The disappearing act: Policy proposals surrounding neonicotinoid use and pollinator populations

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ABSTRACT

Honeybees help provide vital services to farmers and their crops and wild plants in the form of pollination and spreading of seeds. The use of systemic insecticides in agriculture, which include but is not limited to neonicotinoids, has been shown to harm honeybees and other native pollinators due to the presence of the neonicotinoids and residuals in pollen and nectar. This paper highlights the possible policies surrounding the continued use of neonicotinoids weighed against policies that would aim to ban their use in favor of pollinator populations. Two policy recommendations are made at the conclusion. One, where neonicotinoid use is banned in the United States, and the second advocates for a reduction of the use of neonicotinoids on flowering crops and private flowers.

THE POLICY ISSUE

In the past decade several states in the United States have been looking to replicate work that the European Union has done to try to halt and reverse the loss of pollinators worldwide, namely, honeybees.[1] In their effort to protect pollinators the European Union highlighted the use of a subclass of pesticides called Neonicotinoids (neonics or NNIs) that was used in a large number of agricultural pesticides and insecticides. Neonicotinoids are active substances that can be found naturally or sprayed on with chemicals, they are used in plant products to control harmful insects. The name neonicotinoid literally means "new nicotine-like insecticides". They are chemically similar to nicotine which has its own anti-insect properties that naturally occur in tobacco plants.

Neonicotinoids are widely used and promoted because they are typically the cheapest and most effective insecticide available for farmers. They were invented in the late 1980's and were refined and popularized in the 1990's. The most widely used insecticide on Earth is a neonicotinoid called imidacloprid. They have gained popularity because they are very adept at killing insects but are not as toxic to birds and mammals that ingest them. Neonicotinoids are also popular because they can be placed on most commercial field crops including, but not limited to: corn, soybeans, cotton, rice, and flowering plants.

Neonicotinoids are systemic pesticides. The way that they work to kill insects is to block specific neurons in insects that are not present in vertebrates like humans and livestock. Neonicotinoids are particularly adept at killing insects that feed on the plant or its roots or those that live in the soil of the field, but the application coats the entire plant

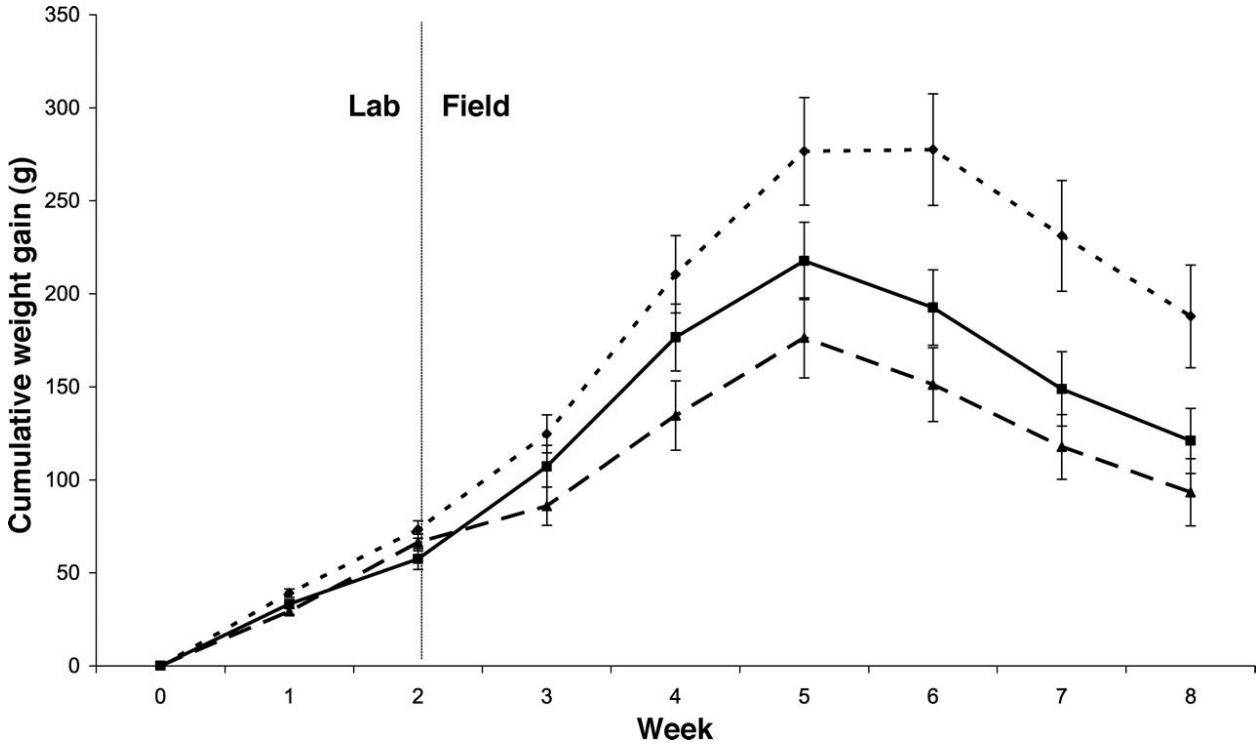
leading to the flowers and pollen to also be contaminated. Unlike contact pesticides, which remain on the surface of the treated parts of plants mainly leaves and stems, systemic pesticides are taken up by the plant and transported throughout the plant imbedding the pesticide into leaves, flowers, roots and stems, as well as pollen and nectar.[2] Thus, pesticide using neonicotinoids imposes risks to the health of native pollinators.

