Neonicotinoids in California

Their Use and Threats to the State's Aquatic Ecosystems and Pollinators, with a Focus on Neonic-Treated Seeds

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EXECUTIVE SUMMARY

Neonicotinoid insecticides (neonics) are the most widely used insecticides in the United States—and the largest proportion of that use comes from neonic-coated crop seeds. The U.S. Environmental Protection Agency (USEPA) and the California Department of Pesticide Regulation (CaDPR) do not regulate treated seeds as "pesticides," allowing them to escape scrutiny and tracking requirements applicable to other pesticide uses. Increasingly, farmers, and even agronomists, are unaware of the extent to which seed treatment insecticides are being used. The lack of accurate information limits the ability to assess neonic-treated seeds' full impacts on agricultural production and economics, pest resistance issues, and the environment.

This report explores the use and impacts of neonics in California with a focus on the possible consequences of ignoring seed treatment applications, particularly with regards to impacts on aquatic life and pollinators. The report finds that neonic-treated seeds have the potential to be the single largest use of neonics in California, making them, therefore, also one of the largest insecticide uses. It also finds that the possible detrimental impacts of neonic-treated seeds on California's aquatic ecosystems and pollinators are wholly uncharacterized and greatly under-appreciated.

Neonic-treated seed use is not tracked in California's Pesticide Use Reporting database (PUR). As a result, neonic-treated seed use has never been estimated in California as opposed to all other states where the data was tracked by the U.S. Geological Survey until the agency discontinued tracking seed treatments in 2014. Accordingly, to examine the possible impact of neonic-treated seeds on California's environment—both now and in the future—this report estimates the total potential use of neonics on crop seeds in the State based on 2016-2017 crop data. In California, exact use patterns are uncertain, but national trends suggest use of neonic-treated seeds is widespread in field crops (such as corn, cotton, and wheat), and likely on the rise in others. The report concludes that:

- If seed treatments were fully used on crops where they are allowed, the amount of neonics applied as seed treatments would equal 512,000 pounds annually. This total exceeds the 410,000 pounds of neonics that are applied by other means and reported through the PUR.
- This potential use of neonic-treated seeds would cover roughly 76% of the total cropland area in California, approximately 4 million acres.

This potential neonic-treated seed use has implications for water quality and ecosystem health. In its modeling approach, USEPA greatly underestimates aquatic contamination from neonic-treated seeds; ample independent field evidence already shows that use of neonic-treated seeds results in neonic levels in water sufficient to cause injury to aquatic habitats. If the use of neonic-treated seeds in California were even a fraction of the total potential use estimated in this report, contamination of and harm to aquatic habitats would be expected.

Regardless of the source, neonics frequently appear in California water at levels where we would expect to see damaging ecosystem-wide impacts. These impacts include widespread losses of aquatic insects and crustacea accompanied by knock-on effects on consumer species such as fish, amphibians, birds, and some mammals such as bats. At agricultural sites monitored by CaDPR, concentrations of the neonic imidacloprid, where detected, always exceeded the USEPA concentration benchmark where ecological damage is expected. At many sites, the benchmark was exceeded by 10X or even 100X. At sites described in this report—for example, tributaries to the Salinas River in Monterey County—every single sample taken over an 8-year period detected imidacloprid 10X above the USEPA ecological damage threshold. This data alone indicate a very high probability that neonics are causing ecosystem-wide damage.

Clothianidin and thiamethoxam are neonic active ingredients commonly used as seed treatments, and water sampling for these chemicals in California has not been adequate. CaDPR does not include these chemicals within a comprehensive agricultural sampling program or track seed treatment products more generally, creating a serious data gap that deprives scientists and policy makers of key information about the likely significant and damaging impacts of neonic-treated seed use. Indeed, even despite minimal sampling, evidence suggests that clothianidin and thiamethoxam residues are likely higher than imidacloprid residues at many agricultural sites. Given that most aquatic systems within agricultural regions will be exposed to the three nitoguanidine products in combination, the combined concentrations of all neonic active ingredients must be considered in assessing injury to the aquatic environment.

USEPA and CaDPR fail to properly characterize the risk of neonic seed treatments to bees, especially wild bees. In particular, the final USEPA (2020) and CaDPR (2018) pollinator risk assessments: (1) underestimate risks to wild bee species and other pollinators by relying on honey bee colony health and survival as a proxy for pollinator health generally; (2) underestimate nectar and pollen contamination levels following the use of neonic-treated seeds by assuming that the majority of crop species will have residue values at the low end of the measured spectrum; (3) ignore risks of dust from neonic-treated seeds at planting, despite ample evidence that this route of exposure is highly relevant; (4) ignore exposures of bees and other pollinators to neonic-contaminated water—including guttation fluid and puddles in or near fields sown with neonic-treated seeds—despite existing field estimates that show that these routes of exposure can completely dwarf the routes that have been formally assessed; (5) ignore risks from neonic uses on crops deemed unattractive to honey bees, despite evidence that neonic residues migrate into adjoining areas, including wildflowers bordering neonic-seeded fields that can contain neonic levels exceeding those in the field proper; (6) exclude available peer-reviewed literature in favor of industry studies; and (7) ignore the growing amount of field data which now links the use of neonic-treated seeds to pollinator failure on a landscape scale. The USEPA and CaDPR therefore fail to account for the likely considerable and damaging effect that neonic-treated seeds are having on California's pollinator populations.

All of these impacts on aquatic systems and pollinators have to be weighed against what appear to be questionable benefits of many seed treatment products to California agriculture.

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1. INTRODUCTION

There has been a large increase, over the last few decades, in the use of insecticidal seed treatments. This has happened in parallel with the introduction of neonicotinoid insecticides or "neonics," which have marked systemic activity. The U.S. Environmental Protection Agency (USEPA), California Department of Pesticide Registration (CaDPR), and other regulatory bodies such as the Canadian Pest Management Regulatory Agency (PMRA) do not directly regulate pesticide-treated seeds under their respective laws. This regulatory loophole or grey area has been of increasing concern to several researchers (Douglas et al. 2015, Hitaj et al. 2020), has already been the subject of articles in popular media (e.g., Allington 2020), and has resulted in a formal citizen's petition from a coalition of farmers, beekeepers, and not-for-profit organizations to USEPA in 2017 (Jenkins 2017). Yet despite their dominance of insecticide markets, neonic seed treatments are, for the most part, untracked. Agronomists are generally unaware to what extent insecticide seed treatments are being used in the crops they work on, and even farmers themselves are often in the dark.

The main objective of this report is to consider the use of neonics, especially the three main nitroguanidine active ingredients: clothianidin, imidacloprid, and thiamethoxam, which represent the bulk of seed treatment uses. For at least two of these active ingredients (clothianidin and thiamethoxam), seed treatment use is the principal way in which they are released into the environment—at least nationally.

Because of its robust pesticide evaluation and registration system as well as arguably the best pesticide tracking system in the world (NRC 2015), the State of California occupies an enviable position in the realm of pesticide regulation and data collection. Yet, it appears that, even in their case, seed treatments are a major blind spot, as the state does not register or track the use of pesticide treated seeds.

Given California's diverse and rich agriculture and its relatively robust data on pesticide use and impacts, the state provides a good test case for understanding how widely neonic seed treatments may be used and what the impact of those treatments and other neonic uses have on water quality and natural systems, with a particular focus on pollinating insects. Accordingly, this report proposes to: (1) construct a snapshot of California agriculture to estimate the amount of total neonic use seed treatments could represent (Section 2); (2) review what is known about the current degree of neonic surface water contamination (Section 3) and; (3) review the possible consequences of these undocumented sources of neonics to pollinator species (Section 4).

2. WHAT IS THE POTENTIAL TOTAL NITROGUANIDINE NEONIC USE IN CALIFORNIA, AND WHAT PROPORTION COMES FROM SEED TREATMENTS?

2.1. The role of neonic-treated seeds in agriculture

The use of insecticidal seed treatments has dramatically increased in the last few decades, in parallel with the introduction of neonicotinoid insecticides (Hitaj et al. 2020). Neonics, especially those in the nitroguanidine group (including imidacloprid, clothianidin, and thiamethoxam),[1] are highly water soluble, systemic, persistent, and broadly toxic to a wide range of terrestrial and aquatic invertebrates. It has been estimated that, by 2008, neonics already constituted 80% of the insecticide seed treatment market (Jeschke et al. 2011), which itself accounts for an increasing proportion of all insecticides used in agriculture. Therefore, nationally at least, a large proportion of current insecticide use is in the form of neonic seed treatments.

As state governments increasingly restrict or prohibit the remaining uses of organophosphorus insecticides (e.g., chlorpyrifos), the use of insecticidal seed treatments is likely to increase further. This shift has been criticized as pesticide seed treatments are, by design, prophylactic—meaning that treatments on an unknown portion of seeds serve no purpose whatsoever. Indeed, research indicates that the benefits of treatment for some crops are slim to non-existent in many cases (MacFadyen et al. 2014, Budge et al. 2015, Douglas and Tooker 2015, 2016, Douglas et al. 2015, Krupke et al. 2017, Alford and Krupke 2017, Hokkanen et al. 2017, Labrie et al. 2020), or can easily be replaced by existing cultural or other methods (Veres et al. 2020). Agronomists and agricultural researchers increasingly recommend against the prophylactic use of the insecticides, especially in major field crops, but the practice persists, in part because pesticide manufacturers also control the seed market.

Despite their dominance of insecticide markets, neonic seed treatments are, for the most part, untracked and ignored.[2] Through 2014, the private polling company Kynetek was the only entity collecting information on seed treatment use in the United States. The company, however, stopped in 2015, in part because of the increasing difficulty of collecting the information (Hitaj et al. 2020). In particular, consolidation of the seed and pesticide manufacturers has led to the bundling of pesticides with seed stock, so that growers are increasingly unaware that they are using a neonic on their field (and therefore unable to accurately answer a survey) (Hitaj et al. 2020). Since 2015, the U.S. Department of Agriculture (USDA) has attempted to fill the information gap through their annual ARMS survey (Agricultural Resource Management Survey), but the effort has been fraught with methodological problems and the survey has been steadily losing effectiveness (Hitaj et al. 2020). Further, USEPA and state regulatory bodies exempt treated seeds from regulation as "pesticides" and do not require the collection of use data. Accordingly, the agencies responsible for the regulation of neonics—the most popular insecticides in the U.S.—fundamentally lack data regarding their primary use (USEPA 2020a, b). As we move further away in time from the last 2014 Kynetek survey, our understanding of the actual neonic use on crop seeds—and, thereby, actual insecticide use in agriculture more generally—becomes less and less clear.

The U.S. Geological Survey (USGS), through the National Water-Quality Assessment's (NAWQA) "Pesticide National Synthesis Project," purchases annual pesticide use surveys from the Kynetec company and makes a summarized version available to the public. These summaries show a sharp drop in estimated neonic use from 2014 (the last year Kynetec included seed treatments in its surveys) to 2015. This drop has been used to infer what proportion of total neonic use was the result of seed treatment use. In previous reports (Mineau 2019a, b), it was estimated that seed treatment use accounted for 58% of imidacloprid, 75% of thiamethoxam, and 92% of clothianidin nationwide. Hitaj et al. (2020) also proposed this one-time method to estimate seed treatment uses.

However, it is now apparent that these estimates are underestimates because pre-2015 USGS data for California—an important contributor to U.S. national agricultural production—did <u>not</u> include seed treatment uses. California is the only state where USGS used a source other than commercial polling—specifically, the CaDPR's Pesticide Use Reporting (PUR) database, which does not track pesticide seed treatment use.

California is unique among U.S. states, indeed worldwide, in that it requires pesticide users (aside from consumers) to log any pesticide application in the PUR system—providing area treated, crop, product, and location. This has typically led

1 Dinotefuran is also a nitroguanidine neonic but is not registered for seed treatment use.

2 Although seed treatment products (i.e., the products used to treat the seeds) must still undergo registration.

agronomists and other researchers to believe that that PUR data provides a “good handle” on pesticide use in the state. The PUR data have been key to investigating relationships between various pesticides and health outcomes (NRC 2015). However, since the PUR does not track seed treatment use, this confidence might be misplaced.

California has a complex and diverse agricultural environment with a large number of possible uses for seed treatments. One objective of this report is to assess how much the absence of seed treatment uses from the PUR system might underestimate the use of neonic insecticides—in particular, imidacloprid, clothianidin, and thiamethoxam.[3] Given the link between neonics—and seed treatment products specifically—to honey bee and other pollinator losses, as well as the increasing reports of broad aquatic contamination from neonic-treated seed use, the question of how much these treated seeds are being used is an important one. As pointed out by Hitaj et al. (2020), the lack of accurate information on pesticide use limits our ability to answer questions regarding agricultural production and economics, pest resistance issues, and the full nature of neonics’ environmental risks and harms.

2.2. Comparing the total potential neonic-treated seed use to PUR estimates of tracked neonic uses

In this section, I estimate the potential amount of nitroguanidine neonics that could be used in California if crops for which neonic seed treatments were permitted made full use of those treated seeds. Full deployment of seed treatments where allowed may seem like an extreme case at first blush, but for some major field crops, neonic seed treatment use has become near total, while others trend in that direction. Over the last decade, there has been an exponential increase in the use of neonics in seed treatments, and the list of crops for which neonic seed treatment products are not registered has greatly diminished. Estimates of the extent of seed treatment use, when available, is therefore likely to be rapidly outdated. The extent to which seed treatment use is covered in the agricultural online press (personal observation) suggests that—despite the agronomic concerns surrounding prophylactic insecticide use and numerous studies showing neonic-treated field crop seeds fail to produce monetary benefits for farmers—they are being aggressively marketed, especially as older pesticide chemistries are being retired (Figure 1).

Figure 1. Excerpt from “The Guide to Seed Treatment Stewardship,” an industry bulletin endorsed by the National Corn Growers Association, Crop Life America, the American Soybean Association, American Seed Trade Association, National Cotton Council of America, Agricultural Retailers Association, and National Association of Wheat Growers.

What are the benefits of neonicotinoid seed treatments?

Neonicotinoids are highly valued by growers who use them in integrated pest management (IPM) programs. They provide a unique mode of action, necessary to manage pests resistant to other insecticides. Neonicotinoids selectively control insect pests, while ensuring beneficial insects remain available to keep other potential insect pests in check.

A comprehensive economic analysis of more than 1,500 field studies conducted over 20 years by AgInfomatics finds neonicotinoid insecticides provided average yield increases ranging from 3.6 percent to 71.3 percent in eight major crops across North America. This research found the average yield benefit of using neonicotinoids far exceeds the cost of treatment and delivers a substantial economic return on investment to the farmer.

3 Another neonicotinoid chemical, acetamiprid, has a few seed treatment registrations also—primarily canola and mustard. Acetamiprid’s market share is unknown at this point, but considered to be small (USEPA 2020k).

2.2.1. Calculating the total potential neonic-treated seed use in California

2.2.1.1. Step 1: Building a snapshot of California agriculture

The first step in approximating the total possible annual neonic-treated seed use in California is to estimate the total planted acreage in California where neonic-treated seed could be used in a given year. To create this "snapshot" of California agriculture, the year 2016 was chosen as the model year, as, when this project started, it was the most recent year for which almost all county reports from the various agriculture commissioners were available, and for which USGS[4] had completed its analysis of neonic applications through the PUR system.

Crop information was downloaded from all county reports for the year 2016. The procedures and assumptions made in order to standardize the data are detailed in Appendix 1.

In many counties, data for various vegetable crops were combined for the purpose of reporting harvested acreages. For many crops, we therefore turned to the 2017 USDA agricultural census, which provided county-specific acreages for many of the main vegetable crops. Our final "snapshot" therefore combined the 2016 and 2017 data.

USDA also developed field crop estimates for 2016. Because field crops (sometimes major ones) were frequently combined in the various state reports, USDA totals were useful to disaggregate the different field crop types. However, USDA data also combine counties and even agricultural districts together, preventing a clear geographical separation of the data. We therefore used a combination of state statistics and USDA estimates to arrive at totals for as many counties and individual field crops as possible. California totals from the various USDA-reported estimates were then used to compute the geographically undefined part of the field crop. These "residuals" are given in Table 1.

For some field crops, county accounting appears to be reasonable; not so for barley and oats where a large residual exists. In those cases, acreages were not available from county reports, usually because they were combined with other field crops. Those residual acreages were included in our estimates of potential seed treatment use but not assigned to any county or agricultural region.

All of the compiled acreages and USDA data refer to harvested acreages. For the purpose of calculating possible seed treatment use, seeded acreages are more relevant than harvested acreages. Where crop failure occurs or where the crop is used as a cover crop (e.g., oats), the planted area can greatly exceed the harvested area. Therefore, USDA field crop totals for California were used also to work out a ratio of seeded to harvested crops (Table 2). For all crops other than those listed in the table, it was assumed that the planted acreage was equal to the harvested acreage. This will underestimate plantings and, therefore, seed treatment use to some extent.

Table 1. Comparison of USDA-reported acreages for 2016 to the summed total acreages reported in 2016 county agricultural reports for several surveyed field crops.

Commodity	Residual acreage not included in county totals (acres)	Proportion this represents of the total acreage for that crop harvested in California
Barley	24,544	40.9%
Cotton	7,817	3.6%
Corn, grain	1,348	1.3%
Oats	6,563	59.7%
Rice	1,725	0.3%
Sunflower	2,404	5.2%

4 Data obtained from: https://water.usgs.gov/nawqa/pnsp/usage/maps/.

Table 2. Ratio of planted to harvested 2016 crop acres for California.[a]					
Crop	Area planted (acres)	Area harvested (acres)	Correction factor	Year	Release date of data
Barley	85,000	60,000	1.417	2016	Mar-18
Cotton	218,000	216,000	1.009	2016	May-18
Dry beans	50,000	49,000	1.020	2016	Apr-18
Corn, total	420,000	415,000	1.012	2016	Feb-18
Oats	110,000	11,000	10.000	2016	Mar-18
Rice	541,000	536,000	1.009	2016	Mar-18
Sunflower	46,600	46,000	1.013	2016	Feb-18
Wheat, total	480,000	217,000	2.212	2016	Mar-18
Safflower	62,000	61,500	1.008	2016	Feb-19
Sugar beet	25,300	25,200	1.004	2016	Feb-19
Potato	39,400	38,300	1.029	2016	Feb-19
Sweet potato	20,000	20,000	1.000	2016	Feb-19

a Data obtained from: https://www.nass.usda.gov/Statistics_by_State/California/Publications/County_Estimates/index.php; https://www.nass.usda.gov/Publications/Todays_Reports/reports/cropan19.pdf.

