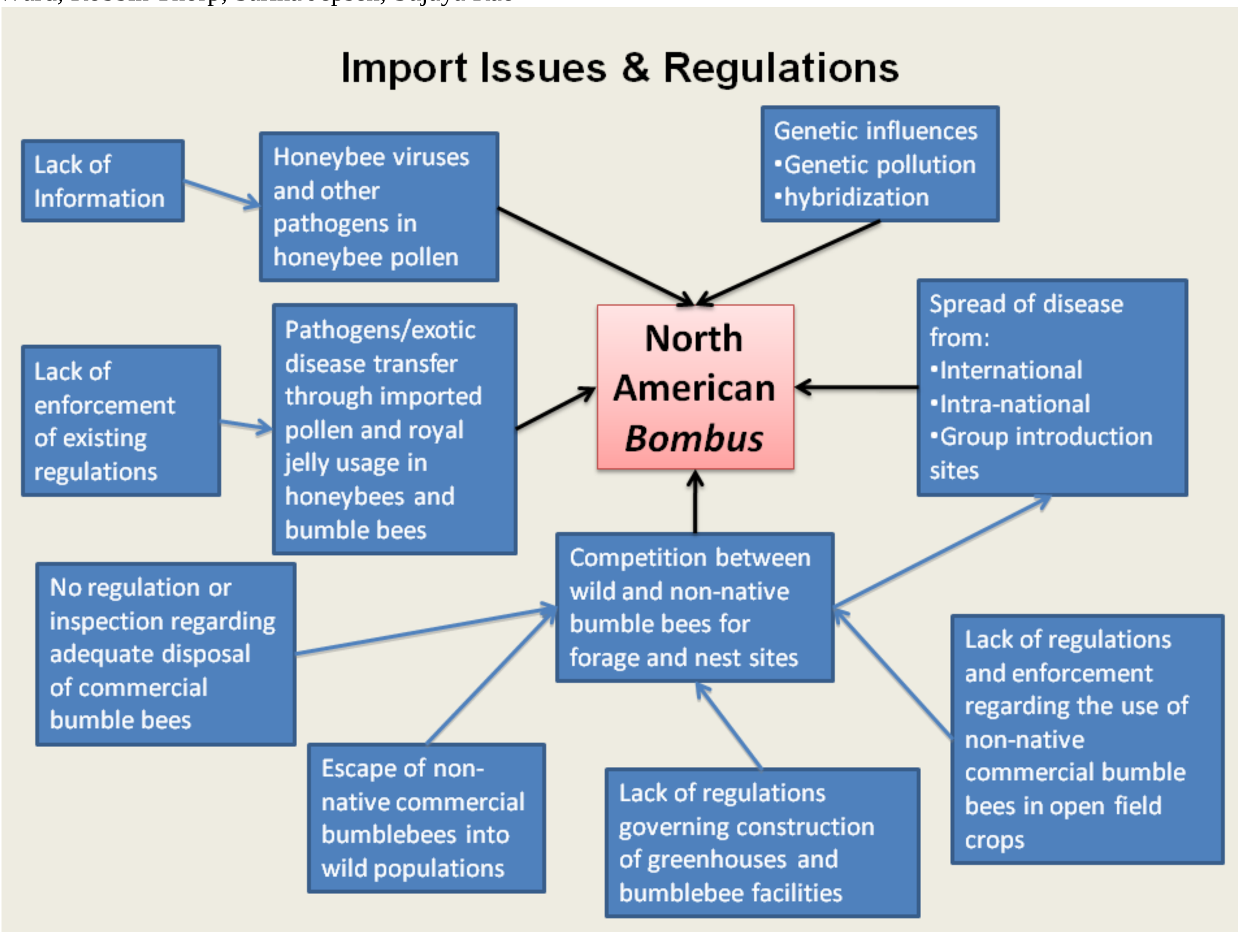
Two immediate products transpired from this meeting. The first was the formation of an IUCN/Species Survival Commission (SSC) Bumblebee Specialist Group that will help to implement and support this and other action plans. A proposal was reviewed by workshop participants to create the IUCN/Species Survival 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. Paul Williams has been selected as the chair and initial members of the working committee have also been selected. 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 and it will not be resubmitted as part of this workshop. Following the submission of petitions for all four of these species, all other North American bumble bee species will be evaluated.

The second projected outcome from the meeting will be 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.

Although a great deal of research remains to be done, the workshop participants hope that the results of their work will begin to reduce declines in bumble bee populations. It was agreed that having representatives from government, nonprofit, industry and research means the priorities discussed at the meeting stand a better chance of being implemented.

Import Issues and Regulations Working Group

Working Group Participants: Colin Stewart, Juan Carlos Salinas Navarrete, Mike Juhl, Rene Ruiter, Richard Ward, Robbin Thorp, Sarina Jepsen, Sujaya Rao



Working Group Focus: Identify threats to wild North American bumble bees and examine regulatory opportunities to address those threats, focusing on general threats associated with the use of commercial bumble bees outside of their native ranges, viruses found in honey bee pollen, and pesticides.
Links to Other Working Groups: Diseases and Pests; Habitat Loss and Degradation; Climate Change and Range Shifts; Genetic and Demographic Issues

INTRODUCTION

Commercially produced bumble bees are used throughout Canada, the U.S. and Mexico in agriculture with varying degrees of regulation by the respective regulatory agencies. In some cases, commercial bumble bee species are moved outside of their native ranges, where the potential exists for these bees to interact with wild bumble bees and spread pathogens, hybridize, and compete. This group made regulatory recommendations to reduce the risks associated with this practice. In addition, the group explored opportunities to rear local, native species of bumble bees.

It has recently been demonstrated that viruses found in honey bee pollen can transfer to bumble bees; this group examined the role that regulatory agencies may be able to play in addressing this problem.

Lastly, the widespread use of pesticides likely poses a threat to wild bumble bees, although little is known about the lethal or sublethal effects of most pesticides on bumble bees. Thus, this group explored opportunities for regulatory agencies to require testing of bumble bees in the pesticide approval process.

This group comprised diverse stakeholders from Canada, Mexico and the U.S., including representatives from research institutions, commercial bumble bee production enterprises, a regulatory agency, and a conservation organization.

LIST OF IDENTIFIED THREATS

INDIRECT THREATS

I. Lack of regulations that prohibit the movement of bumble bees outside of their native ranges
II. Lack of facilities inspections, including greenhouses that use bumble bees and bumble bee production facilities
III. Lack of guidelines for constructing secure greenhouses and bumble bee production facilities
IV. Escape of nonnative commercial bumble bees into wild populations
V. Problems with the enforcement of regulations prohibiting honeybee collected pollen and royal jelly from being diverted to the managed bee trade (bumble bees and honey bees)
VI. Lack of understanding how honey bee viruses in pollen impact commercial and wild bumble bees
VII. Lack of regulations specific to bumble bees in the pesticide approval process
VIII. Lack of testing of bumble bees (lethal and sublethal effects) as part of the pesticide (insecticide, herbicide, fungicide) registration process

DIRECT THREATS

I. Pathogen spillover from greenhouses
II. Spread of disease internationally, within country, and locally (around sites where bumble bees are introduced)
III. Competition between wild and non-native bumble bees (for example for forage and nest sites), as well as colony usurpation
IV. Hybridization of native and non-native bumble bee species
V. Genetic pollution (flow of potentially undesirable traits from commercially produced bumble bees to wild conspecific populations of bumble bees)
VI. Exotic pathogen transfer to bumble bees through honey bee pollen
VII. Transfer of pathogens between honey bees and bumble bees at shared flowers
VIII. Pesticides

IMPACTS OF DIRECT THREATS

I. Reduced health of wild and commercial bumble bee stock
II. Direct mortality
III. Sublethal effects from pesticides at the nest level (on brood, workers and reproductives), and on foraging bumble bees

THREATS STATEMENTS, GOALS, & ACTIONS

Threat Statement I

Preliminary data suggests that escape of non-native commercial bumble bees into wild populations leads to the spread of disease from commercial to wild bumble bees on an international, national and local scale (Goka et al. 2006, Colla et al. 2006, Otterstatter and Thomson 2008) and hybridization (Goka 2010). We assume that escape of non-native commercial bumble bees into wild populations could lead to competition between wild and non-native bumble bees for forage and nest sites, although this assumption has not been tested. Escape of non-native commercial bumble bees into wild populations could be prevented by the development and enforcement of regulations that govern the construction and inspection of greenhouses, bumble bee facilities, and hive design (i.e. queen excluders). Similarly, Federal regulations do not prevent the use of non-native commercial bumble bees in open field crops, nor require the adequate disposal of commercial bumble bee colonies. The use of non-native commercial bumble bees in the western U.S., western Canada, and parts of Mexico is due to a lack of research and development into locally native species suitable for commercial production.

Goal 1: Define native western bumble bee candidate species suitable for commercial production and precisely define their native ranges; develop local native bumble bee species for commercial pollination where native species are currently unavailable.

Action 1

Define the native ranges of western North American and Mexican bumble bees.

- *Responsibility:* Robbin Thorp, Sujaya Rao, Bill Stephen, Jamie Strange, and John Ascher in the U.S. and Canada; Rémy Vandame and other researchers in Mexico
- *Timeline:* Complete by January 2012
- *Funding:* To be determined
- *Outcomes expected:* Defined native ranges of western bumble bee species in the U.S. and Canada and in Mexico
- *Obstacles*: Unconsolidated data generally housed in natural history collections

Action 2

Evaluate the potential of various species to be developed for commercial production in the western U.S., Canada and Mexico. Recovering and using *Bombus occidentalis* commercially will be included in the discussion. Species that are being considered for commercial pollination should undergo scientific assessment for the presence of geographic subspecies or populations, and this information should be considered and evaluated for potential impacts prior to exportation of commercial species outside population boundaries. Queen rearing ability, which is critical for commercial production, should also be considered. As locally native species of bumble bees are developed for commercial use, researchers and industry should progress in an ecologically safe manner. Current efforts to develop local native bumble bee species for western North America are underway at the Logan Bee Lab (Jamie Strange), Oregon State University (Sujaya Rao), and by Mike Juhl, as well as with local native species in Mexico (Rémy Vandame). Koppert Biological Systems has a Cooperative Research and Development Agreement (CREDA) with USDA-ARS in Mississippi for other rearing and will be willing to set up a similar one with interested parties.

- *Responsibility:* Jamie Strange, Sujaya Rao, Robbin Thorp, Bill Stephen, John Ascher, Rémy Vandame, Rene Koppert , Mike Juhl
- *Timeline:* ongoing
- *Funding:* To be determined
- *Outcomes expected:* Local, native species of bumble bees available for commercial use
- *Obstacles*: Funding, queen rearing ability

Goal 2: Ask the regulatory agencies responsible for bumble bee movement in Canada, Mexico, and the United States to develop and implement a regulatory standard to certify bumble bee stock as ‘disease free’ (actions to address this goal are listed below under Goal 4).

Goal 3: Explore the opportunity to develop a new regulation to ban the movement of commercial bumble bees outside of their native ranges (actions to address this goal are listed below under Goal 4).

Goal 4: Explore opportunities for federal or regional regulation and enforcement of greenhouse and bumble bee rearing facility design, construction, inspection, hive design and colony disposal.

Action 1 (to address Goal 2, Goal 3, and Goal 4)
Draft and send a letter to the USDA Animal and Plant Health Inspection Service (APHIS) from this working group. The letter will request that APHIS examine the following regulatory issues: 1) Explore the opportunity to develop a new regulation to ban the movement of commercial bumble bees outside of their native ranges; 2) Explore opportunities for federal or regional regulation and enforcement of greenhouse and bumble bee rearing facility design, construction, and inspection, as well as bumble bee colony design and colony disposal; 3) Explore the opportunity to implement a standard for certifying bumble bee stock as disease free.

- *Responsibility:* Colin Stewart, Juan Carlos Salinas Navarrete, Mike Juhl, Rene Ruiter, Richard Ward, Robbin Thorp, Sarina Jepsen, Sujaya Rao
- *Timeline:* June 2011
- *Funding:* To be determined
- *Outcomes expected:* Exploration of new regulations
- *Obstacles*: Lack of funding, political will

Action 2
Send a similar letter to key individuals within State Departments of Agriculture who may be willing to champion these issues and send their own letter(s) to APHIS.*Responsibility:* Colin Stewart, Xerces Society, others

- *Timeline:* December 2011
- *Funding:* To be determined
- *Outcomes expected:* Response from APHIS to letters from State Departments of Agriculture
- *Obstacles*: Political will

Action 3
Send a similar letter to the permit specialist for agricultural pollinators and Biocontrol agents of the Canadian Food Inspection Agency.

- *Responsibility:* TBD
- *Timeline:* December 2011
- *Funding:* To be determined
- *Outcomes expected:* Response from CFIA
- *Obstacles*: Political will

Action 4
Send a similar letter to director of SENASICA (National Health Service, Food Safety and Food Quality) within the Mexican Ministry of Agriculture (SAGARPA).

- *Responsibility:* Juan Carlos Salinas Navarrete
- *Timeline:* December 2011
- *Funding:* To be determined
- *Outcomes expected:* Response from SENASICA
- *Obstacles*: Political will

Action 5
Send a letter to Mexico's Environmental Ministry (SEMARNAT) asking them to investigate issues associated with escape of non-native commercial bumble bees in to wild populations.

- *Responsibility:* Juan Carlos Salinas Navarrete

- *Timeline:* December 2011
- *Funding:* To be determined
- *Outcomes expected:* Response from SEMARNAT
- *Obstacles*: Political will

Action 6
If permissible under U.S. law, form an interim group to participate in and contribute to the development of regulations that address concerns associated with the above goals..

- *Responsibility:* Colin Stewart will find out if this type of group is permissible
- *Timeline:* To be determined
- *Funding:* To be determined
- *Outcomes expected:* Formation of an interim group
- *Obstacles*: This type of group may not be legal

Threat Statement II
Preliminary data suggest that viruses and other pathogens vectored by pollen can be transferred to wild bumble bees from commercial bumble bees (Otterstatter and Thomson 2008) or honey bees (Singh et al. 2010) when foraging on shared floral resources. We assume that pathogens from other managed pollinators could also be transferred to wild bumble bees in a similar fashion. We assume that viruses and other pathogens found in honey bee hive products threaten wild bumble bees and can be transferred to wild bumble bees from honey bees when foraging on shared floral resources; however, these assumptions remain largely untested and further research is urgently needed. (See a discussion of these issues and recommended research in the Disease and Pests Working Group Report in this document). While regulations exist that prohibit the importation of pollen and royal jelly for bee food into the U.S. and Canada, there is a lack of enforcement preventing the diversion of pollen legally imported for human consumption and diverted to the bee trade. In Mexico, there are regulations that allow bee producers to import irradiated pollen from certain countries (e.g., Spain and Canada) for bee food. There is a lack of information about how viruses and other pathogens from honey bee pollen and royal jelly are transferred to bumble bees and a lack of understanding how those viruses and other pathogens impact the health of bumble bees.

NOTE: Additional research goals were developed to assess the above threat, but there was redundancy between the goals of this working group and the goals of the Disease working group; the goals that were developed by both the Disease and the Regulations groups are found in the Disease working group report.

Goal 1: Encourage the U.S. Food and Drug Administration to enforce existing honey bee pollen importation regulations.

Goal 2: Encourage the Mexican Ministry of Agriculture and Food to enforce existing honey bee pollen importation regulations.

Threat Statement III
There are no specific guidelines regarding bumble bees in the pesticide (insecticide, herbicide, fungicide) approval process. There are currently no requirements that research be done to evaluate the lethal or sublethal effects that pesticides have on bumble bees as part of the pesticide registration process. We assume that this lack of regulation could be leading to the use of pesticides that directly kill bumble bees

and/or reduce the viability of wild bumble bee colonies. Research is urgently needed to determine the effects of different pesticides on bumble bees.

Goal 1: Explore opportunities with the U.S. Environmental Protection Agency (U.S. EPA), the Mexican Ministry of Health's Pesticide Regulatory Agency (COFEPRIS), and the Pest Management Regulatory Agency (PMRA) in Canada to ensure that the lethal and sublethal effects of pesticides on bumble bees are tested in the pesticide registration process.