The current empirical research focuses largely on how neonicotinoids impact the health of bees when it is known that they are being impacted. This information can be used to gain insight into the disease that is referred to as colony collapse disorder (CCD) also referred to as: disappearing disease, spring dwindle, May disease, autumn collapse, and fall dwindle disease. A large amount of concerns surrounding the loss of pollinators are surrounding the cause of colony collapse disorder because the cause is unknown and is likely several factors that are compounding. The reason the colony collapse is especially concerning aside from the fact that the cause and treatments are unknown is the surrounding factors make screening almost impossible. The hallmarks of colony collapse disorder include leaving behind a healthy queen bee with plenty of food stores and a healthy brood. The effects of neonicotinoids are speculated to make an impact in the prevalence of colony collapse along with disease and loss of habitat. It has been shown that the presence of neonicotinoids is not evident in all of the remaining hives that have been impacted by colony collapse disorder.[8]

The prevailing empirical research that is being conducted surrounding the use of neonicotinoids focuses on the weight and relative health of the pollinators in areas that are and are not being impacted by the use of neonicotinoids. In the following graph the

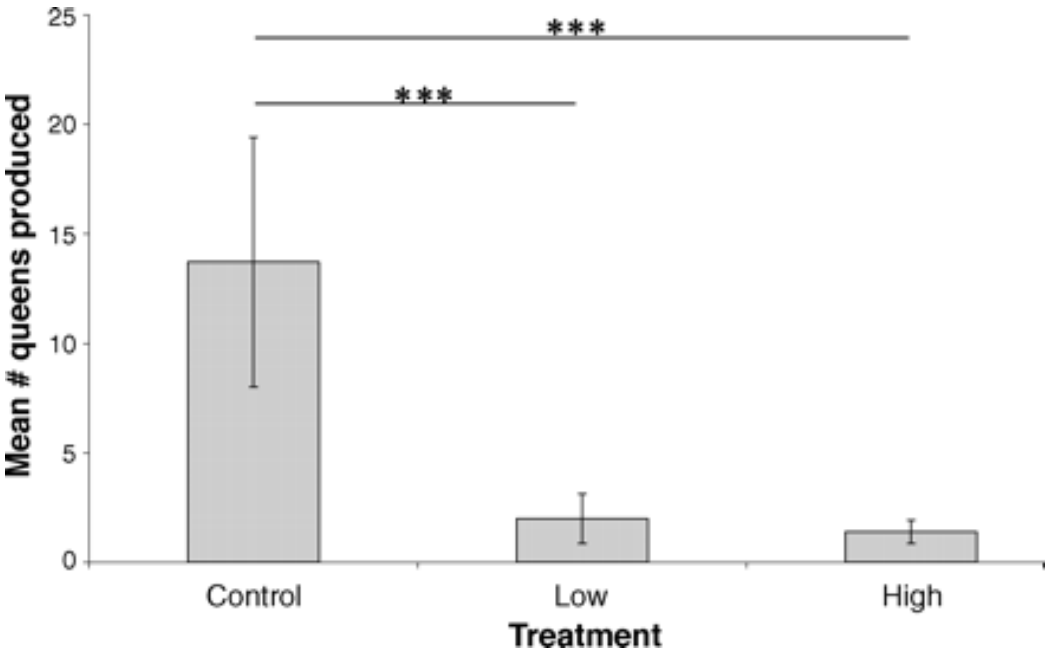
difference between bumble bees that are in a controlled area with low and moderate levels of neonicotinoid use can clearly be seen to have a lower weight than those who are in a controlled environment with similar food and water levels but without the use of neonicotinoids in native bumble bees. In this graph the dotted line on the top of the figure shows the weight of bumble bees that have not been treated with any amount of neonicotinoids. The solid line in the middle of the graph shows bumble bee weights that have treated with a weekly low dose of neonicotinoids. The dashed line at the bottom of the graph shows bumble bee weights that have treated with a weekly high dose of neonicotinoids.[9] The reason this graph is important is that the top line shows approximately healthy weight for bumble bees, less weight means weaker bees who are more susceptible to both disease and less likely to be able to survive inclement weather and food droughts.