Crop statistics could not be found for a number of crops for which neonic seed treatments are registered for use in California (CaDPR 2018). This is in large part because county statistics amalgamated several crops when reporting acreages. These include: amaranth, arrowroot and leren, arugula, borage, buckwheat, canola and rapeseed, cardoon, cassava, crambe, endive, edible flowers (e.g., chrysanthemum), fennel, flax, ginger, ginseng, kohlrabi, lupins, pearl and proso millet, all mustards, purslane, sorrel, soybean, peanuts, teosinte, and turmeric. This will result in an underestimate of potential seed treatment uses.

2.2.1.2. Step 2: Obtaining label rates for registered seed treatments

The second step in approximating neonic-treated seed use is estimating what amount of neonic coating could appear on a given treated crop seed. To achieve this, all registered seed treatment labels were examined, and, for each registered crop, maximum rates of application were retained. It is standard practice in regulatory assessments to assume maximum labeled rates (e.g., CaDPR 2018).[5]

Depending on seed type and product, label rates vary a great deal as to how application rates are expressed—e.g., ounce of product per 100 lbs of seed or per a certain number of seeds (typically 80,000, or 100,000) or amount of active ingredient (usually in milligrams) per individual seed. For our purposes, all rates were converted to either pounds (lbs) of active ingredient (a.i.)/100 lbs of seed or milligrams (mg) of a.i./seed. Given known seed weights and a given seeding density, the amounts of a.i. applied per acre can then be calculated for any situation. To arrive at a rate in lbs a.i./100 lbs for liquid formulations, the specific gravity (in lbs a.i./gal) and the application rates were retained and used as shown in Equation 1.

Equation 1

lbs a.i./100 lbs seed = (lbs a.i./gal) / (128 fl oz/gal) * (fl oz/100 lbs seed)

5 The vast majority of seed treatment products registered by USEPA contain only one neonic active ingredient. A few registered products, however, contain more than one neonic—e.g., Sepresto 75 WS (EPA reg. no. 264-1081). For the purpose of rate calculations in this report, the most dominant neonic active ingredient on label was chosen.

For solid formulations, the percent proportion of active ingredient and rate in ounces were used as shown in Equation 2.

Equation 2

lbs a.i./100 lbs seed = (% a.i.) * (oz/100 lbs seed)

To arrive at an application rate (in mg) per seed, calculations were performed as per Equation 3.

Equation 3

mg a.i./seed = (fl oz per specified number of seeds) / (specified number of seeds) * (lbs a.i./gal) / (128 fl oz/gal) * (453592 mg/lb)

Excluding any label with a prohibition of planting the treated seed in California, we documented 106 different extant EPA labels for seed treatments in various crops—1 acetamiprid label, 12 clothianidin labels, 57 imidacloprid labels and 36 thiamethoxam labels. We also referred to CaDPR (2018), which carried out a similar analysis of California seed treatment uses.

Maximum labeled application rates are provided in Table 3, expressed either as lbs a.i./100 lbs seed or mg a.i./seed for reasons detailed above. Although there tends to be a convergence of labels towards a given rate, it can sometime vary two-or-three-fold, presumably in response to different pests for which the product is registered. Higher rates are usually labeled, for “extended protection” or some such term. It is widely believed that application rates have increased over time (e.g., Douglas and Tooker 2015) and, therefore, the higher registered rate is likely often the most popular. This is also borne out by the fact that the higher rates tend to appear more often on labels.

Table 3. Maximum application rates applied to seed and allowed in California.

Crop or crop group	Clothianidin		Imidacloprid		Thiamethoxam	
	lbs a.i./ 100 lbs seed	mg/seed	lbs a.i./ 100 lbs seed	mg/seed	lbs a.i./ 100 lbs seed	mg/seed
alfalfa						0.001
amaranth		0.050				1.20
arrowroot	0.010					
artichoke	0.010					
Asian vegetables	0.010		0.125		0.050	1.20
barley	0.070		0.094		0.052	
bean	0.010	0.750	0.125		0.050	
borage			1.00		0.040	
broccoli	0.070	2.12				0.100
Brussel sprout						0.100
buckwheat	0.070					
cabbage		2.12	1.00			0.100
canola	0.406		1.00		0.404	
cardoon						1.20
carrot	0.010	0.120				0.050
cassava	0.010					
celery						1.20
chard						1.20

Table 3. Maximum application rates applied to seed and allowed in California.						
Crop or crop group	**Clothianidin**		**Imidacloprid**		**Thiamethoxam**	
	lbs a.i./ 100 lbs seed	**mg/seed**	**lbs a.i./ 100 lbs seed**	**mg/seed**	**lbs a.i./ 100 lbs seed**	**mg/seed**
chicory		0.050				1.20
corn	0.070	1.25	0.528	1.34	0.220	1.25
cotton		0.424	0.502			0.375
crambe					0.400	
cucumber						0.750
endive		0.050				1.20
edible flowers	0.010	0.050				1.20
fennel						1.20
flax			1.00		0.400	
ginger	0.010					
greens	0.406	0.050	1.00			1.20
herbs		0.050				1.20
kale						0.100
kohlrabi						0.100
leek		0.360				
lettuce		1.42				1.20
lentil			0.125		0.050	
lupin	0.010		0.125		0.050	
melon						0.750
millet	0.070		0.250			
mustard			1.00		0.400	
oats	0.070		0.094		0.051	
onion		0.320				0.200
peanuts			0.062		0.045	0.300
peas			0.125		0.050	
potato	0.0125		0.0125		0.006	
rhubarb						1.20
rice					0.141	
rye	0.070		0.094		0.051	
safflower			1.00	0.500	0.400	
sorghum	0.200		0.250		0.199	0.093
sorrel		0.050				1.20
soybean	0.050	0.130	0.125		0.075	0.151

Table 3. Maximum application rates applied to seed and allowed in California.						
Crop or crop group	**Clothianidin**		**Imidacloprid**		**Thiamethoxam**	
	lbs a.i./ 100 lbs seed	**mg/seed**	**lbs a.i./ 100 lbs seed**	**mg/seed**	**lbs a.i./ 100 lbs seed**	**mg/seed**
spinach		0.150	0.199			1.20
squash						0.750
sugar beet		0.720		0.893		
sunflower			1.00	0.500		0.25
sweet corn		0.500	0.250			1.25
sweet potato	0.0100					
taro	0.0100					
turmeric	0.0100					
wheat	0.070		0.094		0.052	

2.2.1.3. Step 3: Calculating allowable application rates per planted acre

From the approximate neonic treatment rate per seed (Table 3), we can calculate the neonic application rate per acre of seeded crop by looking at planting densities in use in California. These were obtained from a USEPA compilation (USEPA 2010). California estimates were used where given in the compilation—otherwise, states in the Pacific Northwest were used as much as possible. While seed treatment product labels sometimes carry an equivalent application rate per acre, we believe that rates calculated here are more realistic. Given that an increasing proportion of growers do not actually know whether or not their seeds were treated with neonics (Hitaj et al. 2020), it stands to reason that actual application rates per acre are driven by the planting density, as chosen by the grower based on prevailing agronomics and their experience with the crop—rather than seed treatment product labels.

In order to work out planting densities, the following measurements are needed: either the finished number of seeds to the acre (when available); or a combination of the pounds of seed to the acre and a measure of seed weight—usually expressed as the number of seeds per pound. Selected high and low estimates for seed weight and planting density compiled by USEPA (2010) are reproduced in Table 4. They reflect different varieties of different crops.

Table 4. Seed weight and planting density extracted from USEPA (2010).[a]						
Crop or crop group	**Seeds per acre (low)**	**Seeds per acre (high)**	**Lbs seed per acre (low)**	**Lbs seed per acre (high)**	**Seeds per lb (low)**	**Seeds per lb (high)**
alfalfa	2,985,000	3,405,000	15.00	15.00	199,000	227,000
artichokes	**2,722**	**2,722**			**3,400**	**3,400**
Asian vegetables	**142,362**	**142,362**	**0.44**	**0.44**	**325,400**	**325,400**
asparagus	29,040	104,544	8.00	10.00		
barley	282,000	420,000	30.00	98.00	9,400	14,000
beans, dry	69,696	104,544	38.42	130.68	800	1,814
beans, fresh	139,392	418,176	58.08	435.60	960	2,400

Table 4. Seed weight and planting density extracted from USEPA (2010).[a]						
Crop or crop group	**Seeds per acre (low)**	**Seeds per acre (high)**	**Lbs seed per acre (low)**	**Lbs seed per acre (high)**	**Seeds per lb (low)**	**Seeds per lb (high)**
beets	52,272	2,090,880	2.17	86.63	24,136	24,136
broccoli	62,726	69,696	0.42	0.87	80,000	150,000
Brussels sprouts	20,908	27,878	0.11	0.44	64,000	192,000
cabbage	22,402	26,136	0.14	0.58	45,000	165,000
carrots	900,000	1,300,000	2.25	7.43	175,000	400,000
cauliflower	17,424	23,232	0.12	0.29	80,000	150,000
celery	34,848	69,696	0.03	0.07	1,000,000	1,152,000
cereal, mixed	1,300,000	1,500,000	60.00	156.00	8,000	18,000
chard	13,068	17,424				
chicory	29,040	52,272	**0.08**	**0.14**	**377,320**	**377,320**
cilantro	313,632	896,091				
corn, grain	26,400	40,250	13.20	29.57	1,361	2,000
corn, silage	26,400	40,250	13.20	29.57	1,361	2,000
cotton	30,000	85,000		18.89	4,500	
cucumbers	7,260	21,780	0.40	1.82	12,000	18,144
daikon	63,360	95,040				
eggplant	6,534	14,520				
escarole & endive	29,040	41,818				
garlic	156,816	241,255				
ginger root						
ginseng			90.00	100.00		
greens					167,000	144,000
hay, alfalfa	2,985,000	3,405,000	15.00		199,000	227,000
hay, cereal	780,000	1,088,640	60.00	90.00	13,000	18,144
herbs	435,600	726,000	1.47	4.84	150,000	296,500
horseradish						
kale	21,780	576,000	0.15	5.76	100,000	144,000
leek	43,560	87,120				
lettuce	157,000	157,000	0.31	0.39	400,000	500,000
melons	29,040	34,848	1.40	2.18	16,000	20,800
mint	34,848	78,408				
oats	780,000	1,088,640	60.00	90.00	13,000	18,144
okra	17,424	40,209				

Table 4. Seed weight and planting density extracted from USEPA (2010).[a]						
Crop or crop group	**Seeds per acre (low)**	**Seeds per acre (high)**	**Lbs seed per acre (low)**	**Lbs seed per acre (high)**	**Seeds per lb (low)**	**Seeds per lb (high)**
onions	522,720	784,080	4.02	7.84	100,000	130,000
parsley	435,600	726,000	1.47	4.84	150,000	296,500
peas	196,020	522,720	39.20	163.35	3,200	5,000
peppers	10,890	26,136	0.15	0.52	50,000	72,000
potatoes	10,500	23,100	2,100.00	2,700.00	5	11
pumpkins	871	7,260	0.14	4.54	1,600	6,400
radishes	1,045,440	1,045,440	20.91	32.67	32,000	50,000
rhubarb	3,630	7,260				
rice	1,742,400	2,439,360	77.00	118.00	15,600	28,100
rye	1,080,000	1,080,000	60.00	90.00	18,000	
safflower	408,240	408,240	30.00	35.00	13,608	
sorghum	45,000	100,000	0.66	9.09	11,000	68,040
spinach	360,000	408,240	9.00	25.00	40,000	45,360
squash	8,712	11,616	1.36	6.05	1,920	6,400
sugar beet	52,272	104,544	1.31	4.75	22,000	40,000
sunflower	6,000	27,000	3.00	4.00	2,000	9,000
sweet corn	15,682	59,739	3.48	33.19	1,800	4,500
sweet potatoes	11,880	18,341				
tomatoes	52,272	69,696	0.28	0.58	120,000	190,000
turnips	29,040	261,360				
vegetable seeds	52,272	69,696	0.28	0.58	120,000	190,000
watercress						
wheat	1,300,000	1,500,000	60.00	156.00	8,000	18,000
wild rice						

a Numbers in italics are calculated from the other entries in different columns of the table. Numbers in bold derive from sources other than the USEPA compilation.

Ranges obtained with calculated values tend to be wider than ranges given in the USEPA 2010 compendium. For example, the calculated minimum of the range of pounds of seeds per acre is calculated by dividing the maximum number of seeds per acre by the minimum number of seeds per pound, while the maximum pounds of seeds per acre is the minimum number of seeds per acre divided by the maximum number of seeds per pound. This is probably a realistic estimate of the degree of variation occurring in real life given different soil types and conditions as well as the myriad of cultivars for any given crop type; whereas USEPA (2010) generally references a single source of information from the state—if any.

Combining the information from Tables 3 and 4 allows us to compute a neonic application rate, equivalent to seeding an acre of any given crop. As mentioned earlier, maximum values are retained for the purpose of this assessment. These are presented in Table 5.

Table 5. Equivalent application rates per acre for neonics in various crops with acreages compiled for this report. See text for groupings and crop substitutions.			
Crop or crop grouping	Clothianidin lbs of a.i. per acre	Imidacloprid lbs of a.i. per acre	Thiamethoxam lbs of a.i. per acre
alfalfa			0.008
artichokes	8.01E-05		
Asian vegetables		0.001	0.377
barley	0.069	0.092	0.051
beans, dry	0.173	0.163	0.065
beans, fresh	0.691	0.545	0.218
broccoli	0.326		0.015
Brussels sprouts			0.006
cabbage	0.122	0.006	0.006
carrots	0.344		0.143
cauliflower			0.005
celery			0.184
cereal, mixed	0.109	0.147	0.081
chard			0.046
chicory	0.006		0.138
corn, grain	0.111	0.156	0.111
corn, silage	0.111	0.156	0.111
cotton	0.079	0.095	0.070
cucumbers			0.036
escarole & endive	0.005		0.111
greens			1.080
hay, alfalfa			0.008
hay, cereal	0.063	0.085	0.046
herbs	0.080		1.921
kale			0.127
leek	0.069		
lettuce	0.491		0.415
melons			0.058
oats	0.063	0.085	0.046
onions	0.553		0.346
parsley	0.080		1.921
peas		0.204	0.082
potatoes	0.338	0.338	0.162

Table 5. Equivalent application rates per acre for neonics in various crops with acreages compiled for this report. See text for groupings and crop substitutions.			
Crop or crop grouping	**Clothianidin lbs of a.i. per acre**	**Imidacloprid lbs of a.i. per acre**	**Thiamethoxam lbs of a.i. per acre**
pumpkins			0.012
rhubarb			0.019
rice			0.166
rye	0.063	0.085	0.046
safflower		0.450	0.140
sorghum	0.018	0.023	0.021
spinach	0.135	0.050	1.080
squash			0.019
sugar beet	0.166	0.206	0.161
sunflower		0.040	0.015
sweet corn	0.066	0.083	0.165
sweet potatoes	0.338		
vegetable seeds			0.019
wheat	0.109	0.147	0.081
wild rice			0.166

2.2.1.4. Step 4: Cross-referencing allowable application rates per acre with California agricultural snapshot data

Steps 1 to 3 detailed above now allow for the calculation of potential total neonic use if all seeded acreages of registered crops did in fact use a neonic seed treatment. Because rates vary among the three seed treatment active ingredients, several assumptions were made regarding the relative market share of each active ingredient by crop. Where information was available from USEPA sources (e.g., USEPA 2017, 2018, 2019a, c), this information was used to work out approximate market shares. Where no information existed (e.g., as for all vegetable crops), all registered active ingredients were assumed to be used in equal proportion. The initial approach had been to note the number of times specific crops were mentioned on labels and use this as an indication of relative market share (see Appendix 2). However, it was decided that this was not a reliable indicator and that the number of products labeled for any given crop had more to do with how different companies market their products—some preferring to have separate labels for different crops rather than one "super-label" that tabulates all possible crops and rates.

Crops for which no evidence of registered seed treatments could be found were excluded from the compilation. This included asparagus, beets, daikon, eggplant, garlic, horseradish, okra, all pepper types, radishes, tomatoes, turnip, and watercress.

A few other crop-specific assumptions were made as follows:

- To apportion market share of treatments in corn, we consulted the USGS published estimates of clothianidin, imidacloprid, and thiamethoxam on corn for 2014, the last year when seed treatments were included in USGS use estimates. For states bordering California (Arizona, Nevada, Oregon), the ratio of clothianidin to thiamethoxam use was roughly 2:1 with no imidacloprid showing. This is the proportion we used for California.
- For cotton, sugar beet, and wheat, the proportion of each neonic was assigned based on the country-wide information provided in the analysis by USEPA's Biological and Economic Analysis Division or "BEAD" (USEPA 2017, 2018). The proportional market share of the three active ingredients in wheat was extended to other cereal crops.

- Clothianidin in sweet potatoes was assumed to be used at the same per acre rate as for potatoes, given the similarity between the respective rates on seeds.

Table 6 provides the possible total quantity of each neonic active ingredient that could be applied via treated seed use, assuming all seeds treated if allowed. County information was amalgamated by USDA agricultural region (see Figure 2).

Figure 2. Agricultural regions of California.

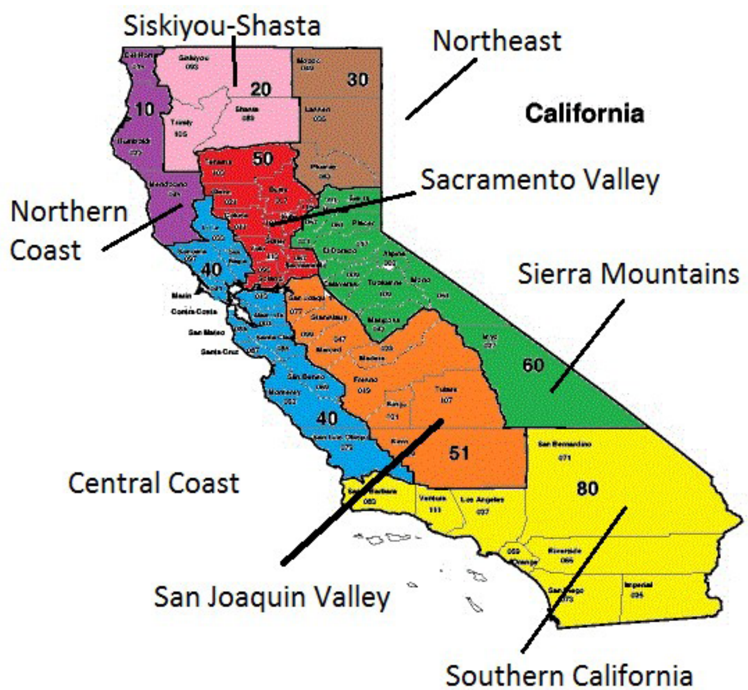


Table 6. The calculated potential use of neonics applied as seed treatments in 2016 by agricultural region of California.