Action 1
Send a letter to the U.S. EPA, COFEPRIS, and the PMRA requesting that research is done to evaluate the lethal and sublethal effects of pesticides on bumble bees, and that those effects are considered when new pesticides are registered and labels are developed.

- *Responsibility:* Sarina Jepsen
- *Timeline:* September 2011
- *Funding:* To be determined
- *Outcomes expected:* Responses from U.S. EPA, COFEPRIS and PMRA
- *Obstacles*: Funding

Action 2
Have a representative participate in the Society for Environmental Toxicology and Chemistry's (SETAC) January 2011 Pellston workshop on Pesticide Risk Assessment for Pollinators to develop a new risk assessment protocol for pollinators, and encourage inclusion of *Bombus* as a test species for pesticide risk assessment.

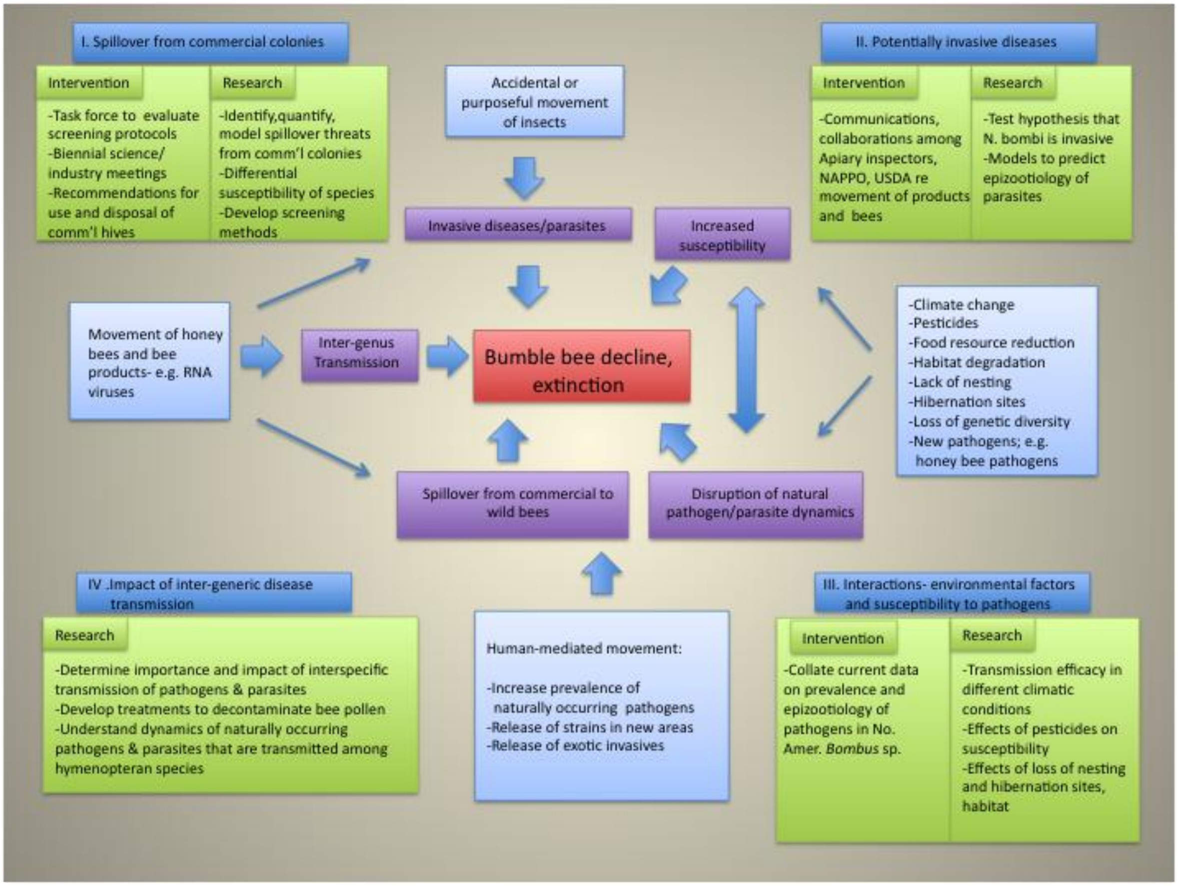
- *Responsibility:* Mace Vaughan participated in this meeting and continues to work to include *Bombus* in the final publication
- *Timeline:* The final publication will be completed by July 2011
- *Funding:* Xerces Society
- *Outcomes expected:* The publication from the Pellston workshop on Pesticide Risk Assessment for Pollinators will recommend that bumble bees be used as test species for pesticide risk assessments
- *Obstacles*: Funding

Action 3
Encourage U.S. EPA, Canadian Pest Management Regulatory Agency, and Mexican Ministry of Health's Pesticide Regulatory Agency (COFEPRIS) to adopt improved risk assessment recommended by the SETAC Pellston workgroup if the final product adequately includes *Bombus* as a test species and as a key component to pesticide risk assessment for pollinators.

- *Responsibility:* Xerces Society and others
- *Timeline:* July 2012
- *Funding:* To be determined
- *Outcomes expected:* Pesticide regulatory agencies adopt risk assessments recommended by the SETAC Pellston workgroup
- *Obstacles*: Funding, political will

Diseases and Pests (Parasites and Pathogens) Working Group

Working Group Participants: Mark Brown, Sydney Cameron, Rene Koppert, Michael Otterstatter, Rajwinder Singh, Lee Solter, Rémy Vandame, Jan Vermeulen



Working Group Focus: Bumble bee decline/extinction due to parasites and pathogens– global or local
Links to Other Working Groups: Import Issues & Regulation; Habitat Loss and Degradation; Climate Change and Range Shifts; Genetic and Demographic Issues

INTRODUCTION

It is critical that policy makers in North America acknowledge pollinator decline as a top priority concern for conservation efforts and research on causes, restoration, and management, and for public education to mitigate existing and future threats. In particular, we need to understand the interactive nature of anthropogenic development, climate change and invasive parasites (see Box 1) as they collide with the needs of wild and managed bumble bee populations. The U.S., Canada and Mexico need to deliver on a promise of sustainable environmental health, because without native bee pollination the repercussions will be severe. On a worldwide scale, reports suggest that reductions in native food plants due to land use changes are a principal factor in pollinator declines, particularly in species with narrow climatic ranges. In North America, other factors, including parasites that have the potential for emergence and spread *via* inter-continental and trans-oceanic movement of commercial colonies, need to be fully studied. In addition, the intra-continental movement of bumble bees is occurring at an increasing rate, thus increasing the potential for rapid spread of parasites by human activity. We desperately need to assess the roles of pesticides, pollen use, and environmental perturbations on host susceptibility and parasite transmission. Raising public awareness is also of great and immediate importance, and has been extraordinarily successful in the United Kingdom.

The following assessments are severely needed, and research commitments targeting bumble bee pathogens and diseases are imperative:

- **Identification of the most important parasites** to target for research on their potential to harm the health of native bumble bees
- Spatial and temporal dynamics of **spillover** of potentially invasive parasites (exotic, emergent, and naturally occurring) from commercial greenhouses and open field crop pollination
- **Dynamics of parasite spread**, including effects of climate change and habitat fragmentation on susceptibility to naturally occurring and exotic parasites
- Potential interactions between **insecticides and herbicides** and host susceptibility to parasites and disease spread

> Box 1: By "parasites" we mean the full range of parasites and pathogens that impact bumble bee fitness, including macroparasites (nematodes, mites, dipteran and hymenopteran parasitoids), and microparasites including microsporidia, protozoans (flagellates, neogregarines), viruses (DNA & RNA), and other unknown organisms.

Even as quantitative data are accumulating on the deteriorating status of bumble bee populations in North America, including new statistics from nationwide surveys and databasing efforts in the U.S., **the factors causing species decline remain uncertain and controversial.** In the U.S. and Canada, shrinking or disappearing populations have been ascribed principally to an invasive microsporidian pathogen, *Nosema bombi*, hypothesized (Thorp & Shepherd, 2005) as having been introduced from Europe in the early 1990s. Yet evidence for this important and timely hypothesis is severely lacking, and only recently has come under scientific investigation. There are clear and compelling reasons to investigate native or exotic parasite release as a potential factor in declining *Bombus* populations across North America, and to differentiate this factor from causal factors that may have influenced, or are influencing, changes in the fitness and stability of populations. There are additional critical needs for research to address our lack of knowledge about host-pathogen interactions and pathogen spread.

> Box 2: List of known parasites of concern
> *Nosema bombi*
> *Crithidia bombi*
> *Apicystis bombi*
> *Locustacaris buchneri*
> *Sphaerularia*
> Viruses (includes RNA viruses as also occurring in honey bees)

LIST OF IDENTIFIED THREATS

DIRECT THREATS

We have identified the four following direct threats of pathogens and parasites to bumble bees:

I. Pathogen spill-over from diseased, commercially reared Bombus to wild populations
II. Potentially invasive diseases and pests (pathogens and parasites)
III. Effects of environmental perturbations on susceptibility of bumble bees to their naturally occurring pathogens and parasites
IV. Potential for inter-generic pathogen transmission among Hymenoptera

THREATS STATEMENTS, GOALS, & ACTIONS

For each goal we identify the rationale for concern, the principal research needs (prioritized by urgency) and specific actions required to implement the research objectives.

Threat Statement I: Pathogen spillover from diseased, commercially reared *Bombus* to wild populations

In North America, bumble bees are reared on a large scale for the pollination of a variety of industrial greenhouse (e.g., tomatoes, peppers) and orchard crops (e.g., blueberries) (Velthuis & van Doorn 2006). Foraging workers, as well as new queens and males, originating from commercially reared hives frequently escape agricultural operations and interact with wild bumble bee populations nearby (Morandin et al. 2001, Whittington et al. 2004). The use of heavily infected commercial hives, and the lack of containment of commercial bees, has allowed pathogens to spread, or 'spillover', into wild bumble bee populations (Otterstatter & Thomson 2008, Colla et al. 2006). Recent widespread declines and disappearances of certain bumble bee species in North America have been implied to result from such spillover (Committee on the Status of Pollinators in 2006, Thorp & Shepherd 2005, Thorp 2005).

Commercially reared bumble bee colonies may become infected through a variety of routes (Velthuis & van Doorn 2006). Pathogens may enter commercial rearing facilities when wild bumble bee queens are used to replenish genetic stock, and when contaminated products, such as the pollen (Singh et al. 2010) and brood of honey bees, are used to rear hives. Within rearing facilities, pathogens may spread through the use of unsterile tools/protocols, and through opportunistic vectors (e.g., wax moths and saprophytic flies). Although several studies have found high levels of infection in commercial hives (Colla et al. 2006, Goka et al. 2000, Niwa et al. 2004, Whittington & Winston 2003), there is little information on pathogen prevalence within rearing facilities, or on the protocols used by such facilities for disease screening and prevention.

The use of infected commercially reared bumble bees for crop pollination has been shown to result in local pathogen spread, or 'spillover', to wild bumble bees (Colla et al. 2006, Goka et al. 2006). In theory, such spillover can result in disease epidemics in wild populations, leading to local bumble bee declines (Otterstatter & Thomson 2008). Commercially-reared bumble bees, and the pathogens they harbor, are transported extensively within and beyond the areas to which they are native (Inari et al. 2005, Goulson 2003); thus spillover from these hives may:

- Boost the prevalence of endemic pathogen species sufficiently to cause epidemics in wild bumble bees;
- Introduce new strains of local pathogen species into wild bumble bees, with unknown consequences;
- Introduce exotic (non-indigenous) pathogen species into wild bumble bees, with unknown consequences.

Goals:

We have identified the following major goals to address Threat I to native bumble bee populations, thus to minimize the potential for pathogen spillover from diseased colonies.

1. Eliminate pathogen spillover from commercially reared bumble bees to wild populations through collaboration and communication among scientists and the producers and users of commercial bumble bees.
2. Develop research programs to identify and quantify potential spillover threats from commercial colonies or other means, such as importation from other countries.

Goal 1, Action 1
The creation of a task force to evaluate screening protocols used in commercial rearing facilities, and promote transparency of protocols among scientists and producers. Protocols should accurately estimate the prevalence of pathogens and allow formal confidence limits to be placed on the degree to which commercial colonies are parasite free. This work will be done cooperatively with commercial bumble bee producers, and include an evaluation of current disease prevention measures and the design of new or improved protocols for pathogen screening and prevalence estimation where deemed necessary.

- *Responsibility:* Rene Ruiter, Mark Brown, and Lee Solter will lead the creation of the task force by January 31, 2011.
- *Timeline:* 2011-2012
- *Funding*: Notable costs include travel expenses of evaluators and expenses related to RNA virus detection. Members of task force will secure individual travel funding. Funds for detection might be secured through the commercial rearing industry and/or government agencies, including the U.S. Department of Agriculture (USDA).
- *Outcomes expected*:
  - Creation of a group to evaluate the efficacy of current control procedures in cooperating commercial rearing facilities;
  - Determination of what pathogens are prevalent in commercial colonies;
  - Report to a selected group of stakeholders, including researchers, commercial interests, farmers, and conservation groups, on evaluation results, with a press release to publicize cooperation and effectiveness of protocols;

  This group can begin the discussion concerning the following implementations:
  - Recommendations for USDA/ Canadian Food Inspection Agency's (CFIA) regulations and inspections related to commercial production of bumble bees;
  - Cooperation among scientists and producers to ensure that, ultimately, bumble bees reared commercially for agriculture are as clean as possible (pathogen/parasite level to be determined among producers and other stakeholders) and have no impacts on wild bees.
- *Obstacles*: Lack of communication and cooperation among partners (scientists, commercial producers) to achieve goals; insufficient funding for evaluations and meetings between industry and other stakeholders.

Goal 1, Action 2
Organization of biennial meetings among scientists and industry (producers and users of commercial bumble bees) for the purposes of knowledge exchange and discussion of quality control issues and new techniques for pathogen diagnosis.

- *Responsibility*: IUCN Bumblebee Specialist Group.
- *Timeline: to be determined*
- *Funding*: Notable costs will include expenses associated with meeting organization and logistics, for which funding will be sought through both the commercial industry and government funding sources, especially the USDA.
- *Outcomes expected*: Inaugural meeting following release of task force reports, potentially in conjunction with the International Union for the Study of Social Insects (2014).
- *Obstacles:* Decreasing interest in an open exchange of ideas by scientists and industry. Funding issues could arise to prevent the cooperative meetings.

Goal 1, Action 3
Development of recommendations for the use and disposal of commercial bumble bee hives by agricultural operations. The objective will be to reduce spillover of pathogens from commercial

hives by focusing on the critical issues of bee-loss from greenhouses (i.e., the escape of foraging workers), the production and dispersal of sexuals (males and queens) from commercial hives in agriculture, and the appropriate disposal of old hives. Recommendations will be drafted in cooperation with users of commercial bumble bees, such as greenhouse growers, to ensure utility and practicality.

- *Responsibility*: Members of the task force and bumble bee experts (to be determined) will draft recommendations in consultation with cooperating users of commercial bumble bees.
- *Timeline*: To be determined
- *Funding*: Notable costs will include travel expenses for scientists to visit agricultural operations and meet with growers. Funding will be secured via government sources.
- *Outcomes expected*: A set of practical recommendations for responsible use of commercial bumble bees; further development of these recommendations as a basis for USDA/CFIA regulations and inspections related to agricultural use of commercial bumble bees; cooperation among scientists and growers with the shared goal of eliminating the escape of commercial bumble bees from agricultural operations.
- *Obstacles*: Decline in efforts of continued communication and cooperation among partners (scientists, users of commercial bumble bees) to achieve goals. Funding might be difficult.

Goal 2, Action 1
Determination of the presence and prevalence of all known bumble bee pathogens (including RNA viruses, microsporidia, flagellates, and neogregarines) in commercial colonies.

Goal 2, Action 2
Determination of disease-related impacts on wild bumble bees when infected commercial bumble bees escape from agricultural operations.

