SAINATH SURYANARAYANAN
DANIEL LEE KLEINMAN

Disappearing Bees and Reluctant Regulators

Imagine this: You're a commercial beekeeper, who relies entirely on keeping honeybees for making a living. You head out one morning to examine your bees and find that thousands of your previously healthy hives have "collapsed" mysteriously, after your bees pollinated crops in the fields of one of the farmers with whom you contract. Your bees have abandoned their hives, and they've not returned.

Beginning in the winter of 2004–2005, many U.S. beekeepers, especially commercial ones, saw this happening. Several commercial beekeeping operations lost between 30 and 90% of their hives, a figure significantly higher than the roughly 15% that is common when hives are afflicted with parasitic mites or common diseases or when bees suffer from poor nutrition. Half a decade later, losses have remained troublingly high, hovering around 30% in each subsequent year.

Bee researchers dubbed this new phenomenon colony collapse disorder (CCD), and more than a half decade after beekeepers first saw their bees ravaged by it, controversy and uncertainty remain about what causes it. The field observations of commercial beekeepers suggest a causal role for systemic agricultural insecticides such as imidacloprid. However, the Environmental Protection Agency's (EPA's) "sound science" approach to regulation does not permit the use of informal observational data such as that gathered by beekeepers in federal rulemaking. **And traditional scientific research consistent with the EPA's Good Laboratory Practice policy has thus far not established a definitive role for imidacloprid in causing CCD.** Accordingly, the EPA has refused to take imidacloprid and other similar agrochemicals off the market. Importantly, the laboratory research on which the EPA based its determination is premised on a preference for type II (false negative) over type I (false positive) errors. A false negative result incorrectly labels as safe a substance that is dangerous; a false positive incorrectly labels as dangerous a substance that is safe. We suggest that given the commercial stakes for beekeepers and the health impacts on bees, the regulatory preference for false negative over false positive results is misguided, and serious consideration should be given to precautionary regulatory policy.

The term CCD was coined by bee researchers to refer to a phenomenon in which managed honeybees abandoned their colonies en masse, leaving behind the queen, young bees, and large stores of honey and pollen. CCD threatens the viability of over 90 different U.S. fruit, nut, and vegetable crops, whose quantity and quality of production depend on the pollination services provided by managed honeybees. Emerging scientific investigations of CCD suggest that microbial pathogens such as viruses are causally involved. However, the fact that different studies identify different sets of associated microbial pathogens has led CCD researchers to surmise that the discovered pathogens are secondary infections. The identity of the primary causal factor(s) that render honeybees susceptible to such secondary infections is a flashpoint within and between groups of beekeepers, researchers, agrochemical representatives, regulatory officials, and environmentalists.

CCD was first discovered by commercial beekeepers, who travel around the country renting out their colonies for pollination purposes to farmers. Several beekeepers observed CCD unfolding in the fields of the commercial growers with whom they contract. They consistently noted connections between the occurrence of CCD and the proximity of their hives to fields treated with relatively new systemic insecticides such as the neonicotinoid imidacloprid. Affected beekeepers reported that CCD occurred in colonies several months after initial exposure to neonicotinyl insecticides. This suggested to the beekeepers that foraging bees, instead of dying immediately (as experienced in bee kills resulting from exposure to more traditional pesticides), were bringing back pollen and nectar contaminated with low levels of the systemic insecticide to the colony. This, the beekeepers surmised, had long-term progressive effects on developing bees that were chronically exposed to accumulating insecticidal stores. To date, U.S. regulators have dismissed beekeepers' on-the-ground evidence. Government officials view beekeeper evidence as anecdotal, and they will not consider it in promulgating regulations, since beekeepers do not isolate causal variables in the way done in formal laboratory and field experiments. From the perspective of many commercial beekeepers, however, with high stakes in maintaining strong and healthy colonies, their hypothesis provides sufficient justification for developing regulations that lead to limiting bee exposure to imidacloprid while more-conclusive evidence is sought. Theirs is a precautionary approach predicated on a false positive error norm.