Agricultural region	Clothianidin lbs of a.i.	Imidacloprid lbs of a.i.	Thiamethoxam lbs of a.i.	Total
Central coast	59,496	6,180	60,012	125,688
Northeast	899	5,849	4,693	11,441
Northern coast	40	357	221	619
Sacramento valley	7,386	30,261	24,551	62,198
San Joaquin valley	62,060	67,018	62,454	191,532
Sierra mountains	46	426	441	913
Siskiyou-Shasta	800	1,780	3,516	6,095
Southern California	34,321	12,815	47,590	94,726
Unspecified[a]	463	13,400	4,827	18,690
Total	165,511	138,086	208,305	511,902

a See section 2.2.1. The "Unspecified" total is based on USDA-reported seeded acreages that cannot be assigned to specific counties based on county statistics.

2.2.2. Comparing the total potential neonic-treated seed use to PUR data for non-seed neonic uses

We can compare the totals from Table 6 with those compiled by USGS from the PUR system in California (Table 7, Appendix 3). As mentioned earlier, the latter exclude seed treatments. Neither total includes *consumer* uses of these active ingredients. Totals for the other neonics acetamiprid and dinotefuran are also included.

Table 7. Total application of neonics in California by certified applicators in 2016 as recorded in PUR system (lbs a.i.).[a]

Agricultural region	Clothianidin	Imidacloprid	Thiamethoxam	Sub-total of the 3 principal nitroguanidine neonics	Acetamiprid	Dinotefuran	Grand total
Central coast	7,998	40,906	12,807	**61,711**	6,056	1,969	**69,736**
Northeast	0	139	6	**145**	0	0	**145**
Northern coast	0	516	8	**524**	2	0	**526**
Sacramento valley	554	19,444	590	**20,588**	8,451	372	**29,411**
San Joaquin valley	11,571	218,289	21,857	**251,716**	31,388	8,749	**291,854**
Sierra mountains	18	178	0	**196**	116	0	**312**
Siskiyou-Shasta	4	208	26	**237**	7	0	**245**
Southern California	1,977	66,787	6,445	**75,210**	4,242	2,323	**81,775**
Grand total	**22,122**	**346,467**	**41,738**	**410,327**	**50,262**	**13,414**	**474,004**

a PUR data compiled by USGS for 2016. Data obtained from: https://water.usgs.gov/nawqa/pnsp/usage/.

As these calculations indicate, full deployment of nitroguanidine neonic seed treatments on crops for which the practice is labeled exceeds the reported (PUR) use of the three active ingredients for 2016 (511,902 lbs a.i. vs. 410,327 lbs a.i.). Thus, not taking seed treatment insecticides into account may seriously underestimate actual pesticide inputs in California.

Appendix 3 explores the potential discrepancy in more detail on a county by county basis. Reported use for counties reporting 0 lbs of neonic use was changed to 1 lb in order to calculate a proportional increase over the reported use. Clearly, those counties with little to no PUR-reported neonic use, but with some crops allowing for seed treatment use showed the greatest increase. However, even heavy agricultural counties showed substantial potential discrepancies suggesting that the use of clothianidin and thiamethoxam, especially, may have been greatly underestimated. For example, the amount of thiamethoxam used in Monterey county on the Central Coast could be over 500% of reported applications in the PUR system. Likewise, San Joaquin County could have application levels 300% higher than reported.

2.3. Estimating the actual total neonic-treated seed use in California

There is no publicly available information on the actual use of neonic seed treatments in California. Even when reported nationally, estimates are now very dated and not geographically explicit, and therefore potentially meaningless. Where information on seed treatments has been tracked following registration (e.g., Douglas and Tooker 2015 for several field crops), it shows that the extent of seed treatment use has increased exponentially. Later registrations and crops with smaller national acreages have not benefitted from the same level of scrutiny. It is reasonable to expect that use patterns registered more recently are still in their exponential growth phase. Also, it is anticipated that removal of the last uses of organophosphorus insecticides (e.g., chlorpyrifos—see Appendix 4) will lead to further increases in neonic use.

Attempts to obtain seed treatment use information from California crop specialists yielded no relevant information. Crop experts who were contacted and kindly responded did not know the use information, often recommending that I contact seed retailers[6] or suggesting (mistakenly) that the information could be obtained from PUR data. That total absence of knowledge illustrates that, as predicted by Hitaj et al. (2020), failure to account for seed treatments does result in a loss of agricultural expertise.

Any information I was able to find is presented in Appendix 4.

3. AQUATIC CONTAMINATION FROM NITROGUANIDINE NEONICOTINOIDS IN CALIFORNIA

This section provides a review of the potential for neonic seed treatment applications to contaminate state surface waters as well as a short analysis of the neonic water sampling performed to date.

3.1. At what level do neonics cause ecological harm?

Before examining the water data in California, we must first examine at what levels neonics would be expected to cause harm to aquatic ecosystems, also known as aquatic "benchmarks." An extensive review of the setting of aquatic benchmarks is provided in my earlier reports on surface water contamination in New York State (Mineau 2019a, b). I will quickly summarize the arguments here in the context of the California situation and explore recent developments. Relevant sections of these reports will be excerpted here.

In my previous reports (Mineau and Palmer 2013, Mineau 2019a, b), I showed how USEPA had erred in its initial benchmark setting exercises with imidacloprid and argued that they were now making the same error in setting their benchmarks for clothianidin and thiamethoxam. My main thesis was that, given the 790,000 fold difference in sensitivity to imidacloprid from the least to the most sensitive organism tested (with 36 species tested as of 2017), setting any benchmark based on the "most sensitive" species for the smaller clothianidin and thiamethoxam datasets had more to do with chance than with good science.

As of June 2020, USEPA had derived the benchmarks appearing in Table 8.

Table 8. USEPA aquatic freshwater benchmarks in effect as of June 2020.[a]

Active ingredient	Acute (µg/L)	Chronic (µg/L)
Imidacloprid	0.385	0.01
Thiamethoxam	17.5	0.74
Clothianidin	11	0.05

a Data obtained from: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-and-ecological-risk (consulted June 2020).

Clearly, USEPA still believed then that clothianidin and thiamethoxam were safer to aquatic life despite ample evidence that this difference was an artifact of the larger dataset for imidacloprid. In 2018, Canada's PMRA (2018a, b) had already proposed chronic benchmarks for clothianidin and thiamethoxam that were 33 and 28-fold lower than the proposed USEPA benchmarks respectively.

As early as 2013, we (Mineau and Palmer 2013) had proposed that the aquatic toxicity of thiamethoxam and clothianidin to aquatic insects and crustacea should be assumed to be similar to that of imidacloprid based on a comparison of toxicity

6 A current (Jan. 2019-June 2020) list of authorized dealers in California numbered more than 950.

tests performed on the same species with different neonics. The argument was strengthened and published in Morrissey et al. (2015), which provided that:

> "*In general, acute and chronic toxicity of the neonicotinoids varies greatly among aquatic arthropods. . . . Based on limited data, however, it appears that differences in relative toxicity among the various individual neonicotinoids are minor.*" (Morrissey et al. 2015)

Other authors have concluded as to the similar toxicity of nitroguanidine neonics (e.g., Hoyle and Code 2016) on the strength of newer data such as Cavallaro et al. (2017). These authors generated comparative data for the three nitroguanidine neonics on the same chironomid species. They found almost identical toxicities for imidacloprid and clothianidin—somewhat less for thiamethoxam.

The publication of more comparative data by Raby et al. (2018a, b) finally provided information sufficient to convince USEPA that differences between neonic active ingredients were indeed not as great as it had originally believed (USEPA 2020c). The upshot was that, for the more sensitive species tested, all nitroguanidine neonics should be considered to be of equivalent toxicity:

> "*When considering the toxicity data for the mayfly, all four chemicals are similar, with clothianidin, dinotefuran and thiamethoxam all having 95% confidence intervals that overlap with the confidence intervals of imidacloprid. For the midge, there are slight differences in toxicity among the chemicals, where both clothianidin and imidacloprid are similar (95% confidence bounds overlap) and dinotefuran and thiamethoxam are slightly less toxic (LC50 values are 2x and 5x higher than imidacloprid; confidence bounds do not overlap with those of imidacloprid or clothianidin).*" (USEPA 2020c)

Similar results were obtained in the chronic toxicity tests with thiamethoxam being slightly less toxic than imidacloprid—but by a two-fold difference only. It should be noted that thiamethoxam breaks down to clothianidin, so the lesser toxicity of the former is not as relevant ecologically. No-effect concentrations for clothianidin and imidacloprid were within a factor of 4 and 2 for the most sensitive and second-most sensitive species respectively. Clothianidin was more toxic than imidacloprid to the most sensitive species (a mayfly) but less toxic than imidacloprid for the second-most toxic, a chironomid. Clearly, the differential toxicity ascribed to the different nitroguanidine products in previous USEPA aquatic risk assessments is not justified scientifically.

Early research by Starner and Goh (2012) in California had shown that flowing water in agricultural watersheds showed concentrations of imidacloprid that remained steady for periods exceeding three months at least. Similarly, Whiting et al. (2014) and Whiting and Lydy (2015) had shown that, runoff water from corn seed treated with clothianidin carried residues for the whole summer. Schaafsma et al.'s 2015 study indicated that residues could persist for a full year following a single application. Given the persistence of the nitroguanidine neonics in soils or waters protected from direct sunlight, and the fact that they are found to contaminate runoff water for months after application, it is clear that there is a very high potential for chronic toxicity, making the chronic toxicity benchmark the most relevant threshold for ecological harm. Several authors have commented on this (reviewed in Mineau 2019a, b). In addition, the cumulative toxicity potential of neonics has been well examined. In a recent expansion of their previous analyses, Sanchez-Bayo and Tennekes (2020) restated their argument that neonics show characteristics of irreversible cumulative toxicity in both aquatic and terrestrial invertebrates. Their sound analysis argues for the fact that any benchmark based on acute or even short-term toxicity data is irrelevant in a real-world exposure situation.

All of this argues for disregarding any acute benchmark in favor of a chronic one. In previous reports, I argued that the 0.01 µg/L chronic benchmark established by USEPA for imidacloprid should be applied to the other nitroguanidine seed treatment chemicals. That has now been conclusively shown to be an appropriate benchmark for residues of any of the nitroguanidine neonics in water, or, where more than one neonic chemical is present, the sum of all nitroguanidine neonic residues.

3.2. Predicted contamination from seed treatments relative to other application methods

Because neonic seed treatments may be one of the greatest (if not the greatest) use of neonics in California, it is critical to understand the extent of aquatic contamination one can expect from them. Two questions that arise are: (1) what is the expected proportion of contamination from each chemical active ingredient; and (2) what is the expected contamination from seed treatments relative to all other uses (soil, foliar, etc.).

On the first question, as discussed below, surface water testing for clothianidin and thiamethoxam—both of which are commonly used as seed treatments—is inadequate. However, we can glean some insight from the active ingredients' surface water mobility indices (SWMIs)—a measure designed by Chen et al. (2002) for the mobility of a chemical in the environment, and therefore its propensity to contaminate surface waters. The index ranges from 0 (low mobility) to 1 (extreme mobility), and the SWMI value for each of the three main nitroguanidine neonic active ingredients is provided in Table 9.

Table 9. Surface Water Mobility Indices (SWMIs) for the main seed treatment neonics based on an algorithm designed by Chen et al. (2002).[a]

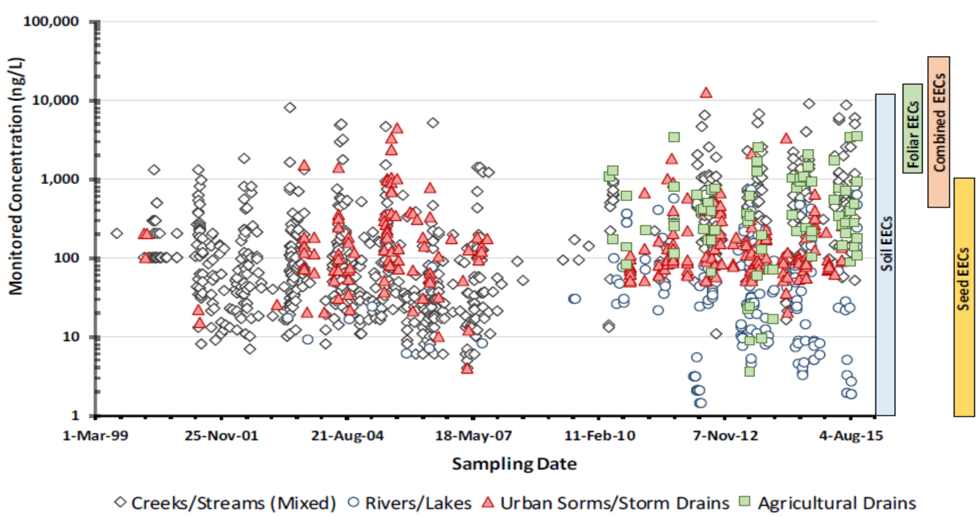
Neonic active ingredient	SWMI value
Clothianidin	0.66
Imidacloprid	0.56
Thiamethoxam	0.82

a Input data from Pesticide Properties Database obtained from: https://sitem.herts.ac.uk/.

As Table 9 shows, the physico-chemical properties of clothianidin and thiamethoxam make them more likely to contaminate surface waters than imidacloprid. Therefore, given similar use patterns, the predicted surface water contamination from clothianidin and thiamethoxam would be more extensive than for imidacloprid.

On the second question, we can first look to attempts by USEPA to assess the risks of neonic water contamination from seed treatments versus other sources in their recent re-evaluation of neonic impacts, which took place as part of a process known as "registration review." In their initial review of imidacloprid residues in surface waters in the United States at large, USEPA (2016) used modeling to predict water concentrations from labeled uses. They argued that runoff concentrations from soil and seed treatment uses would be lower than from foliar applications, as shown in Figure 3. (Seed EECs).[7]

Figure 3. Detected imidacloprid concentrations in U.S. surface waters from routine monitoring efforts relative to the range of modeled concentrations for different use patterns of the pesticide (USEPA 2016).



7 EEC stands for "Expected Environmental Concentration," an estimate generally obtained through models of runoff and/or drift.

Figure 2 shows a great deal of variability in the expected water concentration following the use of seed treatments. Part of this variation has to do with the labeled rate on seed as well as the depth of incorporation into the soil profile. The runoff models used by USEPA initially predicted no runoff when seeds are planted at more than 2 cm in depth (USEPA 2016).[8] Given that recommended seeding depths for both corn and soybean are deeper than this 2 cm depth, the model findings were clearly at odds with the fact that aquatic contamination is very extensive in areas planted to corn and soybeans (Hladik et al. 2014). This contradiction was raised, but not resolved, in USEPA (2016).

USEPA (2020c) summarized the expected environmental concentrations (EECs) it anticipates from various seed treatment uses with the three main seed treatment neonics (Table 10). These are the water concentrations USEPA used to calculate risk quotients and assess the likely environmental damage from seed treatment uses in its recent re-evaluation. These estimates are meant to be conservative (i.e., worst case estimates) at this stage of the evaluation process. However, as seen below, they are clearly not.

Table 10. Estimated environmental water concentrations (EECs) in µg/L predicted by USEPA for neonic seed treatment uses (USEPA 2020c).

	Peak (1 day) EEC µg/L			Chronic (21 day) EEC µg/L		
Crop	**Clothianidin**	**Imidacloprid**	**Thiamethoxam**	**Clothianidin**	**Imidacloprid**	**Thiamethoxam**
Cotton	2.14	2.19	1.18	1.87	1.56	0.97
Corn	0.59	0.78	0.39	0.53	0.56	0.33
Soybean	1.77	3.33	0.46	1.53	2.21	0.40
Sugar beet	1.11	2.63	1.35	0.96	1.83	1.24
Wheat	2.27	2.56	1.08	1.99	1.81	0.86
Rice	71.7	NA	66.4	8.74	NA	35.5

Indeed, long before USEPA published these estimates, there was already evidence from published field studies that the agency had underestimated the potential for seed treatments to contaminate surface water. One possible reason for this is that their modeling ignores the issue of dust that is produced at seeding (USEPA 2016).

In the independent literature, Main et al. (2014) reported clothianidin values as high as 3.1 µg/L from sloughs (small ponds that occur frequently in "knob and kettle" landscapes) in canola-growing areas following the use of clothianidin seed treatments; and Schaafsma et al. (2015) reported levels as high as 16.2 µg/L in ditches outside another corn field seeded to clothianidin and 3.25 µg/L in puddles as far as 100 m from the fields. Whiting et al. (2014) and Whiting and Lydy (2015) documented clothianidin residues of 0.23 µg/L in runoff from a corn field, but this was at one-fifth of the allowable treatment rate;[9] more importantly, residues persisted in runoff water a full 156 days after planting.

The situation is similar with thiamethoxam seed treatments. Main et al. (2014) found values up to 1.49 µg/L from sloughs around canola fields; and Schaafsma et al. (2015) measured levels as high as 7.5 µg/L in ditches outside a seeded field and 16.5 µg/L in puddles outside their Ontario corn fields. The latter two measurements were even more remarkable because they were measured pre-plant and therefore indicated contamination from the previous use of seed treatments in the preceding growing season. Higher levels were recorded in puddles within the field area.

More in line with USEPA (2020c) predictions, recent samples taken from a variety of waterbodies in crop and non-crop sites within an agricultural landscape in Indiana (Miles et al. 2017; with 2018 correction) found concentrations of clothianidin averaging 0.101 µg/L (all sites combined; with samples taken weekly for eight weeks). The highest concentrations of

8 These predictions, obtained through the PWC (Pesticide in Water Calculator), provide 2 cm as the default value beyond which no runoff is expected, although this input can be changed by the user. Data obtained from: https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/pesticide-water-calculator-version-150-and-152-user (consulted June 2020).

9 It is common practice to scale contamination levels with application rate. In this case, this would result in a contamination level approximating 1.15 µg/L.

clothianidin (0.45-0.67 µg/L) were observed in small lentic woodland bodies of water well away from the seeded corn and soybean fields. One of these sites (PWA West) apparently received drainage from nearby fields; how the other got contaminated is unknown.[10] Regardless, levels in these wetlands were higher than those reported in any of the ditch samples taken nearer the seeded fields, showing the difficulty in containing these extremely mobile insecticides within the treatment area.

On the whole, there is now ample model and field data evidence predicting what the expected neonic water contamination would be from seed treatment use. Regardless of whether current USEPA model estimates represent an accurate picture or a considerable underestimate—as the independent scientific literature would suggest—the anticipated neonic levels in water are all well within the range where we would expect considerable injurious impacts on aquatic habitats receiving runoff. Therefore, even if expected contamination levels from seed treatments are lower than from other application methods, the potential scale of use (as outlined in Section 2) is a clear concern with respect to the California environment.

3.3. Evidence of neonic contamination in California surface water data and likely environmental impacts

In California, CaDPR amalgamates all known water analyses into the state Surface Water Database or "SURF."[11] The database includes CaDPR studies as well as the national USGS water sampling programs and others. CaDPR has been analyzing surface waters for pesticide residues since 1981.[12] Since 2000, the CaDPR program performing these analyses has been the Surface Water Protection Program (SWPP) (Goh et al. 2019).

