Evaluating Potential Impacts of Five Neonicotinoid Pesticides on Aquatic Organisms from Applications on Nonproduction Outdoor Ornamental Plants, Trees, and Turf

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1. Executive Summary

Food and Agricultural Code (FAC) section 12838 (Assembly Bill 363 (AB 363)) directs the Department of Pesticide Regulation (DPR) to evaluate the potential impacts of non-agricultural neonicotinoid pesticide uses (as defined) on pollinating insects, aquatic organisms, and human health, taking into account relevant routes of exposure. This report focuses on evaluating the impact on aquatic organisms from use of neonicotinoid pesticides on nonproduction ornamental plants, trees, and turf.

FAC section 12838 defines "neonicotinoid pesticide" to mean a pesticide containing acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam, or any other chemical designated by the department as belonging to the neonicotinoid class of chemicals. Effective January 1, 2025, FAC section 12838 (c) (2) prohibited the sale, possession and use of a pesticide containing one or more neonicotinoid pesticides on nonproduction outdoor ornamental plants, trees, or turf, with the exception of use and possession by state certified applicators and sale by state licensed pest control dealers. As required by the statute, DPR initiated on March 7, 2024, a reevaluation of the neonicotinoid pesticides containing acetamiprid, clothianidin, dinotefuran, imidacloprid, thiamethoxam intended for non-agricultural use on nonproduction outdoor ornamental plants, trees, or turf. Currently 105 registered pesticide products fall within the scope of the reevaluation. Collectively the product labels include several different use patterns and subsequent exposure pathways.

There are a wide variety of non-agricultural outdoor uses of the five neonicotinoids, some examples of which include spot or crack and crevice treatment and perimeter treatment around homes and buildings (i.e., structural applications), applications on landscape, and pre- and post-construction applications for subterranean termite control. The reevaluation focuses on three application sites in the urban landscape – ornamental plants, trees, and turf. DPR's analysis of the impacts of neonicotinoids within the scope of reevaluation focused on offsite movement of foliar and soil applications because these application methods have a relatively higher potential to result in offsite movement of the pesticidal active ingredients (AI) to surface water via irrigation or rainfall. Within the 105 products in reevaluation, 27 products are registered for multiple uses including structural and landscape applications. Moreover, products that are exclusively registered for structural applications or other urban outdoor uses outside the scope of AB 363 are not included in the reevaluation (Table A-1 in Appendix A).

According to the labels of products within reevaluation, the five neonicotinoids may be applied to ornamental plants, trees, or turf via a variety of methods including foliar and soil sprays, granular, soil injection and drench, tree injection, and containerized baits. Soil and foliar applications via sprays or granules could result in offsite movement of the pesticidal active ingredient (AI) to surface water during irrigation and rainfall and thus pose a potential risk to aquatic organisms. For the other application methods, pesticide residue is expected to be confined within the application area and has no expected pathway to surface water; therefore, they are not considered as risks to aquatic organisms. Within the reevaluation there are 76 products for soil and foliar applications and 22 products for applications with no expected pathways to surface water. Seven products are master labels that cannot be used or sold in California. The analysis herein focuses on the 76 products with the most likely pathway to aquatic organisms.

The Pesticide Registration Evaluation Model (PREM, version 6) developed by the Surface Water Protection Program (SWPP; Luo et al., 2024) was used to assess the estimated environmental concentrations (EECs) in the water column resulting from uses included in the non-agricultural neonicotinoid reevaluation. The EECs were estimated for the 76 products based on the application information found on the product labels and the physicochemical properties of the neonicotinoids contained in the products. The model-predicted EECs were adjusted by an AI-specific adoption rate to factor in the maximum possibility that an urban outdoor insecticide application would involve the corresponding AI. The adjusted EECs for each product were further aggregated by AI based on a weighting factor derived from DPR's internal pesticide product sales data. The aggregation resulted in a weighted average EEC for each neonicotinoid. Modeling results were validated with monitoring data sampled from California's urban receiving waters. The weighted average EECs were used to estimate the risk quotients (RQs) and cumulative risk based on toxicity thresholds derived from the USEPA's biological evaluation for invertebrates (USEPA, 2022a, USEPA, 2022b, USEPA, 2022c, USEPA, 2024a, 2024b).

Based on the modeling results, potential chronic risks to aquatic organisms are identified with combined exposures to multiple neonicotinoids from uses on ornamental plants, trees, and turf. The chronic cumulative RQ of all five neonicotinoids is 1.28, which is above the level of concern (LOC) of 1, indicating potential chronic risks to aquatic organisms. Imidacloprid represents the greatest portion of the potential risk (74%), followed by clothianidin (15%) and thiamethoxam (10%). The chronic RQ for imidacloprid is 0.95, which is just below the threshold expected to trigger chronic risk concerns. Clothianidin and thiamethoxam are important contributors to the potential cumulative risk, with a chronic RQ of 0.19 and 0.13, respectively, showing a low potential for aquatic risk from each AI. However, the combined impacts of these AIs with imidacloprid could potentially result in chronic risks to aquatic organisms. Acetamiprid and dinotefuran are less toxic to aquatic organisms compared to other neonicotinoids; the contribution from these two AIs to the potential cumulative risk is minimal (chronic RQs ≤ 0.01). Imidacloprid is also found with higher potential for aquatic risk relative to other neonicotinoids, based on monitoring data collected in urban waterways. The detection frequency of imidacloprid is 63% in DPR monitoring samples for urban receiving waters and the exceedance frequency is 11% relative to the USEPA biological evaluation thresholds for chronic toxicity, both of which are significantly greater than the frequencies of the other four neonicotinoids. In addition, no acute risks to aquatic organisms are identified within the scope of reevaluation, either in the case of combined exposure to multiple neonicotinoids (acute cumulative RQ = 0.12, below the LOC of 0.5) or exposure to individual AIs (acute RQ range: < 0.01 to 0.11).

