Midpeninsula Regional Open Space District
Integrated Pest Management Program

2024 Literature Review
Technical Report

August 2025

Prepared by:

Blankinship, a **BOWMAN** Company
1615 5th Street, Suite A
Davis, CA 95616
Contact: Alyssa Nagai or Michael Blankinship
530.757.0941

Prepared for:

Midpeninsula Regional Open Space District
5050 El Camino Real
Los Altos, CA 94022
Contact: Coty Sifuentes-Winter

Limitations

Services provided by Blankinship, a BOWMAN Company were done in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances at the same time the services were performed. No warranty, express or implied, is included. This report is solely for the Midpeninsula Regional Open Space District's use and information.

Table of Contents

List of Attachments

Executive Summary

Midpeninsula Regional Open Space District (District) is a regional greenbelt system which manages over 72,000 acres of open space land and 27 open space preserves. As part of its land management approach, the District practices Integrated Pest Management (IPM) and implements Best Management Practices (BMPs) to safely and effectively control pests in a manner that minimizes potential risk to humans, wildlife, and the environment. Consistent with BMP #36, a literature review of relevant peer-reviewed research published in 2024 was conducted to evaluate recent research on pesticides used by the District and their effect on the natural and human environments. Key findings from the literature review are summarized in this technical report.

Common areas of study based on the literature review included aquatic toxicity, pollinator health, effects following exposure to non-lethal concentrations of pesticides, and effects observed following pesticide exposure during early stages of growth and development. Approximately 80% of the articles included in the literature reported on the effects of glyphosate, while 12% of the articles focused on fipronil and the remaining 8% of articles focused on aminopyralid, clopyralid, triclopyr, and diatomaceous earth.

It is important to acknowledge that the published research, while peer reviewed, varied in quality and representativeness of typical environmental exposure scenarios or District practices. For example, several of the studies reviewed included very high dose exposures which exceed regulatory triggers or are otherwise unlikely to occur as a result of District practices. Studies testing exposure concentrations significantly higher than those anticipated in the field can be helpful in understanding potential hazards; however, consideration of District application practices, label instructions, and the potential for exposure of humans and wildlife to pesticides is critical in understanding associated risk.

While the majority of publications from 2024 were not considered directly relevant to the District's IPM Program, the complex nature of ecosystem interactions was a notable theme, highlighting the importance of continuing to use pesticides only as needed as part of an IPM approach, in accordance with label instructions and regulatory requirements, and in a manner that minimizes risks to staff, the public, wildlife, and the environment. Based on publications reviewed from 2024, no additional best management practices (BMPs) for the District's IPM Program are proposed. If the District intends to treat vegetation in or near aquatic sites, however, enrollment in the Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Residual Aquatic Pesticide Discharges to Waters of the United States from Algae and Aquatic Weed Control Applications (Water Quality Order 2013-0002-DWQ) ("NPDES Aquatic Weed Permit") is recommended. As part of the NPDES Aquatic Weed Permit requirements, residues of herbicides such as glyphosate, imazapyr, and triclopyr are monitored to assess herbicide concentrations in water and compare them to concentrations that are expected to be protective of representative sensitive aquatic life.

Introduction

Midpeninsula Regional Open Space District (District) is a regional greenbelt system which manages over 72,000 acres of open space land and 27 open space preserves. The District includes parts of San Mateo, Santa Clara, and Santa Cruz counties and provides protection for local wildlife habitats necessary to sustain plant and animal life and natural resources. As part of its land management approach, the District practices Integrated Pest Management (IPM) and implements Best Management Practices (BMPs) to safely and effectively control pests while minimizing risk of adverse impacts to non-target receptors.

Consistent with BMP #36 for the District's IPM Program[1], the purpose of this technical report is to summarize and evaluate recent peer-reviewed research on pesticides and their effect on the natural and human environments. Based on the findings from academic research papers published in 2024, recommendations for IPM Program activities may be provided.

Literature Review

Approach

Google Scholar was used to conduct a comprehensive literature review of peer-reviewed research released in 2024 which studied active ingredients currently approved for use under the

[1] BMP #36: Annual Pesticide Literature Review – To inform updates to the IPM Program, the District shall conduct an annual pesticide literature review of all newly published toxicological research and court proceedings related to pesticides on the "Approved Pesticides List."

District's IPM Program. Due to the volume of publications released during each year, the following criteria were used to select research articles for further review:

- Content must include one or more of the following topics, as it relates to land management with pesticides in natural areas (including timber) or rangeland: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species;
- Published in a peer-reviewed journal with an Impact Factor of 3 or higher[2];
- Publication was readily accessible for review; and
- Included active ingredient name in the publication title.