Knowledge of extensive contamination of California surface waters by imidacloprid is not new. In 2012, Starner and Goh presented data from 2010-2011 demonstrating such contamination. Some of the sampling sites used in that report have continued to be monitored over time, and data from those sites are presented below.

Hoyle and Code (2016) queried SURF for the presence of neonics in samples collected between January 2010 and October 2015. For imidacloprid, this amounted to 790 samples taken from 132 sample sites. They found that 55% of the sites had at least one imidacloprid concentration above the level of detection with a mean detection level of 0.643 µg/L. Despite using the older EPA benchmark of 1.05 µg/L (105X higher than the currently accepted benchmark), they found that 14% of samples fell within the range expected to cause significant biological effects on receiving waters. Hoyle and Code (2016) further pointed out that, using the more protective European chronic benchmark of 0.067 µg/L (closer to the current USEPA and our proposed 0.01 µg/L benchmark), 89% of imidacloprid detections exceeded this benchmark.

Neonic use has dramatically increased since the 2010-2015 period when these water samples were taken. Hoyle and Code (2016) only examined imidacloprid data and, as they point out, it is difficult to separate the agricultural uses of imidacloprid from its domestic and landscaping uses, although high rates of detection in the Santa Maria, Salinas, and Imperial Valley areas did suggest agriculture is an important contributor.

Rather than repeating the Hoyle and Code (2016) analysis, I approached the data differently. Without an analysis of each of the sampling locations, their flow rates, why sites were chosen, and how samples were timed to correspond to agricultural activity and rainfall, the proportion of positive imidacloprid detections does not paint an accurate picture of whether they reflect agricultural or urban sources. New data collected by CaDPR, however, does address this to a certain extent (see below). Data on clothianidin and thiamethoxam—both of which are almost entirely associated with agriculture—are also now available.

The SURF database was queried in May 2020. It consisted of results tabulated to December 2019. Samples consisted of either filtered water samples or whole water samples, but this was not specified in all cases. Because of the high solubility of the three neonics of interest, I ignored this parameter, estimating minimal loss of analytes from filtering out the particulates.

As mentioned, CaDPR monitors both agricultural and urban sources of imidacloprid contamination. Studies are identified as such in the SURF database. I assumed that, if designated as such, the chosen sample locations indeed reflect ongoing

10 This is based on inspection of the PWA East & West sampling site photographs included in the publication and personal communication with two of the authors: C. Krupke and J.T. Hoverman.

11 Data obtained from: https://www.cdpr.ca.gov/docs/emon/surfwtr/surfcont.htm (consulted June 2020).

12 Data obtained from: https://axial.acs.org/2019/07/30/surface-water-protection-program-for-pesticide-use-in-california/ (consulted June 2020).

agricultural or urban land use, although we cannot say whether samples were chosen to represent maximum likelihood of finding the analyte—e.g., presence of cropped fields or time of sampling relative to use patterns and precipitation, type of waterbody, etc. As reviewed in earlier analyses (Mineau 2019a, b) samples taken as part of regular water monitoring programs always underestimate the presence and levels of targeted pesticides.

Over the entire 2010-2018 period,[13] CaDPR sampling for imidacloprid in sites labeled "agricultural" was comprised of 556 samples from 86 sampling sites (Table 11). Imidacloprid was detected at half of those sites, indicating some use in the watershed. All sampled sites had maximum detection levels that exceeded the 0.01 µg/L benchmark and a large proportion exceeded the benchmark by 10X or even 100X (Table 11). Indeed, over half of the sampled sites had maxima that exceeded the USEPA acute benchmark of 0.38 µg/L, a level which, as I argued earlier (see section 3.1), is clearly not protective enough in the case of a persistent compound with cumulative toxicity. The highest recorded maximum level was 41.1 µg/L. The next highest was obtained on the same site, suggesting the maximum reading was not in error. It came in at 9.86 µg/L.

The highest imidacloprid levels were recorded in Monterey County, followed by Santa Barbara, Imperial, and Napa—all intensive agricultural regions. In these counties, the imidacloprid data alone clearly indicates serious adverse impacts for aquatic life in receiving waters. Looking at positive detections over the years (Figure 4), there appears to be a trend for higher levels of detection over time. This could be the result of more targeted monitoring or reflective of the generally increasing amount of use of imidacloprid over that period.

CaDPR also sampled urban sites throughout the same period. A total of 578 samples were noted as being part of urban monitoring studies—roughly half from Orange County (Table 11). Although more of the sampled sites had positive detections, impacts from urban use may be less pronounced than for agricultural uses, as judged by the fewer number of sites registering maximum levels either 10X or 100X benchmark levels. Looking at positive detections over the years (Figure 5)—with the exclusion of one extreme value for 2018—does not reveal any convincing pattern, although there is a slight suggestion of a decline. Given that several of CaDPR's studies mention "mitigation monitoring," one can assume that there has been some effort at containing urban sources of imidacloprid. However, the generally lower levels seen in the urban samples may also be a result of higher flow rates and larger bodies of water being sampled. The ubiquitous presence of neonics in storm water retention ponds and canals has been of increasing concern on the part of municipal and regional governments (Murray 2015).

As was the case with the agricultural samples, one site had an extreme value (165 µg/L) recorded in 2018. The next highest detection (12.7 µg/L) was recorded at the same site some years earlier.

Table 11. CaDPR monitoring results for imidacloprid in studies indicated as agricultural or urban in nature.

	All sites				Sites with positive detections		
Study type	**Number of samples taken**	**Number of sites sampled**	**Number of sites with positive detections**	**Maximum level (ppb)**	**Sites with maximum detections above benchmark**	**Sites with maximum detections 10X above benchmark**	**Sites with maximum detections 100X above benchmark**
Agricultural	556	86	43 (50%)	41.1 (next highest: 9.86)	43 (100%)	33 (77%)	15 (35%)
Urban	578	57	43 (75%)	165 (next highest: 12.7)	43 (100%)	21 (49%)	3 (7%)

13 As of May 2020, no CaDPR agricultural monitoring samples were reported beyond 2018.

Figure 4. Plot of positive detections (in µg/L) by year for CaDPR's agricultural sampling for imidacloprid. The outlying value of 40.1 µg/L from 2017 was omitted. The overall trend in the mean is depicted by the red line.

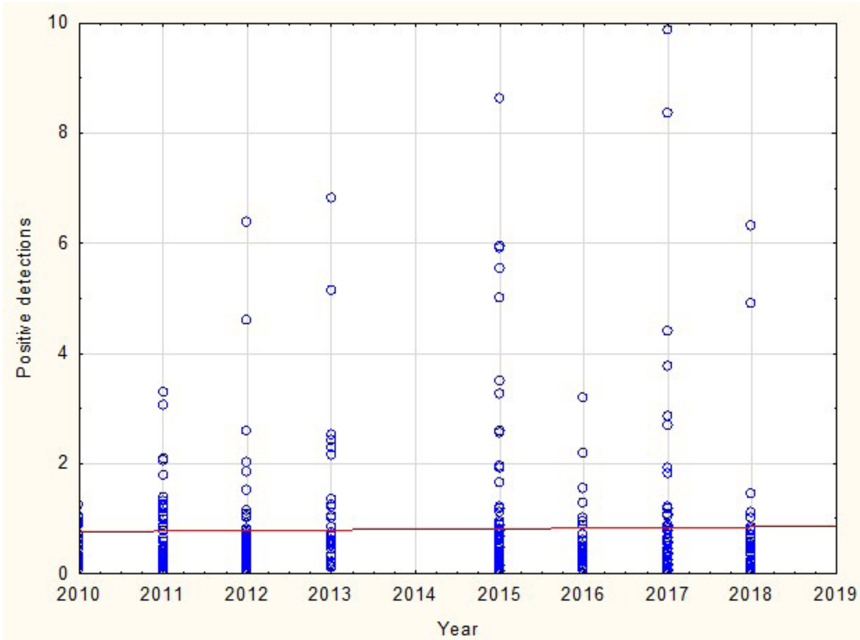
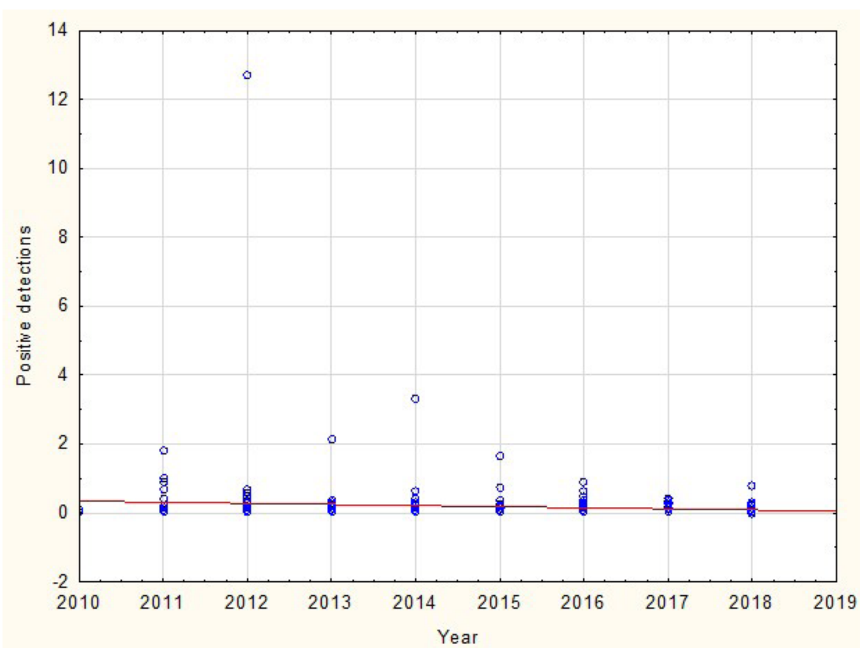


Figure 5. Plot of positive detections (in µg/L) by year for CaDPR's urban sampling for imidacloprid. The outlying value of 165 µg/L from 2018 was omitted. The overall trend in the mean is depicted by the red line.

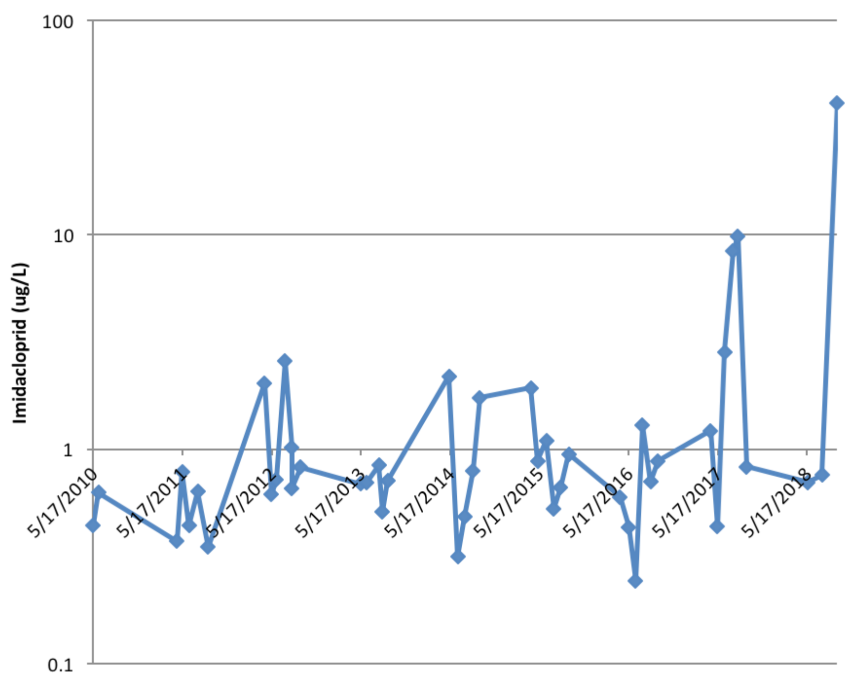


3.3.1. Continued monitoring of imidacloprid at sites from the Starner and Goh (2012) study

As mentioned above, the California data from agricultural sites reported by Starner and Goh (2012) offered good evidence that receiving surface waters were exposed to residues over the entire growing season, which argues in favor of using a chronic benchmark as the ecologically relevant one.

Monitoring continued at many of those sites right up to 2018. I chose to show data from two of the most intensively sampled sites—two tributaries of the Salinas River in Monterey County, Chualar Creek, (Figure 6) and Quail Creek (Figure 7).

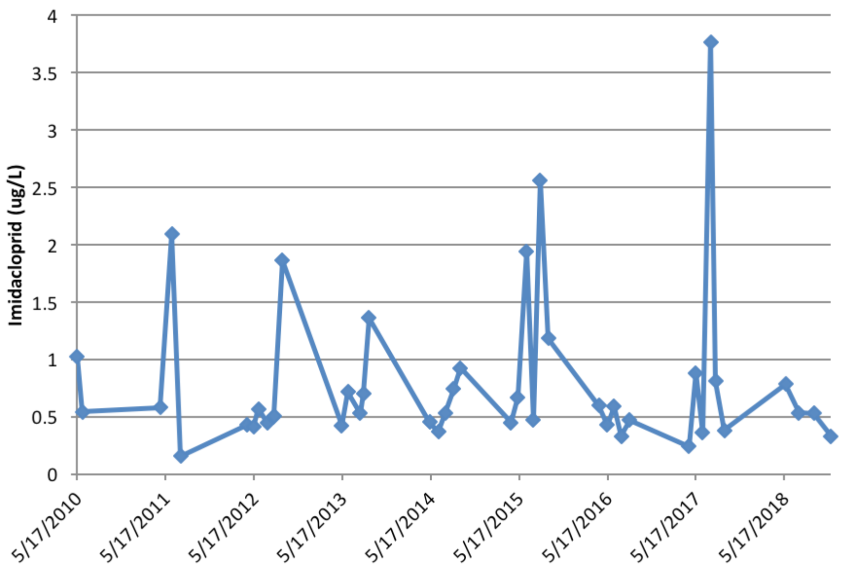
Figure 6. Imidacloprid residues at site 27-8 – Chualar Creek, a tributary to the Salinas River, Monterey County. The scale is shown on a log scale in order to accommodate the wide range in values.



In the case of Chualar Creek, every single water sample taken at that sampling site since 2010 has had a concentration of imidacloprid over 10X the benchmark level for damage to aquatic life (i.e., over 0.1 μg/L) and frequently over 100X that benchmark (i.e., over 1.0 μg/L). The final sample taken in 2018 was the highest at 41.1 μg/L.

Quail Creek shows a similar, although not quite as extreme, pattern. Over the 8 years of sampling, water concentrations measured between May and November seldom dipped below 0.5 μg/L or 50 times over the benchmark level for damage to aquatic life.

Figure 7. Imidacloprid residues at site 27-7 (Quail creek), a tributary to the Salinas River, Monterey County.



3.3.2. Clothianidin and thiamethoxam sampling

Sampling for clothianidin and thiamethoxam in California waters has not been adequate. Although some sampling for clothianidin and thiamethoxam began as early as 2011, it is clear that much of the sampling locations, especially in the earlier years, were not chosen with agriculture in mind, but as part of on-going USGS sampling of urban/industrial areas—e.g., Mallard Slough in Sacramento, or estuarine areas such as Grizzly Bay. Later, other groups became involved in sampling, such as the California State Water Resources Control Board's Surface Water Ambient Monitoring Program or "SWAMP," as well as other coalitions of different regional water boards. Fortunately, these sampling efforts include some of the same CaDPR agricultural long-term monitoring sites, as CaDPR by 2018 had still not incorporated clothianidin or thiamethoxam into its agricultural sampling programs. However, these samples were not taken during the more intensive summer season.

As a result, of the 85 sites monitored for imidacloprid by CaDPR, only 11 (13%) were examined for clothianidin or thiamethoxam residues, and this was only for the years 2017-2018.

Table 12 compares levels of imidacloprid with those of clothianidin and thiamethoxam for the 11 CaDPR agricultural monitoring sites. As mentioned, the comparison is rather inadequate because all of the clothianidin and thiamethoxam samples were taken in either September or December, whereas imidacloprid samples for the most part, were taken between April and September. As discussed in Mineau (2019a, b) the higher the frequency of sampling and the higher the number of samples, the greater the chance of detecting the higher residue concentrations. For example, the "maximum" value of 0.398 µg/L thiamethoxam obtained after only two winter samples at site 27-66 compared to the maximum 0.647 µg/L of imidacloprid following 47 spring and summer samples of imidacloprid strongly suggests that thiamethoxam would be shown to be a more significant contaminant at that site were the sampling adequate.

Table 12. Levels of three neonicotinoids compared at agricultural monitoring sites sampled by CaDPR. Samples taken from 2010-2018 for imidacloprid, and 2017-2018 for clothianidin and thiamethoxam.							
County	Site	Clothianidin		Imidacloprid		Thiamethoxam	
		N[a]	Maximum recorded concentration (μg/L)	N	Maximum recorded concentration (μg/L)	N	Maximum recorded concentration (μg/L)
Monterey	27-12	2	0.060	36	1.12	2	0.482
Monterey	27-13	1	0	27	0.067	1	0.080
Monterey	27-2	1	0	1	0	1	0
Monterey	27-50	2	0	8	0.167	2	0.353
Monterey	27-58	1	0.251	5	0.118	1	1.44
Monterey	27-66	2	0	47	0.647	2	0.398
San Luis Obispo	40-13	2	0	26	1.44	2	0.069
San Luis Obispo	40-23	2	0	6	0	2	0.071
Santa Barbara	42-48	2	0	26	9.14	2	0.113
Santa Barbara	42-49	2	0	11	1.39	2	0.001
Santa Barbara	42-50	2	0.046	34	4.91	2	0.427
Santa Cruz	44-18	2	0	4	0.064	2	0.040

a N denotes the number of samples reported.

These data indicate that clothianidin and, especially, thiamethoxam are major contaminants of agricultural areas of California—which is perhaps predictable given their physico-chemical characteristics (Section 3.2) as well as the large reported and potentially larger unreported use (Section 2.3). Despite very fragmentary and inadequate sampling, maximum thiamethoxam water levels have already surpassed those of imidacloprid at some sites. Given that the potential clothianidin and thiamethoxam seed treatment use may far exceed their other uses in many counties of California (see Appendix 3), the failure to include these insecticides within a comprehensive agricultural sampling program or track seed treatment products more generally, has created a serious data gap—depriving scientists and policy makers of key information about the likely significant and damaging impacts of neonic-treated seed use.

Table 13 shows the total number of positive clothianidin and thiamethoxam detections regardless of sampling site. As discussed earlier, sampling intensity was much lower than for imidacloprid, so benchmark exceedances are not strictly comparable—especially since many sites are not in agricultural areas and clothianidin and thiamethoxam are predominantly used in agriculture.