Figure 1[9] Bumble bee weight



These differences in weight can also impact the future of the colony if all of the bumble bees survive the season. Bumble bees are annual insects with only the queen surviving the winter into the next spring to refill the hive. For a new hive to form a queen has to lay a special egg to make another new queen that can go on to make a new hive or replace the queen of the current hive. A low weight queen is less likely to survive the winter and have fewer, weaker offspring in the following year. In the same study that provided the above graph the researchers studied the number of new queens that were produced by the same three groups in the first study. In this bar graph the bumble bees with no neonicotinoid treatment is in the far right with low and high amount of neonicotinoid treatment following from right to left.

Figure 2[9] Bumble bee queen birth rate



It can be seen in this graph that the control group without the presence of neonicotinoids is much better suited off to grow in population and be able to reproduce their numbers incase of a queen death. The ability to reproduce is critical for bumble

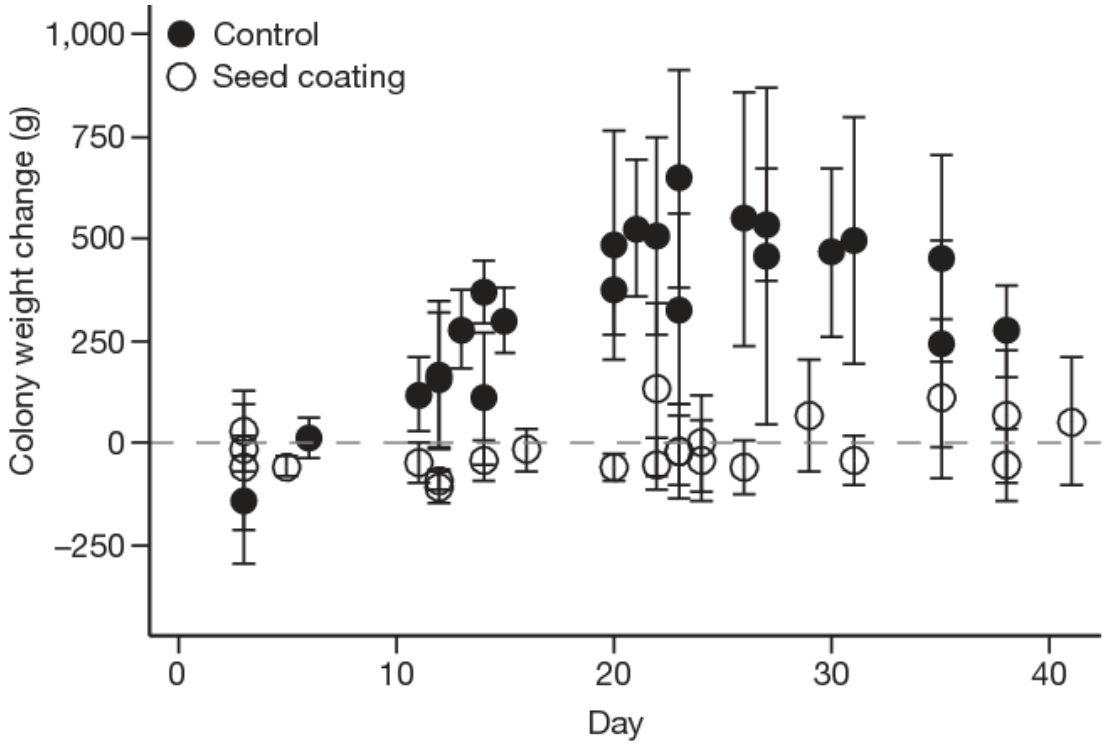
bee population sustainability. With an observed queen birth rate of 2.0 and 1.4 for the low and high neonicotinoid level populations they will be unlikely to be able to even maintain populations due to outside influences unrelated to neonicotinoids. Combined with lower growth rates these new queen birth rates could quickly remove native bumble bee population in areas with neonicotinoids.[9]