Professional judgement on study quality and relevance was also used as appropriate. Papers meeting these criteria are included in the annotated bibliography provided in **Attachment 1**.

Summary of Findings

Of the 73 publications included in the annotated bibliography presented in **Attachment 1**, 58 research papers studied the effects of the herbicide glyphosate and 9 studied the effects of the insecticide fipronil. Active ingredients studied in the remaining 6 publications included the herbicides aminopyralid, clopyralid, triclopyr, and the insecticide diatomaceous earth. No relevant papers published in 2024 met the selection criteria above for potassium phosphite salts,

[2] The Impact Factor represents the average number of times articles in a journal have been cited in a particular year or period.

clethodim, imazapyr, D-trans allethrin, indoxacarb, phenothrin, prallethrin, S-hydroprene, sodium tetraborate decahydrate, cholecalciferol, or adjuvants used by the District.

Common areas of study based on the literature review included aquatic toxicity, pollinator health, oxidative stress[3] and other sublethal effects following exposure to low concentrations of pesticides, effects observed following pesticide exposure during vulnerable stages of growth and development, and potential implications of overreliance on pesticide use. An overview of these studies as they relate to biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species is provided in the following subsections.

It is important to acknowledge that the published research, while peer reviewed, varied in quality and representativeness of typical environmental exposure scenarios or District practices. For example, studies commonly included very high dose exposures, citing concerns with the overuse of pesticides such as glyphosate in agriculture globally. Many studies included the use of international formulations which are not commercially available or registered for use in California. Other studies investigated exposure scenarios which were considered unlikely to occur based on District practices and manner of pesticide use. The District's BMPs, which include avoiding spraying pesticides to plants currently in bloom, maintaining buffers between

[3] In toxicology, the term oxidative stress refers to a "range of pathologic conditions and reactions that together constitute a departure from a baseline homeostatic reductive state in the cell or tissue" (Samet and Wages, 2018). Oxidative stress can be caused by a variety of internal and external factors, including exposure to environmental contaminants and pesticides and indicates an imbalance between free radicals and antioxidants in living organisms.

treatment areas and surface water, and using fipronil in self-contained bait stations in lieu of liquid sprays, for instance, are expected to significantly reduce the potential for chronic oral exposure of pollinators to glyphosate, prolonged exposure of embryonic fish and amphibians to various glyphosate formulations, and exposure of fish larvae to fipronil, respectively.

Effects on Wildlife

The potential effects of pesticide use on wildlife were widely studied in the 2024 publications reviewed. In particular, studies focused heavily on the toxicity and sublethal effects of glyphosate in aquatic species. Studies consistently reported that exposure of aquatic species to glyphosate and glyphosate-based herbicides during early stages of development (e.g., zebrafish and frog embryos) can cause adverse effects (da Silva Durante et al., 2024; Flach et al., 2024; Pompermaier et al., 2024; Stevens et al., 2024), with formulated products being significantly more toxic than glyphosate alone due to surfactant co-formulants (Abe et al., 2024; Spulber et al., 2024; Tóth et al., 2024). Overall, the data continued to demonstrate that co-formulants and additives can substantially contribute to adverse effects observed following exposure to glyphosate-based products and that the toxicity of glyphosate acid alone is relatively low.

Studies also showed that exposure to glyphosate and glyphosate-based herbicides triggers oxidative stress and an increase in defense enzyme activity in aquatic species. Abe et al. (2024), for example, evaluated cellular-level changes that could result in physiological and pathological changes in zebrafish embryos exposed to glyphosate and a Roundup Original formulation commercially available in Brazil. While both Roundup Original and glyphosate alone caused oxidative stress, increased defense system activity, and altered motor activity, only Roundup Original delayed the embryogenesis, affected the cholinergic neurotransmission, and induced DNA damage. Notably, data showed that the occurrence of these cellular level changes is not a direct indication of adverse effects since morphological alterations appeared after several alterations at biochemical levels during embryogenesis.

In adult zebrafish, acute exposure to the glyphosate-based herbicide Shadow led to changes in antioxidant activity in the liver and brain and inhibition of an inflammatory marker; however, no behavioral changes were observed (Bortolon Ribas et al., 2024). In a separate study, chronic exposure to glyphosate resulted in alterations in gut microbiome diversity, increased serotonin and dopamine levels, and increased "anxiety-like" behavior in zebrafish (Bellot et al., 2024).