Table 13. Positive detection of clothianidin and thiamethoxam in California (2011-2018).		
	Clothianidin	Thiamethoxam
Number of sample sites with positive samples	23	47
Maximum level recorded (μg/L)	1.6	9.0
Sites with detections above 0.1 μg/L benchmark	20 (87%)	38 (81%)
Sites with detections 10X above 0.1 μg/L benchmark	13 (57%)	25 (53%)
Sites with detections 100X above 0.1 μg/L benchmark	4 (17%)	9 (19%)

The fact that each active ingredient, despite the inadequate sampling, frequently exceeds benchmark levels is worrisome. Given that most aquatic systems with agricultural regions will be exposed to these three nitroguanidines—along with the other neonics dinotefuran and acetamiprid—in combination, their combined concentrations must be considered when assessing injury to the aquatic environment. Clearly, not sampling comprehensively for neonics other than imidacloprid misses a critically important part of the picture.

4. POLLINATOR IMPACTS FROM NITROGUANIDINE NEONICOTINOID SEED TREATMENTS IN CALIFORNIA

4.1. Recent regulatory reviews of neonics and pollinators

USEPA and CaDPR collaborated on an extensive review and risk assessment of the three main nitroguanidine neonic insecticides (clothianidin, imidacloprid, and thiamethoxam) regarding their impacts on bees.[14] The regulatory agencies, in conjunction with the registrants, developed protocols for honey bee colony studies to be carried out by the registrants. These studies formed the core of the assessments. Given the sheer amount of information available to these agencies, as well as the multitude of neonic use patterns, this evaluation was a complex one. CaDPR (CaDPR 2018, 2019) was first in publishing its version of the assessment, the review document and addendum coming in at almost 1200 pages. The USEPA final published version of the assessment (USEPA 2020d, e, f, g, h, i, j) came in at over 1100 pages, once the various appendices and attachments are factored in. A detailed review of either the USEPA or CaDPR versions of the pollinator assessment is beyond the scope of this report; but this report will highlight a few notable differences between the two assessments as well as some clear inadequacies and shortfalls, specifically with respect to the assessment of seed treatment uses. Simply put, the CaDPR and USEPA assessments both failed to adequately characterize the risk of neonic seed treatments to bees, especially wild bees. This is a serious issue because, while other methods of neonic application may indeed carry a higher risk on a per-application basis, the use of seed treatments can greatly extend the risk to pollinators spatially and involve crops not yet assessed for bee risk.

With the methods outlined in Chapter 2 and Appendix 1, this report can account for a little over 5 million acres of non-organic cropland in the State of California. As reviewed earlier, a number of minor crops—including several for which seed treatments are allowed—are not included in this total. Nevertheless, we can calculate that 76% of this crop area can potentially be sown with a neonic-treated seed. On a county by county basis (see Appendix 5), the proportion of crop area potentially seeded with neonics ranges from a low of 17% (Yuba County) to 100% (Imperial County). The sheer size of the potential treated area is such that it is critical to adequately assess the risk to pollinators posed by seed treatments.

4.2. What does the CaDPR assessment conclude with respect to neonic-treated seeds?

CaDPR (2018) essentially dismissed any risk from neonic-treated seeds on the basis of preliminary joint assessments carried out by itself and with USEPA. On the basis of these preliminary efforts, CaDPR concluded that residues in pollen and nectar resulting from seed treatment use were either below detection limits or at least below any effect levels. As detailed below, the USEPA assessment is much more nuanced and does, in fact, indicate a measurable risk to both individual pollinators and honey bee colonies, even before errors of omission and commission in that assessment are taken into account.

CaDPR (2018) does raise the issue of abraded seed coat dust (see extensive review below) but concludes that USEPA has addressed the issue with best management practices and that there are no records of such incidents occurring in California. To the author's knowledge, the issue of dust at seeding might indeed have been partially addressed, but it is a long way from being solved.

CaDPR only considers risk to honey bee colonies and therefore does not look at risk to individual pollinators in the field. The risk determinations are based on deriving no observable adverse effect concentrations (NOAEC) for pollen and

14 In fact, Canada's PMRA also contributed in this tripartite effort.

nectar residues in treated crops from registrant-supplied honey bee colony feeding studies (Table 14). In other words, the concentrations under which no effects were observable on honey bee colony health.

Table 14. NOAEC values in nectar and pollen used by CaDPR to assess the risk of residues in various crops (modified from Table 1; CaDPR 2018).

Active ingredient	NOAEC in nectar (ng/g)	NOAEC in pollen (ng/g)
Clothianidin	19	372
Imidacloprid	23	97.5
Thiamethoxam	30	372

One notable difference between the CaDPR and USEPA assessments is that CaDPR generates separate risk ratios for nectar and pollen consumption. The CaDPR assessment compares nectar and pollen residue levels in crop plants to the NOAEC levels generated in separate whole hive studies conducted with either spiked sugar solutions (surrogate for nectar) or spiked pollen patties. USEPA uses a "total dietary approach" and makes the assumption that honey bees will consume 20X more nectar than pollen; pollen residue concentrations are therefore divided by 20 to derive "nectar equivalent" residue values. As discussed below, neither approach is satisfactory for assessing the risk to wild bees.

By not considering risk at the individual bee level, CaDPR completely excludes appropriate consideration of any of the 1500+ Californian wild bee species, especially solitary bees, where the death of individuals is the appropriate endpoint against which potential exposure should be compared. In addition, there are many independent studies in the literature that show effects on bumble bee and mason bee colonies at lower exposure concentrations (see below). Curiously CaDPR offers that: "*Apis bees serve as a surrogate for other non-Apis species of bees (e.g., bumble bees) that may be exposed under agricultural conditions*" (CaDPR 2018). In actual fact, honeybees are not adequate surrogates and a honey bee-centric exposure scenario does not inform on the risk to wild bees as argued below. By considering only honey bee colony studies in its assessment, CaDPR explicitly excludes any consideration of solitary bee species.

In the rest of this chapter, we will look at the fuller evaluation of seed treatment uses in the USEPA assessment.

4.3. What does the USEPA assessment conclude with respect to neonic-treated seeds?

The USEPA assessment finds that, for imidacloprid, risk to individual bees falls below levels of concern for all crops except beans, canola, cotton, peanuts, peas, safflower, soybeans, and sunflower. The highest risks are for beans and peanuts, where honey bee colony-level risks of concern were identified. However, the strength of evidence supporting this risk finding was considered "weak."

For clothianidin and thiamethoxam, the assessment concludes that the risk from seed treatments to honey bee colonies was low for all uses except clothianidin application to turmeric seed pieces, but the strength of evidence was considered to be weak there also. However, risk to individual bees was above the level of concern for canola, corn, legumes, sorghum, and soybean (for clothianidin) and beans, cucurbits, legumes, lentils, peanuts, peas, sorghum, soybeans, and sunflower (for thiamethoxam).

It is useful to recall that the earliest reported honey bee toxicity incidents with imidacloprid resulted from its use as a seed treatment in corn and sunflowers (Bonmatin 2005, Maxim and van der Sluijs 2013). As early as 1994, reports were coming in describing aberrant bee behavior, loss of foragers, and reductions in honey production, especially near sunflower crops. The first regulatory restrictions in France, in 2004, were for these seed treatment uses in response to a strong lobbying effort from the bee industry. Indeed, many honey bee mortality incidents reported to USEPA resulted from seed treatment uses.

It is therefore reasonable to ask whether the USEPA assessment is correct in dismissing most risks associated with seed treatment uses. The rest of this chapter explores this question, although some of the issues and problems with the assessment of seed treatments clearly have a bearing on the assessment of other neonic use patterns.

4.4. Deficiencies in USEPA's assessment of pollinator risk from neonic-treated seeds

4.4.1. The USEPA assessment fails to adequately consider risks to pollinators beyond honey bees

Honey bees (*Apis mellifera*) are important for the pollination of certain crops in California and, because of that economic imperative, the USEPA assessment like the California DPR assessment is very "*Apis*-centric." Other species are mentioned in passing and a few bumble and mason bee studies are reviewed, but the emphasis of the assessment is on honey bees.

Like CaDPR, USEPA (2020d-j) concludes that honey bees can be used as an adequate surrogate for non-*Apis* bees—and this because of the circular logic that "… *the bee risk assessment framework used by the EPA indicates the honey bees are **intended** to be reasonable surrogates for other bee species* …" (USEPA 2020e; section 6.2) (emphasis added). This "intention" notwithstanding, the USEPA assessment offers plenty of evidence to the contrary; some of this evidence will be highlighted below.

4.4.1.1. Wild bees may be more sensitive than honey bees

It is known that toxicity within and among bee species can vary greatly. For imidacloprid, USEPA (2020d) reports that within honey bees alone, the acute oral LD_{50} values in tests they deemed acceptable ranged a full two orders of magnitude (100X). Taking the lower value (as was done in the assessment) may provide a certain amount of added safety, but it isn't clear whether this is sufficient to protect the many species of wild bees that will be exposed in California cropland. Indeed, several authors have looked at the relative sensitivity of bee species to a wide range of insecticides (providing more data than what is available for neonics only) and concluded that honey bees are <u>not</u> always the most sensitive for any given active ingredient.

The USEPA assessment also references studies that show that leafcutter bee larvae are more sensitive than honey bee larvae to clothianidin, that adults of the only stingless bee tested (*Nannotrigona perilampoides*) may be more sensitive than honey bees to thiamethoxam, and that bumble bees may be more sensitive to clothianidin and/or thiamethoxam through the oral route.

In their proposed methodology for pollinator assessment, the European pesticide regulators (EFSA 2013) proposed an extrapolation factor of 10X from the accepted honey bee LD_{50} in order to cover other species. This was, in part, a result of a literature review comparing a handful of species only, so they expressed the view that this factor was preliminary and may be insufficient. A more recent analysis of paired toxicity data from the same studies (Arena and Sgolastra 2014) obtained a similar result: a safety factor of 10X applied to the honey bee toxicity endpoints was sufficiently protective of other bee species in 95% of cases. However, the full range of sensitivity ratios between the honey bee and one of the other 19 bee species with which it was paired <u>ranged over 6 orders of magnitude</u>. The differential weight of test bee species appears to be part of the reason for this vast difference, but other factors are also at play (Arena and Sgolastra 2014).

Accordingly, the assumption that the honey bee will be more sensitive that 1500+ wild bee species potentially exposed in the California cropland and adjacent non-crop areas is highly unrealistic. Moreover, a honey bee colony contains tens of thousands of bees; many more individuals can be lost or affected before the hive is compromised. This alone makes the conclusions of the USEPA assessment highly suspect given that the final risk estimate is based on honey bee colony-wide endpoints. For solitary bee species or bees with smaller colonies (e.g., bumble bees) the loss and/or debilitation of individual foraging adults becomes much more critical to population survival. Also, as seen below, the parameters of the USEPA assessment—e.g., the low pollen ingestion by individual honey bees—do not adequately represent other species.

As an aside, several studies reviewed in the USEPA assessment have provided contact LD_{50} estimates that are lower than the ones finally adopted by USEPA. These studies were found to be acceptable but labeled "qualitative" because of the lack of access to the raw data. Given the very small difference obtained with different probit methodologies (i.e., how raw data are processed to arrive at an LD_{50}), this data exclusion seems excessive. Had the non-industry data been accepted, it would have reduced the contact LD_{50} by over 3X. The estimates above also ignore that breakdown products of imidacloprid, especially (imidacloprid olefin), which appear to be more toxic than the parent material (e.g., Suchail et al. 2001).

Yet another serious limitation of the USEPA risk assessment is that it has failed to also consider that the presence of fungicides often included on the same seed treatment, as neonics can greatly enhance the toxicity of the latter. For example, Tsvetkov et al. (2017) showed that clothianidin and thiamethoxam both became twice as toxic in the presence of boscalid at relevant field concentrations.[15]

15 This was established by measuring levels in collected pollen.

4.4.1.2. Wild bees may be in different parts of the agricultural environment than honey bees

The USEPA assessment does concede the fact that many species of wild bees are attracted to crops that honey bees are not attracted to. In addition, many different matrices (both biotic and abiotic, such as foliage or mud) are potentially attractive to non-*Apis* bees. The USEPA assessment only looks at pollen and nectar as sources of exposure. Hopwood et al. (2016) estimates that 70% of North American bees are ground nesting. According to the same authors, most solitary bee species have a smaller foraging range and higher crop fidelity than honey bees. In the USEPA assessment, true cereal crops (for example) are deemed not to be attractive to honey bees and therefore to carry no risk. However, this ignores the possibility of arable weeds in flower in the crop, as well as movement of residues away from treated areas, either through dust drift or runoff. This off-site movement is reviewed in section 4.5 below. By excluding any consideration of crops deemed not to be attractive to honey bees, or crops harvested before flowering, USEPA seriously underestimates potential impacts to both honey bees, and wild bee species.

4.4.1.3. The USEPA risk assessment for individual honey bees is inadequate for wild bee species

To assess the risk to honey bees, the USEPA assessment uses the endpoints summarized in Table 15.

Table 15. Toxicity endpoints used in the USEPA assessment—said to be the lowest endpoints for which raw data were available to allow independent statistical verification—modified from Table 1-2 in USEPA (2020d) and 1.3 in USEPA (2020e).[a]

Study type	Assessment endpoint	Clothianidin	Imidacloprid	Thiamethoxam
Adult acute contact	96-hour LD_{50} µg a.i./bee	0.0275	0.043	0.021
Adult acute oral	48-hour LD_{50} µg a.i./bee	0.0037	0.0039	0.0038
Adult chronic (10-day) oral	NOAEL/LOAEL (effect) µg a.i./bee/day	0.00036/0.00072 (12% mortality)	0.0011/0.0018 (food consumption)	0.0025/0.0049 (70% mortality)
Larval chronic repeat dosing (21-day)	NOAEL/LOAEL µg a.i./larva	N/A	0.0018/>0.0018	0.0037/0.0066
Colony feeding study (Spiked sucrose concentration)	NOAEC/LOAEC (ng/g)	19/36	23/47	44/82[b]

a Values for clothianidin and thiamethoxam are expressed as clothianidin-equivalents (thiamethoxam values being corrected based on the ratio of their molecular weights).

b When assessing risk to honey bee colonies from thiamethoxam, USEPA uses the lower clothianidin values of 19 NOAEC and 36 LOAEC in acknowledgment of the fact that thiamethoxam is transformed to clothianidin in crop plants and in the environment.

For reasons mentioned above, it is appropriate to consider which endpoint should be used in the first tier of the risk assessment, which considers risk to individual foraging bees.[16] In its "refined Tier 1 assessment" (i.e., assessment of risk to individual bees based on measured pollen and nectar residue levels) USEPA assessment computes risk estimates for both acute and chronic exposure scenarios. For a seed treatment use and given the duration of flowering in most crops, it could easily be argued that the chronic (10-day) toxicity test is much more relevant ecologically, especially in the case of bee species with a more limited range.

Because of the contamination of both nectar and pollen, the oral toxicity endpoints are arguably the most relevant for looking at potential effects from seed treatments, once the initial "dust deposition" (see below) has passed. The oral toxicity of all three active ingredients is shown to be virtually identical in the 48-hour adult oral test. Given the variability in test results seen for any given active ingredient (discussed above), this similarity is quite remarkable. However, the lack of a consistent ratio between the 48-hour values and the 10-day values among the different pesticides may have to do more with the vagaries of

16 It has been argued above that this endpoint should be 10X below that established for honey bees in order to cover all bee species, but we will leave this line of argumentation aside for now.

testing (test conditions, bee race and provenance, bee age, etc.) than with any real toxicological or pharmacological difference between the active ingredients. As reviewed by Sanchez-Bayo and Tennekes (2020), both clothianidin and thiamethoxam show a similar relationship between toxicity and exposure time in honey bees. Because of the negligible amount of metabolism, toxicity is effectively cumulative, so the clothianidin chronic results are exactly in line with what one would expect—the lethal dose per day over a 10-day period is approximately one-tenth the one-time lethal dose. Thus, EPA's thiamethoxam chronic oral value (see Table 15 above), being almost the same as the one-time oral dose value, is the aberrant one and not credible.

Accepting for the time being that 0.00036 µg/bee is a more ecologically realistic endpoint for the toxicity of the nitroguanidine neonics, we can back-calculate the nectar concentration needed to deliver this dose to a foraging bee over a 10-day period. Deriving "acceptable" or "limit" concentration levels in nectar and pollen is a direct way of relating measured contamination levels resulting from the use of seed treatments to a harmful or fatal outcome and will be useful in considering measured nectar and pollen concentrations below. This is no different than the USEPA approach of providing "risk quotients," a ratio of measured exposure to toxicity, but will allow us to unpack this ratio and look specifically at the assumptions the USEPA uses to derive expected nectar and pollen concentrations.

Using the consumption rate of 292 mg nectar per foraging bee/day provided by the USEPA assessment[17] allows the calculation of a "limit" concentration considered safe to honey bees if the bee is going to forage on the treated crop for 10 days:

0.00036 ug a.i./bee = "limit" nectar concentration (ug a.i./mg nectar) X 292 mg nectar/bee

Limit nectar concentration (ug a.i./mg nectar) = 0.00036 ug/bee / 292 mg nectar/bee

Therefore, this limit nectar concentration would be equal to 0.00000123 ug a.i./mg nectar or 1.23 ng a.i./g nectar. A review of expected nectar residue concentration levels in treated crops and surrounding habitat following the use of seed treatments (below) confirms the high lethal risk to individual foraging bees—whether *Apis* or non-*Apis*.

In addition, many papers have examined neonics' sub-lethal effects on bee learning, reproduction, immune function etc. (see partial review in Hopwood et al. 2016). These sub-lethal endpoints are critical for assessing risk to wild bee species, whether solitary bees or even colonial ones given their smaller size and lack of "buffering," which a honey bee colony with tens of thousands of individuals enjoys. The 1.23 ng a.i./g nectar value computed above only refers to lethal effects on half of the population and is therefore not fully protective.

4.4.1.3. The USEPA higher-tiered risk assessments for hive effects do not apply to other colonial wild bee species

The USEPA assessment proposes that drone honey bees represent a worst case with respect to pollen ingestion by bees and equates this value with consumption by nurse bees. This value is given as 3.6 mg/day.[18] However, in their guidance document (EFSA 2013) European regulators point out that pollen ingestion ranges between 26.6 and 30.3 mg/bee/day for bumble bees; and 10.2 mg/bee/day for solitary bees—in other words, roughly 2.5 to 8 times more than USEPA's "worst case." Clearly, non-*Apis* bees may consume much more pollen than honey bees, making the USEPA assessment an almost certain underestimate if applied to wild colony-forming bees. Even for honey bees, other authors have used pollen ingestion values in their risk assessments that are much higher than that proposed in the USEPA assessment (e.g., 9.5 mg/bee/day in Stoner and Eitzer 2013).