Goal 2, Action 3
Studies of differential susceptibility to pathogens among wild bumble bee species, and the virulence of pathogens that are introduced into wild populations from infected commercial hives.

Goal 2, Action 4
Modeling of the dynamics and impacts of pathogen spillover in order to identify opportunities for effective intervention.

Goal 2, Action 5
Development of screening methods for pathogens residing in pollen used in bumble bee rearing.

Threat Statement II: Potentially invasive diseases and parasites
Pathogen invasions may occur due to accidental or purposeful movement of bees and bee products via global commerce and movement by individuals. To date, knowledge of bumble bee pathogens invasive to North American *Bombus* spp. populations is speculative, but efforts are currently underway to address the potential that invasion has occurred. Invasion of pathogens such as *Geomyces destructans* in bats and *Batrachochytrium dendrobatidis* in amphibians suggests that impacts to susceptible species can be severe and long-term, and permanent population declines are possible. *Nosema bombi* and *Crythidia bombi* both have adverse effects on their host populations. The effects of strains of these pathogens on susceptible species, to which they were not previously exposed, are unknown.

Goals:
We have identified the following goals to address Threat II to native bumble bee populations, thus to minimize the potential for invasion of exotic diseases:

1. Testing the hypothesis that *Nosema bombi* in *Bombus occidentalis* and other *Bombus* species is invasive from Europe (research in progress)
2. Develop models to predict potential epizootiology of parasites based on natural movement of bees at the landscape scale.
3. Establish and maintain communications among researchers, the Apiary Inspectors of America, the North American Plant Protection Organization (NAPPO), and USDA APHIS and their Canadian and Mexican counterparts (mainly SAGARPA, the ministry of Agriculture) to address issues of movement of pollen and other bee products into North America.

Goal 1, Action 1
Studies are in progress to test the 'invasion hypothesis' of *Nosema bombi,* including analyses of strain variation of the pathogen across its known range in Europe and North America and comparison of current variation with that obtained from museum collections..

- *Responsibility*: Sydney Cameron, University of Illinois
- *Timeline*: 2010-2013
- *Funding*: USDA AFRI
- *Outcomes expected*: Determine whether *N. bombi* is native or introduced; development of Single Nucleotide Polymorphism's (SNPs) for application to population level questions, including variation and structure.
- *Obstacles*: Potential absence of variation among strains to make determination; insufficient levels of infection in some museum samples to amplify *N. bombi* from the host.

Goal 2, Action 1
Compare pathogen data from recent surveys (Cameron et al. 2010) and from new surveys in Mexico (Vandame unpublished data) and Alaska (Strange and Koch, unpublished data) to the hypothesized spread of pathogens from spill-over and spread from greenhouses, as originally modeled for *Crithidia bombi* by Otterstatter and Thomson (2008). We anticipate publication of these data in 2011.

- *Responsibility:* Leellen Solter and Nils Cordes
- *Timeline: 2011-2012*
- *Funding*: USDA AFRI; potentially NSF/NIH co-funding
- *Outcomes expected*: A better understanding of the epizootiology of *Crithidia bombi* in North American bumble bee populations and potential that the pathogen is an invasive species.
- *Obstacles*: Funding

Goal 2, Action 2
Organize collaborative efforts and funding to develop models of epizootiology. Use current survey data to develop estimates of species decline using diffusion models (Reeve).

Potential funding sources: USDA AFRI; NSF

Outcomes: Understand the patterns of transmission and spread of *Nosema bombi* and other pathogens to predict spread of invasive diseases in bumble bee populations..

The development of pathogen diffusion models to further test the possibility of *N. bombi* spread from a point source in time and space.

- *Responsibility*: Sydney Cameron, University of Illinois, John Reeve, Southern Illinois University, Mark Brown, Royal Holloway, Univ. of London, Michael Otterstatter, Health Canada.
- *Timeline*: 2011
- *Funding*: Still in the proposal stage
- *Outcomes expected*: Insights into the potential that *N. bombi* could have spread in the last 16-18 years to its current U.S. distribution and into new species from its original hypothetical introduction in Western California (1992-1994).
- *Obstacles*: Sufficient current pathogen distribution data in the U.S. to allow rigorous tests of new diffusion models.

Goal 3, Action 1

Colin Stewart of USDA-APHIS is currently in close communication with Apiary Inspectors of America, attending their national meetings and communicating new information to them regarding bumble bee decline. They are an excellent resource for information on the status and health of honey bees. He has offered to serve as the liaison for NAPPO and the Apiary Inspectors.

- *Responsibility*: Colin Stewart, USDA APHIS, who will serve as the liaison for NAPPO and the Apiary Inspectors
- *Timeline*: 2010- 2013
- *Funding*: None required
- *Outcomes expected*: Increased dialog between researchers, industry, and State and Federal regulators who work with bumble bees and/or honey bees. Consideration of bumble bees and their diseases in any plan to regulate the importation of pollen and/or royal jelly.
- *Obstacles*: Time commitment.

Threat Statement III: Effects of environmental perturbations on susceptibility of bumble bees to their naturally occurring pathogens and parasites

Climate change, pesticides, habitat reduction/degradation, and loss of or suboptimal food resources, nesting sites, hibernation sites and genetic diversity may all lead to perturbations of natural host-disease/parasite dynamics and increased susceptibility to naturally occurring pathogens and parasites. Such perturbations could potentially lead to local or global declines of *Bombus* species. We have identified the following goals to assess how these factors impact natural pathogen dynamics and susceptibility of *Bombus* species to pathogens and parasites and we highlight specific actions (research efforts) that we believe require prioritizing:

Goals:

The following goals address Threat III to understand potential environmental perturbations on pathogen susceptibility in natural *Bombus* populations.

1. Understand interactions between environmental factors and parasites
2. Understand the impact of genetic degradation and inbreeding on susceptibility to pathogens

Goal 1, Action 1

Determine prevalence of parasites and epizootiology in natural populations, focusing first on *Nosema bombi, Crithidia bombi* and viruses

- *Responsibility:* Sydney Cameron, Jeffrey Lozier, Haw Chuan Lim, Michael Otterstatter
- *Timeline:* Dependent on funding
- *Funding*: USDA AFRI
- *Outcomes expected*: A better understanding of parasite prevalence on a national scale and their epizootiology in North American bumble bee populations.

- *Obstacles*: Funding

Goal 1, Action 2
Determine transmission efficacy change under different climatic conditions.

- *Responsibility:* Sydney Cameron and colleagues are planning a research effort to model the spread of *Nosema bombi* under different scenarios of male/female dispersal, including different climatic and habitat effects on species dispersal. This could be extended to include other potentially detrimental parasites. In addition, Remy Vandame may organize an effort to examine the distribution of of *N. bombi* in Mexican species of Bombus, and to test infection susceptibility of laboratory reared colonies under different environmental conditions.
- *Timeline: 2011-2013*
- *Funding*: USDA AFRI; potentially NSF/NIH co-funding
- *Outcomes expected*: A better understanding of pathogen transmission in native North American *Bombus* populations.
- *Obstacles*: Funding

Goal 1, Action 3
Evaluate the effects of pesticides/herbicides/miticides on susceptibility to pathogens

- *Responsibility:* Uncertain expertise at this time; possible collaborations with UK labs and/or Jeff Pettis, USDA-ARS who has experimented on similar issues with *Apis mellifera*
- *Timeline:* Dependent on expertise development
- *Funding*: USDA AFRI
- *Outcomes expected*: A better understanding of the interaction between bumble bee susceptibility to pathogens when stressed by human use of pest chemicals.
- *Obstacles*: Current expertise is unavailable

Goal 1, Action 4
Determine the effects of degradation of nesting and hibernation sites on susceptibility of pathogens and epizootiology

- *Responsibility:* None identified to date
- *Timeline:* None identified to date
- *Funding*: USDA AFRI
- *Outcomes expected*: A better understanding of the epizootiology and susceptibility of pathogens relative to different nesting behavior in different species. For example, are surface nesting species more likely to be affected by pesticide and herbicide spray regimes than those who inhabit underground nests?
- *Obstacles*: Funding

Goal 1, Action 5
Determine changes in foraging and disease transmission due to habitat changes; organize collaborative research efforts and funding

- *Responsibility:* Cameron lab is discussing preliminary experiments
- *Timeline:* None identified to date
- *Funding*: USDA AFRI; potentially NSF/NIH co-funding through the Ecology of Infectious Diseases
- *Outcomes expected*: Knowledge about the interactive effects of habitat fragmentation relative to nearby floral and nesting resources on the distances that different pathogens and parasites might spread. Knowledge of the roles of temperature and humidity on the expression of pathogenic diseases and parasite effects and transmission.

- *Obstacles*: Funding

Overall outcomes: Better understand the impacts of anthropogenic development on disease epizootiology in bumble bees. Provide information that would feed into recommendations for land use strategies and conservation.

Threats Statement IV: Potential for inter-generic pathogen transmission among Hymenoptera
Movement of honey bees, honey bee products and other managed pollinators could potentially lead to emergence of new diseases in bumble bees as well as the introduction of more virulent strains of naturally occurring diseases via intergeneric transmission of pathogens and parasites. There are increasing reports of bumble bees infected with RNA viruses (deformed wing virus, acute bee paralysis virus, black queen cell virus, sacbrood virus, Kashmir bee virus and Israeli acute paralysis virus) that were originally isolated from honey bees (Genersch et al. 2006; Meeus et al. 2010; Singh et al. 2010). In fact, these viruses have been recently detected in eleven other non-*Apis* hymenopteran species, ranging from solitary bees to several bumble bee species and wasps (Singh et al. 2010). Moreover, it has been experimentally demonstrated that these viruses remain infectious in pollen (bee bread) for at least six months under ambient outdoor environment, and can move from infected honey bees to bumble bees and from bumble bees to honey bees via pollen (Singh et al. 2010). For bumble bee rearing, frozen pollen is used, which further increases the chances of pathogens and parasites in pollen to remain viable and infectious for prolonged periods. Impacts of such diseases on bumble bees are currently unknown, but potentially could lead to severe consequences in terms of colony survival and population dynamics as has been observed in honey bees. Immediate research efforts are needed to understand the disease dynamics and potential health impacts of multi-host parasites on bumble bees and to develop risk mitigation strategies for rational use of pollen in bee rearing.

The following goals have been identified to address this threat (Threat IV) to North American bumble bees and to minimize the potential for disease spread and epizootics.

Goals:

1. Determine the impact and epizootiology of RNA viruses and other transmissible diseases and parasites on bumble bees.
2. Develop treatments to decontaminate bee-collected pollen
3. Understand the dynamics of diseases that are observed to be naturally occurring in multiple hymenopteran hosts.

Goal 1, Action 1
Determine the importance and potential impact of diseases transmitted among multiple hymenopteran species.

Project is in progress in Europe to examine the impact and epizootiology of deformed wing virus (DWV) in bumble bees.

- *Responsibility*: Mark Brown
- *Timeline*: To be determined
- *Funding*: To be determined
- *Outcomes expected*: An understanding of the potential threat of DWV to bumble bees.
- *Obstacles*:

Goal 1, Action 2
Studies are in progress at Pennsylvania State University to determine the health impact and epizootiology of Israeli acute paralysis virus (IAPV) in commercial greenhouse bumble bees, *Bombus impatiens.*

- *Responsibility*: Rajwinder Singh, Diana Cox-Foster; Penn State University
- *Timeline*: 2009-2011
- *Funding*: North American Pollinator Protection Campaign (NAPPC); Hatch funds from the Experiment Station, Pennsylvania State University.
- *Outcomes expected*: An understanding of the potential threat of IAPV to North American bumble bees.
- *Obstacles*: Availability of disease free stock to use as control.

Goal 2, Action 1
Initiate collaborative efforts and create funding to develop treatment methods to decontaminate pollen before using it for bee rearing e.g., gamma irradiation, UV, ozone (Yook, et al., 1998). Gamma irradiation of pollen provisions has been used against a fungal disease (chalkbrood) in alfalfa leaf cutting bees (Xu and James 2009). Research is needed to figure out the correct dosage and timing for gamma irradiation and other methods that can effectively kill various bee pathogens and parasites in pollen without adversely impacting its nutritional and other physiochemical properties essential for successful bee rearing,

- *Responsibility*: Rajwinder Singh, Diana Cox-Foster; Penn State University. Depending upon the availability of funding, Rajwinder Singh is interested in this as potential postdoc project. Coordinate with Rosalind James (USDA-ARS Logan Bee Lab) who has similar project with leaf-cutter bees.
- *Timeline*: To be determined
- *Funding*: Looking for funding; potentially APHIS may help here
- *Outcomes expected*: Minimize the potential for disease spread and to mitigate the risks involved with the importation, movement and use of honey bee collected pollen in bee rearing.
- *Obstacles*: Funding

Goal 3, Action 1
Initiate collaborative efforts and create funding to understand the dynamics of diseases shared by multiple hymenopteran hosts. The potential for intergeneric disease transmission calls for a broader epizootiological approach and to study the disease dynamics of pollinator community as a whole instead of dealing on individual species basis. Potentially, some species may serve as reservoirs for particular pathogens. There is a need to develop community-based disease modeling approaches to better understand disease spread and potentially predict disease epizootics in pollinators. In fact, this can be developed into multi-collaborator modeling/network analysis project. However, some basic research is needed to determine various transmission parameters and factors that impact the infection dynamics in the field before any model will allow adequate prediction.

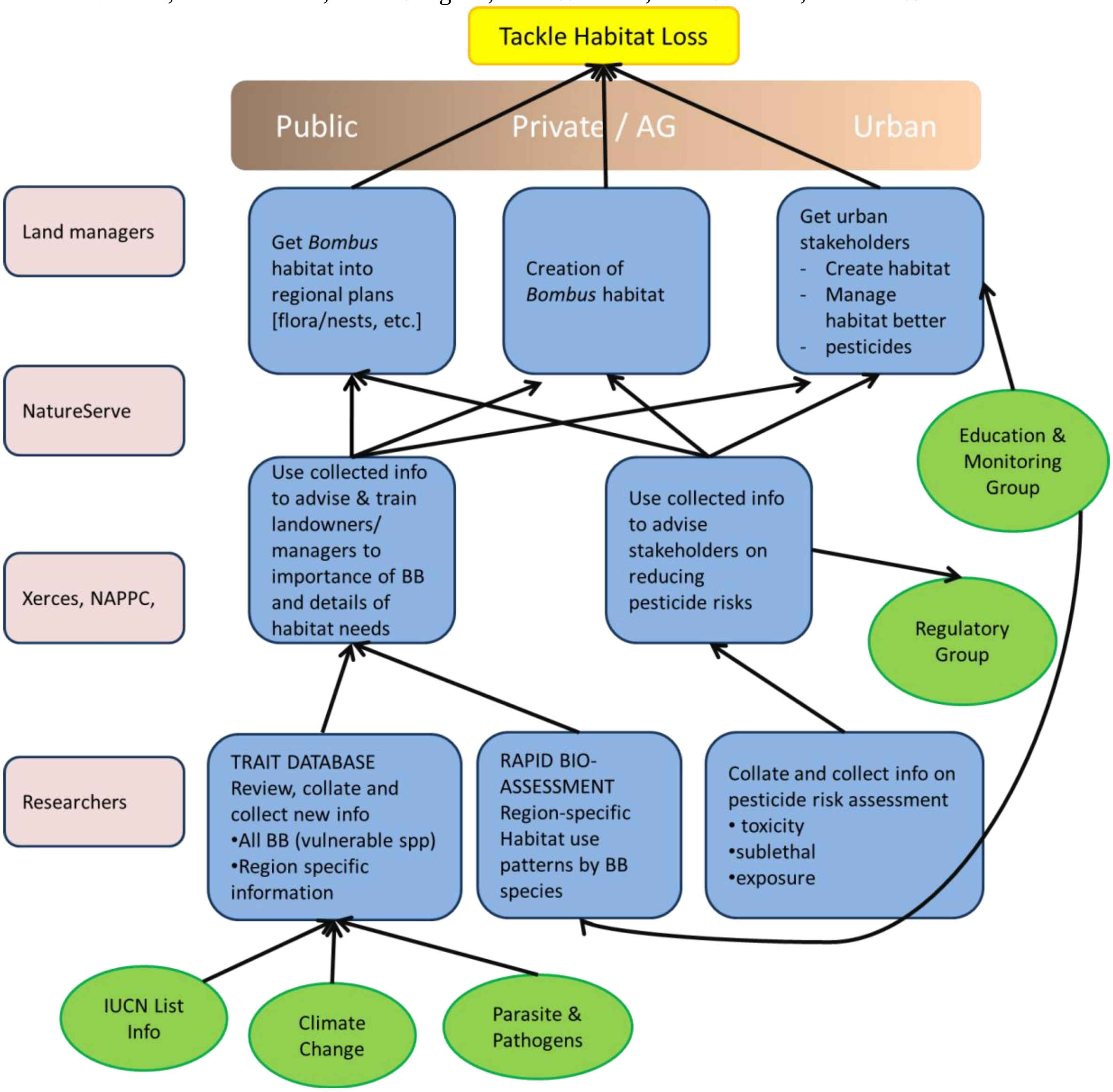
- *Responsibility*: Diana Cox-Foster and Rajwinder Singh are interested in this project with possible collaboration with Katriona Shea and Reka Albert; Penn State University. There is potential for multiple collaborators in this project.
- *Timeline*: To be determined
- *Funding*: Grant needs to be written
- *Outcomes expected*: Better understanding of disease epizootiology.
- *Obstacles*: Funding