Not all researchers and papers agree that neonicotinoids are especially dangerous to honeybees and native pollinators. A 2004 study published in Crop Protection studied the effect that specific kinds of neonicotinoids had on the mortality rate of honeybees in a laboratory setting. Their finding was that the substituted neonicotinoids were less toxic to honeybees by more than two orders of magnitude as compared to the typical method for application used in laboratory studies where the insecticides were topically applied. The researchers also found that in cage studies where acetamiprid and triflumizole, which are both neonicotinoids, were applied in combination to alfalfa at the maximum recommended rate, no bee mortality was detected, suggesting that acetamiprid and triflumizole alone are safe to honeybees and would likely be safe for other pollinators.[11]

In a similar study conducted in 2015 researchers in southern Sweden wanted to study the impact that plants with seeds that were treated with neonicotinoids had on local wild bee populations. The method of coating seeds is advanced as a safer alternative so that the neonicotinoids are not being applied across and area and are instead built into the plant in a way. The researchers took weights of the bees in an uncontrolled field study and compared them to a controlled population without the presence of neonicotinoids. Their results are shown in the graph below.[10] An important

piece of information to note with this study is that it shows that while healthy non-treated bees were gaining weight, the hives with bees fed on treated plants were actually losing weight in the same time period

Figure 3[10] Bee weight related to seed coating

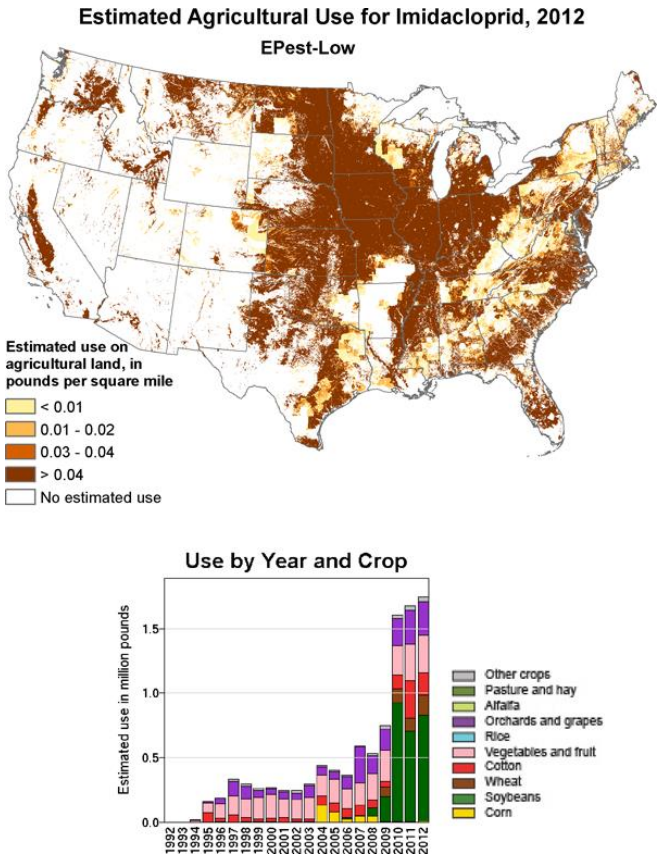


POLICY

There are currently laws in place in the European Union to limit the use across the board of neonicotinoids. In 2013, the Commission of the European Union severely restricted the use of plant protection products in the form of both aerosol pesticides and in treated seeds containing three neonicotinoids. Those three are: clothianidin, imidacloprid and thiamethoxam. They did this order to protect both honeybees and native pollinators inside the union. The European Union identified certain crops high acute risks for bees from plant protection products containing those three neonicotinoids. The three were selected because they are representative of over 80%

of the market share while also being more dangerous than the other types of neonicotinoids. According to the European Union the measure was based on a risk assessment of the European Food Safety Authority (EFSA) in 2012. It prohibits the use of the three neonicotinoids mentioned earlier in crops that they deemed to be bee-attractive these included: most fruits, oilseed rape, and sunflowers. There were written exceptions of the uses in greenhouses, they could be used in the treatment of some crops after flowering, and of winter cereals. At the same time, the applicants of the three substances were obliged to provide further data what is called by the European Food Safety Authority as "confirmatory information" for each of their substances in order to confirm the safety of the uses still allowed in the restricted settings. Of these three the pesticide deemed the most detrimental by the European Food Safety Authority to pollinator health is imidacloprid that was mentioned earlier in the paper. This is important and unfortunate for American pollinating insects because imidacloprid is one of the most widely used insecticides in the country and is the most popular worldwide. The following image using information from 2012 shows just how prevalent its use was in the United States.