Effective January 1, 2025, FAC section 12838 (c) (2) prohibited the sale, possession and use of a pesticide containing one or more neonicotinoid pesticides on nonproduction outdoor ornamental plants, trees, or turf, with the exception of use and possession by state certified applicators and sale by state licensed pest control dealers. Within the 105 products in reevaluation, 88 products were impacted as they were available to non-professionals before the sales/use restrictions went into effect (Table A-2 in Appendix A). DPR expects the overall use of neonicotinoids for these three applications to decline given the limitations of applications solely by professional applicators. However, we are unable to evaluate the extent of impact by eliminating non-professional use. One of the biggest challenges is parsing out the contribution of non-professional use from professional applications since most products could be used by both groups. No pesticide use or sales data are available after the restrictions went in place. Modeling efforts, therefore, focus on a conservative upper limit of use indicated by the available pesticide use and sales data (through 2022), and the upper bound of adoption rate for imidacloprid suggested by an applicator survey of the most popular insecticides (e.g., bifenthrin and fipronil) used in California for urban outdoor pest control (Section 2.4). As a result, we expect modeling results to represent the worst-case scenario of exposures and consequently a conservative estimate of risk to aquatic organisms.

2. Methods and Materials

2.1 Physicochemical Properties and Environmental Fate

The physicochemical properties and environmental fate of each neonicotinoid were retrieved from the USEPA ecological risk assessment reports. For variables that were not available in the USEPA reports, the median of DPR-approved values was used. Table 1 shows the values used in the PREM input for each neonicotinoid.

Table 1. Physicochemical properties and environmental fate of each neonicotinoid for PREM input.

Parameter	Description	Unit	Acetamiprid	Clothianidin	Dinotefuran	Imidacloprid	Thiamethoxam
SOL	Water solubility	mg/L	4250	327	39830	610	4100
KOC	Organic carbon-normalized soil adsorption coefficient	L/kg [OC]	227.2	161	31.4	266	70.23
HYDRO	Hydrolysis half-life	day	Stable	Stable	Stable	Stable	Stable
AERO	Aerobic soil metabolism half-life	day	12	2709	155.7	254	236
ANAER	Anaerobic soil metabolism half-life	day	330*	26.7*	77*	27.1*	19.45*
FD	Field dissipation half-life	day	13.55*	841*	59.2*	64.8*	91*
AERO_W	Aerobic aquatic metabolism half-life	day	106	187	63.6	236	34.4
ANAER_W	Anaerobic aquatic metabolism half-life	day	697	81	86.3	81	29.19
MWT	Molecular weight	g/mole	222.68	249.7	202.2	255.7	291.7
VP	Vapor pressure	torr	7.50E-10	2.90E-13	3.80E-07	1.50E-09	4.95E-11
AQPHOT	Aqueous photolysis half-life	day	34	0.6	1.8	0.2	4.46
SPHOT	Soil photolysis half-life	day	17*	34	46*	171	88.5

* Data is from DPR's internal Pest Chem database based on DPR-approved studies. Other data without an asterisk (*) is from the USEPA reports – acetamiprid (USEPA, 2024a), clothianidin (USEPA, 2017a), dinotefuran (USEPA, 2024b), imidacloprid (USEPA, 2016), and thiamethoxam (USEPA, 2017b).

2.2 Toxicity Thresholds

Acute and chronic toxicity thresholds of each neonicotinoid were obtained from the USEPA biological evaluation reports (USEPA, 2022a, USEPA, 2022b, USEPA, 2022c, 2024a, 2024b). The USEPA biological evaluations, published in 2022 and 2024, assessed the potential impacts of the five neonicotinoids on federally listed threatened and endangered species, as well as their critical habitats. These evaluations established clear criteria for data review and incorporated the most recent toxicity studies, deriving acute thresholds using species sensitivity distributions. Compared to the USEPA Aquatic Life Benchmarks, the biological evaluations integrated more up-to-date toxicity data and applied a more robust methodology such as species sensitivity distribution for deriving thresholds when sufficient data sets are available. To ensure a conservative estimate of risk, the most sensitive acute and chronic thresholds from both freshwater and marine/estuarine taxa from the USEPA biological evaluations were selected for this analysis.

2.3 Application Rate and Frequency

Three application sites (ornamental plants, trees, and turf) are included in the reevaluation of the non-agricultural use of the five neonicotinoids. Two PREM scenarios, (a) foliar spray (residential ornamental plants and trees) and (b) broadcast application (residential lawns), were identified as relevant to evaluate the impact of non-agricultural use of neonicotinoids within the scope of the reevaluation. PREM assumes 5% of the residential lot area is made up of ornamental plants and trees. Unfortunately, there is no additional data to further estimate the percentage of area that are separately covered by ornamental plants and trees; therefore, the two application sites are grouped in the modeling scenario.

Application information such as the maximum application rate in a single application (kg AI/ha), the minimum reapplication interval (days), and number of applications in a year were obtained for each product from a comprehensive review of products labels conducted by SWPP staff. For labels that have a restriction on the mass of AI that can be applied per unit area within a year (n = 67 products), we assume that there is one application in a year at the annual capped rate. In the case where the annual capped rate is not available (n = 9 products), we retrieved information for a single application and the reapplication based on the use instructions from label and modeling assumptions.

2.4 Adoption Rate Relative to Imidacloprid

For modeling insecticide applications in urban outdoor pest control, Luo et al. (2023) suggests using 30% as the upper bound of the probability that a certain insecticide will be used in an urban outdoor application. The probability of 30%, called an “adoption rate”, was determined from survey results for the most popular insecticides used in California: 27.1% for bifenthrin and 26.3% for fipronil (Winchell, 2013). The survey focused on professional applicators, whose adoption pattern was expected to be representative of all applicators, including non-professionals. The probability of 30% is considered to be a conservative upper bound of the adoption rate and has been verified by DPR’s previous modeling of urban outdoor applications for pyrethroids (Luo et al., 2023). Neonicotinoids were not included in the applicator survey and therefore no surveyed adoption rates were available. However, since bifenthrin and fipronil are the most popular insecticides for urban outdoor applications, we expect the adoption rate for the most popular neonicotinoid (i.e., imidacloprid) will not exceed the upper bound of the adoption rates for bifenthrin and fipronil. Therefore, we assume the adoption rate of imidacloprid is 30%, which represents that at most 30% of urban outdoor insecticide applications may involve imidacloprid. The applicator survey was conducted one decade ago. While we acknowledge that the survey data is potentially outdated and the numerical numbers (e.g., 26.3% and 27.1%) from the survey are associated with great uncertainty; no new survey studies are available to update this value. Moreover, we are unable to calculate an adoption rate from available data such as the Pesticide Use Report (PUR), pesticide product sales data (available for DPR internal only), and survey results in retail stores. Given the uncertainty around the assumption of 30%, we verified this assumption in model validation (Section 3).