The sublethal effects of triclopyr exposure in embryos were investigated by Bertoni et al. (2024). Similar to studies using glyphosate, researchers found that zebrafish embryo exposure to sublethal concentrations of triclopyr during critical stages of development can cause adverse effects such as yolk sac malabsorption and reduced swimming activity once hatched. At the highest concentration tested (13 mg/L), triclopyr exposure exhibited delayed egg hatchability and uninflated swim bladder.

The sublethal behavioral effects of fipronil exposure in water fleas were also studied. Following a pre-exposure period, water fleas preferentially moved toward less areas containing less fipronil, demonstrating an ability to detect and avoid fipronil residues in water. However, fipronil exposure also impaired swimming ability, reducing total distance traveled (Moreira et al., 2024).

Only one study assessed the potential effects of herbicide exposure in terrestrial vertebrates. Chronic dietary exposure of young female broilers to the glyphosate-based herbicide Gallup Super 360 was associated with dose-dependent reductions in food intake, body weight, and fattening, alongside increased oxidative stress and ovarian weight (Mathias et al., 2024). Decreased steroid secretion and dose-dependent reduction in sex hormone production was also seen. Interestingly, the authors found that the more Gallup Super 360 the food contained, the less the broilers consumed.

Effects on Non-Target Species

Effects on non-target species including terrestrial and aquatic invertebrates and non-target plants were studied for glyphosate, fipronil, and diatomaceous earth. Similar to recent years, sublethal effects in pollinators following pesticide exposure were of particular interest. In acute toxicity studies, glyphosate exposure resulted in altered motor activity (e.g., walking distance and velocity) (Fernandes Farder-Gomes et al., 2024a), body fat morphology, and decreased body weight in pollinators (Fernandes Farder-Gomes et al., 2024a, 2024b).

Chronic dietary exposure of honeybees to both glyphosate and the glyphosate-based herbicide Roundup Transorb R was associated with significantly increased honeybee mortality, damaged midgut epithelium (Battisti et al., 2024), and reduced sugar consumption (Ma et al., 2024) when tested at labeled application rates. In these studies, honeybees were fed an artificial diet spiked with glyphosate or Roundup Transorb R.

Studies on other terrestrial invertebrate species as well as aquatic invertebrates were also identified. Exposure of the model organisms *Caenorhabditis elegans* (a nematode) and *Saccharomyces cerevisiae* (yeast) to Roundup Weed and Grass Killer Concentrate Plus, for example, increased mortality and reduced reproduction in both species (Dinep-Schneider et al., 2024). Since *C. elegans* lacks the shikimate pathway targeted by glyphosate, oxidative stress was thought to be a potential mechanism of toxicity. Similarly, juvenile agrobiont wolf spiders (*Pardosa pseudoannulata*) exhibited reduced survival and fecundity and increased oxidative stress when the glyphosate-based herbicide Nongxingwang was applied before or during overwintering in treated vegetation (Yu et al., 2024). In golden apple snails exposed to high doses of Roundup, acute effects included reduced gut microbiome diversity and impacts to metabolic pathways (e.g., lipid, amino acid, and glucose metabolism) (Bao et al., 2024).

Two studies investigated the effects of co-exposure to glyphosate and microplastics in terrestrial and aquatic invertebrate species. Honeybee larvae exposed to glyphosate alone exhibited oxidative/immune changes and reduced bodyweight (Mitton et al., 2024). Co-exposure to glyphosate and microplastics led to decreased survival rates and larval weight. Additionally, Pacific white shrimp exposed to the glyphosate-based herbicide Roundup Flex 480 alone significantly reduced acetylcholinesterase activity and altered oxidative stress markers while co-exposure with microplastics appeared to modulate the toxicity of the formulated product by altering acetylcholinesterase concentration and immune gene expression (Thammartorn et al., 2024). In both studies, microplastics alone had minor effects.

Contact exposure of pollinators to glyphosate (Battisti et al., 2024) and diatomaceous earth (Demirozer et al., 2024) did not result in adverse effects.

In a phytotoxicity study on chickpea and mung bean seedlings, exposure to high concentrations of fipronil (200-300 mg/L) resulted in significantly reduced seedling survival, root-shoot elongation, and vigor indices and increased oxidative stress (Shahid et al., 2024).

Mammalian Toxicity and Human Health

The mammalian toxicity and potential human health impacts of glyphosate exposure was also studied. Similar to studies in aquatic species, exposure during critical development life stages can cause adverse effects in mammals. Exposure to glyphosate-based herbicides (MAGNUM SUPER II, Roundup) during pregnancy in rats and mice led to effects such as reduced gene expression (Almiron et al., 2024a, 2024b), oxidative stress, behavioral changes, and delayed pup development (Anarghou et al., 2024). In a study on the impact of glyphosate alone and as part of a formulated product (Turnout Liquid Agent) on cerebellar development in rats, the formulated product, and glyphosate alone to a lesser extent, temporarily disrupted normal cerebellar development (Ojiro et al., 2024).

