TINY BUT CRUCIAL: WHY BEE POLLINATION MUST BE CONSERVED FOR AGRICULTURAL PURPOSES

BY KELLEE BYARD

Why should humans and governments care about bees, and why should they be protected? A disturbing trend is occurring worldwide: many bee populations are in decline or are experiencing negative effects. This phenomena can be attributed to climate change and human activity. Globally, this decrease in population is resulting in a decline in species' richness and diversity. Many scientific studies focus on honeybees (*apis*), because of their commercial use in pollinating crops (Carreck and Williams, 1998) and bumblebees (*bombus*), because of their importance in pollinating their natural ecosystems and crops in the same area (Memmott et al., 2004; Cameron et al., 2011). Research indicates that human interference and climate change are negatively affecting honeybee and bumblebee populations worldwide and likely will continue to do so in the future. Consequently, ecosystem services, specifically pollination, that are provided by these bees and others will be negatively affected in various ways.

Over the last fifty years, the species' richness of bees and other wild pollinators has decreased (Goulson, Nicholls, Botias, and Rotheray 2015), leading to various consequences. There was a 25% loss in European bee colonies between 1985 and 2005 and a 59% loss in North American bee colonies between 1947 and 2005 (Potts et al. 2009; Bartomeusa et al. 2013; Engelsdorp et al., 2008). Because bee diversity has decreased in Europe and North America, it can be reasonably inferred that decline is occurring globally. Yet, many people are not aware that insect species are endangered, and this applies to bees, too. This lack of awareness ultimately leads to bees being

poorly protected (Winfree, 2010). Negative effects on pollination services should be expected as bee populations decrease, and this will result in economic losses in agriculture worldwide. Because the conservation of bees is a necessity to food crop production for humans, there should be an emphasis on agricultural conservation.

Human Interference: Negative Results

There are multiple ways human activity is negatively affecting bee populations. Species' richness amongst bumblebees is declining in Europe, North America, South America, China, and Japan (Goulson et al., 2008; Williams and Osborne, 2009; Williams et al., 2014; Schmid-Hempel et al., 2013; Xie et al. 2008; Matsumura et al. 2004). This can be attributed to agriculture intensification and the introduction of new diseases and parasites to bees without the proper coevolution for defense. As the human population increases, so will the need for food, which will cause an increase in agricultural production. Intensifying agriculture is likely to have several harmful effects on bumblebees, including a decline in bumblebees' preferred natural forage plants, loss of habitat, and less bee-friendly crops being planted that produced nitrogen for the soil, such as legumes, due to a rise in fertilizers (Goulson 2003, Goulson, Lye and Darvill 2008). Agriculture intensification leads to the destruction of bees' habitats, inevitably destroying or reducing their food source and reducing their fitness.

Another way in which human activity is negatively affecting bee populations is pesticides. These chemicals have harmful effects on bee populations both directly and indirectly. Increased pesticide exposure and the loss of preferential foods will lead to food stress, which results in weakened immune and detox systems. This renders the bees more susceptible to possible parasites or disease (Goulson, Nicholls, Botias, and Rotheray, 2015). In North America, wild bumblebees are showing decline due to disease, like *Nosema bombi*, due to imported commercial bumblebees from Europe (Evans et al., 2008). The introduction of pathogen-linked disease will result in reduced fitness and fecundity in bumblebees, and the spread of pathogens will increase as commercial bumblebees are traded, likely causing a steeper decline in their population (Rutrecht and Brown, 2008; Goulson and Hughes, 2015). So, although disease and parasites are natural environmental challenges to bumblebees, they are being spread to new areas due to the commercial trade of bees by humans to meet worldwide demands for agriculture. Since pesticides are weakening bee immune systems, these new

diseases and parasites are even more dangerous to native bees. If disease and parasites continue to proliferate and infect hosts in widened ranges, bee populations worldwide will experience debilitating effects.

Climate Change Effects

Increasing global temperatures are expected to have negative impacts on bumblebee and honeybee populations. Research anticipates that increasing temperatures will occur and cause extreme weather events, like drought, which will affect plant-pollinator interactions (Kjøhl et al., 2011). Increased temperatures also will affect the distribution of species (Kerr et al., 2015) and their phenology (Hegland et al., 2009; Bartomeus et al., 2013). Pollinator services will likely be negatively impacted due to temperature-induced changes in diurnal activity and search behavior (Corbet et al., 1993; Willmer and Stone, 1997). Honeybee foraging activity is more sensitive to ambient temperature change than bumblebee foraging activity; therefore, Brysting et al. suggests that honeybee pollination in crop production may suffer worse consequences due to climate change than bumblebees (2017). Increases in temperature will reconfigure bee behavior and distribution in a way harmful for their abundance and their pollination services.