In addition, the adoption rate of 30% for imidacloprid is assumed to represent the combined effects of adoption from all applicators, including professional applicators and non-professionals. However, the restrictions on sale of non-agricultural, non-professional products containing any of the five neonicotinoids for applications on ornamental plants, trees, and turf went into effect January 1, 2025. With the elimination of non-professional use, DPR expects the overall use of neonicotinoids for these three application types will decline. However, based on the available data, we are unable to verify the expected decline in use or estimate the extent of decline and the subsequent impacts on adoption rate. Moreover, monitoring data that is available for model validation was mainly collected before the sales/use restrictions went into effect; therefore, the adoption rate of 30% was validated with monitoring data representing the sum of uses from non-professionals and professional applicators. As a result, we expect modeling represents a conservative upper limit of use based on the pre-regulation adoption information.

For other neonicotinoids, the adoption rate of 30% was applied with an adjustment based on a comparison to imidacloprid (i.e., “relative adoption rate”). The concept of “relative adoption rate” was first designed to estimate the adoption rates for a group of pyrethroids based on the reference adoption rate for bifenthrin (Luo et al., 2023). The concept was adopted in this analysis as it is a systematic approach to evaluate the adoption rate for a group of AIs with the same mode of action. The relative adoption rate compares the total treated acreage of a neonicotinoid to imidacloprid, which conceptually represents the probability for the neonicotinoid, relative to imidacloprid, to be used in urban outdoor pest control. The total treated acreage is estimated from the total mass of a neonicotinoid applied divided by the representative application rate for a certain type of application, which is the non-agricultural applications on ornamental plants, trees, and turf in this case. Two datasets are available to estimate the total mass of AI applied – (a) the PUR data, and (b) pesticide product sales data.

The PUR data is specific to applications completed by professional applicators. However, the data is available up to 2022 at the time of writing, which is before the sales/use restrictions went in place. The available PUR data therefore represents professional use while non-professionals take up a part of the total use. Although non-professionals have been prohibited from applications of neonicotinoids on ornamental plants, trees, and turf, they may hire professional applicators for these applications, which can result in an increase in professional use compared to the use recorded within the currently available PUR. Since no PUR data is available after the sales/use restrictions went in place, SWPP decided to use the product sales data for the calculation of the relative adoption rate. The sales data records the mass of a product sold within the state and thus represents the maximum possible use by all applicators. Sales data for the most recent three years (2020-2022) were used in this analysis, and we expect the data to represent a conservative upper limit of use post regulations. Note that the selection of PUR versus sales data for relative adoption rate will not affect the pre-assumed adoption rate of 30% for imidacloprid. Similarly to imidacloprid, the model configurations on the relative adoption rate of other neonicotinoids were validated with monitoring data in the model performance evaluation (Section 3). For reference, the relative adoption rates were also estimated based on the available PUR data for the most recent three years (2020-2022), see Appendix B.

Table 2 shows the annual mass sold for each neonicotinoid within the 76 modeled products and the corresponding relative adoption rate. The relative adoption rate for imidacloprid is 100%, and less than 100% for other neonicotinoids. The final adoption rate is 30% for imidacloprid and 30% multiplied by the relative adoption rate for other neonicotinoids.

Table 2. Estimation of relative and final adoption rate for each neonicotinoid based on the annual average mass sold within the 76 modeled products reported in the product sales data from 2020 to 2022.

Pesticides	Annual Average Mass Sold (pounds/year)	Application Rate of Product with Max Mass Sold (kg/ha)	Relative Adoption Rate (%)	Final Adoption Rate (%)
Imidacloprid	43,516	0.45	100.0	30.0
Dinotefuran	7,271	0.61	12.3	3.7
Acetamiprid	2,056	0.21	10.1	3.0
Clothianidin	3,481	0.45	8.0	2.4
Thiamethoxam	1,815	0.3	6.3	1.9

The relative adoption rate of a neonicotinoid (n) is calculated in Equation [1].

[1] $$Relative\ Adoption\ Rate(n) = \frac{Mass\ Sold(n)/Rate(n)}{Mass\ Sold(Imidacloprid)/Rate(Imidacloprid)}$$

where *Mass Sold* is the annual average mass sold for each neonicotinoid within the 76 modeled products and Rate is the application rate for uses on ornamental plants, trees, and turf found on the label of the product that is associated with the greatest mass sold for each neonicotinoid within the 76 modeled products (Table 2). The product sales data has no information on application site, making it difficult to estimate the percentage of mass sold that is applied within the scope of reevaluation. Fourteen out of the 76 modeled products include allowable uses on impervious surfaces, in which case we assume 50% of the mass sold is relevant to uses within the scope of reevaluation.

2.5 Weighted Average EEC and Cumulative Risk

The cumulative risk to aquatic organisms was evaluated for the five neonicotinoids by using a weighted method on the 76 modeled products. First the adoption-rate adjusted EEC for product

(p) (µg/L) was weighted by the ratio of the mass of AI sold (pounds/year) for this product to the total mass of AI sold (pounds/year) for products containing the same AI within the 76 products, as shown in Equation [2]. The mass of AI sold for each of the 76 products was determined from the statewide pesticide product sales data with the same procedure depicted in Section 2.4.

[2] $$Weighted\ EEC\ (p) = \frac{Adoption\text{−}Rate\ Adjusted\ EEC\ (p) \times Mass\ of\ AI\ Sold\ (p)}{Total\ Mass\ of\ AI\ Sold\ for\ Products\ with\ The\ Same\ AI}$$

Second, the weighted average EEC for a specific neonicotinoid (n) (µg/L) was computed by summing the weighted EECs for products containing the corresponding AI (µg/L) (Equation [3]). For the exposure characterization, instead of using the EEC from a subset of products, such as the top-use products, to represent the exposure concentration from the whole population of products being analyzed, the weighted average EEC accounts for the relative contribution from each product to the total exposure and tends to be more robust for its comprehensiveness.