The chronic oral toxicity of glyphosate was studied by Cresto et al. (2024) in a mouse dietary study. Continuous daily exposure to glyphosate at the Acceptable Daily Intake (ADI) level (0.5 mg/kg/day) and No Observed Adverse Effect Level (NOAEL) (50 mg/kg/day) led to alterations in specific synaptic transmission measures and density in the mouse brain, particularly for male mice at the higher dose. A hypothesis of a long-term frail brain condition associated with chronic glyphosate exposure has been suggested, though actual pathological significance remains unclear. In a chronic drinking water study by Hsiao et al. (2024), also in mice, behavioral tests showed minimal alterations, while metabolomic analysis showed localized disruption to the gut metabolome in a dose-dependent manner. However, serum metabolites remained largely unchanged, suggesting that glyphosate-induced gut microbiota disruption does not significantly impact systemic neurotoxicity.

In human prostate cells exposed to high and low doses of glyphosate, cytotoxicity and disruptions in hormone signaling pathways were observed (Chianese et al., 2024). In this study, the authors hypothesized that cells stressed by glyphosate exposure try to compensate for glyphosate-induced alterations by working at high efficiency, which could lead to oxidative stress and aggravate cellular damage.

Soil Health

The effects of soil microbe exposure to the herbicides clopyralid and glyphosate and the insecticide fipronil were studied. Clopyralid reduced microbial respiration and caused fluctuations in enzymatic activity throughout a 90-day study conducted by Rouhi-Kelarlou et al. (2024), particularly at higher doses. Based on this study, soil microbes may require an extended period of time to adapt to the presence of residues of herbicides such as clopyralid in soil. In a study on the effects of the glyphosate-based herbicides WeatherMax and Transorb on *Methylobacterium*, a genus of beneficial plant-associated bacteria, glyphosate did not significantly impact bacterial growth unless combined with a surfactant that increases membrane permeability (Palberg et al., 2024). Surfactants, even when non-toxic alone, amplified glyphosate toxicity. In a separate study, glyphosate was shown to degrade rapidly in soil; however, despite rapid degradation, microbial community composition and abundance remained largely unchanged (Langarcia-Fuentes et al., 2024). Glyphosate is also known to bind tightly to soil, which can play a role in its limited bioavailability. Following fipronil exposure, plant-beneficial bacteria exhibited varied impacts on bacterial growth, cell survival, growth-regulating substances, and inner membrane permeability (Shahid et al., 2024).

In a glyphosate-based grassland restoration project conducted in Colorado in which Roundup ProMax was applied 2 to 5 times per year for 4 years, heavy application of glyphosate was associated with shifts in nematode abundance, diversity, composition, and potential interactions with other trophic levels such as plants, fungivores, and omnivores/predators (McQueen et al., 2024). Effects were persistent for the duration of the study. Because effects varied among and within trophic groups and taxa, indirect effects on factors such as plant cover, soil chemistry, and food source availability were thought to be more influential than direct effects (i.e., toxicity).

In a separate study conducted by Zhang et al. (2024) in worms (*Enchytraeus crypticus)*, 14-day exposure to glyphosate was associated with oxidative stress, shifts in digestive enzyme activity, and reduced gut microbial diversity and composition. Increased activity of reactive oxygen species following exposure was associated with a temporary increase in the abundance of antibiotic-resistant genes and mobile genetic elements, with effects largely resolved by the end of the 14-day exposure. Soil microbial composition was not significantly affected.

In a study conducted by De Oliveira et al. (2024), the toxicity of fipronil to soil invertebrates in tropical soils was evaluated. While fipronil exposure caused high risk to soil invertebrates at recommended application rates, the magnitude of toxicity was variable between species.

Drift and Water Quality

In an herbicide drift study conducted by Andersson et al. (2024), Roundup Ultra (glyphosate) spray drift from herbicide-spraying trains was shown to impact non-target vegetation up to 5 feet from the application area. Despite concerns over drift, glyphosate concentrations in railway ditches remained below 0.1 mg/L.

The bioremediation potential of free-floating plants such as water hyacinth and water lettuce in water containing fipronil residues was evaluated by Ogura et al. (2024). While fipronil residues accumulated in plant roots, concentrations in water were not significantly reduced.