Furthermore, the geographic distribution and local abundance of plants and pollinators are being affected by climate change, resulting in temporal mismatch due to earlier flowering by plants in the last twenty to fifty years (Hegland et al., 2009; Fitter and Fitter, 2002). Bees are important pollinators, and it can be inferred that incongruity between flowering plants and bee phenology will result in less available food for bees. This may end in the rapid evolution of bees in order to compensate for the change in the plant-pollinator relationship. This will occur at a great fitness consequence (Skelly et al. 2007). Consequently, these great fitness costs could lead to bee population decline. Climate change may alter the life cycle of bee populations in temperate climates, causing their breeding season to be prolonged and periods of nutritional intake to decrease. Parasites also may benefit from prolonged breeding periods and proliferate (Grünewald, 2010). Lack of food and parasitic increases will be detrimental to bees.

Pollination Decrease and Economic Importance

Bee pollination will experience adverse effects as a result of honeybee and bumblebee population declines. Pollination services provided by general

pollinating organisms are valued globally at $215 billion in food production (Gallai, Salles, Settele J, and Vaissière BE 2009), and 70% of the 124 crops used for human consumption are dependent on insect pollinators (Gallai et al., p. 811, 2009). Wild pollinators, particularly bees, contribute significantly to the pollination of a multitude of crops (Kremen et al. 2002). An assumption can be made that bees contribute significantly to the pollination of crops for human consumption and comprise a bulk of these economic benefits. This indicates how negative effects on bee populations will cause negative economic effects. Studies suggest that the European Union will experience a decline in agricultural revenue due to declining pollinators. Loss of honeybees is associated with a decrease in crop production (Bauer and Wing, 2010), and it is clear both honeybee and wild bee abundance are declining or at risk (Biesmeijer et al., 2006; Olroyd, 2007). If conservation of bees, especially commercial bees, does not become a priority it is likely that the economies of countries with large amounts of agriculture will experience monetary losses. The importance of wild bees, like bumblebees, to crop production and economic health cannot be ignored.

Conservation of Bees in Agriculture

Humans rely on bumblebees and honeybees to pollinate crops for human consumption, so a significant mode of conservation to be considered is those in agricultural contexts. As human populations continue to increase, so will the need to cultivate food crops, and it has already been asserted that insect pollinators, particularly bees, are important in this process. Agricultural restoration programs that protect common species, such as honeybees and bumblebees, may be one of the most effective conservation efforts that protect ecosystem services, though they may not conserve biodiversity (Kleijin et al. 2006). Agricultural conservation programs already have significant funding, whereas other nonagricultural programs lack significant amounts of funds. Also, in regard to protecting bees and their commercial pollination services, agricultural-focused programs are most relevant. Agricultural systems may even provide habitats for bee species (Winfree, 2010). One method of agricultural restoration is organic farming; incorporating organic farming into conventional farm fields can provide more food resources to sustain higher commercial pollinator species' richness. So, despite organic farming still occupying the natural habitats for wild bees, it may allow for a greater abundance of food resources, and may be more beneficial for commercial bees. Agricultural landscapes that utilize organic farming benefit bees by using fewer insecticides that result in bee mortality, and there is higher flower cover and species' richness than conventional fields (Holzschuh,

Steffan-Dewenter, Tscharntke, 2008). Unfortunately, organic farming may not preserve the most biodiversity in wild pollinators, but it is an important mode of conservation to consider to maintain the necessary bee abundance for pollination and in the natural ecosystems surrounding agricultural fields.

Implications

Researchers face several challenges when evaluating the effects of climate change or human activity on bee populations. One study reveals that the understanding of interactions between environmental drivers on bees is limited, and these interactions have complex, ambiguous, and overall not well-researched results (Gonzalez-Varo et al., 2013). Another issue is that in order to analyze data on bee pollination and populations, long-term monitoring systems need to be put into effect. Most of these systems were not established until after the recognition of their necessity during the International Convention on Biological Diversity in 1993. The systems were incorporated after 168 countries agreed on the terms at the International Convention, and now, nearly twenty-five years later, long-term data series can be evaluated (Winfree 2010). Despite lack of long-term data, scientists can draw conclusions from data that currently exists. From the existing data it is evident that bee populations and pollination services are experiencing harmful effects due to human activity and climate change.