[3] $$Weighted\ Average\ EEC\ (n) = \sum Weighted\ EEC\ (p)$$

Finally, to determine the aquatic risk quotient (RQ), the weighted average EEC for each neonicotinoid (n) (µg/L) was compared to the USEPA biological evaluation toxicity thresholds for the corresponding AI (µg/L). The cumulative risk was the sum of the RQ values for the five neonicotinoids (Equation [4]).

[4] $$Cumulative\ Risk = \sum \frac{Weighted\ Average\ EEC\ (n)}{Toxicity\ Threshold\ (n)}$$

The USEPA biological evaluations include both acute and chronic toxicity thresholds for invertebrates. The PREM model outputs two results – the 1-in-10-year daily average EEC and the 21-day average EEC, in the water column. The weighted average EEC derived from the daily average EEC and the 21-day average EEC was used to estimate the acute and chronic RQ values, respectively. The weighted average of the daily average EEC was also used to validate the modeling results.

3. Model Performance

Modeling results were compared to urban monitoring data for evaluation of model performance. The total concentration of neonicotinoids in urban waterways includes runoff from all urban outdoor surfaces. The scope of modeling, however, only focuses on pervious surfaces (ornamental plants, trees, and turf). To evaluate the goodness-of-fit of modeled EECs from pervious surfaces, we included EECs from impervious surfaces (i.e., structural applications) in comparison with monitoring data. Structural applications of neonicotinoids include two use types, including spot or crack and crevice treatment, and perimeter treatment.

Table 3 shows the daily average EEC of each neonicotinoid modeled for three major types of urban outdoor applications, including (a) foliar and soil applications on ornamental plants, trees, and turf, (b) spot or crack and crevices treatments, and (c) perimeter treatments. The sum of daily average EECs from the three types of application was compared to the upper percentiles of urban monitoring data for model validation.

Table 3. Daily average EEC in water column (µg/L) from applications on ornamental plants, trees, and turf, and from structural applications (spot or crack and crevice treatment and perimeter treatment). EECs are adjusted with adoption rate.

Pesticides	Ornamental plants, Trees, and Turf[a]	Spot or C&C[b]	Perimeter[b]	Total[d]
Acetamiprid	0.007	0.010	0.097	0.114
Clothianidin	0.011	0.016	NA[c]	0.027
Dinotefuran	0.008	0.090	NA[c]	0.098
Imidacloprid	0.155	0.228	0.653	1.036
Thiamethoxam	0.007	0.011	0.091	0.109

Notes:
[a] Daily average EECs from uses on ornamental plants, trees, and turf are the weighted average EECs for each neonicotinoid based on the 76 modeled products within reevaluation.
[b] C&C = crack and crevice. Daily average EECs from spot or C&C and perimeter treatment were estimated based on the label information of the most-used product of each neonicotinoid for structural pest control, as recorded within PUR in 2022. Except for clothianidin, the top-use product for structural application is also labeled for uses within reevaluation. The top-use product for clothianidin is exclusively registered for structural application with no allowable uses within reevaluation.
[c] NA = not applicable. For clothianidin and dinotefuran, perimeter treatment is not within the intended use for the representative product of structural application.
[d] Total = the sum of daily average EECs from applications on ornamental plants, trees, and turf and from structural applications (i.e., spot or C&C and perimeter). The total EEC is used for model validation.

The upper percentiles of monitoring data collected in urban receiving waters for each neonicotinoid are presented in Table C-1 of Appendix C, based on DPR's Surface Water Monitoring Database (SURF) accessed on December 17, 2024. The DPR monitoring data (from October 2010 to August 2023) shows non-detects at the 95th or 90th percentile of concentrations for acetamiprid, clothianidin (zero detection), and thiamethoxam; therefore, we included data collected by other agencies (from March 2000 to September 2023) for verification and the data showed a similar detection pattern with the DPR data. The modeling performance is evaluated based on a P/O ratio, where P is the predicted concentration or EEC, and O is the observed concentration from monitoring data. For model validation, there is no preference for the use of the maximum, 95th, or 90th percentile in the calculation of the P/O ratios. Therefore, the three resulting ratios, based on the maximum, 95th, and 90th percentiles, define the range of model performance for comparison with the expected range of 1 to 10 (i.e., overestimation within an order of magnitude). Table 4 shows the P/O ratios for model validation based on DPR urban monitoring data. The total daily average EEC is the sum of daily average EECs from uses on ornamental plants, trees, and turf, and uses on impervious surfaces via spot or crack and crevices treatment and perimeter treatment, as presented in Table 4.

Table 4. Summary of observed concentration in water column (µg/L) and P/O ratios for model validation, based on monitoring data collected by DPR in urban waterways.

Pesticides	Total Daily Average EEC in Water Column (µg/L)[a]	Water Concentration Max[b]	Water Concentration P95[b]	Water Concentration P90[b]	P/O Ratio Max[b]	P/O Ratio P95[b]	P/O Ratio P90[b]
Acetamiprid	0.114	0.039	ND (0.02)[c]	ND (0.02)[c]	2.9	5.7[c]	5.7[c]
Clothianidin	0.027	ND (0.02)[c]	ND (0.02)[c]	ND (0.02)[c]	1.3[c]	1.3[c]	1.3[c]
Dinotefuran	0.098	0.032	0.023	0.013	3.0	4.3	7.6
Imidacloprid	1.036	0.740	0.186	0.130	1.4	5.6	8.0
Thiamethoxam	0.109	0.222	0.025	ND (0.02)[c]	0.5	4.3	5.5[c]

Notes:
[a] Total daily average EEC is the sum of EECs from uses on ornamental plants, trees, and turf and uses on impervious surfaces via spot or crack and crevice treatment and perimeter treatment, as shown in Table 3.
[b] Max = maximum, P90 = the 90th percentile, and P95 = the 95th percentile of observed concentrations.
[c] ND = non-detect. In the case of max, P95, or P90 are non-detects, the median limit of quantification (LOQ) for all non-detect samples is provided in the parathesis. The P/O ratio is calculated based on the comparison of total EEC to the median LOQ for all non-detects.

Most of the P/O ratios are within or close to the range of 1 to 10, which is considered as a reasonable overestimate for the purpose of modeling. For thiamethoxam, the P/O ratio for the maximum concentration is below 1 (i.e., underestimation), but since both P/O ratios for the 95th and 90th percentile of monitoring concentrations is within the expected range of 1 to 10, the modeling results are still considered satisfactory.