Efficacy and Effectiveness

The efficacy and effectiveness of several active ingredients was validated in the studies reviewed. While aminopyralid is typically applied in the fall for pre-emergent control of medusahead, a study conducted by Jones et al. (2024) demonstrated that the management window can be increased through the implementation of post-emergent spring applications. Based on study sites in Idaho and Utah, post-emergent application of aminopyralid to medusahead seedlings (<2-cm tall) significantly reduced germination rate, which in turn improved control the following year. The results indicated that aminopyralid can effectively control medusahead either directly with a fall pre-emergent application or indirectly by reducing seed viability with a spring post-emergent application. In the study, higher rates were needed to achieve control when applied under drier and highly degraded conditions.

In a study by Baccin and Moretti (2024), clopyralid effectively controlled Canada thistle when applied via foliar spray and sponge wiper in Oregon hopyards. Results indicated that both sponge wipers and foliar sprays provided effective control; however, the sponge wiper method reduced herbicide use and cost compared to spraying. Two applications of clopyralid provided the greatest control, achieving an 88% reduction in biomass, whereas a single application reduced biomass by 68%. Compared to glyphosate, clopyralid provided greater control and did not injure surrounding hops. Note that labor costs and worker exposure when applying clopyralid by sponge wiper v. spraying were not considered.

Finally, a study by Farder-Gomes et al. (2024) in which Egyptian mosquito (*Aedes aegypti)* larvae which were exposed to low concentrations of the fipronil-based insecticide Tuit Florestal for 24-hours demonstrated fipronil's potential as a mosquito larvicide. Note that fipronil is not currently registered for this use in California.

Potential for Research Author Bias and Conflicts of Interest

It is important to acknowledge the potential for research author bias and conflicts of interest when reviewing academic research. Caution is highly recommended when reading review articles and surveys. Review articles, for instance, reflect authors' opinions on data evaluated in other studies as opposed to drawing their own conclusions based on a body of newly generated data. Epidemiology studies such as case control and cohort studies may introduce intentional or unintentional bias, for example, when questions are hard to understand or are asked in a manner which is more likely to result in a specific response. Additionally, bias of study participants must be considered.

Some bias also originates in the publishing process. The page charge associated with publishing in prestigious journals, for example, may influence authors of sound research to publish in lesser known or smaller journals with no page charge. Funding to complete and publish a given study tends to be more readily available for controversial issues and less readily available for studies that address more mundane topics.

In a meta-analysis systematically evaluating the effects of glyphosate and glyphosate-based herbicides on animal health, Evalen et al. (2024) identified publication bias in most sub-group analyses, suggesting that studies showing negative effects might be overrepresented while non-significant results could be underreported. Publications on glyphosate-based herbicides and vertebrate datasets were thought to be particularly impacted.

The quality of a given study can be difficult to characterize and is often based on the scientific integrity of the researcher as opposed to the researcher's affiliation. While conflict of interest statements made in published research papers may be informative in some cases, generally speaking they are not always a useful indicator of study quality. Use of resources such as Retraction Watch can be helpful by providing information on research articles which have been retracted and the reason(s) for retraction (e.g., falsified or reused data, author bias, conflicts of interest, and errors).

Management Implications and IPM Program Recommendations

Based on publications reviewed from 2024, no additional best management practices (BMPs) for the District's IPM Program are currently proposed. If the District intends to treat vegetation in or near aquatic sites, enrollment in the Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Residual Aquatic Pesticide Discharges to Waters of the United States from Algae and Aquatic Weed Control Applications (Water Quality

Order 2013-0002-DWQ) ("NPDES Aquatic Weed Permit") is recommended. As part of the NPDES Aquatic Weed Permit requirements, residues of herbicides such as glyphosate, imazapyr, and triclopyr are monitored to assess herbicide concentrations in water and compared to concentrations that are expected to be protective of representative sensitive aquatic life.

Note that several of the studies reviewed included pesticide dose exposures which exceed regulatory triggers, are unlikely to occur as a result of District practices, or are not relevant because they are significantly higher than the expected environmental concentrations when the pesticide is used according to its label. For example, several aquatic toxicity studies tested concentrations of glyphosate that exceeded the U.S. Environmental Protection Agency's (USEPA's) Maximum Contaminant Level (MCL) and NPDES water quality objective (WQO) of 0.7 mg/L. The MCL represents the highest level of a contaminant allowed in human drinking water, while the WQO is a threshold established to protect the beneficial uses of a waterbody (e.g., drinking water supply, recreation, or aquatic habitat). Studies testing exposure concentrations significantly higher than those anticipated in the field can be helpful in understanding potential hazards. District application practices include adherence to label instructions and use of BMPs that reduce or eliminate non-target exposure. As a result, many of the studies examined include data and/or draw conclusions that are not relevant to the District's use of pesticides.