Conclusion

Bees are suffering negative consequences from human interference and the anthropogenic changes in global climate. Agriculture intensification due to the increase in human population, proliferation of disease and parasites, and discrepancies between bees and habitat, plants, and pollination times are all contributors to declining bee populations and their pollination services. Species richness is in decline as well as populations, so pollination services are being detrimentally affected. This paper mainly explores the effects on honeybees and bumblebees for the purpose of their abundance and relevance in agriculture, but many wild bee species are also being affected. Wild bees should also be considered in bee conservation because they contribute copious amount of pollination to crops as an ecosystem service (Winfree, 2007). Since honeybees and bumblebees are essential to agriculture cultivation, conservation efforts should focus on agriculture restoration programs. Yet, in order for conservation programs to be fully effective, there must be improved information flow between countries' monitoring programs and between scientists, farmers, beekeepers, and land

managers (Grünewald, 2010). With all the people involved in bee conservation having the maximum information from multiple sources, a unified and cooperative approach to bee conservation can be achieved.

Works Cited

Bartomeusa I, Ascherc JS, Gibbse J, Danforthe BN, Wagnerf DL, M. Hedtkee SM, and Winfree R (2013) Historical changes in northeastern US bee pollinators related to shared ecological traits. PNAS *110*: 4656-4660

Goulson D, Nicholls E, Botias C, Rotheray EL (2015) Bee declines driven by combined
stress from parasites, pesticides, and lack of flowers. Science *347*

Brysting AK, Nielsen A, Reitan T, Rinvoll AW (2017) Effects of competition and climate on a crop pollinator community. Agriculture, Ecosystems, and Environment *246*: 253-260.

Cameron SA, Cordes N, Griswold TL, Koch JB, Lozier JD, Solter LF, Strange JP (2011) Patterns of widespread decline in North American bumble bees. PNAS *108*: 662-667

Gallai N, Salles JM, Settele J, Vaissière BE (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecol. Econ. *68*: 810–821

Rader R, Reilly J, Bartomeus I, Winfree R. (2013) Native bees buffer the negative impact of climate warming on honey bee pollination of watermelon crops. Global Change Biology *19*: 3103-3110

Winfree R (2010) The conservation and restoration of wild bees. Annals of the New York Academy of Sciences *1195*: 169-197

Goulson D (2003) Bumblebees: their Behavior and Ecology. Oxford University Press. New York.

Goulson D, Lye GC, Darvill B (2008) Decline and conservation of bumble bees. Annu. Rev. Entomol. *53*:191–208.

Carvell C, David RB, Simon SM (2006) Declines in forage availability for bumblebees at a national scale. Biol. Conservation *132*: 481–489.

Kleijn D, Raemakers I (2008) A retrospective analysis of pollen host plant use by stable and declining bumblebee species. Ecology *89*: 1811–1823.

Kleijn D et al. (2006) Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecol. Lett. *9*: 243–254.

Holzschuh A, Steffan-Dewenter I, Tscharntke T (2008) Agricultural landscapes with organic crops support higher pollinator diversity. Oikos *117*: 354–361.