Modeling results for imidacloprid are also used to verify the assumption in the model configurations on the reference adoption rate for imidacloprid (Section 2.4), which was derived from the 2009 survey results and DPR's modeling exercise on outdoor structural application for pyrethroids. The model reasonably predicts the monitoring data of imidacloprid in the water column with the P/O ratios ranging from 1.4 to 8. The results support the use of the previously determined adoption rate for modeling the application practices of imidacloprid built on an upper limit of adoption based on pre-regulation conditions. Moreover, modeling results for other neonicotinoids show good P/O ratios, which validates the model configuration of the relative adoption rate.

The overall performance of the PREM model and its configurations provide satisfactory model simulations of outdoor uses on ornamental plants, trees, and turf for all five neonicotinoids. The sum of EECs from uses on landscape and impervious surfaces is comparable to the maximum and upper percentiles of monitoring concentrations, representing the worst-case scenario of exposure to the aquatic organisms. The model results can be used to estimate the risk quotients to aquatic life in surface water to determine a conservative estimate of risk.

4. Results and Discussion

Table 5 shows a summary of the weighted average EECs for each neonicotinoid from uses on ornamental plants and trees, and uses on turf, and the corresponding risk quotients (RQs) estimated based on the USEPA's biological evaluation toxicity thresholds for invertebrates. The acute toxicity thresholds from the USEPA biological evaluations are the hazardous concentrations (HC_{05}) derived from the species sensitivity distribution of invertebrates, at which 5% of the tested species are expected to experience an adverse effect. The more sensitive HC_{05} thresholds between freshwater and marine/estuarine species (i.e., the lowest HC_{05}) are applied to calculate the acute RQ values. The lowest no-observed adverse effect concentrations (NOAEC) among all taxa in freshwater and marine/estuarine species are used for chronic RQ calculation. For risk analysis, the level of concerns (LOC) for RQs are 0.5 for acute risk and 1 for chronic risk. Details of application information used for PREM input and the corresponding model-predicted EECs (before adjustment with adoption rate) are demonstrated in Appendix D.

Table 5 a: Weighted average of daily average EEC in water column (µg/L) for each neonicotinoid from uses on ornamental plants and trees, and uses on turf, and the sum of the two uses (total), and the corresponding risk quotients (RQ) and cumulative risk estimated based on toxicity thresholds for invertebrates from the USEPA biological evaluations.

Pesticides	Lowest HC_{05} (µg/L)	EEC Ornamental Plants & Trees	EEC Turf	EEC Total	RQ Ornamental plants & Trees	RQ Turf	RQ Total[a,b]
Acetamiprid	3.83	0.004	0.003	0.007	< 0.01	< 0.01	< 0.01
Clothianidin	3.58	0.003	0.007	0.011	< 0.01	< 0.01	< 0.01
Dinotefuran	9.8	0.007	0.0004	0.008	< 0.01	< 0.01	< 0.01
Imidacloprid	1.43	0.061	0.094	0.155	0.04	0.07	0.11
Thiamethoxam	3.58	0.002	0.005	0.007	< 0.01	< 0.01	< 0.01
Cumulative					0.05	0.07	0.12

[a]Acute Risk LOC = 0.5.
[b]Due to rounding, cumulative risk may not be equivalent to sum of RQs from individual pesticides.

Table 5 b: Weighted average of 21-day average EEC in water column (µg/L) for each neonicotinoid from uses on ornamental plants and trees, and uses on turf, and the sum of the two uses (total), and the corresponding risk quotients (RQ) and cumulative risk estimated based on toxicity thresholds for invertebrates from the USEPA biological evaluations.

Pesticides	Lowest NOAEC (µg/L)	EEC Ornamental Plants & Trees	EEC Turf	EEC Total	RQ Ornamental plants & Trees	RQ Turf	RQ Total[b,c]
Acetamiprid	0.71	0.004	0.003	0.007	0.01	< 0.01	0.01
Clothianidin	0.05	0.003	0.006	0.009	0.06	0.13	0.19
Dinotefuran	4.4	0.007	0.0004	0.007	< 0.01	< 0.01	< 0.01
Imidacloprid	0.125	0.042	0.076	0.119	0.34	0.61	0.95
Thiamethoxam	0.05	0.002	0.005	0.007	0.04	0.09	0.13
Cumulative					0.44	0.83	**1.28**

[b]Chronic risk (LOC = 1). Risk quotients that are above the LOC are highlighted in red.
[c]Due to rounding, cumulative risk may not be equivalent to sum of RQs from individual pesticides.

Based on modeling results, imidacloprid results in the greatest EECs among the five neonicotinoids. The total weighted average EECs of imidacloprid are 0.155 and 0.119 µg/L for the daily average and 21-day average, respectively. For other neonicotinoids, the total weighted average EECs range between 0.007 and 0.011 and between 0.007 and 0.009 µg/L for the daily average and 21-day average, respectively, which are about two orders of magnitude smaller than the total weighted average EECs for imidacloprid.

Within the scope of reevaluation, the greatest potential risk identified for aquatic organisms pertains to the cumulative chronic exposure to multiple neonicotinoids with applications on ornamental plants, trees, and turf. The chronic cumulative RQ with combined exposures to all five neonicotinoids is 1.28 (Table 5b), which is slightly above the chronic risk LOC of 1, indicating potential chronic risk to aquatic organisms. Imidacloprid is the primary driving factor, accounting for 74% of the potential chronic risk, followed by clothianidin and thiamethoxam, which represent 15% and 10% of the potential chronic risk, respectively. The chronic RQ of imidacloprid is 0.95 with the combined uses on ornamental plants, trees, and turf, which is on the edge of triggering chronic risk concerns to aquatic organisms. The chronic RQs of clothianidin and thiamethoxam are 0.19 and 0.13, respectively, which is substantially below the chronic risk LOC, and thus indicating a low potential for aquatic risks from the exposures to individual AIs. However, the combined exposures with imidacloprid could potentially trigger chronic risk concerns to aquatic organisms. Acetamiprid and dinotefuran are considered to have a minimal risk to aquatic organisms within the three uses in reevaluation. The chronic RQ values of the two neonicotinoids are less than 0.01, representing a minimal contribution to the potential cumulative risk. Acetamiprid and dinotefuran are less toxic to aquatic organisms, compared to imidacloprid, clothianidin, and thiamethoxam. Although the modeled EECs for acetamiprid and dinotefuran are about the same as clothianidin and thiamethoxam, the RQs of acetamiprid and dinotefuran are much lower. In addition, no acute risks to aquatic organisms are identified within the scope of reevaluation, either in the case of exposure to each AI (maximum acute RQ = 0.11 for imidacloprid which is lower than LOC of 0.5) or the case of cumulative exposure to all AIs (acute cumulative RQ = 0.12). Applications on turf generally result in higher RQs than applications on ornamental plants and trees.