If we were to use the midpoint value for bumble bee ingestion (28.45 mg/bee/day), and ignoring that bumble bees appear to be more sensitive than honey bees to clothianidin or thiamethoxam by the oral route, the calculation equivalent to the above for nectar returns a "limit" pollen value of 12.7 ng a.i./g pollen, clearly much lower than the 97.5 - 372 ng/g NOAEC pollen values derived from honey bee colony studies (Table 14).

The USEPA assessment does concede (2020d; section 6.3.2.2) that several studies in the open literature indicate risk to bumble bee colonies at concentrations of imidacloprid much lower than those known to affect honey bee hives. Indeed, at least four studies reviewed by USEPA documented significant colony effects at exposure levels of 10 ng/g, and one study documented

17 E.g., Table 4.12 in USEPA 2020d. Although we will accept EPA's value for now, it should be noted that this value is not a worst-case scenario. According to the compilation of EFSA (2012, 2013), sugar requirements in a forager can be as high as 128 mg sugar/day. Given nectar concentrations that range between 15% and 30%, this means that nectar ingestion could be as high as 427-853 mg nectar/day. Note that the USEPA in their guidance (EPA/PMRA/CaDPR 2014) use the "least protective" value of 30% sugar concentration in nectar.

18 The USEPA assessment compares colony effects to a combined nectar/pollen exposure calculated as the sum of the nectar concentration plus the pollen concentration divided by 20 given their estimation that honey bees consume 20X more nectar than pollen.

effects at exposure levels as low as 0.7-1.4 ng/g. These exposure levels are much lower than the 19 - 23 ng/g colony effect levels derived for honey bees. Similarly, USEPA (2020e; pp. 97-98) reviewed studies documenting effects of clothianidin and thiamethoxam on bumble bee colonies, including Sandrock et al. (2014). That study found that syrup concentrations of 0.45 ng/g of clothianidin or 2.87 ng/g of thiamethoxam significantly decreased reproduction (50% decline) and modified sex ratio in the red mason bee (*Osmia bicornis*). Although the entire experiment ran for 35 days, the treated colonies started diverging from control approximately 6-7 days after the beginning of dosing—less than the 10-day period used in the chronic toxicity assessments. These effect levels are 7-42 times below the 19 ng/g concentration used by USEPA (2020e) (see Table 15).[19]

Despite the highly congruent nature of these findings, USEPA dismissed all these studies as unsuitable for "quantitative use in the risk assessment," in large part because none of the authors analytically verified the concentration of their dosing solutions (USEPA 2020d; Table 5-13). This effectively ensured that only industry studies on honey bees were used in the final risk assessment. Although analytical confirmation of residues in the non-industry studies would have been desirable, it is difficult to believe that all of the researchers similarly erred and grossly miscalculated dosing levels. Verification of dosing levels is especially critical when there is the possibility that the active ingredient will degrade over time in the dosing solutions. Here, any degradation would mean that effect levels would effectively be *lower* than those reported. Given this, the number of colony studies and their congruent results, and that the effect levels are in line with chronic toxicity estimates from pollen ingestion as shown above, to have excluded the entire corpus of independent effect studies was not justified and resulted in USEPA almost certainly underestimating colony risk to bumble bees.

In addition, this exclusion of independent studies must be weighed against a possible bias in studies sponsored by pesticide registrants for the purposes of gaining regulatory approval of pesticides (e.g., Boone et al. 2014; Bero et al. 2016; Mie et al 2018; Sheppard et al 2020).

4.4.2. The USEPA assessment underestimates nectar and pollen contamination that results from the use of seed treatments

The USEPA assessment estimates the expected nectar and pollen neonic residues in certain crops planted with neonic-treated seed, but the scope of these estimates is limited and underestimates the likely real world residue levels.

In the USEPA assessment, residue values varied considerably between the few crops that were studied. Unfortunately, residue levels have not been established for the vast majority of crops where the products are registered. This is an unacceptable situation from a regulatory perspective. Submission of residue data should have been made a condition of registration.

Where information for a specific crop is lacking, USEPA recommends using the combined individual study data for all crops. For pollen, the sheer number of studies clearly gives a strong weighting to corn, which, incidentally, has the lowest pollen residue values of all crops studied to date. Soybean and cotton represent most of the data for nectar. Of the few crops studied, canola (oilseed rape) had the highest pollen and nectar residue values once normalized by application rate per seed (Table 15; Appendix 6), but these values are overshadowed by the other field crop data. A more precautionary (and I believe appropriate) approach to that proposed in the USEPA assessment would have been to take the crop with the higher pollen and nectar residues as a surrogate for those crops without residue information—or at least give equal weighting to the different crops studied rather than treating each study as an independent sample, which clearly they are not. Indeed, using canola as the surrogate for crops without residue information would still likely fail to capture the greatest risk. Given that only 4 crops have been studied (3 for pollen), it is likely that several crops for which neonics are registered will indeed show higher residues in nectar and pollen than the current maxima generated in canola.

In an earlier compilation, the European Food Safety Authority (EFSA 2013) had already arrived at higher values (Table 16), likely due to consideration of more oilseed rape studies as well as a few sunflower studies.[20] However, that compilation appeared to combine all values together without regard to individual study means or maximum values as done in the USEPA assessment and is therefore not as robust.

19 Although the NOAEC for thiamethoxam is 44 ng/g (Table 15), USEPA correctly uses the lower value of 19 ng/g for clothianidin because thiamethoxam breaks down to clothianidin within crop plants.

20 It is also clear that some studies showing higher corn pollen levels were omitted from the USEPA assessment. For example, Bonmatin (2005) recorded maximum corn pollen levels of 18 ng a.i./g with seed treated at 77% of the currently allowable treatment.

Table 16. Summary of expected pollen and nectar concentrations in crops planted with neonic-treated seeds. Data for the USEPA 2020 assessment is shown in Appendix 6.					
	90th percentile concentration (ng a.i./g) normalized to 0.1 mg a.i./seed				
Matrix	**USEPA 2020 all crop study means**	**USEPA 2020 all crop study maxima**	**EFSA 2013 individual values**	**USEPA 2020 canola only mean**	**USEPA 2020 canola only maximum**
Pollen	1.8	3.2	4.2	32.7	43.3
Nectar	4.5	7.6	7.7	8.0	11.3

USEPA's overreliance on corn pollen values and soybean/cotton nectar values is clearly consequential and results in risks from seed treatments often being downplayed. Table 17 compares the USEPA-estimated pollen and nectar concentrations with those derived from the precautionary assumption that any given crop might be more "canola-like" than "corn-like" or "soybean-like." The newly estimated pollen levels alone clearly place bumble bee individuals and colonies at extreme risk in a number of crops.[21]

As shown in Table 17, the precautionary approach of taking the crop with the higher pollen and nectar residues as a surrogate for those crops without residue information would show the risk to be more than an order of magnitude higher for pollen ingestion; about double for nectar ingestion.

Table 17. Comparison of averagea nectar and pollen concentration estimates between the USEPA assessment approach (i.e., taking the average of all studies heavily weighted to a few crops) versus an alternative approach that supposes crops will develop flower residues more in line with canola.

Crop	Concentration per seed (mg)	Active ingredient	USEPA predicted mean pollen concentration based on data for all crops heavily weighted to corn (ng/g)	Predicted mean pollen concentration if plant is more "canola-like" (ng/g)	USEPA predicted mean nectar concentration based on data for all crops heavily weighted to soybean and cotton (ng/g)	Predicted mean nectar concentration if plant is more "canola-like" (ng/g)
cucurbits	0.750	thiamethoxam	13.5	245	33.75	60
carrot	0.120	clothianidin	2.16	39.2	5.4	9.6
safflower	0.50	imidacloprid	9.0	163	22.5	40
sugar beet	0.720	clothianidin	12.96	235	32.4	57.6

a The mean value given is the 90th higher percentile of means obtained from each study. This is the value recommended to test against a chronic (10-day) exposure for foraging bees.

In the USEPA assessment, any risk quotient which showed a possible effect for any given crop led to a Tier 2 assessment where honey bee colony health and survival became the endpoint. This resulted in all risks to bees from seed treatments being dismissed or considered to be low, often being above an individual NOAEL, but below the defined colony LOAEL. While this method already likely underestimates risks to solitary bee species, it also is clearly questionable for colony forming species, given the weakness of USEPA's underlying assumptions about potential exposure levels.

It should be noted also that the dismissal of risk can be at odds with the available evidence. For example, soybeans were said to represent no risk when applied as a foliar spray and carry the "weakest evidence of risk" as a seed treatment—yet USEPA acknowledges three possible or probable bee kill incidents reported in that crop (USEPA 2020d; Table 6-32).

21 Compare estimated pollen levels of 100 or 200+ ng/g in Table 17 with the 10-day limit lethal concentration of 12.7 ng/g calculated above or the many excluded bumblebee studies showing colony effects at 10 ng/g.

4.4.3. The USEPA assessment ignores critical exposure routes

The USEPA assessment fundamentally considers only two routes of exposure: Direct contact with insecticide droplets at the time of application (foliar application) as well as the consumption of nectar and pollen containing neonic residues in target crop plants. This greatly underestimates the actual neonic exposures bees and other pollinators are likely to face from many exposure routes under real world conditions.

Pollinator assessment schemes (e.g., EPA/PMRA/CaDPR 2014, EFSA 2013) have discussed the need to consider other routes of exposure such as neonic dust produced by the planting of neonic-treated seeds, plant guttation fluids, and surface water (including puddles potentially used as drinking water—particularly relevant in California's predominantly arid and irrigation-dependent agricultural environment). Other possible routes include honey dew, soil (for ground-nesting bees) and leaves (leaf-cutting bees). Several of those routes of exposure have already been built into risk calculators for bees (e.g., Mineau 2014). Some of the literature review carried out in the context of this indicator is reproduced here.

4.4.4.1. Dust as a route of exposure

Dust production from the abraded seed treatments during planting is known to be an important source of neonic exposure. Many kills of honey bee colonies have been reported from this route of exposure in Europe as well as North America. However, the USEPA assessment only acknowledges, but does not include, this route of exposure in its calculation of risk.

Other researchers have attempted to quantify this risk. For example, Tapparo et al. (2012) conducted experiments where individual bees trying to reach a food source were captured after flying over a corn field during planting (the entire test running for 1h). These authors measured amounts of 0.078-1.240 µg/bee (N=5, mean=0.570 µg/bee) for clothianidin at 1.25 mg a.i./seed and 0.128-0.302 µg/bee (N=4, mean=0.189 µg/bee) for thiamethoxam at 1 mg a.i. /seed. The same authors reported maximum concentrations of 3.65 µg/bee (approximately 36.5 ppm) obtained in previous work with imidacloprid-treated seed. After a few hours and normal activities in the hive, residues had dropped by an order of magnitude; the bulk of the insecticide-laden dust on bee surfaces was thought to have been taken back to the hive but dislodged though normal hive activities. With potentially thousands of foragers returning to a hive, large quantities of insecticide can thus be transferred efficiently to the hive environment.

Krupke et al. (2012) analyzed samples of honey bees from kills associated with the planting of treated maize seed. Clothianidin levels in dead and dying bees were much lower than in the Tapparo et al. (2012) study, ranging from 0.0038 to 0.013 ppm. Bees die from a number of causes not associated with insecticide exposure; Tapparo et al. (2012) also mentioned that dead bees sampled in the hive after sowing showed no exposure or at least had residue levels that were below detection limits.

From a "residue per unit dose" point of view, it appears that seeding results in higher contamination of insects than an equivalent spray application (Mineau and Callaghan 2018), but due to the lower per acre rates of application for seed treatments, neonic concentrations available to pollinators are still lower than following a typical foliar application. The USEPA assessment relies on a single study by Koch and Weisser (1997) to estimate the amount of residues bees would accumulate while flying through a cloud of spray droplets. Yet, they ignore very similar data produced by Tapparo et al. (2012) and others for bees flying through dust generated at seeding.

Mitigation strategies for minimizing the impact of abraded seed dust are not fully implemented or fully effective. In North America, it is customary for farmers to use talc or graphite as lubricants in their seeding machinery (e.g., Krupke et al. 2012). Canada has banned the use of these seed lubricants on the grounds that they may cause more abrasion and loss of pesticide (Health Canada/OMAFRA 2014). Since 2014, any lubricant used in Canada is mandated to be a patented lubricant marketed by Bayer, which, according to the manufacturer, reduces the amount of clothianidin contamination at seeding (Bayer 2020). However, the use of a lubricant is not mandatory. Moreover, it has been shown that the efficacy of lubricants at reducing insecticide dust has probably been exaggerated (Schaafsma et al. 2017) because of deficiencies in the test protocols, namely the fact that soil dust in the incoming airstream greatly increases the abrasion of the pesticide from the seeds.

Another seed dust mitigation strategy consists of using deflectors which redirects the flow of air from the seeder towards the ground. This reduces, but does not eliminate, dust drift (see below). In a ground-breaking Canadian study (Tsvetkov et al. 2017) following Canada's regulations mandating low-fluency agents, in-hive contamination levels were still sufficiently high to negatively impact colony health (see Section 3.3).

Dust produced at seeding has given rise to visible mortality. To date, seed treatment and soil uses (not foliar uses) comprise the bulk of imidacloprid bee-mortality incidents reported to USEPA (USEPA 2020f). Yet, both the USEPA and CaDPR maintain that they are working with different stakeholders to identify best management practices (of the type already found to be inadequate in Canada) and to promote some sort of as-yet unidentified technological fix to the problem. Schaafsma et al. (2017) indicated that several corrective actions would be needed to adequately reduce abraded seed exhaust from air seeders; both intake and exhaust air supplies from air seeders need to be scrubbed and seed polymer coatings need to be improved. At this point in time, neither USEPA nor CaDPR appear inclined to adopt enforceable regulations to reduce seed dust, and the cost of technology-based solutions will likely discourage widespread adoption anytime in the near future. While beekeepers are now aware of this risk and move their honey bee hives to avoid seeding time, this does nothing to protect wild bees from the impact.

In Europe, risk assessments take dust production at seeding into account. As early as 2013, EFSA had proposed deposition rates associated with various types of application. EFSA also examined the efficacy of some of the "best management practices" likely to be proposed eventually by USEPA—e.g., deflectors that direct the dust towards the ground to reduce exposure to flying insects (see Table 18). For example, without deflectors, the amount of dust drift in field margins during corn seeding is deemed to be 17% of the applied field rate, very much of similar magnitude as drift documented from high drift foliar application scenarios, such as fruit tree spray applications. This estimate, however, is likely a worst-case scenario recommended for risk assessment purposes; the exact rate is highly variable and dependent on a multitude of factors starting with the seeding equipment (Xue et al. 2015). Regardless, dust production at seeding can be incorporated into an assessment of risks to bees—albeit with some assumptions as to realistically possible and enforceable improvements in seeding technology.

Table 18. Default deposition percentages for dust drift into field margins to be used for the different combinations of application technique and types of plants. From EFSA (2013; Appendix H).

Application type	Crop type	For purpose of measuring concentrations in nectar and pollen (% of application rate)	For purpose of contact exposure assessment (% of application rate)
Spray applications (spray drift)	Field crops	0.92	2.8
	Early fruit	9.7	29.2
	Late fruit	5.2	15.7
	Early grapevine	0.9	2.7
	Late grapevine	2.7	8
	Hops	6.4	19.3
Seed treatments (dust drift)	Maize with deflector	0.56	1.7
	Maize without deflector	5.6	17
	Oil seed rape with deflector	0.22	0.66
	Oil seed rape without deflector	2.2	6.6
	Cereals with deflector	0.33	0.99
	Cereals without deflector	3.3	9.9
	Sugar beets with deflector	0.001	0.003
	Sugar beets without deflector	0.01	0.03
Granule applications (dust drift)	All crops	3.2	9.6

There is a clear parallel between EPA, PMRA, and CaDPR's collective failure to adequately assess the risk from seed treatment uses of neonics and their decision to exempt pesticide-treated seeds from tracking or regulation.

4.4.4.2. Surface water as a route of exposure

The USEPA assessment determined *a priori* that risk from surface water ingestion was a minor route of exposure for bees (e.g., Fig. 2-3 in EPA 2020d), and therefore excluded exposures to neonics from water contact or consumption in its calculation of risk. Yet, in the context of California's arid climate where irrigation is often critical to crops, irrigation water and puddles or other available surface waters are likely critical sources of water for many insect species, including non-*Apis* bees.

Water needs in bees are expected to be quite variable and thought to be dependent on temperature and local nectar yields. Most of the research on this subject has been carried out in the honey bee. A low availability of nectar means that water needs to be obtained from extraneous sources rather than from nectar alone (Kühnholtz and Seeley 1997). This suggests that extraneous water needs might be higher in intensively farmed landscapes with low nectar yields dominated by corn or other field crops. Regardless, water needs in spring and early summer are typically large, in part to dilute winter stores (Butler 1940). At one of their study sites, Kühnholtz and Seeley (1997) noted that the bees favored the muddy wet ground on the edge of a pond for water collecting. Mineau and Kegley (2014) reported on the observation that bees appeared to prefer wet muddy ground to a nearby pond. It has been known for a long time (e.g., Butler 1940) that bees are often attracted to "unsanitary" sources of water, such as rainwater gutters choked with organic debris, sewage effluents, or puddles on top of cow dung in preference to clean water supplies provided for their use. Butler (1940) was able to confirm that bees preferred some concentrations of sodium and ammonium chloride to distilled water. However, dilute organic solutions (leaf debris, manure, and urine) proved more popular still. In the context of an agricultural field, this raises interesting questions. For example, the attractiveness of water puddles may vary depending on the use of fertilizers (both natural or synthetic) and possibly even some pesticides (especially dissociated ionic compounds). Finally, Visscher at al. (1996) reviewed older evidence that water-collecting bees took heavier loads of water when the water was warm; any source of water in fields is likely to heat up faster than deeper bodies of water when exposed to the sun. These authors calculated that a water collecting bee is restricted to obtaining water within a 2.1 km radius of the hive based on energetics—compared to the 13.5 km that has been observed for nectar foragers.

Taken as a whole, these finding suggest that bees will seek out puddles in and around farm fields as a water source, particularly in the spring planting time. Considerable neonic levels have been detected in these kinds of puddles—likely due to the use of neonic-treated seeds. Samson-Robert et al. (2014) measured the concentration of pesticides in rain puddles at seeding (while planting was still in progress) and one month after seeding in corn. The puddles were large ones—described as 1.5-3 sq. m in size and between 4-6 cm in depth. No field spiking (adding a known quantity of pesticide to the samples to ensure no breakdown or loss in transit) was carried out, so reported values should be considered minimum values. Based on two years of sampling, all water samples taken from corn fields contained residues of either clothianidin or thiamethoxam; 83% of samples contained both. Several other pesticides were also detected, but, in samples taken one month after seeding, only clothianidin, thiamethoxam and the fungicide azoxystrobin were still found at levels exceeding the level of quantification (1 ppb). Levels were higher immediately after seeding, suggesting that dust production during seeding might be an important pathway by which puddles became contaminated. For clothianidin, mean and maximum concentrations were 4.6 and 56 ng/g; for thiamethoxam, 7.7 and 63 ng/g. These values are in the range of expected nectar residues documented above. Clearly any use of in-field water by bees will add substantially to their overall exposure.