Lab and field studies

Some ecotoxicological laboratory studies of the influence of the newer systemic insecticides on honeybees have shown adverse effects that can potentially culminate in CCD. Chronic feeding of neonicotinyl insecticides to honeybees at sublethal doses comparable to levels found in pollen and nectar of treated field crops had deleterious effects on learning, memory, behavior, and longevity. Lab studies also suggest that synergistic interactions between the newer systemic insecticides and other environmental toxins and pathogens could enhance the toxicity to honey bees.

EPA officials recognize that these data on the ecological effects of the newer systemic toxins is a cause for some concern but maintain that it is too inconsistent to restrict the use of these toxins. And although regulatory officials point to the agency's own risk assessments conducted during the registration process in order to support the claim that these insecticides pose minimal risks to honeybees, they also acknowledge that their current risk assessments do not systematically consider the effects of either short-term or chronic exposure to sublethal doses of these insecticides on honeybees. Neither do they assess the effects of multiple interactions between insecticidal toxins and other environmental variables on honeybees. Insecticidal effects on younger honeybee brood are not part of the EPA's evaluation scheme either. In effect, the EPA's sound science approach permits the release of the newer systemic insecticides based on experimental practices that tend to ignore the findings highlighted by some laboratory- and many beekeeper-initiated studies. EPA officials note that indirect laboratory findings on individual bees do not necessarily translate to what is actually occurring to whole colonies in the field. The agency persists in demanding more direct causal experimental evidence from field studies on colonies. The direct causal experimental evidence available to date is inconclusive.

Experimental field studies typically impose conditions whereby one set of colonies receives no pesticide while other sets receive known doses, with other variables of interest ideally controlled. But the actual environmental settings in which commercial beekeepers work expose honeybees throughout their life cycle to a multitude of local environmental variables such as nutrition, other toxins, pathogens, and parasites, many of which are known to interact with the newer systemic insecticides. Contemporary field study designs, which tend to focus on only one or two toxins, do not test real-life scenarios in which low levels of the toxins by themselves may not cause CCD but may do so through intricate interactions with multiple other environmental variables across the life cycle. Additionally, the statistical norm for accepting field experiment findings (95% confidence that a result is not a product of chance) is an academic convention with no intrinsic justification. It is predicated on a preference for false negative conclusions, and this in turn reflects a predilection to overlook potentially valuable findings rather than suffer the embarrassment of having to withdraw results later determined to be incorrect. These are matters of social history, not nature.

Following this logic, field experiments tend toward finding no significant difference between pesticide-treated and untreated colonies, when in fact there might be. These historically established biases in field studies are further compounded by the fact that the EPA gives greater weight to studies that comply with the regulatory standards of good laboratory practice (GLP) than those that do not. GLP standards specify how a study should be constituted, performed, recorded, and interpreted, and by whom. In order to be GLP-compliant, an investigation has to be validated by regulatory bodies composed of academic and agrochemical company researchers. GLP requires traditional standards of isolating causal factors and establishing experimental controls. As a result, cutting-edge studies on the effects of sublethal chronic doses of the newer systemic insecticides on honeybee adults and brood, which are academically sound but have yet to be validated as GLP, are typically not considered in federal rulemaking. Moreover, the exorbitant expenditure required to meet GLP standards means that public researchers and beekeepers will have difficulty undertaking investigations that are GLP-compliant.

Although ecotoxicological field study designs may appear sound from the standpoint of established regulatory standards, they bear little resemblance to the reality that beekeepers and honeybees face. Consequently, we should not take their policy relevance for granted. It is time for the EPA to take seriously innovative ecotoxicological practices that push at the very limits of what is seen as experimentally feasible. Of course, because such studies will probably not be able to sharply isolate and control for the effects of the myriad factors plausibly at play in CCD, these kinds of investigation are likely to produce only suggestive results. Virtually inevitably, they will not provide the kind of unambiguous proof that the EPA's regulators demand as part of their sound science approach. Instead of dismissing such studies, however, we suggest that the CCD epidemic should prompt us to revisit the bases for pesticide regulation.

The precautionary approach

Instead of a sound science approach to pesticide regulation, we advocate a broadly precautionary orientation. This entails a regulatory preference for false positives over false negatives. Regulators must accept suggestive data when all uncertainties are not resolved. Government decisionmakers would need to seriously value a much broader

array of knowledge forms, practices, and actors, both certified and noncertified, in discussions that frame research questions, study designs, data interpretations, and policy decisions regarding pesticides than the EPA currently considers. This approach shifts the onus of showing no harm from at-risk groups, such as commercial beekeepers, to those who produce or deploy the technology of concern, which in this case would be the manufacturers of systemic agricultural insecticides such as imidacloprid.