Figure 4 Via USGS.gov Imidacloprid use in the US



Starting in 2013 the United States house of representatives has received three bills and proposals calling for bans and reforms on the use of neonicotinoids. More actions were taken by the Environmental Protection agency in May of 2019 that revoked approval for a dozen pesticides containing clothianidin and thiamethoxam. This was a part of a legal settlement against those two.[3] They did this in part due to the concerns that these specific insecticides were causing a disproportionate amount of harm to the native populations of insects. These first steps are critical when drafting new policy. With a heavy emphasis on climate and environmental change in the current presidential race it will be increasing likely that a federal mandate on the use of neonicotinoids will

be introduced in the house or by executive action in the event of a democratic candidate taking office. Both sides of the argument need to be taken into consideration to make an informed decision that can help both farmers trying to make a healthy crop and the health of pollinators.

ALTERNATIVES CONSIDERED

The prevailing literature on the subject has a heavy implication that the banning of neonicotinoids will lead to an increase in pollinator health and numbers in the areas with extensive use of the insecticide. On the subject of neonicotinoids there are only two options for policy ban the use, or continue allowing the use. There are other options for insecticide and pesticide use that do not fall under the label of neonicotinoids. A study conducted in France in 2019 identified 152 authorized uses of neonicotinoids in France, which was encompassing of 120 crops that suffered from 279 pest insect species. What the researchers found was that there was an effective alternative to neonicotinoid use that was available in 96% of the 2968 case studies analyzed from the literature. These cases included single combinations of one alternative pest control method or product, or one target crop plant, or one target pest insect. The most common alternative to neonicotinoids that was found in 89% of cases that the researchers studied was the use of another chemical insecticide. In the cases they looked at, it was mostly pyrethroids, which have been shown to be dramatically less lethal to bees than neonicotinoids.[12] However, in 78% of cases, at least one non-chemical alternative method could replace neonicotinoids. The relevance of non-chemical alternatives to neonicotinoids depends on pest feeding habits. Insects that feed on the leaf and flower

of the plant are easier to eliminate with methods that do not involve the use of chemicals. The types of insects that feed on the woody parts of plants or stem and root feeders are more difficult to manage by such methods.[13] The current body of literature makes use of studies and experiments that are in agreement that the continued use of neonicotinoids has, and will continue to, degrade the populations of pollinators.[4]