Box 3: Additional comments from participants not directly addressed:

- Discussion on what needs to be done in rearing facilities.
- How important (possible) is it to maintain 100% pathogen-free commercial rearing?
- What pathogens are we talking about?
- Do pathogens undergo selection in commercial rearing facilities?
- What kind of screening protocol is workable, economically feasible and makes sense for both commercial enterprise and conservationists?
- What are the commercial companies doing and what needs to be done, if anything to improve the screening process? (e.g., impact of moving brood from hive to hive to augment numbers).
- Huge opportunity for horizontal transmission.
- BioBest only screens for Canada to Mexico shipments.
- What is level of horizontal transmission?
- Pathogen Group + Regulatory Group

Habitat Loss and Degradation Working Group

Working Group Participants: Mike Arduser, Steve Brady, Steve Buchmann, Liz Day, Joe Engler, Juliet Osborne, Dale Schweitzer, Julianna Tuell, Mace Vaughan, Neal Williams, Paul Williams, Rachael Winfree



Working Group Focus: Strategies for restoring and protecting habitat.
Links to Other Working Groups: Diseases and Pests (Parasites and Pathogens); Climate Change and Range Shifts; Genetic and Demographic Issues in Conservation Strategies; Bombus Education, Outreach and Citizen Science; Compilation of IUCN Red List Data Sheet information

INTRODUCTION

Habitat loss and degradation has wide-spread implications to wildlife and plant populations on an international, national, regional, and local scale. While these impacts have been relatively well-studied for many species or guilds, such as birds and large mammals, little is known about the impacts to less-studied species, such as invertebrates. This paucity of data does not negate the significant concerns that can be surmised for smaller, less mobile species such as bumble bees. Both the temporal and spatial scales of habitat loss and degradation likely have immediate and long-term impacts on bee populations.

While addressing the ubiquitous and drastic conversion of native habitats is daunting, this issue also lends itself to ground-level, grass roots type programs that can provide immediate benefits to bumble bee habitat. Local solutions can be implemented by NGO's, lay persons and land managers without concerns over technical expertise and unfunded research mandates. Many projects not only have near-immediate habitat results but they also provide tangible examples of bee conservation that can foster increased local and regional support for conservation. Local efforts may help mitigate bumble bee declines until large-scale solutions can be developed and implemented.

LIST OF IDENTIFIED THREATS

I. Insufficient amount (inconsistent or low temporal and spatial predictability) of bumble bee-specific floral, nesting and overwintering resources caused by an overall loss and fragmentation of habitat in different landscapes (e.g., agricultural, urban, and natural areas).

II. Use of pesticides directly and indirectly toxic to bumble bees.

GOALS, OBJECTIVES, & ACTIONS

Note: Several of these activities are already underway, but may not be coordinated across all of North America, nor internationally.

Goal 1: Develop a database of bumble bee life-history and ecological traits

Objectives: Compile habitat use, life history and ecological details for vulnerable or declining species. Information will be region specific whenever possible. This database will identify gaps in our knowledge of floral, nesting, overwintering, and mating requirements. The database may also inform us about the spatial scale at which interventions are required based on biology of movement and dispersal

Specific examples of trait information:

- Preferred floral resources by species and region
- Patterns of habitat use (forest, meadow, edges, hedgerows, farmland, etc.)
- Dispersal distances of queens and males
- Tongue length
- Body size distribution of queens and workers
- Colony size
- Nesting locations
- Foraging distance

Barriers to adoption: Funding to pay individuals to compile data has not been identified. Additional support is required to collect critical missing data for key bumble bee species where possible. Unclear whether lead/ point person has been identified.

Actions:

- Initial design and data collection should focus on the life histories and ecological traits of the most vulnerable bumble bee species. Sarina Jepsen (Xerces Society) is taking the lead on assembling core life history traits for bumble bee species of greatest conservation need.

- *Responsibility*: S. Jepsen for bumble bees of greatest conservation need; others for additional species
- *Timeline*: 2011 - completion
- *Funding*: Xerces Society for initial species; TBD
- *Outcomes Expected*: Concise table of bumble bee life histories and ecological traits
- *Obstacles*: Funding, personnel with time to accomplish

- Identify and select an online database service to house the database. *Responsibility*: TBD, coordinate with Climate Change Working Group
  - *Timeline*: 2010 - completion
  - *Funding*: TBD
  - *Outcomes Expected*: This data will be essential to quickly access regionally relevant data and information on bumble bees for design and inclusion into field-based projects
  - *Obstacles*: Funding, mechanism for efficiently collecting and summarizing existing data

- Explore opportunities to integrate the traits database with technologies being developed by epidemiologists and others to develop modeling capabilities that are GIS-based.
  - *Responsibility*: S. Jepsen, Collaborate with IUCN group, climate change group, pathogen/parasite group, and population genetics group
  - *Timeline*: 2011- completion
  - *Funding*: TBD
  - *Outcomes Expected*: A consolidated accessible GIS-based or linked database with all known life history, ecological traits, distributions, and risk assessment information.
  - *Obstacles*: Funding, unwillingness by some to share unpublished information and data

Goal 2: Increase bumble bee flowering, nesting, and overwintering resources

Objectives 1: Agricultural Lands

1. Increase area of suitable vegetation in field boundaries, set-aside and uncropped areas.
2. Increase polyculture farming
3. Decrease broad-leaf herbicide use or partition its use over space and time.
4. Optimize livestock grazing regimes to increase flowering plants.
5. Promote staggered, strip mowing.
6. Promote staggered, strip burning.
7. Manage riparian areas to increase forb and flower availability and diversity.
8. Encourage flowering cover crops (e.g., clovers, phacelia, etc.) for crop rotations and erosion control, as enhancements to soil quality, and to benefit native bees.
9. Modify state "Roadsides for Wildlife" programs to include bumble bee considerations in farm landscapes.

Barriers to adoption: Barriers are common across many specific objectives within Obj. 1. Relevant numbers are listed in parentheses following the barrier.

- Sociological/cultural reluctance to change cultivation /land management practice (1-8)
- Implementation is costly compared to business as usual and standard cultivation (1-7)
- Mandated food safety regulations may conflict with best practice strategies for on-farm habitat improvement. (1)
- Lack of bumble bee specific information for local/regional implementation and a general need to continue to improve our knowledge and experience in implementing pollinator habitat conservation projects (1, 4, 7, 9)
- Legal restriction of burning (6)

Actions 1: Agricultural Lands

1. Determine total patch size, spatial distribution, and relative size of native plantings in relation to the extent of the crop and demonstrate effectiveness. This is ongoing in many parts of the U.S. and Canada (topographical land use planning) already, but this should be expanded in other parts of NA.
    - *Responsibility*: Multiple academic partners from universities, Xerces and other relevant NGO's
    - *Timeline*: 2011 - completion
    - *Funding*: TBD
    - *Outcomes Expected*: Regionally-specific criteria for buffers and natural area plots within varied agricultural regimes and crops
    - *Obstacles*: Funding, time needed to conduct studies and produce information in an efficient and timely manner, unwillingness by some to provide unpublished information

2. Develop regionally-specific plant phenology and planting guidelines and demonstrate their effectiveness
    - *Responsibility*: Xerces Society, NRCS, N. Williams (University of California - Davis), R. Winfree (Rutgers University), other academic and research entities
    - *Timeline*: ongoing
    - *Funding*: NRCS, NSF, USDA-Specialty Crop Research Initiative, USDA-Agriculture and Food Research Initiative, other funding TBD
    - *Outcomes Expected*: Planting guides that are regionally to locally- specific that span North American bumble bee habitats
    - *Obstacles*: Funding, timeline to complete

3. Develop management protocols based on known vegetation structural diversity management practices.
    - *Responsibility*: Xerces Society
    - *Timeline*: Ongoing
    - *Funding*: Various government and private foundations
    - *Outcomes Expected*: Consolidated library of protocols that can be utilized in appropriate areas of North America
    - *Obstacles*: Funding, timeline to complete

Partners for Objective 1: Natural Resources Conservation Service, Xerces Society, private growers, farm bureaus, soil and water conservation districts, Ontario Federation of Agric., Farm Service Agency, Cooperative Extension, Canadian Pollination Initiative, wildlife groups (Pheasants Forever, Ducks Unlimited, National Wild Turkey Federation, etc.)

Objectives 2: Public/Natural Lands

1. Incorporate vulnerable *Bombus* species as a target species in management plans, and ensure that vulnerable *Bombus* species are listed as species of concern for federal and state land management agencies. The Xerces Society is currently working on this.
2. Apply holistic natural community management, where land managers use multiple management tools (e.g. fire, mowing, invasive species removal, grazing, etc.) to manage habitat to support overall biodiversity and ecosystem integrity, ensuring inclusion of the habitat needs of bumble bees are addressed. Such management can apply to Midwest prairies, western rangeland, forest meadows or glades, riparian corridors, and more.
3. Where feasible, incorporate bumble bees into multi-species management of forest areas.
4. Work with federal, state, county DOT's and utility companies to include bumble bee habitat in roadsides and ROW's.
5. Work with wildlife habitat conservation programs to include bumble bee considerations (e.g., NRCS, State Wildlife agencies, Ducks Unlimited, Pheasants Forever, National Wild Turkey Federation, etc.).

Barriers to adoption:

- Land Managers are already overburdened and staffing levels are inadequate to assume additional workloads, which decreases likelihood of adoption of new complex procedures.
- Additional costs associated with adding conservation targets to planning and monitoring programs.
- No existing assessment of potential trade-offs between bumble bee requirements and current management objectives and strategies.
- Lack of botanical and entomological expertise within agency staffs

Actions 2: Public/Natural Lands

1. Researchers provide summaries of bumble bee habitat and, ultimately, very specific recovery requirements to Xerces (Note: much of this very specific data on habitat or recovery requirements will also be housed in the database referenced in Goal 1), then Xerces will design education programs which will:
   a) Incorporate habitat and recovery criteria into state wildlife action plans
   b) Add habitat and recovery criteria into Federal management plans for federal lands (again USFS, BLM, NPS, and USFWS)
   c) Incorporate habitat and recovery criteria into other regional and national plans developed by Non-governmental Organizations (NGOs) such as NatureServe, Xerces, NAPPC Taskforce, The Nature Conservancy, etc.
   d) Provide core content for pollinator-related training to agency staff
   - *Responsibility*: S. Jepsen, other Xerces Society staff
   - *Timeline*: Ongoing
   - *Funding*: Various private and government foundations
   - *Outcomes Expected*: Concise table of bumble bee life histories, habitat parameters, and ecological traits
   - *Obstacles*: Funding, timeline to complete, unwillingness of land managers to incorporate bumble bees into management plans and work projects

2. Completion and distribution the Xerces Society's Bee Habitat Assessment Guides
   - *Responsibility*: Xerces Society

- *Timeline*: Ongoing
- *Funding*: TBD
- *Outcomes Expected*: A habitat assessment product for land managers to effectively determine the suitability and site potential for providing habitat for bumble bees and other pollinators
- *Obstacles*: Funding, timeline to complete, unwillingness of land managers to incorporate bumble bees into management plans and work projects

3. Draft a letter from the Bumblebee Specialist Group to key land management agencies, such as the Forest Service, Park Service, Bureau of Land Management, Fish and Wildlife Service, etc., to include declining bumble bees in land management.
    - *Responsibility*: IUCN SSC Bumble Bee Specialist Group
    - *Timeline*: 2012
    - *Funding*: TBD
    - *Outcomes Expected*: A multi-organizational and agency acceptance to incorporating bumble bee habitat needs into natural lands management
    - *Obstacles*: Funding, timeline to complete, unwillingness of land managers to incorporate bumble bees into management plans and work projects

Objectives 3: Urban Lands

1. Provide educational programs and materials about the importance of nectar and pollen producing plants for bumble bees.
2. Promote and develop plans for bumble bee gardens/habitat in municipal parks, hiking, and bike trails.

Barriers to adoption:

- Complex coordination of messages because of the diversity of urban landscapes and human populations within and among regions.
- Large geographic area of North America and diversity of ecoregions necessitates region-specific plant species targets.
- Cost of development

Actions 3: Urban Lands

1. Marketing plans for nurseries and other plant centers that target bumble bee conservation (overlap with Education, Outreach and Citizen Science Working Group) For example, this could be modeled after bumble bee garden kits developed by Xerces (http://www.xerces.org/spring-ahead-with-bumble-bee-garden-kits/)
    - *Responsibility*: TBD
    - *Timeline*: TBD
    - *Funding*: TBD
    - *Outcomes Expected*:
    - *Obstacles*: Funding

2. Education programs designed for lay people
    - Via Cooperative extension, Xerces, Audubon, Wild Ones, Garden Clubs
    - *Responsibility*: Refer to *Bombus* Education, Outreach, and Citizen Science Working Group

3. Promote the adoption of pollinator-friendly neighborhoods, townships, cities, counties, regions, etc.
    - Modeled after Pollination Guelph (Xerces Society, Cooperative extension, Audubon, Wild Ones, Garden Clubs, etc.)
    - Encourage Home Owners Associations (HOAs) to accept bumble bee habitat plantings.
    - *Responsibility*: Xerces Society, multiple community groups, agencies, academic institutes
    - *Timeline*: ongoing
    - *Funding*: no consolidated source at this time
    - *Outcomes Expected*: Continent-wide acceptance and land use practice of incorporating bee-friendly habitat within communities
    - *Obstacles*: Funding, insufficient staff and/or organizations to reach all communities

4. Increase the conversion of golf course roughs into bee habitat
    - *Responsibility*: Xerces Society
    - *Timeline*: ongoing
    - *Funding*: none current to complete nation-wide
    - *Outcomes Expected*: one publication completed
    - *Obstacles*: Funding

5. Work with land managers of wastelands or brownfields in industrial areas.
6. Incorporate nectar and pollen producing plants into landscape architecture programs.
7. Develop bumble bee gardens/habitats in municipal parks, and along hiking and biking trails.

Goal 3: Reduce bumble bee mortality from pesticides

Objectives 1: Agricultural Lands

1. Increase transition to bee-“safe” insecticides.
2. Decrease use of systemic, bee-offensive insecticides on horticultural crops.
3. Increase adoption of IPM/reduced-risk practices to reduce the number of pesticide applications.
4. Develop and/or promote guidelines that mitigate pesticide toxicity and/or exposure to bumble bees (e.g. only apply insecticides when bees are not actively foraging, or utilize precision application methods to minimize off-target movement of pesticides).
5. Promote vegetative barriers to pesticides (i.e. using plants NOT attractive to bumble bees).
6. Promote alternative, bumble bee habitats that are protected from pesticide drift and also located away from horticultural crops.