Monitoring data (Appendix C) and PUR data (Table A-3 in Appendix A) were investigated to provide additional lines of evidence to verify the model prediction on the relative contribution within the five neonicotinoids to cumulative exposure. Monitoring data shows that imidacloprid has a higher potential for chronic risk to aquatic organisms than other neonicotinoids. Within the five neonicotinoids in reevaluation, imidacloprid is the most frequently detected in surface water samples collected in urban receiving waters. The detection frequency of imidacloprid is 63% in DPR monitoring samples for urban receiving waters, which is significantly higher than the detection frequency of the other four neonicotinoids (ranging from 0 to 14%, see Table C-1 in Appendix C). Similarly, the exceedance frequency relative to chronic toxicity thresholds is 11% for imidacloprid in DPR monitoring samples for urban receiving waters, which is significantly higher than the exceedance frequency of the other four neonicotinoids (ranging from 0 to 3%, see Table C-2 in Appendix C). The small sample size for clothianidin and dinotefuran in DPR monitoring data may skew the comparison; however, imidacloprid is also found to have the greatest detection frequency and exceedance frequency based on a larger dataset including all monitoring data of urban receiving waters available in SURF (Appendix C). Note that the acute toxicity thresholds are much higher than the chronic thresholds; no exceedance relative to acute toxicity thresholds were detected for the five neonicotinoids except imidacloprid (0.4% and 0.2% based on DPR data and all SURF data, respectively, see Table C-2). The findings from monitoring data are in line with the modeling results, both of which suggest imidacloprid be the primary driving factor of the potential cumulative risk.

The sources of imidacloprid in surface water involve multiple non-agricultural uses including structural and landscape applications. For professional applications, structural pest control accounts for the largest non-agricultural use of imidacloprid. The mass used in structural pest control (29,352 lbs AI/year) is about two times more than the mass used in landscape maintenance (14,786 lbs AI/year), according to the PUR data from 2020 to 2022 (Table A-3 in Appendix A). However, a portion of the mass used in structural pest control is relevant to pre- and post-construction termiticide applications, which have no expected pathway to surface water. The mass used on impervious surfaces, which is a high risk for urban runoff concerns, may be much less than the reported use in PUR. Nonetheless, the PUR data suggests that landscape applications are an important source of imidacloprid in surface water. Modeling results further estimate that landscape applications of imidacloprid are on the edge of triggering chronic risk concerns to aquatic organisms.

In addition to imidacloprid, clothianidin and thiamethoxam are found to be important contributors to the potential cumulative risk identified in the modeling results. The detection frequency of thiamethoxam is 7% and the exceedance frequency relative to chronic toxicity thresholds is 3% in DPR monitoring samples for urban receiving waters (Tables C-1 and C-2 in Appendix C). The biggest source of thiamethoxam in urban surface water may be structural applications (2,653 lbs AI/year), which account for over 90% of the sum of mass used in structural pest control and landscape maintenance recorded within PUR (Table A-3 in Appendix A). Modeling results are in line with the findings from monitoring and pesticide use data, showing no potential risks to aquatic organism with exposure to thiamethoxam from landscape applications; however, the combined exposure with other neonicotinoids (mainly imidacloprid) could potentially cause chronic risks.

In the case of clothianidin, there were no detections of the AI in DPR monitoring samples for urban receiving waters. However, only eight samples of clothianidin are available in DPR data; therefore, we included monitoring data collected by other agencies for the analysis of clothianidin. Within the 128 samples available for clothianidin in California's urban receiving waters, the detection frequency is 5%, with no samples exceeding the chronic toxicity thresholds (Tables C-1 and C-2 in Appendix C). For the sources of clothianidin in surface water, the PUR shows that the major non-agricultural use of clothianidin is landscape maintenance (2.304 lbs AI/year), accounting for about 80% of the sum of mass used in structural pest control and landscape maintenance (Table A-3 in Appendix A). Modeling results further show that landscape applications of clothianidin will not trigger risk concerns to aquatic organisms; however, the AI may contribute to the potential chronic risk if combined with imidacloprid,

Some observations of acetamiprid and dinotefuran from monitoring and PUR data are highlighted here for additional information of the analysis of cumulative impacts of exposure.

The detection frequency of dinotefuran is 14% in DPR urban monitoring samples and 18% in all samples available in urban receiving waters, which is higher than the detection frequency of other neonicotinoids (< 7%) except imidacloprid (Table C-1 in Appendix C). None of the samples exceed toxicity thresholds to aquatic organisms. As reported in PUR, the major non-agricultural use of dinotefuran is structural pest control (57,428 lbs AI/year), which is ranked third highest for mass of insecticide used and reported in this category between 2020 and 2022 (Table A-3 in Appendix A). For acetamiprid, the detection frequency is 2% in DPR monitoring samples for urban receiving waters, and similar to dinotefuran, no samples exceed the toxicity thresholds (Tables C-1 and C-2 in Appendix C). The non-agricultural use of acetamiprid in professional applications is minimal compared to other neonicotinoids (Table A-3 in Appendix A).

5. Conclusions

The risk assessment presented in this report focuses on the potential impacts on aquatic organisms from the non-agricultural use of five neonicotinoids (acetamiprid, clothianidin, dinotefuran, imidacloprid, and thiamethoxam) on nonproduction outdoor ornamental plants, trees, and turf. Based on the modeling results, potential chronic risks to aquatic organisms are identified with combined exposures to multiple neonicotinoids from the three uses within reevaluation. Imidacloprid is the primary driving factor of the potential cumulative risk. The use of imidacloprid within the scope of reevaluation is expected to result in a chronic RQ value of 0.95, which is just below the threshold of triggering chronic risk concerns to aquatic organisms in surface water. Clothianidin and thiamethoxam are important contributors to the potential cumulative risk, with a chronic RQ of 0.19 and 0.13, respectively. The two RQ values are substantially below the LOC of 1, indicating a low potential for aquatic risk from each AI; however, the combined impacts with imidacloprid could potentially result in chronic risks to aquatic organisms. The contributions from acetamiprid and dinotefuran to the potential cumulative risk are minimal (RQs ≤ 0.01). In addition, no acute risks are identified for the uses within reevaluation, either in the case of collective exposures to multiple neonicotinoids or the case of exposures to individual AIs.