While the majority of publications from 2024 were not considered directly relevant to the District's IPM Program, the complex nature of ecosystem interactions was a notable theme. For instance, glyphosate's effects on microbes are influenced by factors like soil type, farming practices, presence of microplastics, and other environmental conditions, while pH, temperature, and formulation have been shown to influence fipronil toxicity. Because it is not possible to study or predict all possible ecosystem interactions, it is important to continue to use pesticides only when needed as part of an IPM approach, in accordance with label instructions and regulatory requirements, and in a manner that minimizes risks to staff, the public, wildlife, and the environment.

References

Abe, F. R., Dorta, D. J., Gravato, C., & de Oliveira, D. P. (2024). Elucidating the effects of pure glyphosate and a commercial formulation on early life stages of zebrafish using a complete biomarker approach: All-or-nothing! *Science of the Total Environment*, 916, 170012. https://doi.org/10.1016/j.scitotenv.2024.170012

Almirón, A., Lorenz, V., Doná, F., Varayoud, J., & Milesi, M. M. (2024a). Epigenetic alteration of uterine leukemia inhibitory factor gene after glyphosate or a glyphosate-based herbicide exposure in rats. *Environmental Toxicology and Pharmacology*, 111, 104564. https://doi.org/10.1016/j.etap.2024.104564

Almirón, A., Lorenz, V., Varayoud, J., Durando, M., & Milesi, M. M. (2024b). Perinatal exposure to glyphosate or a commercial formulation alters uterine mechanistic pathways associated with implantation failure in rats. *Toxics*, 12(8), 590. https://doi.org/10.3390/toxics12080590

Anarghou, H., Malqui, H., Ihbour, S., Laaroussi, M., Essaidi, O., Fetoui, H., Bouhrim, M., Najimi, M., & Chigr, F. (2024). Impact of glyphosate-based herbicide exposure through maternal milk on offspring's antioxidant status, neurodevelopment, and behavior. *Naunyn-*

Schmiedeberg's Archives of Pharmacology, 397, 6591-6609. https://doi.org/10.1007/s00210-024-03035-5

Andersson, F., Barthelemy, S., & Cederlund, H. (2024). An investigation of spray drift deposition of glyphosate from an herbicide spraying train and its potential impact on non-target vegetation and railway ditches. *Science of the Total Environment*, 956, 177208. https://doi.org/10.1016/j.scitotenv.2024.177208

Baccin, L., & Moretti, M. L. (2024). Clopyralid applied with sponge wiper for Cirsium arvense control in hops in the western United States. *Crop Protection*, 177, 106518. https://doi.org/10.1016/j.cropro.2023.106518

Bao, Y., He, X., Zhai, Y., Shen, W., Jing, M., Liu, Y., Yang, H., & Chen, L. (2024). Effects of glyphosate-based herbicide on gut microbes and hepatopancreatic metabolism in *Pomacea canaliculata*. *Ecotoxicology and Environmental Safety*, 280, 116549. https://doi.org/10.1016/j.ecoenv.2024.116549

Battisti, L., Potrich, M., Abati, R., Sampaio, A. R., Libardoni, G., Costa-Maia, F. M., Berte, E. A., Martinez, C. B. R., & Sofia, S. H. (2024). Toxicity of glyphosate herbicides formulated for Africanized Apis mellifera Linnaeus, 1758 (Hymenoptera: Apidae). *Ecotoxicology and Environmental Safety*, 287, 117247. https://doi.org/10.1016/j.ecoenv.2024.117247

Bellot, M., Carrillo, M. P., Bedrossiantz, J., Zheng, J., Mandal, R., Wishart, D. S., Gómez-Canela, C., Vila-Costa, M., Prats, E., Piña, B., & Raldúa, D. (2024). From dysbiosis to neuropathologies: Toxic effects of glyphosate in zebrafish. *Ecotoxicology and Environmental Safety*, 270, 115888. https://doi.org/10.1016/j.ecoenv.2023.115888

Bortolon Ribas, E., Dal-Pont, G. C., Centa, A., Bueno, M. O., Cervini, R., Silva Ogoshi, R. C., & Locatelli, C. (2024). Effects of low concentration of glyphosate-based herbicide on genotoxic, oxidative, inflammatory, and behavioral markers in *Danio rerio* (Teleostei and Cyprinidae). *Biochemistry Research International*, 2024, 1542152. https://doi.org/10.1155/2024/1542152

Bertoni, Í., Sales, B. C. P., Viriato, C., Peixoto, P. V. L., & Pereira, L. C. (2024). Embryotoxicity induced by triclopyr in zebrafish (*Danio rerio*) early life stage. *Toxics*, 12(255). https://doi.org/10.3390/toxics12040255