SUMMARY OF FINDINGS AND TRADEOFFS

The empirical evidence that backs up and supports both arguments is examined in the table below, but the results are directly supporting both sides and could be pointed at by either side as the obvious answer. There is no evidence supporting the arguments in favor of continued use of neonicotinoids if the person is in favor of the continued existence of pollinating insects. On the other side of the argument the economic repercussions and loss of revue and harvest makes the banning of neonicotinoids impractical at the current time. The types of insects that are impacted by neonicotinoids typically do not respond as well to other types of treatments. A policy decision based dispassionately on facts, where even moderate concern about wildlife conservation is involved, would lead directly to a ban on neonicotinoids. Realistically it must be acknowledged that this outcome will be strongly opposed by powerful agronomy and pharmaceutical chemical companies which have a large sway in lobbying and in the current research. Any decision to support the science on this issue and advocate for a ban on neonicotinoids would have to include a campaign to emphasize the facts, shape the debate, and neutralize opposition through careful crafting.

EVIDENCE AND ARGUMENTS

There is near universal support for the continued health of pollinators while understanding that farmers and chemical companies are almost required to produce the most amount of food for the least amount of cost. Unfortunate for pollinators their economic contribution is not factored into the cost benefit analysis that is run when measuring effectiveness of insecticides. The argument in this policy battle is whether there is sufficient evidence and benefits to either continue or ban neonicotinoids in the United States.

The Argument in Favor of Banning the Use of Neonicotinoids

"The way humanity manages or mismanages its nature-based assets, including pollinators, will in part define our collective future in the 21st century……The fact is that of the 100 crop species that provide 90 per cent of the world's food, over 70 are pollinated by bees."- Achim Steiner, Executive Director UN Environment Program (UNEP). An October 2015 study showed significant effects on the reproductive and survival capacities of honeybee and native bee queens exposed to neonicotinoids. Those exposed to neonicotinoids had a 60% survival rate over winter, as compared to 80% survival rate for control groups. Lower worker egg production and changes to surviving queens' reproductive physiology likely corresponded to reduced queen success. The authors further claim "our study suggests that these substances are, at least partially, responsible for harming queens and causing population declines of social bee species."[6]

Failure of queens exposed to neonicotinoids during development to successfully lay fertilized eggs that then develop into workers or queens is catastrophic due to the fact they are vital to colony survival.[6] In 2017, researchers demonstrated the combined effects of nutritional stress and low doses of common, widely used neonicotinoids found in nectar and pollen. Their results provided the first demonstration that neonicotinoids and nutrition levels can interact and cause significant harm to insect survival. In addition, the combined exposure reduced honeybee food both in the hive and in the wild, consumption also had a negative impact on hemolymph (bee blood sugar) levels overall.[7]

The Argument in Favor of Continued Use of Neonicotinoids

In January 2013, before the European Union voted to ban the use of neonicotinoids, the Humboldt Forum for Food and Agriculture published a report on the value of neonicotinoids in the European Union. The study was supported and financed by neonicotinoid manufacturers Bayer Crop Science and Syngenta which has cast some doubt on the findings. The report looked at the short-term and medium-term impacts of a complete ban of all neonicotinoids on agricultural holdings. These included total value added (VA), employment, global prices, land use and greenhouse gas (GHG) emissions. In the first year, agricultural and total VA would decline by €2.8 in the European Union. The greatest losses would be in wheat, maize and rapeseed in the UK, Germany, Romania and France. 22,000 jobs would be lost, primarily in Romania and Poland, and agricultural incomes would decrease by 4.7%.[5] In the medium-term (5-year ban), losses would amount to €17 billion in value added, and 27,000 jobs.