The modeling efforts focus on a conservative upper limit of use, which represents the worst-case scenario of exposure for baseline risk characterization. As per AB363, beginning January 1, 2025, non-professionals, who were a major group of users, are prohibited from buying and using any one of the five neonicotinoids for non-agricultural uses on nonproduction outdoor ornamental plants, trees, and turf. With the sales/use restrictions in place, DPR expects the overall use of neonicotinoids for these three applications will decline. However, it is uncertain to what extent the decline would be. The restrictions on non-professional use may result in an increase in professional use if non-professionals hire professional applicators who have access to neonicotinoids for landscape applications. Moreover, the sales/use restrictions are on the application sites (ornamental plants, trees, and turf), not the actual product. In that sense, products that are registered for multiple application sites (e.g., structural) would still be allowed for use by the non-professional. With products that are labeled for a wide range of application types, we would not be able to predict the future effect of limiting application sites, specifically. Therefore, modeling efforts are based on the upper limit of use indicated by the available pesticide use and sales data, and the applicator survey that suggests an upper bound of adoption rate for imidacloprid. While modeling results may overestimate the potential risks, the model configurations are the most robust while maintaining a level of conservatism based on available data.

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Appendix A. Overview of Urban Outdoor Products Containing the Five Neonicotinoid Pesticides

Table A-1. Number of neonicotinoid products under reevaluation (UR), not in reevaluation (NR) and not reviewed.

Pesticides	UR Landscape	UR Landscape & Impervious	NR High Risk[a]	NR Low Risk[b]	Not Reviewed[c]
Acetamiprid	7	4	0	0	2
Clothianidin	5	2	6	5	0
Dinotefuran	4	4	6	1	0
Imidacloprid	55	15	4	28	17
Thiamethoxam	7	2	1	1	4
Total	78	27	17	35	23

Notes:
[a] High risk refers to application to urban outdoor impervious surfaces via spot or crack and cervices treatment and perimeter treatment.
[b] Low risk refers to any urban outdoor use patterns other than the application to impervious surfaces.
[c] Products that are registered after January 1, 2024 have not been reviewed.

Table A-2. Breakdown of the 105 products within reevaluation by intended applicator.

Pesticides	Professional Applicator Only	No Restriction on Applicator
Acetamiprid	2	9
Clothianidin	1	6
Dinotefuran	2	6
Imidacloprid	12	58
Thiamethoxam	0	9
Total	17	88

Table A-3. Annual average mass used in landscape maintenance (LM) and structural pest control (SPC) for each neonicotinoid and the group of other insecticides, and the corresponding percentage in total mass used, based on PUR data from 2020 and 2022.

Pesticides	LM Annual Average Mass Used (pounds/year)	LM in Total Use (%)	SPC Annual Average Mass Used (pounds/year)	SPC in Total Use (%)
Imidacloprid	14,786	38.6	29,352	6.5
Clothianidin	2,304	6.0	585	0.1
Dinotefuran	1,313	3.4	57,428	12.8
Thiamethoxam	282	0.7	2,653	0.6
Acetamiprid	124	0.3	6,71	0.1
Other Insecticides	19,530	50.9	357,794	79.8
Total	38,339	100	448,483	100

Appendix B. Relative Adoption Rate Based on Available PUR Data.

For reference, the relative and final adoption rates derived from the currently available PUR data are presented in Table B-1. The annual average mass used was determined for each neonicotinoid within the 76 modeled products based on PUR data for site code 30 (landscape maintenance) from 2020 to 2022. For most neonicotinoids (dinotefuran, thiamethoxam, and acetamiprid), the relative adoption rates based on the PUR data are smaller than the rates derived from the sales data (Table 2). Clothianidin is the only exception that the relative adoption rate is higher in PUR data. Adoption rate is positively correlated to modeled EECs. By using the lower adoption rate derived from sales data, we expect the modeled EECs for clothianidin to be smaller than using the adoption rate derived from PUR. However, urban monitoring data (Table C-1 in Appendix C) shows that the detection frequency of clothianidin is lower than 5%, meaning that the upper percentiles of monitoring concentrations that are used for model validation will be non-detects. This further indicates the observed concentrations are more relevant to the adoption rate derived from sales data (i.e., smaller EECs) than from the PUR.

Table B-1. Estimation of relative and final adoption rate for each neonicotinoid based on the annual average mass used within the 76 modeled products based on PUR site code 30 (landscape maintenance) from 2020 to 2022.

Pesticides	Annual Average Mass Used (pounds/year)	Application Rate of Product with Max Mass Used (kg/ha)	Relative Adoption Rate (%)	Final Adoption Rate (%)
Imidacloprid	12,543	0.45	100.0	30.0
Dinotefuran	986	0.61	5.8	1.7
Acetamiprid	45	0.21	0.8	0.2
Clothianidin	1,559	0.45	12.4	3.7
Thiamethoxam	49	0.30	0.6	0.2

Appendix C. Summary of Monitoring Data in Urban Waterways

Urban waterways refer to receiving waters in urban catchments (i.e., less than 10% of the catchment is agricultural land and more than 25% is urban). Engineered conveyances (storm drains) are not included.

Table C-1. Sample size, detection frequency, and upper percentiles of DPR and SURF monitoring data for each neonicotinoid collected from urban waterways.