Barriers to adoption:

- Availability, higher cost, or ineffectiveness of bee-“safe” insecticides against target pests (1).
- Cost to the pesticide companies for development of new insecticides or in testing the safety (1).
- Complexity of management and thus grower resistance (1-6)
- Grower priority rests with immediate pest threat– if pest are active at the same time and reaching thresholds spray pesticides will be applied (3, 4).

- Cost (aerial applications may be less expensive than tractor applied in some situations) (5).
- Lack of enforcement of product regulations regarding minimum distance between crop and habitat (spray drift issues) (6).

Actions 1: Agricultural Lands

1. Testing of non-*Apis* bees (*Bombus* and a solitary bee species) to determine LD50s of current and new products/formulations and in particular sub lethal effects of systemic insecticides.
   - *Responsibility*: Defer to Import Issues and regulations Working Group
2. Evaluating exposure risks in field settings.
   - *Responsibility*: Defer to Import Issues and regulations Working Group

Objectives 2: Public/Natural Lands

1. Promote targeting of the source of pest populations and most vulnerable life stages of pests (e.g., mosquito larvae control, instead of broadcast spraying for adults); ensure assessment of the non-target lethality of each option.
2. Improved precision of broad spectrum aerial spray programs (e.g., for gypsy moth or grasshopper control).

Barriers to adoption:

- Cost

Actions 2: Public/Natural Lands

- Identify types and locations of spray programs (i.e., mosquito, grasshopper, gypsy moth) that may impact bumble bees.
  - *Responsibility*: Federal and State Land Management Agencies
  - *Timeline*: ongoing
  - *Funding*: TBD
  - *Outcomes Expected*: Consolidated catalog of widespread insect control programs that may be impacting bumble bees on a local or regional basis
  - *Obstacles*: Funding, unwillingness of some land managers to contribute information
- Identify agency-specific BMPs (Best Management Practices) for bees within these programs.
  - *Responsibility*: Xerces Society, NRCS, USFWS, USFS, BLM
  - *Timeline*: ongoing
  - *Funding*: TBD
  - *Outcomes Expected*: BMP's available but not yet incorporated into agency management*Obstacles*: Funding

Objectives 3: Urban Lands

1. Promote public outreach about which insecticides are toxic vs. bee-"safe".
2. Promote bee-"safe" insecticides and application techniques in retail stores, especially large chains such as Lowe's, Home Depot and Wal-Mart.

Barriers to adoption:

- Cost
- Lack of existing outreach material

Actions 3: Urban Lands

1. Educate household pest control companies, Home Owners Associations (HOAs), retail supply stores, and homeowners about beneficial insects and methods to avoid poisoning them.
    - o *Responsibility*: Xerces Society, University Cooperative Extension
    - o *Timeline*: ongoing
    - o *Funding*: TBD
    - o *Outcomes Expected*: Incorporation of information into all state pesticide applicator's training programs
    - o *Obstacles*: Funding, time

2. Educate household pest control companies, HOAs, retail supply stores, and homeowners about bee-"safe" products.
    - o *Responsibility*: Xerces Society, University Cooperative Extension, others
    - o *Timeline*: ongoing
    - o *Funding*: TBD
    - o *Outcomes Expected*: BMP's available but not yet 'distributed'
3. *Obstacles*: Funding, time

Climate Change and Range Shifts Working Group

Working Group Participants: Laura Burkle, Terry Griswold, Javier Hernandez, David Inouye, Jonathan Koch

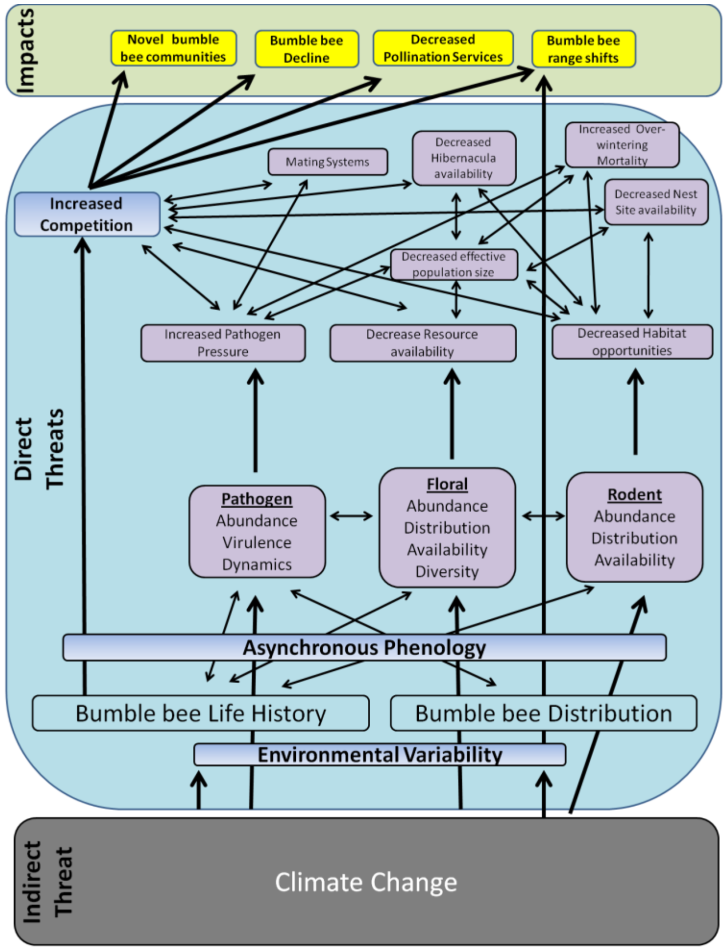


Figure 1. A summary of threats and impacts to North American bumble bees due to Climate Change.

Focus: Response of bumble bees to global climate change
Links to other groups: Habitat Loss; Disease and Parasites; Genetic and Demographic Conservation Issues

INTRODUCTION

Like many other organisms, climate change threatens the ultimate survival of bumble bees. Considering their role as vital pollinators of flowering plants in wild and managed landscapes, the loss of bumble bee species will place increasing pressure on ecosystem function and food security (Eilers et al. 2011). In the context of climate change (see Box 1), fluctuations in temperature and precipitation may facilitate phenological asynchrony between bumble bees and the plants they forage on for nectar and pollen (Memmott et al. 2007; Thomson 2010). For example, in sub-alpine environments, the effects of a variable climate have materialized to changes in snowpack and summer precipitation, affecting the spatial and temporal distribution and abundance of several plant species, some of which are visited by bumble bees (Forrest et al. 2010, Inouye 2008). Despite global reports of bumble bee decline (Cameron et al. 2011, Colla & Packer 2008, Kosior et al. 2007) and modeled effects of asynchrony between pollinators and flowering plants (Memmott et al. 2007, Memmott et al. 2010, Hegland et al. 2008), little research attention has been given on the effects of climate change on bumble bee biology and distribution (but see Williams et al. 2006).

We identify climate change as an *indirect threat* to bumble bees, materializing into a series of *direct threats* (Figure 1). While several of the direct threats we propose are being discussed by other working groups (e.g., habitat loss, decreased effective population size, disease and pests), we consider themes of phenological asynchrony exclusive to our working group. Given the magnitude of climate change, we do not provide action statements to reduce its impacts on bumble bees. Rather we identify *research actions* that are urgently needed to assess current and potential impacts of climate change on North American bumble bees.

Box 1: Climate Change is defined as the change in the state of the global climate that can be identified by observed changes in the mean or variability of temperature and precipitation, persisting for an extended period of time. These changes may be the result of natural variability over time or induced by human activities (IPCC 2007).

We advocate for (1) a pan-national database effort of bumble bee species to establish historic distributions and general natural history (e.g., floral host, collection or observation date, caste activity), (2) long-term bumble bee monitoring sites, preferably at established field research stations such as the Rocky Mountain Biological Laboratory, (3) targeted experimental research on bumble bee over-wintering physiology and nesting biology and (4) an assessment of bumble bees that may be at greatest risk due to narrow bioclimatic and geographic ranges.

LIST OF IDENTIFIED THREATS

INDIRECT THREATS

We have identified Climate Change as an indirect threat (Figure 1) to bumble bee survival. We have identified the following four properties of climate change that will affect bumble bees at the colony and community level.

I. Increase temperatures/ Increased variability of temperature extremes
II. Increased precipitation/Increased variability of precipitation extremes
III. Early snow melt
IV. Late frost events

DIRECT THREATS

We have identified three categories of direct threats: bumble bee life history, community interactions, and habitat structure. These are discussed in the context of climate change.

I. Climate change may adversely affect bumble bee life history
    a. Variable/Unpredictable environmental cues
    b. Changes in the timing of emergence
    c. Changes in the timing of caste production
    d. Increased overwintering mortality (diapause)
    e. Inadequate fat bodies
II. Climate change may adversely affect necessary community interactions and resources bumble bees need to persist
    a. Asynchronous flowering phenology
    b. Changes in wildfire frequency and intensity

c. Plant community composition
d. Timing and availability of flora resources
e. Quantity and quality of floral rewards
f. Mating system asynchrony
g. Asynchrony in resident rodent population phenology
h. Increased competition for habitat
    i. Hibernacula
    ii. Nesting
i. Increased competition for floral resources
j. Increased/variable pathogen and disease dynamics

III. Climate change may alter habitat structure
    a. Reduction in effective population size of bumble bees
        i. Loss of corridors with adequate floral resources
        ii. Range shifts of climatically narrow bumble bees and resources
    b. Development of novel communities
    c. Spatial and temporal separation of floral resources and habitat requirements

THREATS STATEMENTS, GOALS, & ACTIONS

Threat Statement 1: Climate change may adversely affect bumble bee life history
Climate change may alter the environmental cues (e.g., temperature, precipitation, humidity, etc.) that bumble bees rely on for optimal emergence times, caste production and diapause. Alterations to these important phases of the bumble bee life cycle may increase overwintering mortality, nest collapse and phenological mismatches. Inadequate fat bodies of overwintering queens may not be sufficient for overwintering in highly variable temperatures.

Research Goals:
We have identified the following two major research goals to address Threat 1 to native bumble bees.

Goal 1, Action 1
We propose a survey of the existing literature on bumble bee natural history to identify research gaps. The literature search will include the identification of life history traits that may be particularly influenced by changes in the environment associated with climate change (e.g., diapause, emergence phenology, current and historic ranges, mating requirements, dispersal, lethal temperatures, nest initiation period, and caste production). Our working group is interested in the possibility of synthesizing this life history information into a publishable scientific paper, emphasizing the gaps in knowledge that would be useful to address the conservation needs of bumble bees in the face of changing climate.

- *Responsibility*: *Bombus* scientific community, especially those studying bumble bee physiology and nesting biology.
- *Timeline*: 2010 - present
- *Measureable*: Produce a database with life history data at a species level that can be accessed by the scientific community to identify gaps in knowledge of bumble bee life history traits and to assess priorities for research and conservation (see also Section II.B. Habitat Loss and Degradation).
- *Collaborators*: USDA-ARS Pollinating Insect Research Unit (Strange Lab), Sujaya Rao's lab (Oregon State University), Michael Dillon's lab (University of Wyoming), and in Mexico, El Colegio de la Frontera Sur, Rémy Vandame's lab.
- *Resources needed*: Access to online database services, place to house the database.

- *Consequences*: These data will be essential as the base for any conservation risk assessment, and will provide points for comparison of habitat requirements across species as well as life history similarities at a phylogenetic and/or ecological level. The data will help us understand the abiotic limitations of bumble bee nesting biology and colony development.
- *Obstacles*: Reluctance of individual labs and commercial bumble bee producers to share unpublished life history data. There is a need for research collaboration on a variety of species, particularly those considered "at-risk".

Goal 1, Action 2
We propose experimental manipulation of biotic and abiotic factors to determine effects on bumble bee behavior, survival, dispersal, and spatial and temporal distribution, in the field and laboratory. Experimental manipulation of climate-related themes (e.g., temperature, precipitation, fire) may elucidate the mechanisms that affect bumble bee community composition and species richness (Forrest et al. 2010, Memmott et al. 2010). We suggest the establishment of monitoring sites in already established field stations (e.g., Rocky Mountain Biological Laboratory (RMBL) and other members of the Organization of Biological Field Stations) to conduct controlled and natural field studies. RMBL provides a relatively unique montane situation. It will be important to identify other, more typical, research sites (e.g. Midwest prairie, western rangeland, and coastal areas). We also suggest close collaboration between government labs and commercial bumble bee growers to investigate bumble bee life history traits.

Threat Statement 2: Climate change may adversely affect necessary community interactions and resources bumble bees need to persist
Both natural experiments and modeling simulations suggest that climate change will affect the spatial and temporal dynamics of flowering plants, fire regimes, rodent populations and pathogens. Forrest et al. (2010) found that changes in snowpack over a 30-year period affected the spatial and temporal distribution of flowering plant species, and although less is known about community-level effects of changes in floral resources on *Bombus* (Memmott et al. 2010), a recent paper suggests that a mid-season gap in flower abundance may be developing in a montane environment as the growing season lengthens (Aldridge et al. 2011). We hypothesize that climate changes will affect the spatial and temporal distribution of important flowering plants, ultimately facilitating asynchrony between flowering plants and bumble bees. Asynchrony among bumble bees, flowering plants, habitat, predators and pathogens may facilitate the development of novel communities that have unknown effects on bumble bees (Hegland et al. 2009).

Goal 2, Action 1
We propose retroactive data capture of major and regional natural history collections and literature of all bumble bee species to determine historic ranges, phenology, floral associations and levels of genetic diversity. Retroactive data capture will help identify interactions, distributions and phenology of bumble bees that may be at most risk. It will also provide data to construct the impacts of climate change on bumble bee distributions and phenology.

- *Responsibility*: Strange and Griswold (USDA-ARS Pollinating Insect Research Unit); Lozier and Cameron (University of Illinois); Colla and Ascher (York University, AMNH); Jeremy Kerr (University of Ottawa); Leif Richardson (Dartmouth College)
- *Timeline*: 2008-2015
- *Measureable*: Produce maps of historical ranges for each species as well as an image database (virtual specimens). Produce a database of this information for mining by others in the scientific community. Use data to see if there are any phenological trends to pull out. Use

data to help inform a bioclimatic envelope model. Greater understanding (data coverage) of species distribution and environmental range, species distribution models, extremity maps.

- *Collaborators*: Natural History Collection Curators and interested parties.
- *Resources needed*: Place to house the data [e.g., GBIF (http://gbif.org), Discover Life (http://discoverlife.org), National Pollinating Insect Database (Logan, UT)]
- *Consequences*: Provide baseline data for a risk assessment. Identify areas where we should be looking – geographic gaps (places that haven't been collected to see if species are there). Understanding geographic spread, gaps in knowledge, identification of 'island' bee populations, community diversity, floral associations and floral phenology, parasite-host associations.
- *Obstacles*: Reluctance to collaborate and share data. A clear method for accreditation of contributors.

Goal 2, Action 2

Establish monitoring projects and long-term research sites with standardized protocols. Monitoring could include species identification, abundance, and floral associations. Monitoring should also capture some aspects of plant phenology. The data collected at long-term monitoring sites should include: (1) bumble bee voucher specimens, (2) distribution data (latitude, longitude, elevation), (3) bee phenology, (4) floral associations, and (5) abiotic data. Monitoring in geographic gaps where we have strong historic data and in isolated populations (e.g., isolated mountain ranges, maritime islands, and/or vulnerable habitats that are most susceptible to change). Monitoring, by its nature, will be contributing to the collection of current *Bombus* data, but there may be collection of current data that is not part of long-term monitoring. Also, monitoring in biodiversity hotspots should be given priority such as mountain and desert habitats.