Following a ban, the lowered production would require that there be more imports of agricultural commodities into the European Union. Agricultural production outside the European Union would have to expand by 3.3 million hectares in order to make up for demand. The authors claim this would lead to additional emissions of 600 million tons of carbon dioxide equivalent.[5]

EVALUATING THE OUTCOMES

Criteria	**Outcome: BAN NNI's**	**Outcome: CONTINUE NNI USE**
What measurable harm to wildlife will occur?	none	projected decline of 24% of honeybees annually[8]
Is this option viewed as environmentally sound?	yes	no
What are the projected environmental costs of this alternative?	Increase in Carbon emissions[5] with an additional increase in chemicals used per field	increased mortality rate in pollinating and ground insects[10]
What are the projected costs for private individuals of this option?	Marginal food price increase (Approx. ~4%)	no additional cost for use, potentially $9.1 billion loss if there are no honeybees[14]

Does substantive evidence exist that support this option?	yes, studies show evidence NNI use being detrimental to pollinators[8 9 10]	yes, studies show evidence of increased costs after a ban[5] and some studies show pollinator loss can be mitigated.[11]
Is this option used successfully in other areas?	Yes, the European Union has banned the use of three neonicotinoids they deemed especially harmful	Yes, as of right now neonicotinoids are not banned in the United States and the bee and native pollinator numbers are still acceptable
What community values are affected?	concern for loss of pollinators	concern for changing crop practices and yields
Who would be most impacted by this option?	Farmers and chemical companies	People who enjoy fruits and vegetables, framers, and apiarists who make a living from bees
What are projected side effects of this option?	Potential decreased yields in grain crops and increased application of other chemicals, increased food costs	Potential extinction of flowering plants in agricultural and private communities

COMPARING OUTCOMES

Continuing the use of neonicotinoids will likely lead to a decrease of the number of pollinators that an area can support due to decreased numbers, but the crops that do not rely on pollinators will continue to have increased protection from harmful pests and insects. Those who support the continued use claim that the results of the experiments are inconclusive or not scientifically valid, usually due to claims of correlation without causation. Neonicotinoids are rare in the fact that they have not been shown to cause damage to mammalian, including human, fish, or bird life in the environments that they are used in, unlike most other crop applications.

Banning the use of neonicotinoids would, according to the research, likely mean fewer deaths of pollinators every year. This ban would likely have a net benefit outcome according to supporters who say that the neonicotinoids are a large factor in the declining population of pollinators. If this decline in population is not curbed, the end results could be disastrous with an almost complete extinction of any fruit or vegetable that flowers, along with all most flowering plants. The loss of pollinators would automatically remove 70 of the 100 types of agricultural products that supply 90 percent of the world's food supply.

The policy being proposed by this paper is one that follows in the footsteps of the law advanced by the European Union and the European Food Safety Authority. To ensure that there is no more harm being done to honeybees and native pollinators there should be a complete ban on all the use of the restricted neonicotinoids in the use of plant protection products in the form of both aerosol pesticides and in treated seeds containing the three neonicotinoids: clothianidin, imidacloprid, and thiamethoxam.

Those three neonicotinoids were mentioned as being especially detrimental and having already been banned by the European Food Safety Authority in crops that they deemed to be bee-attractive these included: maize (field and sweet corn), oilseed rape, and sunflowers. This paper proposes that this be taken further to include private sales of at least these three neonicotinoids except for use in greenhouses and other closed off environments that cannot be accessed by bees and pollinators at any time. This suggestion is due to the fact that a large amount of bees, beehives, and native pollinators gain a large amount of their pollen and food stores from non-agricultural food stores like landscaping and private flower beds. If neonicotinoids are banned for the use of agriculture but pollinators are still being exposed to them from private sources, not much good has been done.

A compromise to this policy that would hopefully benefit all parties, but leave no one party satisfied would be a partial ban. In the current mix a partial ban would be the most likely due to the lack of overwhelming evidence and no completely clear causations that neonicotinoids are killing bees and pollinators. The compromise position being forwarded by this paper is fairly simple, only treat plants that are not pollinated by pollinators with neonicotinoids. These types of plants are pollinated abiotically, abiotic pollination uses methods of transportation that are not alive, like wind and water This would mean that there are still neonicotinoids in the air and water and they would still likely impact the native pollinator health and numbers, but they would be better off than they are in the current system in which all plants are treated with the neonicotinoids. The major crops that would still be able to be treated with neonicotinoids are crops that are pollinated by the wind. In the United States the largest

of these is corn, but it also includes wheat, rice, and barley. These crops being able to be treated with neonicotinoids would mean that they would retain their current insect protection, but would be less likely to impact native pollinators and honeybees. Any step that can be taken to ensure the survival of pollinators should be taken, even if it is small steps that may only impact a small number of pollinators that are lucky enough to not be near a grain field.