EFSA (2013) in their pollinator guidance, recommended using a water consumption figure of 11.4 µL/day per foraging bee or 111 µL/day per larva, but did not provide further justification for those figures other than to mention they were at the high end of values obtained from the literature. The USEPA/PMRA/CaDPR guidance (2014) looked at two estimates of water consumption rates in honey bees. One of those estimates (450-1800 µL/day) was based on direct observations and calculations from water forager bees. References were supplied to show that between 30-60 µL were collected per foraging trip (e.g., see the work of Visscher et al. 1996) and that 30% of all water collected was consumed by the bee. However, because these estimates relate to water foragers and not to other worker bees, and because the estimates work out to a very high (5-20X) turnover of body water, USEPA favored another estimate, this one based on water flux in a similarly-sized species, the brown paper wasp. Indeed, their analysis concluded that, depending on conditions and food supply, bee food (i.e., nectar, honey) represents between 7—>100% of daily water needs. USEPA thus arrived at a maximum water consumption estimate of 47 µL/day, which the agency recommended for risk assessment purposes; yet, 8 years later, USEPA still does not factor water intake into its calculation of risk.

The possibility of exposure through water is made more complicated by the fact that pesticides can be absorbed from the bee's foregut; i.e., by water foragers bringing water back to the hive, rather than drinking it for their own water needs (Conner et al. 1978). Absorption was found to be highest at low sucrose concentrations—i.e., the situation in a water forager vs. the usual test situation in oral toxicity tests. It is known also that worker bees do collect water to cool the hive. This may not be equivalent to drinking exposure, but does undoubtedly lead to difficult-to-measure exposure.

4.4.4.3. Guttation water as a route of exposure

The USEPA assessment (e.g., Fig. 2-3 in EPA 2020d) also determined *a priori* that risk from consumption of neonic-contaminated guttation fluids (the excretion of excess water or nutrients through small openings on a plant's leaves or stems) was minor, likewise excluding it from the risk calculation. However, research on the high concentration of neonics in the guttation fluid of treated crop plants indicates that these fluids, if consumed, would constitute a highly significant exposure route.

Several researchers have documented concentrations of various neonics in guttation water following their use as seed treatments in corn (Table 19). They reported that, on corn plants, experimenters were able to reliably and easily collect guttation droplets for at least three weeks after seeding under field conditions. Unlike what had been suggested in the literature, and assumed by regulatory authorities regarding this exposure route, they found that the phenomenon was not restricted to situations of high soil moisture and high humidity; moreover, droplets tended to pool in the leaf whorl of the developing plant. Only evaporation reduced the availability of droplets; however, the researchers proposed that concentrations could increase over time following repeated drying and droplet formation cycles.

Table 19. Measured concentrations of neonicotinoids and fipronil in guttation water from seed-treated corn.

Active ingredient	Rate of a.i. per seed (mg)	Concentration (mg/L) Mean (SE) or range (days 1-6 after germination)	Concentration (mg/L) reported maxima	Concentration normalized to 0.1 mg/seed (ng a.i./g)	Reference
imidacloprid	0.5 (field)	47 (9.96)	>200	9,400	Girolami et al. 2009
imidacloprid	0.5 (pots)	82.8 (14.07)		16,600	Girolami et al. 2009
imidacloprid	1.25	103-346 (leaf tip)	346	8,200-27,700	Tapparo et al. 2011
imidacloprid	1.25	8.2-120 (whorl)	120	660-9,600	Tapparo et al. 2011
clothianidin	1.25	23.3 (4.2)	>100	1,900	Girolami et al. 2009
clothianidin	1.25	76-102 (leaf tip)	102	6,100-8,200	Tapparo et al. 2011
clothianidin	1.25	7.3-47 (whorl)	47	580-3,800	Tapparo et al. 2011
clothianidin	1.25	7.5 - 8		600-640	Reetz et al. 2011
thiamethoxam	1	12 (3.3)	>100	1,200	Girolami et al. 2009
thiamethoxam	1	16-41 (leaf tip)	41	1,600-4,100	Tapparo et al. 2011
thiamethoxam	1	2.9-26	26	290-2,600	Tapparo et al. 2011

Comparison between these values and those predicted in nectar and pollen shows that the neonic concentrations in guttation droplets are typically two to three orders of magnitude higher. Accordingly, consumption of even a small amount of this water would dramatically change the risk picture for pollinators.

In its proposed problem formulation for pollinator risk assessments, USEPA (2012) downplays pollinator exposure risks from drinking neonic-contaminated water because: (1) some of those sources such as dew, puddles, or guttation droplets are not always present and ephemeral when present; and (2) the majority of foraging bees are expected to obtain most of their water needs through nectar. However, USEPA acknowledges that, if water was indeed to be obtained through puddles or guttation fluids, these routes of exposure would dwarf other routes of exposure such as direct sprays or dietary exposure through nectar or pollen. Regardless, USEPA/PMRA/CDPR (2014), in their final guidance document, opted not to include risks from exposure to neonics from drinking water, including guttation fluids.

In contrast, EFSA (2013) recommended that guttation water be included in the first tier of assessment, but that there also be an assessment of the likelihood of guttation droplet formation based on location conditions and calendar date.

I concur with EFSA (2013) and Blacquière et al. (2012) that prudence requires that drinking water routes of exposure be considered, at least until more information is obtained on their real world importance. This should be done not just for honey bees, but other bee species as well. The USEPA and CaDPR risk assessments are likely dramatically underestimating true risks to pollinators if potential neonic exposures from water sources, like guttation fluid, are excluded.

4.5. Risks and impacts to pollinators from neonic-treated seeds are not restricted to the crop area

Despite their recent analysis of risk for pollinators, both USEPA and CaDPR fail to accurately account for risks from neonic-treated seeds and, arguably, underestimate risks from neonics more generally. Failure to characterize the risk from seed treatments is a huge oversight given the potentially large area where treated seeds are planted, notwithstanding that higher risk may result from other application methods—notably, foliar and ground sprays.

Initially, the USEPA and CaDPR assessments incorrectly assume that neonic active ingredients on treated seeds remain restricted to the field area. As such, the assessment excludes crops that are not attractive to pollinators or that are harvested before flowering; in doing so, the assessments fail to consider the movement of residues off site—whether through dust, runoff, or windblown soil—into the pollen and nectar of adjacent wildflowers. This movement, however, is well documented. For example, Stewart et al. (2014) looked at seed treatments in corn, cotton, and soybean. They found evidence of contamination of wildflowers situated 20m on average from seeded fields. Residues were detected in a quarter of wildflower samples and, when detected, averaged 10 ng/g. This is about 10X the limit concentration calculated above as causing mortality in honey bees after 10 days of feeding. Rundlöf et al. (2015) similarly documented clothianidin in pollen and nectar in wild plants in the edges of oilseed rape sowed with a seed treatment containing clothianidin. Botias et al. (2016) documented significant contamination of wildlflowers in field edges near oilseed rape fields, which had an average residue level of 14.8 ng/g of thiamethoxam, while the canola flowers in the treated field had an average residue level of 3.26 ng/g. Higher levels still were recorded on the foliage of wild plants in the margins; and, similarly, at greater levels than in crop foliage (Botias et al. 2016). Long and Krupke (2016) likewise found that pollen originating from a large number of non-crop plants in field borders was contaminated with a multitude of pesticides, not all from the adjoining crop. Finally, Bredeson and Lundgren (2019) found high residues in cover crops inter-seeded with corn; which is perhaps ironic given that the practice is intended in part to promote beneficial insect communities.

4.6. Harmful impacts from neonic-treated seeds have already been demonstrated

Importantly, the risks and harms posed by the use of neonic-treated seeds are not purely theoretical. Studies have shown adverse impacts at the levels of neonic contamination documented following seed treatment uses.

Tsvetkov et al. (2017)—published in the prestigious journal “Science”—showed that bee food stores were heavily contaminated with clothianidin or thiamethoxam when hives were placed near corn fields having used those seed treatments. They then carried out a controlled exposure study that showed that measured levels of contamination were sufficient to negatively affect colony health. Indeed, their chosen levels of dosing (4.9 ng/g initially, declining to 2.0 ng/g of clothianidin on pollen patties) were below the measurements of actual hive exposures. These levels are also a fraction of the levels considered to be safe based on the industry studies used in the CaDPR and USEPA assessment (16 ng/g for a total nectar and pollen blended exposure; 372 ng/g for pollen alone). What also makes the Tsetkov et al. study particularly compelling is that the statistical analysis was performed under blind conditions, and that all of the raw data has been made available from a data depository site. Also, the study took place well after the mandated requirement for better fluency agents in Canada (Health Canada/OMAFRA 2004). It therefore highlights a situation that is already much more protective against neonic exposures to pollinators from abraded seed dust than the current status quo in the United States. In agreement with the work of Botias et al. (2015) and Long and Krupke (2016), the bulk of pollen stores were from non-crop plants. There is no indication that this study was considered in the 2020 USEPA assessment, despite its 2017 publication date. Several industry-submitted studies, however, with much higher effect levels, were considered.

Further, while it is typically difficult to tease out the effect of a specific stressor in ecological field studies, this has been done in several cases with neonic seed treatments.

Gilburn et al. (2015) noted a strong association between an increase in the area of oilseed rape (canola) treated with neonic seed treatments and significant decreases in population counts for 17 species of butterflies in the United Kingdom (UK). Like the analysis of Hallman et al. (2014) for insectivorous birds, Gilburn et al. were able to show that, prior to the introduction of neonics (1985-1998), butterfly numbers were actually increasing in those same areas making it less likely that butterfly numbers were simply reflective of intensive cropping.

Also in the UK, Woodcock et al. (2016) found that distribution data for 62 wild bee species showed an increase in the probability of local population extinction rates in areas of oilseed rape seeded with neonics. The most affected species were those foraging in the crop (it is useful at this point to recall that the USEPA assessment considers risk from canola to be low). Importantly, Woodcock et al. (2016) also showed that the use of foliar insecticides did not appear to have an effect on bee extinction probability, however, several best management practices implemented in English farming systems specifically to protect pollinators may have helped reduce the impact of sprays.

In California, Forister et al. (2016) , working on four different long-term monitoring sites, were able to associate butterfly declines to neonic use measured on a county basis. The authors were able to remove the effects of other insecticides as well to isolate the effect of neonic use; however, their pesticide data came from the PUR which means that seed treatments were not included in their pesticide use estimates.

Rundlöf et al. 2015 found that oilseed rape seed treatments containing both clothianidin and the pyrethroid beta cyfluthrin affected both bumble bees (*Bombus terrestris*) and the solitary bee *Osmia bicornis* in field borders of Swedish farms. Because beta-cyfluthrin in not systemic and tighly bound to soil, the authors surmised that the impacts they were seeing were primarily from the clothianidin component.

A recent study (Main et al. 2020) looked at native bee diversity in and around corn or soybean in rotation treated with imidacloprid or clothianidin. Although they found less contamination of flowers in field edges than Botias et al. (2015), they measured lower diversity of wild bees associated with treated fields. Even their untreated fields showed the presence of neonicotinoid residues, although lower and not as frequent. The presence of a diverse wildflower community proved to be the most important factor controlling wild bee abundance—but not diversity.

An industry-funded study in Germany (Peters et al. 2016) failed to find an impact from the same clothianidin & beta-cyfluthrin product examined by Rundlöf et al. (2015), and reported levels of hive contamination were lower. Another industry-funded study (Sterk et al. 2016) similarly did not find any effects from this same seed treatment on bumble bees. Again, the authors commented on the fact that levels of contamination in their study were lower than in non-industry studies. This suggests that there were more alternative resources available for the bees in the German industry studies. Ultimately, it appears that whether or not bees have access to a large quantity of clean floral resources well away from neonic-treated fields or whether they are more restricted to feeding within immediate field borders greatly affects risk. The greater risk associated with floral resources in or near treated fields, however, appears driven by the use of neonic-treated seeds as well as foliar and soil applications.

4.7. Conclusions of the pollinator assessment

In summary, the CaDPR and USEPA assessments greatly underestimate the risks to pollinators from the use of nitroguanadine-neonic-treated seeds. In particular, the assessments: (1) underestimate risks to wild bee species and other pollinators by relying on honey bee colony survival as a proxy for overall pollinator health; (2) underestimate nectar and pollen contamination levels following the use of neonic-treated seeds by assuming that the majority of crop species will have residue values at the low end of the measured spectrum; (3) ignore risks of dust from neonic-treated seeds at planting, despite ample evidence that this route of exposure is highly relevant; (4) ignore exposures of bees and other pollinators to neonic contaminated water—including, guttation fluid and puddles in or near fields sown with neonic-treated seeds—despite existing field estimates that show that these routes of exposure can completely dwarf the routes that have been formally assessed; and (5) ignore risks from neonic uses on crops deemed unattractive to honey bees, despite evidence that neonic residues migrate into adjoining areas, including adjacent wildflowers that can exceed levels in the field proper; (6) exclude available peer-reviewed literature from quantitative risk assessment in favor of industry studies; and (7) ignore the growing amount of field data which now links the use of neonic-treated seeds to pollinator failure on a landscape scale. The USEPA and CaDPR therefore fail to appreciate and acknowledge the likely considerable and damaging effect that neonic-treated seeds are having on California's pollinator populations.

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APPENDIX 1. DATA STANDARDIZATION PROCEDURES TO BUILD AN ESTIMATE OF POTENTIAL NEONIC SEED TREATMENT USES IN CALIFORNIA FROM STATE AND USDA SOURCES

- Crop names were standardized and grouped to be consistent among counties.
- For the purpose of identifying areas where seed treatments might have been used, tree fruits, all vine and small fruits, and mushrooms were excluded.
- Areas in range or rangeland were excluded as we assumed no use of seed treatments in these areas.
- Areas in pasture, whether irrigated or not, were assumed to be in permanent pasture, which excluded any possible seed treatment use. This is a critical assumption as it represents a large area—almost 18 million acres according to 2016 county reports—but probably not an unreasonable one given that we can find no registered uses of neonicotinoids on pasture grasses. Seed treatments, however, are registered for cereals and alfalfa.
- Small areas reported as "mixed cereals" (barley, oats, rye, triticale, and wheat) were assumed to be "wheat" for calculation purposes. In fact, rates per seed of the different active ingredients are generally similar for all cereal species.
- Areas recorded as being in stubble post-harvest were counted as mixed cereal.
- Hay and haylage crop areas were separated into alfalfa and cereals (where seed treatments would be allowed) versus other types (grass crops including Sudan grass, ryegrass, timothy, clover, vetch, etc.) for which we have not found any registered seed treatment uses. Based on totals from the combined county statistics, harvested hay crops were divided almost equally between alfalfa, cereals, and other species. Therefore, for those counties where different types of hay crops were combined, we assigned 1/3 of the total acreage to each of these hay subtypes. For the purpose of calculations, cereal hay and haylage were considered to be "oats."
- Acreages noted to be in "volunteer" hay were excluded, as no seeding was involved.
- Alfalfa seed and hay production were kept separate.
- Wheat and triticale crops were combined, as they were often combined in county reports.
- Sweet potato and yam crops were similarly combined.
- "Vegetable vine crops" were considered to be cucurbits—specifically, "cucumbers" for the purpose of calculations.
- All organic crop acreages were excluded from the tallies.
- Specialty Asian vegetables were usually combined in state statistics. For the purpose of calculating possible seed treatment uses, they were considered to be leafy greens—e.g., bok choy.
- For seed weight and rate calculations, the combined "herb" crop was assumed to be parsley.
- For seed weight and rate calculations, crop acreages reported as "greens" were assumed to be part spinach and part kale.
- "Vegetable seed production" in open fields is usually combined in statistics. Given the wide variety of possible crops and varietals, and for the purpose of calculating seed treatment rates, squash was used as the model crop.
- Asparagus are either direct seeded or started from crowns—in which case, seeds are also used, but in starting beds elsewhere. Both planting scenarios were combined.
- Roughly half of the artichoke crop is seeded annually; the other half of the crop consists of perennial plants (Smith et al. 2008). The reported artichoke areas were therefore divided in half when considering possible seed treatment use.
- It was assumed that only 10% of the California rice crop was available for seed treatment use, the bulk of the crop being water seeded (paddy rice). Neonic seed treatments are not registered for paddy seeding.

APPENDIX 2. TABULATION OF HOW OFTEN EACH CROP OR CROP GROUPING[22] APPEARED AS AN APPROVED NEONIC SEED TREATMENT FOR POTENTIAL USE IN CALIFORNIA FROM 106 SEPARATE PESTICIDE LABELS DOWNLOADED IN MARCH 2020

Crop or crop grouping	Acetamiprid	Clothianidin	Imidacloprid	Thiamethoxam	All neonics
alfalfa				1	1
amaranth		3		1	4
arrowroot		2			2
artichoke		1			1
Asian vegetables		1	2	16	19
barley		8	45	7	60
bean		4	42	122	168
borage			13	2	15
broccoli		3		3	6
Brussel sprouts				1	1
buckwheat		6		1	7
cabbage		1	13	1	15
canola	2	6	43	6	57
cardoon				1	1
carrot		2	17	1	20
cassava		1			1
cauliflower				1	1
celery				1	1
chard				1	1
chicory		3		1	4
corn		15	41	9	65
cotton		1	25	4	30
crambe				2	2
cucumber				3	3
endive		3		1	4
fennel				1	1
flax			13	2	15
Edible flowers		10		1	11
ginger		1			1
greens		18	1	11	30
herbs		6		2	8

22 This is a more granular grouping of crops than the legal framework provided by USEPA and recognized by California (Appendix 4.40 CFR 180.41).

Crop or crop grouping	Acetamiprid	Clothianidin	Imidacloprid	Thiamethoxam	All neonics
kale				1	1
kohlrabi				1	1
leek		3			3
lentil			2	6	8
lettuce		13		4	17
lupin			8	8	16
melon				14	14
millet		8	10	2	20
mustard	1		18	4	23
oats		8	35	5	48
onion		6		1	7
pea			30	55	85
peanuts			1	3	4
potato	1	3	10	5	19
pumpkin				1	1
rhubarb				1	1
rice				2	2
rye		6	24	5	35
safflower			11	2	13
sorghum		2	25	2	29
sorrel		3		1	4
soybean		2	28	15	45
spinach		12		3	15
squash				13	13
sugar beet		4	24	1	29
sunflower			5	2	7
sweet corn		3	24	1	28
sweet potato		2			2
taro		1			1
turmeric		1			1
wheat		14	82	16	112
wild rice				1	1

For certain crop groups with many varietals separately mentioned on labels, a high number of tabulated listings may be partly artefactual. For example, the "bean" group includes adzuki bean, wax bean, kidney bean, etc., and the table shows how often "bean" is listed on a label. Similarly, issues may arise with the number of individual specialty crop species amalgamated into larger groups (e.g., greens, herbs, or Asian vegetables). Nevertheless, the tabulation shows the sheer number and diversity of approved seed treatment uses and the incredible penetration of neonics into the agricultural seed treatment business.