- *Responsibility:* Gretchen LeBuhn (San Francisco State University), Jamie Strange (USDA-ARS Pollinating Insects Research Unit), David Inouye (University of Maryland), Sydney Cameron (University of Illinois), Terry Griswold (USDA-ARS Pollinating Insects Research Unit)
- *Timeline:* 2011 - present
- *Measureable:* Assessment of trend over time
- *Collaborators:* Xerces, NAPPC, RMBL-based researchers (e.g., Graham Pyke, James Thomson, Rebecca Irwin, Martina Stang)
- *Resources needed:* funding, time, logistics
- *Consequences:* Identification of species at risk.
- *Obstacles:* funding, time, logistics

Threat Statement 3: Climate change may alter habitat and community structure

As climate changes, bumble bees and other organisms may shift in their distribution across elevation and latitude, facilitating the development of novel communities in which new bumble bee species will come together and compete in unknown ways. For example, in research at the Rocky Mountain Biological Laboratory, *Bombus* queens of eight species sampled along an altitudinal gradient were found to have moved up on average 230 m between 1974 – 2007 (G. Pyke, J. Thomson, and D.Inouye, unpublished). In these novel communities, there may also be increased hybridization through previously non-overlapping ranges of *Bombus* species, which may decrease fertility of *Bombus* colonies and cause loss of species. We hypothesize that climate change may change the physical structure (habitat structure) of the environment in which *Bombus* live or move to. Such changes in habitat structure will impact ability to find mates, nest successfully, etc. For example, for species of *Bombus* in which males perch to find mates, if their preferred plant for perching is no longer available, we hypothesize that their mating success may be compromised. Similarly, if bumble bees move up in elevation in mountainous regions to achieve their desired temperature environment, they may move from a meadow habitat with soils amenable for nesting to a scree habitat with rocky areas that are not conducive to nesting and reproductive success.

Finally, climate change may require changes in land use practices. For example, if current agricultural regions become too hot or dry to grow food, people may move agricultural areas to current *Bombus* habitat, which is already limited and fragmented. Loss and fragmentation of habitat (see Habitat Loss and Degradation Working Group) is known in other systems to result in less-viable populations and loss of species. Mechanistically, there may be a reduction in suitable corridor areas that affect the movement of species. Movement is particularly important for *Bombus* to change ranges in response to climate changes. In addition, there may be changes in genetic structure of *Bombus* and decreased effective population size as a result of habitat loss and fragmentation (see Genetic and Demographic Issues in Conservation Working Group).

Goal 3, Action 1

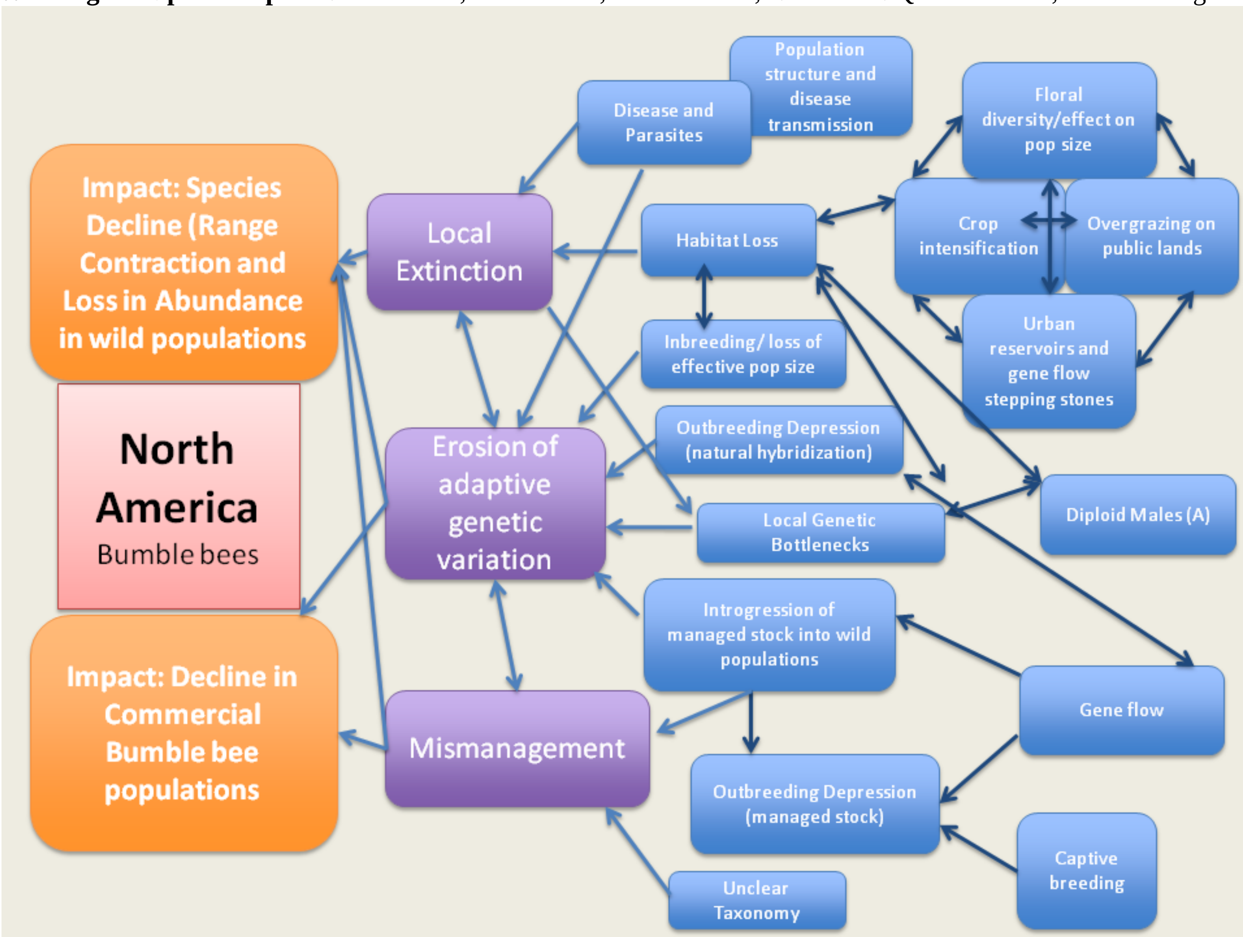
We advocate for the initiation of risk assessments of all North American bumble bees; this assessment must include climate change as a risk factor. We suggest the use of climate change models to predict fragmentation of the habitat and isolation of *Bombus* populations. These types of models do not currently take into account interspecific interactions (e.g., positive and negative, how multispecies systems are changing, and how novel communities are developing), but they should. That is, models need improvement, and can be improved through incorporating knowledge of natural history (see Goal 1, Action 1) and species interactions.

Goal 3, Action 2

We recommend the development and implementation of educational programs and campaigns on impacts of climate change on *Bombus* conservation, targeting the general public and policy makers (see Bombus Education, Outreach and Citizen Science Working Group).

Genetic and Demographic Issues in Conservation Strategies Working Group

Working Group Participants: Jeff Lozier, Shalene Jha, Koicha Goka, J. Javier G. Quezada-Euan, James Strange



Working Group Focus: Identifying needs and potential applications of genetic and demographic work to the conservation of bumble bees.
Links to Other Working Groups: Habitat loss and degradation, Disease and parasites, Climate change

INTRODUCTION

The Genetic and Demographic Issues working group was focused on issues affecting the genetic structure of populations of at-risk species, the identification of taxonomic problems and the effects of immigration and emigration on populations. The primary focus was to identify areas related to systematics, population genetics and demographics that will be problematic for conservation efforts and to generate strategies for dealing with those problems. We also considered areas where a population genetics approach could aid in conservation efforts.

LIST OF IDENTIFIED THREATS

INDIRECT THREATS

I. Taxonomic ambiguity hinders conservation efforts
II. Movement of pollinators outside of their native range
   A. Competitive exclusion
   B. Pathogen and pest transport

i. Loss of adaptive variation
ii. Decline in effective population size
C. Hybridization and genetic introgression
D. Genetic erosion of captive populations
III. Loss of habitat and habitat fragmentation
E. Loss of genetic diversity
F. Isolation of populations leading to reduced gene flow
G. Population bottlenecks
IV. Climate change and other environmental factors

DIRECT THREATS

I. Local and global extinction of wild, native bumble bees
II. Declines in range and abundance
III. Collapse of commercial species in production facilities

IMPACTS OF DIRECT THREATS

I. Decrease in pollinator abundance
II. Increase in cost of pollination services
III. Lower fitness of wild and commercial pollinator populations

THREATS STATEMENTS, GOALS, & ACTIONS

Threat Statement 1: Ambiguity in the identity of taxonomic status and Evolutionary Significant Units (ESUs) make conservation planning difficult.

One of the major challenges in wildlife conservation is the diagnosis of groups of individuals that behave as independent population units and that may thus require separate management strategies. There are several ways in which to think about what constitutes a population, both in terms of ecology (Odum and Odum 1959) and evolution (Waples and Gaggiotti 2006; Hartl 2007). Precise definitions, however, are not always possible in nature, and should not necessarily be problematic as long as intent is clearly described. The ultimate goal of assessing ESUs is to allow management decisions to be based on biologically relevant entities or Management Units (MUs). These MUs may be suspected *a priori* and tested (hypothesis-oriented), or evaluated with no *a priori* expectations (discovery-oriented); both can have important implications for understanding the biology of an organism and for its conservation. The issue of defining bumble bee populations is critical and, at the same time, problematic. Many species are restricted to specific habitat types such as high elevation meadows, prairie, or riparian areas in dry climates. The degree to which demographic (emigration and immigration) and genetic (gene flow and genetic drift) phenomena influence ESUs is not well understood in bumble bees.

Definitions

Management Units (MUs): sets of populations that are currently demographically isolated

Evolutionarily Significant Unit (ESUs): historically isolated sets of populations that together encompass the evolutionary diversity of a taxon (Moritz 1994)

Higher-level ESU: well defined lineages with little or no hybridization, for example species or highly diverged subspecies (Crandall et al. 2000)

Lower-level ESU: lineages which are not easily defined and undergo substantial hybridization and introgression, for example populations (Crandall et al. 2000, Hartl et al. 2007)

Goal 1: Identify High-level ESUs

Candidate cryptic lineages, color morphs, or other taxonomically ambiguous groups must be identified and tested for genetic support for proposed designations. There is still a great deal of taxonomic confusion at the species and, possibly, subspecies level within North American *Bombus*. There is a need to develop approaches to address the taxonomic status of the North American species for which high-level ESU questions exist.

Action 1: Marker Standardization
Description: While many genetic markers are currently available for *Bombus*, often they have been developed and selected for variability in a single species, and thus may bias patterns of genetic diversity when used to genotype congeneric species. We recommend a set of standardized microsatellite markers (20-40) to be used for estimating pedigree relationships and comparing population structure and genetic variation across all North American species. Ideally, a novel set of genetic markers, developed on a pool of species from each subgenus, collected across different geographic regions, should be developed to eliminate ascertainment bias, in particular when comparing genetic diversity. Efforts must be made only to include markers that have low scoring error (e.g., tri- and tetra-nucleotide motifs), and that vary in a stepwise manner (i.e., alleles differ in size only in units of the proper motif, with no obvious indels or imperfect repeats). If the same species are to be genotyped in different laboratories, a set of standard genotypes or positive control allelic ladders should be established so that data sets can be adjusted appropriately prior to synthesis.

- *Responsibility*: This work is will be performed by S. Jha, J. Lozier, J. Strange and others to be identified.
- *Timeline*: 2011-2012.
- *Funding*: NSF/USDA
- *Outcomes expected*: An unbiased set of markers that can be genotyped in North American *Bombus* species.
- *Obstacles*: Cost and obtaining material for research. Although several marker sets exist in the literature, testing them on multiple species is expensive.

Action 2: Developing MLG population pools for species discrimination
Develop a reference genotype set (see Threat Statement 1, Goal 1, Action 1) from multiple individuals (e.g., 20) for each American bumble bee species so that assignment testing (e.g., GENECLASS) or clustering (e.g., STRUCTURE; PCA; DFA) of unknown individuals to species-level can be achieved cheaply and rapidly. This would allow for the assignment of unknown or poorly preserved specimens to be identified. It will also allow for non-destructive sampling of rare or at-risk species in the field for both genetic studies and species identification.

- *Responsibility*: J. Lozier, J. Strange and Mexican counterparts (J. Quezada-Euan)
- *Timeline*: Several years to complete, but several species are currently being tested for feasibility.
- *Funding*: NSF/USDA
- *Outcomes expected*: Methodology for rapid and inexpensive species determination for non-destructive sampling techniques.
- *Obstacles*: Developing the marker sets described in Threat Statement 1, Goal 1, Action 1; however, preliminary assessments are ongoing.

Action 3: Research into sampling requirements for genetic assessments
Genetic studies of *Bombus* species that occur across the eastern U.S., where there are few major barriers to dispersal, suggest that populations of bumble bees are essentially continuous, with low levels of inter-locality genetic differentiation. This has led to the observation that, in general, to sample a large fraction of genetic diversity of these species, it is not necessary to sample large numbers of populations. Furthermore, estimates of allelic richness per site tend to asymptote with samples of ~30 unrelated individuals. Thus, for species where few barriers to gene flow are

expected, it may be sufficient to obtain samples of fewer than 50 workers from a small number of geographically representative samples for estimating species-wide levels of variation. However, in the western U.S. there is some indication that populations are more heavily structured, as might be expected given the montane distributions of many species. In such species, further evaluation is needed for determining what constitutes a representative sample of species-wide genetic diversity, although it stands to reason that genetically distinct populations (see low-level ESUs) should be identified and explicitly included in any MU design. It should be noted that the above discussion applies largely to evaluating genetic diversity, and that alternative study aims will require specific sampling requirements (e.g., estimating numbers of nests and foraging distances, or examining patterns of population structure in particular species of interest).

- *Responsibility*: J. Lozier
- *Timeline*: Long term, with ongoing intermediate goals
- *Funding*: To be determined
- *Outcomes expected*: Recommendations for sample size in genetic assessment of populations for establishing Management Units
- *Obstacle*: Funding necessary to carry out the required work

Action 4: Non-destructive sampling techniques

Assess the effects of non-lethal sampling on bumble bees. Prior studies suggest that removal of a single tarsus from a live bumble bee is sufficient to perform genetic analysis, yet does not cause premature mortality of the bee (Holehouse et al. 2003). Research into evaluation of non-lethal sampling needs to be conducted, ideally under field conditions.

- *Responsibility*: J. Strange and J. Koch.
- *Timeline*: 2011, with work expected to be completed within a year
- *Funding*: J. Strange in house
- *Outcomes expected*: A recommendation for surveying bumble bee populations using non-destructive sampling techniques.
- *Obstacles*: No major obstacles

Action 5: Resolve ambiguous high level ESUs

Several ambiguities have been defined: *B. bifarius*; *B. fervidus*/*B. californicus*; *B. occidentalis/B. terricola; B. ephippiatus/B. wilmattae.* Associated threats include: local extinction of diversity; genetic admixture of maladaptive traits; transport of commercial species; disease, climate and other environmental factors.

- *Responsibility*: The bee genetics research community (examples: Strange, Lozier, Koch; *B. bifarius*; *B. fervidus*/*B. californicus*; *B. occidentalis/B. terricola* in addition to barcoding effort by others ongoing (Packer Lab, York University); Cameron et al. *B. ephippiatus/B. wilmattae*).
- *Timeline*: Species status of *B. occidentalis* and *B. terricola* (Strange) will commence in 2011, with concurrent work on *B. bifarius* (Strange and Koch) while others remain long term goals.
- *Funding*: NSF/USDA
- *Outcomes expected*: Species (subspecies) unit designations. Conservation/management designations will be refined; Impacts of commercial rearing (Threat Statement 2) on genetic integrity of MUs will be understood.
- *Obstacles*: Funding, personnel, and the need to integrate markers that are informative about different processes (Threat Statement 1, Goal 1, Action 1).

Goal 2: Identify Low-level ESUs (i.e., Management Units)
A need exists to identify candidate populations of interest (e.g., disjoint populations on sky islands) and test for demographic independence from main species population body. These populations are at risk from local extinction of diversity; transport of commercial species; disease, climate change and other environmental factors.

Action: Define and locate low-level ESU
Our current knowledge of low-level ESUs is limited to several species although several other species seem to have similar distributional patterns. The current focus should be on *B. balteatus* (investigated by J. Strange), *B. vosnesenskii* (investigated by S. Jha); *B. sylvicola* (TBD).