Chianese, T., Trinchese, G., Leandri, R., De Falco, M., Mollica, M. P., Scudiero, R., & Rosati, L. (2024). Glyphosate exposure induces cytotoxicity, mitochondrial dysfunction, and activation of ERα and ERβ estrogen receptors in human prostate PNT1A cells. *International Journal of Molecular Sciences*, 25(13), 7039. https://doi.org/10.3390/ijms25137039

Cresto, N., Courret, M., Génin, A., Martin, C. M. P., Bourret, J., Sakkaki, S., de Bock, F., Janvier, A., Polizzi, A., Payrastre, L., Ellero-Simatos, S., Audinat, E., Perroy, J., & Marchi, N. (2024). Continuous low-level dietary exposure to glyphosate elicits dose and sex-dependent synaptic and microglial adaptations in the rodent brain. *Environmental Pollution*, 345, 123477. https://doi.org/10.1016/j.envpol.2024.123477

da Silva Durante, L., Hollmann, G., & Nazari, E. M. (2024). Impact of exposure to glyphosate-based herbicide on morphological and physiological parameters in embryonic and larval development of zebrafish. *Environmental Toxicology*, 39(3), 1822-1835. https://doi.org/10.1002/tox.24024

de Oliveira, D., Tadei, R., Triques, M. C., Goulart, B. V., Montagner, C. C., Espíndola, E. L. G., & de Menezes-Oliveira, V. B. (2024). Fipronil risk assessment in tropical soils: Relevant concentrations cause high risk to the edaphic community. *Water, Air, & Soil Pollution*, 235(123). https://doi.org/10.1007/s11270-024-06925-9.

Demirozer, O., Bulus, I. Y., Yanik, G., Uzun, A., & Gosterit, A. (2024). Does diatomaceous earth (DE) cause mortality on *Apis mellifera* and *Bombus terrestris*? *Journal of Apicultural Research*, 63(4), 778-784. https://doi.org/10.1080/00218839.2022.2146343

Dinep-Schneider, O., Appiah, E., Dapper, A., Patterson, S., Vermulst, M., & Gout, J.-F. (2024). Effects of the glyphosate-based herbicide Roundup on *C. elegans* and *S. cerevisiae* mortality, reproduction, and transcription fidelity. *Environmental Pollution*, 356, 124203. https://doi.org/10.1016/j.envpol.2024.124203

Evalen, P. S., Barnhardt, E. N., Ryu, J., & Stahlschmidt, Z. R. (2024). Toxicity of glyphosate to animals: A meta-analytical approach. *Environmental Pollution*, 347, 123669. https://doi.org/10.1016/j.envpol.2024.123669

Farder-Gomes, C. F., Miranda, F. R., Fernandes, K. M., Bernardes, R. C., Bastos, D. S. S., de Oliveira, L. L., Martins, G. F., & Serrão, J. E. (2024). Exposure to low-concentration fipronil impairs survival, behavior, midgut morphology, and physiology of *Aedes aegypti* larvae. *Chemosphere*, 358, 142240. https://doi.org/10.1016/j.chemosphere.2024.142240

Fernandes Farder-Gomes, C., Grella, T. C., Malaspina, O., & Nocelli, R. F. C. (2024a). Exposure to sublethal concentrations of imidacloprid, pyraclostrobin, and glyphosate harm the behavior and fat body cells of the stingless bee *Scaptotrigona postica**. *Science of the Total Environment*, 907, 168072. https://doi.org/10.1016/j.scitotenv.2023.168072

Fernandes Farder-Gomes, C., de Oliveira, M. A., Malaspina, O., & Cornélio Nocelli, R. F. (2024b). Exposure of the stingless bee *Melipona scutellaris* to imidacloprid, pyraclostrobin, and glyphosate, alone and in combination, impairs its walking activity and fat body morphology and physiology. *Environmental Pollution*, 348, 123783. https://doi.org/10.1016/j.envpol.2024.123783

Flach, H., Pfeffer, S., Dietmann, P., Kühl, M., & Kühl, S. J. (2024). Glyphosate formulations cause mortality and diverse sublethal defects during embryonic development of the amphibian Xenopus laevis. *Chemosphere*, 367, 143624. https://doi.org/10.1016/j.chemosphere.2024.143624

Hsiao, Y.-C., Johnson, G., Yang, Y., Liu, C.-W., Feng, J., Zhao, H., Moy, S. S., Harper, K. M., & Lu, K. (2024). Evaluation of neurological behavior alterations and metabolic changes in mice under chronic glyphosate exposure. *Archives of Toxicology*, 98, 277-288. https://doi.org/10.1007/s00204-023-03622-0