In 1999, the French government set the precautionary precedent for the regulation of newer systemic insecticides in the case of honeybee exposure. French policymakers decided to limit the use of Gaucho (imidacloprid) and Regent TS (fipronil) in the face of uncertainty surrounding the risks they pose to honeybee health. They drew on a preponderance of indirect evidence from observations in actual crop settings by French beekeepers and followup studies by researchers affiliated with the government. This research suggested that sublethal levels of the systemic insecticides were available in the pollen and nectar of treated crop plants and were retained in soils over multiple years and reentered crops during subsequent cultivations. These studies also provided evidence that chronic exposure to systemic insecticides in laboratory and semi-field settings significantly impaired honeybee foraging, learning, and longevity.

Advocates for the established sound science approach to pesticide regulation tout it as unbiased. In fact, all research requires choices and thus has biases. There is nothing inherently superior about type II (false negative) over type I (false positive) errors. There is nothing intrinsically better about the preference for higher levels of certainty on more narrowly construed problems as against greater uncertainty in understanding more complex relationships. These matters are value-laden, political, and in the case of CCD, they affect different stakeholders differently. The current approach to sound science–based regulation benefits the short-term interests of agrochemical producers by treating the absence of conclusive evidence of pesticide harm as justification for allowing a given chemical to remain on the market. A precautionary approach in the case of CCD, in contrast, could hurt agrochemical companies, because indirect evidence of the sublethal effects might justify removing certain systemic insecticides from the market or, more likely, restricting their use in some fashion. For commercial beekeepers, on the other hand, sound science regulatory policy in the case of CCD offers no immediate advantage. If certain agricultural systemic insecticides contribute to CCD, then beekeepers are helped by restricting bee exposure to these chemicals. If it turns out that the toxins of concern are not involved in CCD, beekeepers will be harmed less by the move to remove it from use than they would be if it transpired that they contributed to CCD, but exposure had not been restricted.

There are those who express fears that removing or limiting the use of the newer systemic insecticides, which are categorized by the EPA as reduced risk, would force growers to revert to older pesticides considered more harmful to human and environmental health. These fears are not entirely unreasonable, given the current structure of U.S. agriculture, with its predilection for large monoculture crops, which depend heavily on pesticides and herbicides in order to survive. Consequently, any significant reduction in the use of these insecticides will not ultimately be effective without a broader shift toward more sustainable forms of agriculture, including an increase in smaller-scale farm production, polycultures, and ecological strategies of pest management. Perhaps the case of CCD can serve as an opportunity to prompt broad

dialogue about the future of U.S. agriculture and lead to experiments on the advantages and drawbacks of a wide array of alternative agricultural practices.

At a minimum, the complicated knowledge landscape surrounding CCD should lead the EPA to consider supporting methodologically innovative research that would improve our understanding of CCD and the multitude of factors that may interact in complex ways to cause it. The decision to seek an understanding of real-world environmental complexity and not to base regulation on artificially reductive experimental designs requires different standards of statistical rigor and experimental control than those that are currently practiced. This research would monitor real-time effects on long-term colony health from chronic exposure to toxins used in commercial beekeeping and farming practices. Crucially, it would be transdisciplinary in incorporating traditional honeybee research with beekeepers' on-the-ground knowledge, along with sociologists and humanists versed in the social, economic, and political dimensions of scientific and agricultural practices.

More generally, the CCD case should lead us to consider the value and drawbacks of EPA's sound science approach to pesticide regulation. If sound science is not inherently superior to a precautionary approach, why should we use it? Should the federal government have regulatory policies whose scientific foundations systematically support the interests of some economic actors over others? If not, then debates that inform policy on pesticide regulation need to represent more equitably the methodological and epistemological commitments and values of a broader range of actors than what is currently occurring under the paradigm of sound science. A precautionary approach, broadly along the lines of what we have outlined, would allow scientifically justifiable and fairer means of serving environmental health and the interests of those involved in agricultural production.