- *Responsibility*: J. Strange, S. Jha., others
- *Timeline*: Long term (2-5 years)
- *Funding*: NSF/USDA
- *Outcomes expected*: Management unit designations
- *Obstacles*: Funding, personnel and appropriate genetic markers (Threat Statement 1, Goal 1, Action 1)

Threat Statement 2: Movement of pollinators outside of their native range threatens native species
Movement of managed pollinators to meet the needs of modern agriculture has intensified in the past 50 years. Currently, several species (*Apis mellifera*, *B. impatiens*, *Megachile rotundata* and *Osmia lignaria* being the principals) are moved throughout North America with varying levels of regulatory control. The risks of pollinator movement are not new and include competitive exclusion by an invading species (Africanized honey bees) and spread of novel pests and pathogens (honey bee mites, perhaps *N. bombi* and/or RNA viruses). In some cases, the genetic factors are well understood, while, in the case of bumble bees, we are just beginning to understand the genetic consequences of population declines (Cameron et al. 2011). Here we detail several areas where targeted research will illuminate conservation strategies in the future.

Goal 1: Understand the effects of genetic introgression and disease outbreaks on bumble bee population genetics
This issue may prove particularly important for developing commercial pollinators. There is a need to consider both inter and intra specific genetic structure when moving pollinators developed from geographically disparate populations. The impacts of such activities could result in introgression of maladaptive genetic variation or “genetic pollution”. There also needs to be an understanding of the effects of both pandemic outbreaks and localized pathogen spillover events on the genetic structure of bumble bees.

Action 1: ESU identity and issues with hybridization.
Research into potentially existing introgression due to previous movements of pollinators is needed to evaluate this possibility. It has been demonstrated that native and introduced bumble bee species in Japanwill mate and produce hybrid eggs (Tsuchida *et al.* 2010). No research has been done in North America to illuminate the effects of *B. impatiens* movements on native populations or potential hybridization with other species. It is possible to use genetic markers to inform movement and introduction of commercial pollinators (i.e. commercial pollinator genes) outside of clearly defined boundaries of genetically distinct populations. This action addresses the threat of local extinction of diversity; transport of commercial species; disease, climate and other environmental factors.

- *Responsibility*: J. Strange, J. Lozier and S. Jha are identifying ESU in some species.
- *Timeline*: Initial studies in 2011, longer term studies to follow.

- *Funding*: NSF/USDA
- *Outcomes expected*: Identification of ESUs and evaluation of the risk of genetic introgression
- *Obstacles*: Personnel and funding.

Action 2: Associated parasite infection and patterns of genetic variation
As pathogens have been implicated in population declines it is necessary to identify a correlation of individual and population levels of genetic diversity with environmental variables that might affect fitness. By identifying genes under selection or associated with particular traits, we can identify how individual genetic variation correlates with pathogen infection. We can also understand how loss of genetic variation affects a population's ability to respond to pathogens in the environment.

- *Responsibility*: L. Solter, S. Cameron, J. Strange and J. Lozier.
- *Timeline*: This is a long term goal (3-5 years) with potential short term steps related to individual species.
- *Funding*: NIH/NSF/USDA
- *Outcomes expected*: An understanding of how the environment can interact with individual-level genome wide variation in stable and declining species
- *Obstacles*: Need to identify useful candidate species (stable and declining) for development of conservation genomics resources. This goal will require substantial input from bioinformatics specialists, substantial marker development or sequencing costs and substantial labor.

Action 3: Maximizing genetic diversity in rearing
For both the development of new species for commercialization and the captive rearing of at-risk species for reintroductions, it will be necessary to quantify the genetic diversity in captive populations.

Action 3a. Rearing for captive release, and in commercial breeding
An estimation of the minimum genetic diversity in captive populations is necessary for rearing in closed systems. Sex allele diversity must be maintained to manage health productive populations (see Threat Statement 3, Goal 1, Action 3).

- *Responsible party*: J. Strange
- *Timeline:* 2011-2012
- *Funding*: USDA/National Park Service
- *Outcome expected*: Release of captive raised bees for population augmentation
- *Obstacles*: Funding

Action 3b. Genetic monitoring of recovery effort
A list of guidelines for sampling and monitoring reintroduction efforts will be generated so the success of the effort can be quantified.

- *Responsibility*: J. Strange
- *Timeline*: 2011-2012
- *Funding*: USDA/NPS
- *Outcomes expected*: Guidelines for sampling and monitoring
- *Obstacle*: Funding, personnel

Threat Statement 3: Loss of habitat and habitat fragmentation erode genetic diversity

Goal 1: Assess the effects of habitat fragmentation on disturbed populations.
The loss and fragmentation of habitat containing food or nesting resources associated with urbanization or agriculture may affect the ability of workers to efficiently forage and for reproductives to disperse, limiting the acquisition of resources during a colony's life cycle and potentially disrupting gene flow in previously well connected populations. Such patterns may result in smaller colonies, increased population isolation, and the associated problems with inbreeding.

Action 1: Use GIS applications to identify fragmented habitat or areas of potential population isolation
GIS modeling of species distributions can identify areas where recent or ancient fragmentation may have occurred, thus illuminating future study sites. Species distribution models generated from natural history collection data can provide a basis for genetic studies. Further research into fine-scale local movement of individuals within a heterogeneous landscape (i.e., identifying barriers to movement, foraging range, etc.) could also help with landscape management to either remove barriers or enhance movement via habitat stepping stones. The effects of gene flow and population divergence can be retained in a set of populations for a number of generations and may be reflective of ancient or recent population fragmentation. Understanding how naturally isolated populations maintain genetic diversity may inform future management of ESUs.

Action 1a. Prioritize species for study
This sub action is a short term goal and will be accomplished by the IUCN Red List Authority as species are evaluated.

Action 1b. Create GIS models to illustrate areas where population fragmentation is affecting gene flow
This sub-action is long term and the principals are to be decided. The measurable will be measures of the impact of landscape deterioration on gene flow and guidelines to increase connectivity of populations.

Action 2: Effects of landscape-scale habitat fragmentation

Action 2a. Distinguishing historical versus contemporary gene flow
Estimates of migration using genetic markers (indirect estimates of dispersal) can reflect both contemporary (ongoing, ecologically and demographically relevant) and historical levels of gene flow. For example, a species that occurs in a highly fragmented landscape may not regularly exchange migrants with neighboring populations, but in the past (i.e. pre-human alteration of the landscape) population connectivity was high. There is a need to improve population genetic models to take such historical connectivity into account when estimating current levels of migration. This action is long term and will require the identification of responsible parties.

Action 2b. Mechanisms of gene flow (e.g., male vs. female)
Furthermore, identifying the details of gene flow in bumble bee populations (i.e. males versus queens) would help explain the mechanism of population connectivity, and potentially enhance management of landscapes.

- *Responsibility*: J. Strange, S. Jha and S. Rao
- *Timeline*: mid-term (2-4 years)
- *Funding*: NSF/USDA

- *Outcomes expected*: Understanding of bumble bee dispersal, recommendations for habitat connectivity planning
- *Obstacles*: funding, acquiring specimens for study, personnel to perform analyses.

Action 2c. Impacts of landscape barriers/corridors on gene flow/dispersal
Further research into fine-scale local movement of individuals within a heterogeneous landscape (i.e., identifying barriers to movement, foraging range, etc) could also help with landscape management to either remove barriers or enhance movement via habitat stepping stones.

- *Responsibility*: S. Jha
- *Timeline*: mid-term 2-4 years
- *Funding*: NSF/USDA
- *Outcomes expected*: Understanding of bumble bee dispersal, recommendations for habitat connectivity planning
- *Obstacles*: funding

Action 3: Identify the effects of population bottlenecks
In hymenoptera, one of the supposed effects of population bottlenecks is the loss of sex allele diversity through inbreeding. Diploid males are produced due to the single locus sex determination (SLSD) mechanism in haplodiploids, whereby individuals that are heterozygous at the SLSD locus are female, haploids are male, and homozygotes at the SLSD locus are diploid males, which could represent a genetic load upon a species (e.g., diploid male extinction vortex). *For this, and all sub-actions, responsible parties and timelines need to be identified.*

Action 3a. Screen for diploid males across species
Screening for diploid males (ideally early in the colony life-cycle) could be a straightforward way to detect inbreeding in a population.

Action 3b. Identify sex loci and compare population diversity for sex loci
Additionally, using forthcoming genomic data from *Bombus* spp. to identify the SLSD locus and screening this gene region for levels of diversity could be a useful strategy for determining the likelihood of high diploid male production in a population.

Action 3c. Identify viability of diploid males across species
Further, research into the actual genetic load represented by diploid males (e.g., viability, actual frequency in population, product of triploid queens, etc) could reveal whether diploid males are an actual threat to population viability, especially given the apparent temporal variability in diploid male frequencies across generations (Zayed and Packer 2005; Souza et al. 2010).

Action 4: Use estimates of effective population size (N_e) to prioritize species of potential conservation concern
Genetic diversity is a key parameter underlying a population's ability to adapt and survive in the face of environmental change. Small populations may suffer a loss of genetic diversity (at both neutral and functional genes) due to the effects of genetic drift and increased inbreeding, and may thus be more susceptible to extinction. One mechanism to identify potentially threatened populations is to use genetic markers to screen for small effective population sizes. A survey of six bumble bee species has shown that stable species have significantly higher genetic diversity than species undergoing declines. Additional screening of species or populations for genetic

diversity could be used to identify those that have small effective populations and may be susceptible to decline. *For this action responsible parties and timelines need to be identified.*

Threat Statements 4: Climate change and other environmental factors threaten genetic diversity of natural populations

Goal 1: Associate environmental factors/other phenotypes with adaptive/coding polymorphisms

Understanding geographical patterns of lineage diversification through time both within species and among species assemblages can lead to the identification of geographically important areas of diversification (e.g., biogeographic hotspots). These areas of high bumble bee diversity may be important areas of conservation for multiple species that have similar evolutionary histories. Conservation of such areas provides the highest return in conservation effort on a global scale. Using comparative phylogeographic studies across multiple co-occurring species, areas of high refugial genetic diversity can be identified and targeted for refuge designation. These data can also be applied to understanding how species have changed in response to past climates and may respond to future change.

Action 1: Identify phylogeographic hotspots

Phylogeography research is also needed for bumble bee parasites. In the case of pathogen invasions, for example, molecular analysis of samples from the suspected native range and from the invasive range can be used to both test whether an invasion actually occurred and, if so, pinpoint the geographic source and possible routes of introduction. Such methods can then be used to ensure that such pathways are shut down to prevent additional introductions or further spread. It must also be remembered that bumble bees provide a resource for many native parasites, and the survival of these organisms depends on conservation of their hosts.

- *Responsibility*: J. Lozier, J. Strange and S. Cameron, but others need to be identified who can assist with this work.
- *Timeline*: 2011-2015
- *Funding*: NSF
- *Outcome expected*: Identified phylogeographic hot spots for *Bombus* in North America
- *Obstacles*: Funding, personnel and theoretical underpinning for the research

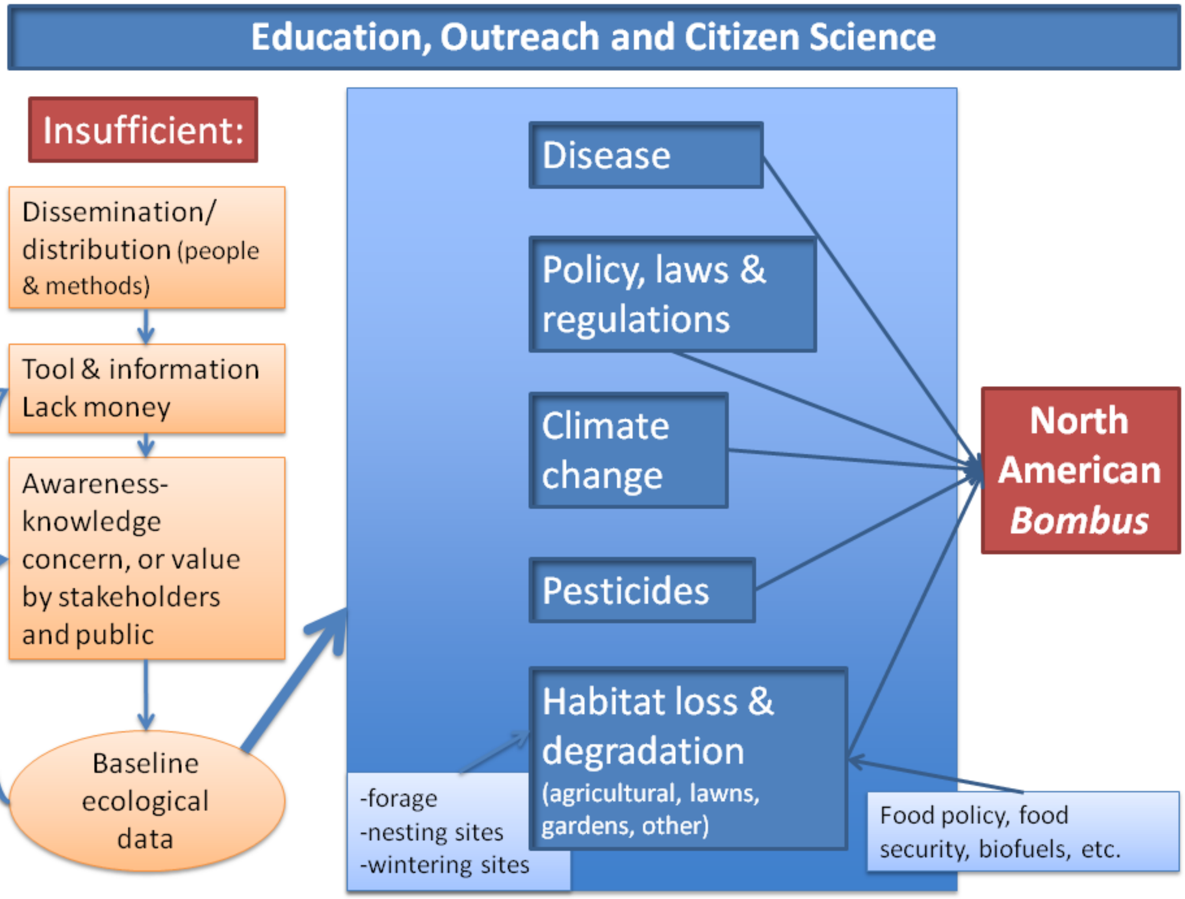
Action 2: Tracing parasite invasion routes

A phylogeographic approach to understanding the coevolution of bumble bees and their native parasite populations will allow a better means of preserving these local interactions and identifying disruptions to these interactions associated with the spread of exotic species.

- *Responsibility*: S. Cameron, J.Lozier, R. Thorp, and H. C. Lim are currently studying the possibility of invasion routes for *Nosema bombi* into North America.
- *Timeline*: Long term (2001-2015) with short term sub-objectives.
- *Funding*: USDA
- *Outcomes expected*: Identified pathways of invasion for parasites and understanding coevolutionary interactions between bumble bee hosts and their parasites
- *Obstacles*: time, funding, required theoretical and practical discussion and the impracticality of sampling all possible areas of refugial diversity**.**

Bombus Education, Outreach and Citizen Science Working Group

Working Group Participants: Marion Ellis, Dave Goulson, Jennifer Hopwood, Gretchen LeBuhn, Randy Morgan, Elizabeth Sellers, Ed Spevak, Larry Stritch, Occasional contributions from Peter Kevan



Working Group Focus: Strategies to increase public knowledge, inform public opinion, and promote public involvement and action by policy makers towards bumble bee conservation, including but not limited to Education and Outreach, Citizen Scientist programs
Links to Other Working Groups: Climate Change and Range Shifts, Diseases and Pests, Habitat Loss and Degradation, Import Issues and Regulations, Diseases and Pests

INTRODUCTION

We believe that education, broadly speaking, is at the heart of many of the issues that the other working groups are discussing. For example, outreach and education are key components to: encouraging people to conserve or restore bumble bee habitat in its many forms; providing disease science information to glasshouse growers about bumble bee escape and disease transfer; providing policy makers and IUCN committees with the necessary background to make informed decisions; and working with agencies or landowners to develop conservation strategies based on population genetics and potential shifts in climate.