Pesticides	DPR Sample Size[a]	DPR DF (%)	DPR Max[b]	DPR P95[b]	DPR P90[b]	SURF Sample Size[c]	SURF DF (%)	SURF Max	SURF P95	SURF P90
Acetamiprid	236	2	0.039	ND (0.02)[d]	ND (0.02)[d]	348	1	0.039	ND (0.02)[d]	ND (0.02)[d]
Clothianidin	8	0	ND (0.02)	ND (0.02)[d]	ND (0.02)[d]	128	5	0.022	ND (0.02)[d]	ND (0.02)[d]
Dinotefuran	7	14	0.032	0.023	0.013	117	18	0.452	0.036	0.016
Imidacloprid	552	63	0.740	0.186	0.130	1322	43	0.740	0.129	0.089
Thiamethoxam	236	7	0.222	0.025	ND (0.02)[d]	359	7	0.268	0.023	ND (0.02)[d]

Notes:
[a] DPR data only = monitoring data collected by DPR, available from 2010 to 2023.
[b] Max = Maximum, P95 = the 95th percentile, and P90 = the 90th percentile of monitoring concentrations.
[c] All SURF data include DPR data and other data recorded within SURF based on a data pull from the California Environmental Data Exchange Network (CEDEN) and the Water Quality Portal, available from 2003 to 2023.
[d] ND = non detect. Median limit of quantification (LOQ) for non-detects is shown in parathesis.

Table C-2. Exceedance frequency in monitoring data based on the USEPA biological evaluation toxicity thresholds.

(a) DPR data only (from October 2010 to August 2023).

Pesticides	Sample Size	Lowest Chronic NOAEC (µg/L)	Chronic Exceedance Frequency (%)	0.5*Lowest Acute HC_{05} (µg/L)	Acute Exceedance Frequency[a] (%)
Acetamiprid	236	0.71	0	1.915	0
Clothianidin	8	0.05	0	1.79	0
Dinotefuran	7	4.4	0	4.9	0
Imidacloprid	552	0.125	11	0.715	0.4
Thiamethoxam	236	0.05	3	1.79	0

(b) All SURF data, including DPR data and other data recorded within SURF based on a data pull from the California Environmental Data Exchange Network (CEDEN) and the Water Quality Portal (from March 2000 to September 2023).

Pesticide	Sample Size	Lowest Chronic NOAEC (µg/L)	Chronic Exceedance Frequency (%)	0.5*Lowest Acute HC_{05} (µg/L)	Acute Exceedance Frequency[a] (%)
Acetamiprid	348	0.71	0	1.915	0
Clothianidin	128	0.05	0	1.79	0
Dinotefuran	117	4.4	0	4.9	0
Imidacloprid	1322	0.125	5	0.715	0.2
Thiamethoxam	359	0.05	4	1.79	0

[a] Exceedance frequency relative acute toxicity thresholds are calculated based on the lowest HC_{05} divided by a safety factor of 2.

Appendix D. Application Information for PREM Input and the corresponding EECs

Table D-1. Application information used for PREM input and the corresponding model-predicted EECs (before adjustment with adoption rate) based on the label of the 76 modeled products and the top-use product of each neonicotinoid for structural applications (i.e., PUR site code 10 for the year 2022).

Pesticides	PREM Scenario	Granule	Application Rate (kg[AI]/ha)	Application Interval (day)	Number of Applications in A Year	Daily Average EEC	21-Day Average EEC
Acetamiprid	Ornamental Plants and Trees	No	0.62		1	0.242	0.227
	Ornamental Plants and Trees	No	0.21		1	0.082	0.077
	Lawns and Turf	No	0.21		1	0.159	0.151
	Spot or Crack & Crevices	No	0.21		1	0.346	0.323
	Perimeter (10 ft wide 3 ft up)	No	0.21		1	3.246	3.035
Clothianidin	Ornamental Plants and Trees	No	0.45		1	0.196	0.167
	Ornamental Plants and Trees	Yes	0.45		1	0.102	0.087
	Lawns	No	0.45		1	0.402	0.349
	Lawns	Yes	0.45		1	0.228	0.201
	Ornamental Plants and Trees	Yes	0.155	90	4	0.124	0.131
	Spot or Crack & Crevices	Yes	0.36		1	0.648	0.560
Dinotefuran	Ornamental Plants and Trees	No	0.61		1	0.202	0.185
	Lawns	No	0.61		1	0.647	0.594
	Ornamental Plants and Trees	No	0.43		1	0.143	0.130
	Lawns	No	0.43		1	0.456	0.419
	Ornamental Plants and Trees	Yes	0.02	30	12	0.024	0.021
	Spot or Crack & Crevices	No	1.29		1	2.439	2.238
Imidacloprid	Ornamental Plants and trees	No	0.56		1	0.248	0.170
	Ornamental Plants and Trees	Yes	0.56		1	0.161	0.109
	Lawns	No	0.56		1	0.403	0.330
	Lawns	Yes	0.56		1	0.181	0.128
	Ornamental Plants and Trees	No	0.45		1	0.199	0.137
	Ornamental Plants and Trees	Yes	0.45		1	0.129	0.087

Pesticides	PREM Scenario	Granule	Application Rate (kg[AI]/ha)	Application Interval (day)	Number of Applications in A Year	Daily Average EEC	21-Day Average EEC
	Lawns	No	0.45		1	0.324	0.265
	Lawns	Yes	0.45		1	0.146	0.103
	Ornamental Plants and Trees	No	0.44		1	0.195	0.134
	Ornamental Plants and Trees	No	0.38		1	0.168	0.116
	Ornamental Plants and Trees	Yes	0.27	56	3	0.08	0.054
	Ornamental Plants and Trees	No	0.25		1	0.111	0.076
	Ornamental Plants and Trees	Yes	0.2	56	3	0.059	0.040
	Lawns	Yes	0.12	7	8	0.252	0.179
	Ornamental Plants and Trees	Yes	0.12	7	8	0.127	0.095
	Spot or Crack & Crevices	No	0.18	7	3	0.76	0.540
	Perimeter (0 ft wide 3 ft up)	No	0.18	7	3	2.175	1.546
Thiamethoxam	Ornamental Plants and Trees	No	0.3		1	0.115	0.103
	Ornamental Plants and Trees	Yes	0.3		1	0.067	0.060
	Lawns	No	0.3		1	0.324	0.291
	Lawns	Yes	0.3		1	0.209	0.189
	Ornamental Plants and Trees	No	0.08	7	12	0.155	0.144
	Spot or Crack & Crevices	No	0.3		1	0.57	0.514
	Perimeter (7 ft wide 3 ft up)	No	0.3		1	4.79	4.318