Palmer M, et al. (2004) Ecology for a crowded planet. Science. *304*: 1251–1252.
Steffan-Dewenter I, Potts SG, Packer L (2005) Pollinator diversity and crop pollination services are at risk. Trends Ecol. Evol. *20*: 651–652.
Carreck N, Williams I (1998) The economic value of bees in the UK. Bee World *79*: 115-123
J. Memmott NM, Waser MV (2004) Price Tolerance of pollination networks to species extinctions Proc. R. Soc. Lond., B, Biol. Sci. *271*: 2605-2611
Cameron SA, Lozier JD, Strange JP, Koch JB, Cordes N, Solter LF, Griswold TL (2011) Patterns of widespread decline in North American bumble bees Proc. Natl. Acad. Sci. U. S. A., *108*: 662-667
van Engelsdorp D, Hayes Jr. J, Underwood RM, Pettis J (2008) A survey of honey bee colony losses in the U.S., Fall 2007 to Spring 2008. PLOS ONE *3*: 1-6
Williams PH, Osborne JL (2009) Bumblebee vulnerability and conservation world-wide. Apidologie *40*: 367–387
Williams PH, Thorp RW, Richardson LL, Colla SR, (2014) Bumble Bees of North America: An Identification Guide. Princeton, NJ: Princeton University Press.
Schmid-Hempel R, Eckhardt M, Goulson D, Heinzmann D, Lange C, Plischuk S, Escudero LR, Salathé R, Scriven JJ, Schmid-Hempel P (2013) The invasion of southern South America by imported bumblebees and associated parasites. J. Anim. Ecol. *83*: 823–837
Xie Z, Williams PH, Tang Y (2008) The effect of grazing on bumblebees in the high rangelands of the eastern Tibetan Plateau of Sichuan. J. Insect Conserv. *12*: 695–703
Matsumura C, Yokoyama J, Washitani I (2004) Invasion status and potential ecological impacts of an invasive alien bumblebee, *Bombus terrestris L*. (Hymenoptera: Apidae) naturalized in Southern Hokkaido, Japan. Glob. Environ. Res. *8*: 51–66
Rutrecht ST, Brown MJF (2008) The life-history impact and implications of multiple parasites for bumble bee queens. Int. J. Parasitol. *38*: 799– 808.
Goulson D, Hughes WOH (2015) Mitigating the anthropogenic spread of bee parasites to protect wild pollinators. Biol. Conserv. 191: 10-19.
Kerr JT, Pindar A, Galpern P, Packer L, Potts SG, Roberts SM, Rasmont P, Schweiger O, Colla SR, Richardson LL, Wagner DL, Gall LF, Sikes DS, Pantoja A (2015) Climate change impacts on bumblebees converge across continents. Science *349*: 177-180
Hegland SJ, Nielsen A, Lazaro A, Bjerknes AL, Totland O (2009) How does climate warming affect plant-pollinator interactions? Ecol. Lett. *12*:184-195

Corbet SA, Fussell M, Ake R, Fraser A, Gunson C, Savage A, Smith K (1993) Temperature and the pollinating activity of social bees Ecol. Entomol. *18*: 17-30
Willmer P, Stone G (1997) Temperature and water relations in desert bees. Journal of Thermal Biology *22*: 453-465
Fitter AH, Fitter RSR (2002). Rapid changes in flowering time in British plants. Science *296*: 1689–1691.
Skelly DK., Joseph LN, Possingham HP, Freidenburg LK, Farrugia, TJ, Kinnison, M.T. et al. (2007). Evolutionary responses to climate change. Conserv. Biol., *21*: 1353–1355.
Klein AM, Vaissière BE, Cane JH, Steffan-Dewenter I, Cunnigham SA, Kremen C, Tscharntke T (2007) Importance of pollinators in changing landscapes for world crops
Proceedings of the Royal Society *274*: 303-313
Kremen C, Williams NM, Thorp RW (2002) Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences USA *99*: 16812-16816
Bauer DM, Wing, IS (2010). Economic consequences of pollinator declines: A synthesis. Agr. Resource Econ. Rev. *39*: 368-383.
Biesmeijer, JC, Roberts SPM, Reemer M, Ohlemüller R, Edwards M, Peeters T, Schaffers AP, Potts SG, Kleukers R, Thomas CD, Settele J, Kunin WE (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science *313*: 251–353.
Olroyd BP (2007) What's killing American honey bee? PLoS Biology *5*: 1195-1199
Grünewald B (2010) Is Pollination at Risk? Current Threats to and Conservation of Bees. Gaia. *19*: 61-67
Leonhard SD, Gallai N, Garibaldi LA, Michael Kuhlmann M, Kleina AM (2013) Economic gain, stability of pollination and bee diversity decrease from southern to northern Europe. Basic and Applied Ecology *14*: 461-471
Gonzalez-Varo JP, Biesmeijer JC, Bommarco R, Potts SG, Schweiger O, Smith HG, Steffan-Dewenter I, Szentgyorgyi H, Woyciechowski M, Vila M (2013) Combined effects of global change pressures on animal-mediated pollination Trends Ecol. Evol. *28*: 524-530
Evans, E. Thorp R, Jepsen S, Black SH (2008) Status review of three formerly common species of bumble bee in the subgenus Bombus. Xerces Society for Invertebrate Conservation
Winfree R, Williams NM, Dushoff J, Kremen C (2007) Native bees provide insurance against ongoing honey bee losses. Ecol. Lett. *10*: 1105–1113.