LIST OF IDENTIFIED THREATS

We considered threats to be factors that impede the ability of decision makers (local, regional, or national) to understand and address key bumble bee conservation issues, such as habitat loss, genetic consequences of habitat fragmentation, development of policy surrounding movement and disease monitoring of commercial bumble bees, and potential effects of climate change). We suggest that a lack of awareness and appreciation for bumble bees among public and private land managers and government agencies needs to be overcome in order to achieve conservation goals.

I. A lack of awareness of bumble bees, their life cycles and requirements by land managers
II. A lack of economic incentives
III. A lack of tools and information directed to a particular audience (such as how to broadly manage public lands)
IV. The ability to distribute and disseminate tools and information
V. A lack of baseline data is a major underlying factor/threat that impedes the development of tools/best management practices and subsequent actions that address bumble bee conservation.

THREATS STATEMENTS, GOALS, & ACTIONS

Threat Statement 1: The general populace lacks value for and awareness of the need to conserve or contribute to the well-being of bumble bees.

Goal 1: Build a community support base and public awareness of bumble bees that will later allow scientists and conservationists to address threats to bumble bees.

Action 1: Develop a set of key messages and talking points for education, PR and media, etc

- *Responsibility:* Ed Spevak, Jennifer Hopwood, Larry Stritch
- *Timeline:* 2011-2012
- *Funding*: Negligible
- *Outcomes expected*: Key messages represent a set of messages that can be reinforced by a variety of organizations (e.g., Xerces Society, Forest Service, Great Sunflower Project, American Association of Zoos and Aquariums (AZA), American Association of Botanical Gardens and Arboreta (AABGA), American Public Gardens Association (APGA))

  Potential key messages:
  - There are more than 50 species of bumble bees native to North America.
  - Bumble bees are among the most important wild pollinators of many fruit and vegetable crops, and are often more efficient (at the individual bee level) at pollinating certain crops than the non-native honey bee (e.g. tomatoes, blueberries, cranberries, squash, etc.).
  - Many wildflowers depend on bumble bees for pollination.
  - Flowering plants provide pollen and nectar that are critical to healthy bumble bee populations.
  - Many ornamental flowers do not provide food for bees.
  - Bumble bees are affected by many diseases and parasites.
  - Misuse of insecticides may have a negative impact on bumble bees.
  - Bumble bees are great vehicles for teaching young learners about the interconnectedness of living things.
  - Bumble bee populations are declining in many areas and should be included in conservation efforts.

  Note: *It will be desirable to have key statements from other groups – especially statements targeted at specific audiences that we may not have considered.*
- *Obstacles*: None.

Action 2: Identify stakeholders for whom key messages will be important for a consistent message. Educators and land managers should be the initial priority, as these persons can facilitate communication with additional stakeholders. Examples of other stakeholders might include children, conservation biologists, and private citizens.

- *Responsibility:* E. Spevak, J, Hopwood, L. Stritch, D. Goulson, M. Ellis, G. LeBuhn
- *Timeline:* 2011-2012
- *Funding*: Negligible
- *Outcomes expected*: List of individuals, institutions, organizations, NGOs, researchers, policy makers for whom specific messages and methodologies of dissemination will be important. This list will also be organized by region, i.e., local, regional, national, and international, and prioritized for potential impact for various messages.
- *Obstacles*: None

Action 3: Communicate with stakeholder groups with targeted key messages. (e.g. "Yes bees, yes pizza" for grade-schoolers).

- *Responsibility:* All members will need to help and identify key stakeholders for message dissemination
- *Timeline:* We will initiate the development of a communication strategy after completion of key messages. We will brainstorm and consider key modes of dissemination and audiences in the meantime. Time line is flexible and will be initiated Fall of 2011
- *Funding*: Negligible
- *Outcomes expected*: Increased public awareness of bumble bee issues
- *Obstacles*: Time and funding

Action 4: Develop an outreach tool that highlights the direct contributions of bumble bees to food economics, in order to demonstrate the economic value of bumble bee conservation.

- *Responsibility:* E. Spevak, J. Strange, J. Hopwood, Xerces Society, NAPPC Bumble Bee Task Force
- *Timeline:* 2011-2013
- *Funding*: TBD, but may include NAPPC, Saint Louis Zoo, Xerces Society, and member institutions of AZA, AABGA, and APGA
- *Outcomes expected*: Publications, handouts, graphics and signage for use in community and public gardens, zoos, and botanical gardens, and possible Presentations for distribution and dissemination
- *Obstacles*: Time and funding for development and production

Goal 2: Develop new citizen science schemes to engage the public and engender a sense of commitment while potentially collecting valuable data. Utilizing the general public to gather good quality data can feed back in to our understanding of *Bombus* while simultaneously promoting public awareness. Potential models include the Great Sunflower Project, Xerces Society bumble bee monitoring work, Beespotters, the Great Pollinator Project, and Bumble Boosters.

Actions: Offer a photography contest to get people to take photos off bumble bees, with the goal of finding a rare species. Citizens have an incentive to participate, and the contest could provide informative distribution data.

Zoos or other educational institutions could coordinate bumble bee art or essay contests. Similar to University of Nebraska's Bumble Boosters work, institutions could offer nest design contests, or bumble bee garden design contests.

Programs could be offered through libraries, zoos, etc that teach kids how to draw insects (e.g. Lincoln Children's Zoo and University of Nebraska partnership). Teaching young people to value and understand more about insects will lead to adults having higher regard for insects.

Solicit bumble bee photos from Bugguide.net participants to aid in collecting distribution data of common as well as rare species. It would be very important to track where the pictures are taken (exact location and notes on environment: urban vs. suburban vs. natural areas) and when (season, year). This information could provide some insights on distributions in areas highly impacted by humans, as well as phenology changes.

Incorporate master gardeners, master naturalists, and groups/individuals who require outdoor activities in order to complete their certification process, into citizen science programs. These individuals are highly motivated and would likely gather reliable data. They also provide outreach to other groups.

- *Responsibility*: J. Hopwood, E. Spevak, S. Cameron, M. Ellis, M. Berenbaum, D. Goulson, G. LeBuhn, L. Stritch
- *Timeline*: 2011-2013
- *Funding*: TBD
- *Outcomes expected*: Increased enrollment and expansion of programs such as BeeSpotter and the Great Sunflower Project, development of further citizen scientist and education programs through colleges and universities and member institutions of AZA, AABGA, and APGA, as well as organizations, e.g. the Xerces Society.
- *Obstacles*: Time and funding,

Goal 3: Design educational initiatives that incorporate national and state science standards (K-12).

- *Responsibility:* E. Sellers, M. Ellis, E. Spevak, L. Bradshaw (Saint Louis Zoo), NAPPC
- *Timeline:* Ongoing
- *Funding*: TBD
- *Outcomes expected*: Compilation of existing curricula and development of additional curricula modules
- *Obstacles*: implementation within existing school and educational curricula

Goal 4: Actively engage media.

Action: Encourage researchers to contact media and/or submit press releases with new developments in their work. This can have great outreach value. This is a point that needs to be stressed to all researchers and their institutions and organizations. Researchers also need to develop an effective line of dialogue that reduces or simplifies jargon and engages the media and the public.

- *Responsibility:* M. Ellis, G. Lebuhn, D. Goulson, J. Strange
- *Timeline:* 2011-2012
- *Funding*: Negligible

- *Outcomes expected*: A publication of stories on current and future research and discoveries.
- *Obstacles*: Time and media interest.

Threat Statement 2: Lack of tools (species ID guide, habitat assessment plans, habitat management guidelines, baseline data) and incentives, including incentives for landowners to create bumble bee habitat). Lack of funding streams and/or institutional support for long-term monitoring through citizen science projects.

Goal 1: Develop materials/tools to inform policy and landowners.

Action 1: Pull together known best management practices (BMP) for bumble bee habitat conservation and then tailor them to specific audiences. Work with habitat group closely to identify sources of BMP. Work with organizations that develop BMP.

- *Responsibility:* Xerces Society and others
- *Timeline:* 2011-2013
- *Funding*: TBD
- *Outcomes expected*: A document of best management practices that can be used for education, outreach, and extension service education
- *Obstacles*: implementation of BMP courses and follow-up on BMP practices. Funding.

Action 2: Collect and communicate success stories. Develop case studies about pollinators that can be used for policy. For example, research from Gretchen LeBuhn's lab was influential in the city of San Francisco's habitat restoration efforts.

- *Responsibility:* M. Ellis, G. Lebuhn, D. Goulson, J. Hopwood, E. Spevak
- *Timeline:* 2011-2012
- *Funding*: Negligible
- *Outcomes expected*: A publication of stories that can be used in conjunction with key messages for use with the public, education classes and the media.
- *Obstacles*: Funding and capacity.

Action 3: Develop an outreach publication geared towards glasshouses and bumble bee escape/disease transfer.

- *Responsibility:* Ed Spevak, Jamie Strange, NAPPC Bumble Bee Task Force
- *Timeline:* 2011-2013
- *Funding*: NAPPC, Saint Louis Zoo
- *Outcomes expected*: Publication(s) that can be distributed to and through Glasshouse Vegetable Growers Association. It would also be beneficial if these could be distributed through the commercial bumble bee suppliers, e.g., Biobest and Koppert
- *Obstacles*: Possible lack of acceptance by Greenhouse Growers Associations

Action 5: Make sure bumble bees are part of messaging for gardening groups, etc. in urban/suburban landscapes. Communicate with nurseries about promoting plants for bumble bees (e.g. this could be modeled after bumble bee garden kits developed by Xerces, http://www.xerces.org/spring-ahead-with-bumble-bee-garden-kits/).

- *Responsibility:* E. Spevak, J. Strange, J. Hopwood, NAPPC Bumble Bee Task Force
- *Timeline:* 2011-2013

- *Funding*: NAPPC, Saint Louis Zoo, Xerces Society, and others
- *Outcomes expected*: Publication(s) that can be distributed to and through Nurseries and Garden Supply companies, e.g., Home Depot and Lowes. Graphics and Signage that can be used at Nurseries and Garden Supply companies to identify Bumble Bee friendly plants and practices
- *Obstacles*: Time and funding for publication and production and possible lack of acceptance by Nurseries and Garden Supply companies

Goal 2: To find institutional and financial support.
Grants involving citizen science including primary and secondary education components are more fundable. If grants include a large outreach component, they are also more readily fundable. Also, a nationwide effort may be more fundable. Multi-agency input and support from the research community is critical to obtaining agency funding (e.g., Forest Service enter into cost-share agreement with botanic gardens to use scientists to engage volunteers).

- *Responsibility:* E. Spevak, J. Strange, J. Hopwood, L. Stritch, M. Ellis, NAPPC Bumble Bee Task Force
- *Timeline:* 2011-2012
- *Funding*: TBD
- *Outcomes expected*: Survey of AZA, AABGA, and APGA members as to their current involvement and capacity to support and fund conservation, education, and research regarding bumble bees/native bees, list of existing institutional, organization and agency grants for conservation and education grants that focus on pollinators, outreach, education, native wildlife, habitat conservation/restoration and agriculture.
- *Obstacles*: Time and response from institutions and organizations

Goal 3: Increase baseline data. We will explore and promote opportunities to use citizen science as a tool to collect data (such as phenology, distribution and relative abundance, floral visitation information, presence/absence, survey of species).

By generating data we can engage people and raise awareness and concern in participants. These programs are a way to build broad respect for bumble bees.

Action 1: Agree upon standardized monitoring protocols.

- *Responsibility:* G. LeBuhn, S. Cameron, J. Strange, D. Goulson and others
- *Timeline:* 2011-2012
- *Funding*: TBD
- *Outcomes expected*: One or more standardized protocols that can be used by professionals and non-professionals
- *Obstacles*: Individuals and institutions that are able to collect, compile, and analyze data submitted.

Action 2: Coordinate citizen science projects such as bee walks. Using the same protocol as the UK would be preferable and would make a very powerful data set. Explore how to keep volunteers engaged over the long term.

- *Responsibility:* G. LeBuhn, D. Goulson, E. Spevak, Xerces Society
- *Timeline:* 2011-2013
- *Funding*: TBD
- *Outcomes expected*: A Series of Citizen Scientist projects that can be implemented locally, regionally, and nationally and developed as an coordinated effort

- *Obstacles*: Funding and institutional capacity. Individuals and institutions that are able to collect, compile, and analyze data submitted.

Compilation of IUCN Red List Data Sheet Information

Working Group Participants: John Ascher, Sheila Colla, Elaine Evans, Peter Kevan

Working Group Focus: List and prioritize species of North American bumble bees that are being submitted for evaluation
Links to Other Working Groups: Education, Outreach and Citizen Science

INTRODUCTION

We reviewed documents submitted by attendees at the IUCN North American Bumble Bee Conservation Strategy Meeting with distribution information for potentially vulnerable North American bumble bee species. We made a list of all species thought to have declining populations through significant portions of their ranges. We then prioritized this list in terms of both urgency and importance, and practicality in terms of existence of sufficient information. Red List Assessment Sheets were created for all species of concern. Data present at the meeting were compiled for each species. Potential assessors and contributors of additional data were identified. We also confirmed commitment with potential assessors and data contributors who were present at the meeting. We recommend that each assessment be made available to members of this group and other relevant individuals at large for comments and review before submission. National Biological Information Infrastructure (NBII) will create an online interface for the attendees of the IUCN North American Bumble Bee Conservation Strategy Meeting to have access to Assessment sheets for review. After this, these documents will be made available to a wider audience. The goal of this comment and review period is to ensure accuracy of data in an appropriate global context included in the assessments.

Species for which there is currently sufficient information to assess population:
B. occidentalis
Needs summarized, distribution data from Canada and western U.S. This information is available, needs to be compiled.
Possible assessors: Jamie Strange, Jonathan Koch, Michael Otterstatter, Sheila Colla, Robbin Thorp, Elaine Evans, Sarina Jepsen
Possible data providers: Jamie Strange, Jonathan Koch, Michael Otterstatter, Sheila Colla, Robbin Thorp, Elaine Evans, David Inouye, Robin Owen, Ralph Carter, John Ascher, Sarina Jepsen
Goal for submission date: March 2011

B. terricola
Needs summarized, distribution data from Canada. This information is available, needs to be compiled.
Possible assessors: Sheila Colla, John Ascher, Elaine Evans, Jeff Lozier, Sydney Cameron, Sarina Jepsen
Possible data providers: Michael Otterstatter, Sheila Colla, Elaine Evans, Robin Owen, Ralph Carter, Jeff Lozier, Sydney Cameron, John Ascher, Sam Droege, Sarina Jepsen
Goal for submission date: June 2011

B. pensylvanicus
Needs summarized distribution information with specific distribution information. Map of distribution.
Possible assessors: Jeff Lozier, Sydney Cameron, Sheila Colla, John Ascher
Possible data providers: Neal Williams, Jeff Lozier, Sydney Cameron, John Ascher, Mike Arduser, Glenn Hall, Sam Droege

Species for which population information has not been compiled
Higher priority
B. variabilis
**B. ashtoni*

B. suckleyi
Possible assessor: John Ascher, Sheila Colla
Possible data contributors: John Ascher, Cory Sheffield, Elaine Evans, Mike Arduser, Sam Droege and others.

**B. sonorous* (a subspecies of *B. pensylvanicus)*
Possible assessor: Robbin Thorp
Possible data contributors: UC collections, Doug Yanega, Byron Love, Terry Griswold

B. haueri
B. macgregori
B. trinominatus
Possible assessors: Ricardo Ayala or someone he recommends, Gabriella Chavarria
Possible data providers: UC collection, Doug Yanega, John Ascher, Paul Williams, Ricardo Ayala, Rémy Vandame, Carlos Vergara,

Lower priority
B. insularis
**B. fernaldae*
Possible assessors: Sheila Colla, Cory Sheffield
Possible data contributors: Paul Williams, John Ascher, Sheila Colla, Cory Sheffield

B. fraternus
Possible assessors: Elaine Evans
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**B. californicus*
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**B. fervidus*
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*Additional problem: taxonomy needs to be resolved
For all species, either note BugGuide record or lack thereof.

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