APPENDIX 3. COUNTY BY COUNTY COMPARISON OF POTENTIAL SEED TREATMENT USE OF NITROGUANIDINE NEONICS VERSUS THEIR REPORTED USE ACCORDING TO THE PUR SYSTEM

Agricultural region	County	Potential seed treatment use			PUR data			Proportional increase from seed treatments[b]
		CLO[a] lbs a.i.	IMI lbs a.i.	THI lbs a.i.	CLO lbs a.i.	IMI lbs a.i.	THI lbs a.i.	
Central coast	Alameda	12	103	58	0	461	13	1.37
	Contra Costa	846	789	773	69	1,284	48	2.72
	Lake	1	20	11	0	420	0	1.08
	Marin	88	86	98	0	0	0	273
	Monterey	54,146	1,606	53,185	6,538	18,975	10,287	4.04
	Napa	3	7	7	242	1,309	812	1.01
	San Benito	1,132	647	1,847	278	1,633	300	2.64
	San Luis Obispo	1,752	1,349	2,142	143	12,962	642	1.38
	San Mateo	68	76	73	0	73	55	2.70
	Santa Clara	205	188	276	416	572	340	1.50
	Santa Cruz	1,113	22	956	74	493	137	3.97
	Sonoma	129	1,288	584	239	2,723	172	1.64
Northeast	Lassen	138	2,624	1,481	0	0	0	4,240
	Modoc	755	3,177	3,157	0	139	6	50.0
	Plumas	5	48	55	0	0	0	109
Northern coast	Del Norte	3	56	30	0	0	0	90.1
	Humboldt	23	177	111	0	0	0	312
	Mendocino	14	124	80	0	516	8	1.42
Sacramento valley	Butte	102	810	1,935	89	1,060	1	3.48
	Colusa	418	3,892	4,097	5	1,170	2	8.14
	Glenn	1,347	2,625	3,087	2	1,467	0	5.81
	Sacramento	2,568	4,859	3,401	171	10,255	407	2.00
	Solano	805	5,907	2,685	163	1,248	30	7.52
	Sutter	1,093	2,923	3,800	60	749	0	10.7
	Tehama	159	1,458	615	7	101	0	21.8
	Yolo	888	7,724	4,245	32	3,116	150	4.90
	Yuba	5	63	687	25	278	0	3.49

Agricultural region	County	Potential seed treatment use			PUR data			Proportional increase from seed treatments[b]
		CLO[a] lbs a.i.	IMI lbs a.i.	THI lbs a.i.	CLO lbs a.i.	IMI lbs a.i.	THI lbs a.i.	
San Joaquin valley	Fresno	8,749	8,886	12,759	4,193	69,604	6,218	1.38
	Kern	10,229	7,950	8,318	2,140	50,131	2,855	1.48
	Kings	4,291	9,815	8,555	1,185	14,891	1,494	2.29
	Madera	1,449	1,506	1,289	549	17,359	512	1.23
	Merced	14,584	11,974	9,687	1,467	11,861	867	3.55
	San Joaquin	7,589	14,475	9,517	251	18,316	1,788	2.55
	Stanislaus	1,850	3,833	2,125	190	5,769	276	2.25
	Tulare	13,319	8,579	10,205	1,597	30,358	7,846	1.81
Sierra mountains	Amador	4	59	27	0	33	0	3.77
	Calaveras	5	14	22	0	9	0	5.58
	El Dorado	5	5	8	18	67	0	1.20
	Inyo	2	34	18	0	0	0	53.9
	Mariposa	1	12	6	0	0	0	19.4
	Mono	6	119	63	0	0	0	189
	Nevada	9	12	20	0	1	0	63.0
	Placer	14	152	261	0	69	0	7.20
	Sierra	1	20	17	0	0	0	40.0
	Tuolomne	0	0	0	0	0	0	1.00
Siskiyou-Shasta	Shasta	56	627	1,715	4	6	7	137
	Siskiyou	743	1,147	1,796	0	202	18	17.8
	Trinity	1	5	5	0	0	0	11.9
Southern California	Imperial	22,605	7,073	22,117	626	21,225	664	3.30
	Los Angeles	13	85	64	0	735	20	1.21
	Orange	23	0	16	0	213	55	1.15
	Riverside	1,800	4,263	4,187	17	9,586	6	2.07
	San Bernardino	129	530	746	0	643	77	2.95
	San Diego	88	115	216	0	2,717	182	1.14
	Santa Barbara	7,895	401	6,717	1,022	24,720	1,266	1.56
	Ventura	1,768	348	13,528	313	6,948	4,176	2.37
Unspecified		463	13,400	4,827				

a CLO= clothianidin; IMI= imidacloprid; THI=thiamethoxam.

b To avoid division by 0, reported PUR uses changed from 0 to 1 lb.

APPENDIX 4. WHAT WE KNOW ABOUT THE CURRENT USE OF NEONIC SEED TREATMENTS IN CALIFORNIA

Corn

Corn is known to extensively use neonic seed treatments. Douglas and Tooker (2015) estimated that, by 2011, between 79% and 100% of the corn acreage nationwide used neonic seed treatments and found evidence that the rate was still increasing. By now, most of the corn crop area is expected to be treated with either clothianidin or thiamethoxam. Indeed, it may be difficult for growers to find untreated seed to plant should they wish to do so. Lack of crop rotation remains the main impediment for moving away from prophylactic control of corn rootworm (Veres et al. 2020).

Cotton

The bulk of neonic use in cotton comes from seed treatments. The number of seed treatment applications slightly exceeded the number of base acres—1.04 to 1—when assessed (USEPA 2017). This suggests that all cotton acres receive a seed treatment, primarily thiamethoxam and imidacloprid.

Wheat and other cereal crops

USEPA (2018) estimated that 20% of winter wheat and 27% of spring wheat received a neonic seed treatment. However, these data date from the period 2010-2014 and likely are underestimates of current conditions.

Because aphids in small grain crops including cereals can vector diseases, extension recommendations often advise using neonic seed treatments for early season control of aphids (USEPA 2018). In comments sent to USEPA during the current review of neonicotinoid benefits, a representative of the National Barley growers association argued against possible restrictions of neonic use (USEPA 2019b). Similarly, the National Association of Wheat growers argued that seed treatments provided the most efficient treatment of early season pests (USEPA 2019b).

Sugar beets

As is the case with small grain crops, the possibility of vector-borne disease in sugar beets means that the use of seed treatments is often recommended (USEPA 2019b). Based on data collected between 2010 and 2014, USEPA (2018) estimated that 46% of the crop acreage nationally received a seed treatment.

Small grain and oilseed crops

USEPA (2019b) estimated that 44% of the sorghum crop received a neonic seed treatment. Once again, this was based on now-outdated information (2010-2014).

All three active ingredients are registered for oilseeds; a seed treatment is now considered the "standard" in canola as judged by the many articles looking into its use. No information could be obtained on sorghum, flax, safflower, and sunflower.

Vegetable crops

USEPA (2018) reviewed seed treatment uses of neonics in vegetable crops. Of most concern when considering seed treatments are crops that are direct seeded given that transplants are more likely to be grown under controlled conditions—e.g., in a greenhouse. Depending on how greenhouse effluents are collected and treated, greenhouse use may also pose contamination concerns, particularly for water contamination—but likely from a point source rather than diffuse sources.

In its benefits review of neonics, USEPA (2018) had this to say about vegetable crops:

> "*BEAD does not have data on the use of neonicotinoid seed treatments in vegetable crops and thus sought stakeholder feedback concerning usage. Per the American Seed Trade Association* [ASTA]*, less than 15% of vegetable acreage is estimated to be planted with neonicotinoid seed treatments based on best professional judgement (ASTA pers. comm. 2018); ASTA did not provide estimates by individual crops. ASTA reported that clothianidin and thiamethoxam are preferred by growers over imidacloprid seed treatments.*"

USEPA (2018) believed that there was a greater reliance on soil-applied insecticides (granules or drenches) than seed treatments because the former (presumably drenches) may better target above ground pests. However, they also acknowledged that several extension services recommend neonic-treated seeds. Further, it is likely that upcoming possible restrictions on the foliar use of neonics (e.g., in cucurbits) will result in a shift to more seed treatment uses.

I attempted to verify the 15% estimate by means of the differential 2014/2015 use reported from commercial surveys and made public by USGS. USGS reports the use of the main nitroguanidine neonics separately on "vegetable and fruit" crops. Excluding California (because seed treatment use was not estimated in either year), the total quantity of use dropped by 14% between 2014 and 2015. Assuming negligible use of seed treatments in fruit production, this drop may be ascribed to vegetable production and suggests that the ASTA 15% total use estimate appears to be reasonable. However, reliance on the USGS-reported differential for 2014/15 assumes that the Kynetec commercial surveys had a good handle on seed treatment uses in 2014. They stopped collecting the information in 2015, in part, because of the increased difficulty of acquiring reliable data from users (Hitaj et al. 2020).

It is clear also that seed treatment use will vary widely among the many vegetable crops. Whitefly and thrips are key targets of neonic seed treatments in vegetable production. Leafy vegetables and green onions are especially likely to be treated given that an economic threshold has not been established (USEPA 2018). Additionally, there is wide resistance to most other insecticide groups in those crops.

A study proposing to look at the fate of neonics applied as seed treatments to lettuce (USGS 2020) stated unambiguously that "*in California, lettuce is grown from neonicotinoid treated seeds*." There appears to be no doubt in the mind of these researchers that use of seed treatments in that crop is the norm rather than a 15% possibility.

A recent development is the appearance of a new pest, the introduced bagrada bug (*Bagrada hilaris* - a species of stink bug). It is considered to be problematic for cole crops especially. The pest has now expanded from southern California to the entire state making the use of neonic seed treatments much more likely in broccoli, cauliflower, and cabbage. When its favored plants are not present, it attacks a wide range of other crop species (bell pepper, melon, papaya, tomato, and capers, corn, Sudan grass, sorghum, sunflowers, potato, cotton, and some legumes, including snap beans) (Reed et al. 2014).

Finally, USEPA (2018) proposes that neonic seed treatments may be more important in low-acreage vegetable crops for which other options have not been well developed. Keeping all of this in mind, it is clear that 15% should be considered a low estimate and that usage is probably increasing steadily in many vegetable crops.

Potatoes

It is unclear where potato "seeds" are treated—and if treated on farm, whether this is recorded in PUR data. In response to EPA request for comments, the National Potato Council and other state organizations stressed the importance of neonics as seed treatments in potato culture (USEPA 2019b). The first uses of neonicotinoids were in potato.

Rice

Most of the rice in California is water-seeded. Seed treatments are only registered for use in dry-seeded systems and are therefore of limited or no utility in California. Elsewhere, an estimated 45-75% of the rice is treated with a seed treatment (USEPA 2019c). This prohibition, interestingly, does not seem to apply to wild rice. Our understanding is that the crop is also seeded by air into paddies. This grass crop grows in wetlands. However, thiamethoxam is registered for use. It is unclear why it is registered if this crop is indeed wet seeded.

Forages

A key uncertainty in our assessment is the issue of neonic seed treatments for forages. Alfalfa and cereal forages, specifically, make up a large proportion (23.7%) of the total crop area on which crops could be planted with the use of seed treatments. This excludes 1/3 of the forage area planted to grasses and other species for which seed treatments are not registered, such as "pasture and hay," for which USGS 2014 estimates reported no use of neonics.

For alfalfa (presumably grown for seed), the amounts reported by USGS (from PUR data) were identical in 2014 and 2015 suggesting no or minimal seed treatment use. Only thiamethoxam was reported as being used at all. The use of thiamethoxam on treated seed is likely to increase given that they were only introduced in time for 2013 plantings (AG Professional 2013), although neonic seed treatments were already registered for cereal use. According to AG professional (2013), the thiamethoxam component of the formulated seed treatment is able to "*help alfalfa crops develop stronger roots, use inputs more efficiently; emerge faster, and grow more evenly, **even in the absence of insects***" (emphasis added).

It isn't known at this stage whether we will see the same exponential growth in alfalfa that was seen in corn, soy, and cereals. It also is not clear whether any of the cereal hay and haylage is grown with the use of the many available seed treatments.

APPENDIX 5. COUNTY BY COUNTY COMPARISON OF TOTAL CROPLAND CONSIDERED IN THIS REPORT COMPARED TO THE POTENTIAL AREA WITH NEONIC SEED TREATMENTS

Agricultural district	County	Sum of planted acreage	Sum of possible treated acreage	Proportion with possible seed treatment
Central coast	Total - all counties	511,155	462,742	91%
	Alameda	4,377	3,342	76%
	Contra costa	26,623	21,965	83%
	Lake	1,282	856	67%
	Marin	4,769	3,359	70%
	Monterey	344,009	337,438	98%
	Napa	475	311	65%
	San Benito	36,547	20,894	57%
	San Luis Obispo	39,405	38,138	97%
	San Mateo	2,735	2,218	81%
	Santa Clara	16,497	7,479	45%
	Santa Cruz	5,675	5,095	90%
	Sonoma	28,762	21,648	75%
Northeast	Total - all counties	165,643	130,587	79%
	Lassen	73,442	63,667	87%
	Modoc	85,566	61,288	72%
	Plumas	6,634	5,631	85%
Northern coast	Total - all counties	22,166	14,821	67%
	Del Norte	3,513	2,343	67%
	Humboldt	10,859	7,272	67%
	Mendocino	7,794	5,206	67%
Sacramento valley	Total - all counties	1,267,490	660,722	52%
	Butte	107,061	20,708	19%
	Colusa	223,016	76,999	35%
	Glenn	159,144	75,481	47%
	Sacramento	129,877	113,442	87%
	Solano	126,267	111,434	88%
	Sutter	189,108	68,073	36%
	Tehama	27,859	23,154	83%
	Yolo	262,330	164,350	63%
	Yuba	42,828	7,082	17%

Agricultural district	County	Sum of planted acreage	Sum of possible treated acreage	Proportion with possible seed treatment
San Joaquin valley	Total - all counties	2,465,333	1,968,959	80%
	Fresno	437,493	289,337	66%
	Kern	253,893	232,180	91%
	Kings	332,773	257,386	77%
	Madera	76,116	49,463	65%
	Merced	370,133	306,500	83%
	San Joaquin	341,058	310,159	91%
	Stanislaus	232,374	159,316	69%
	Tulare	421,494	364,620	87%
Sierra mountains	Total - all counties	35,071	16,628	47%
	Amador	3,108	1,869	60%
	Calaveras	888	584	66%
	El dorado	326	215	66%
	Inyo	2,087	1,391	67%
	Mariposa	726	484	67%
	Mono	7,378	4,919	67%
	Nevada	796	536	67%
	Placer	17,598	4,892	28%
	Sierra	2,164	1,739	80%
Siskiyou-Shasta	Total - all counties	104,697	85,684	82%
	Shasta	36,073	22,981	64%
	Siskiyou	68,295	62,486	91%
	Trinity	329	217	66%
Southern California	Total - all counties	531,425	509,531	96%
	Imperial	236,768	236,768	100%
	Los Angeles	5,748	4,023	70%
	Orange	201	184	92%
	Riverside	132,102	126,306	96%
	San Bernardino	21,642	20,167	93%
	San Diego	5,825	3,318	57%
	Santa Barbara	86,712	81,814	94%
	Ventura	42,427	36,951	87%
Unspecified	Unspecified	150,352	148,785	99%
California Total	Grand total	5,253,331	3,998,459	76%

APPENDIX 6. SUMMARY OF POLLEN AND NECTAR NEONIC RESIDUE LEVELS FOLLOWING SEED TREATMENT USE IN REGISTRANT STUDIES REVIEWED IN THE USEPA ASSESSMENT

Figure 20 from EPA 2020j (Attachment 4) summarizing industry data on mean pollen residues in three crops following the use of seed treatments. Residue levels are normalized to 0.1 mg a.i./seed. Open circles indicate that none of the samples had levels above detection. Crosses indicate that at least one sample was below the limit of detection.

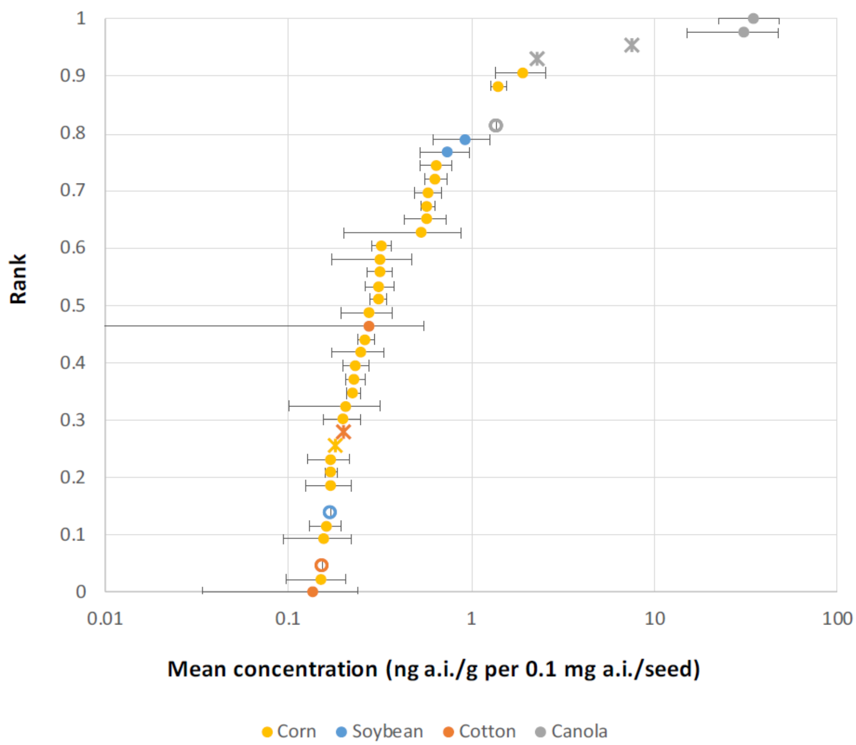

Figure 21 from EPA 2020j (Attachment 4) summarizing industry data on mean nectar residues in four crops following the use of seed treatments. Residue levels are normalized to 0.1 mg a.i./seed. Open circles indicate that none of the samples had levels above detection. Crosses indicate that at least one sample was below the limit of detection.