On a closing note Marcus Aurelius was quoted saying, “That which is not good for the bee-hive cannot be good for the bees.” The environmental impact that would befall the entire planet if pollinators were removed from the ecosystem cannot be understated. The crops that do not directly require pollination from pollinating insects benefit greatly from their presence and the presence of other systems that rely on them. It is clear that something needs to be done in order to preserve the pollinators in this country before the collective beehive is too far gone.

References

[1]Food Safety - European Commission. (2020). Neonicotinoids - Food Safety - European Commission. [online] Available at: https://ec.europa.eu/food/plant/pesticides/approval_active_substances/approval_renewal/neonicotinoids_en

[2] Ensley, Steve M. "Neonicotinoids." Veterinary Toxicology. Academic Press, 2018. 521-524.

[3] Allington, A. (2020). EPA Curbs Use of 12 Bee-Harming Pesticides. [online] News.bloombergenvironment.com. Available at: https://news.bloombergenvironment.com/environment-and-energy/epa-curbs-use-of-12-bee-harming-pesticides

[4] Woodcock, B. A., Bullock, J. M., Shore, R. F., Heard, M. S., Pereira, M. G., Redhead, J., & Peyton, J. (2017). Country-specific effects of neonicotinoid pesticides on honey bees and wild bees. *Science*, *356*(6345), 1393-1395.

[5]Noleppa, Steffen, and Thomas Hahn. "The value of Neonicotinoid seed treatment in the European Union." *HFFA Working Paper* 1 (2013).

[6]Straub, Lars, et al. "Neonicotinoid insecticides can serve as inadvertent insect contraceptives." *Proceedings of the Royal Society B: Biological Sciences* 283.1835 (2016): 20160506.

[7]Tosi, Simone, et al. "Neonicotinoid pesticides and nutritional stress synergistically reduce survival in honey bees." *Proceedings of the Royal Society B: Biological Sciences* 284.1869 (2017): 20171711.

[8]Cepero, Almudena; Ravoet, Jorgen; Gómez-Moracho, Tamara; Bernal, José Luis; Del Nozal, Maria J.; Bartolomé, Carolina; Maside, Xulio; Meana, Aránzazu; González-Porto, Amelia V.; de Graaf, Dirk C.; Martín-Hernández, Raquel; Higes, Mariano (15 September 2014). "Holistic screening of collapsing honey bee colonies in Spain: a case study".

[9]Whitehorn, Penelope R., et al. "Neonicotinoid pesticide reduces bumble bee colony growth and queen production." *Science* 336.6079 (2012): 351-352.

[10]Rundlöf, Maj, et al. "Seed coating with a neonicotinoid insecticide negatively affects wild bees." *Nature* 521.7550 (2015): 77-80

[11] Iwasa, Takao, et al. "Mechanism for the differential toxicity of neonicotinoid insecticides in the honey bee, Apis mellifera." Crop protection 23.5 (2004): 371-378.

[12] Johnson, R. M., Wen, Z., Schuler, M. A., & Berenbaum, M. R. (2006). Mediation of pyrethroid insecticide toxicity to honey bees (Hymenoptera: Apidae) by cytochrome P450 monooxygenases. *Journal of economic entomology*, *99*(4), 1046-1050.

[13]Jactel, Hervé, et al. "Alternatives to neonicotinoids." *Environment international* 129 (2019): 423-429.

[14]Southwick, Edward E., and Lawrence Southwick Jr. "Estimating the economic value of honey bees (Hymenoptera: Apidae) as agricultural pollinators in the United States." *Journal of Economic Entomology* 85.3 (1992): 621-633.

[15] Di Prisco, G., Cavaliere, V., Annoscia, D., Varricchio, P., Caprio, E., Nazzi, F., ... & Pennacchio, F. (2013). Neonicotinoid clothianidin adversely affects insect immunity and promotes replication of a viral pathogen in honey bees. *Proceedings of the National Academy of Sciences*, *110*(46), 18466-18471.