Jones, L. C., Beckley, C., Ransom, C. V., & Prather, T. S. (2024). Fall or spring aminopyralid applications control *Taeniatherum caput-medusae*. *Invasive Plant Science and Management*, 17, 46-54. https://doi.org/10.1017/inp.2024.6

Langarica-Fuentes, A., Straub, D., Wimmer, B., Thompson, K., Nahnsen, S., Huhn, C., Kleindienst, S. (2024). Subtle microbial community changes despite rapid glyphosate degradation in microcosms with four German agricultural soils. *Applied Soil Ecology*, 198, 105381. https://doi.org/10.1016/j.apsoil.2024.105381

Ma, C., Gu, G., Chen, S., Shi, X., Li, Z., Li-Byarlay, H., & Bai, L. (2024). Impact of chronic exposure to field level glyphosate on the food consumption, survival, gene expression, gut microbiota, and metabolomic profiles of honeybees. *Environmental Research*, 250, 118509. https://doi.org/10.1016/j.envres.2024.118509.

Mathias, F., Estienne, A., Ramée, C., Lefort, G., Piégu, B., Chahnamian, M., Froment, P., & Dupont, J. (2024). Chronic dietary exposure to a glyphosate-based herbicide alters ovarian functions in young female broilers. *Poultry Science*, 103, 103767. https://doi.org/10.1016/j.psj.2024.103767.

McQueen, J. P., Gendron, E. M. S., Solon, A. J., Bueno de Mesquita, C. P., Hufft, R. A., Shackelford, N., Suding, K. N., Schmidt, S. K., & Porazinska, D. L. (2024). Glyphosate-based restoration of a degraded grassland threatens soil health and the diversity of nematode communities. *Soil Biology and Biochemistry*, 191, 109350. https://doi.org/10.1016/j.soilbio.2024.109350

Mitton, G. A., Corona, M., Alburaki, M., Iglesias, A. E., Ramos, F., Fuentes, G., Vázquez, M. M., Mitton, F. M., Chan, P., Ruffinengo, S. R., & Maggi, M. D. (2024). Synergistic effects between microplastics and glyphosate on honey bee larvae. *Environmental Toxicology and Pharmacology*, 111, 104550. https://doi.org/10.1016/j.etap.2024.104550

Moreira, R. A., González, M. P., Dias, M. A., Ogura, A. P., Mena, F., Montagner, C. C., Espíndola, E. L. G., Blasco, J., Parra, G., & Araújo, C. V. M. (2024). Ecological consequences when organisms avoid a contaminated environment: A study evaluating the toxicity of fipronil. *Science of the Total Environment*, 926, 171480. https://doi.org/10.1016/j.scitotenv.2024.171480

Ogura, A. P., Dias, M. A., Marestoni, I. F., Bernegossi, A. C., Felipe, M. C., Montagner, C. C., & Espíndola, E. L. G. (2024). Chemical and ecotoxicological assessment of the uptake of pesticides 2,4-D and fipronil by free-floating aquatic macrophytes. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-024-06287-z.

Ojiro, R., Ozawa, S., Zou, X., Tang, Q., Woo, G.-H., & Shibutani, M. (2024). Similar toxicity potential of glyphosate and glyphosate-based herbicide on cerebellar development after maternal exposure in rats. *Environmental Toxicology*, 39(5), 3040-3054. https://doi.org/10.1002/tox.24163

Palberg, D., Kaszecki, E., Dhanjal, C., Kisiała, A., Morrison, E. N., Stock, N., & Emery, R. J. N. (2024). Impact of glyphosate and glyphosate-based herbicides on phyllospheric Methylobacterium. *BMC Plant Biology*, 24(119). https://doi.org/10.1186/s12870-024-04818-x

Pompermaier, A., Alves, C., Chagas, F. B., Tamagno, W. A., Bridi, C., Ferreira, G. F., Hartmann, P. A., & Hartmann, M. (2024). Effects of glyphosate-based herbicide exposure in early developmental stages of *Physalaemus gracilis*. *Scientific Reports*, 14, 25652. https://doi.org/10.1038/s41598-024-76338-5

Rouhi-Kelarlou, T., Golchin, A., & Soltani Toularoud, A. A. (2024). Ecotoxicological impact of butisanstar and clopyralid herbicides on soil microbial respiration and enzymatic activities. *Chemosphere*, 357, 142029. https://doi.org/10.1016/j.chemosphere.2024.142029

Samet, J. M., & P. A. Wages. (2018). Oxidative Stress from Environmental Exposures. *Current Opinion in Toxicology*, 7: 60-66.

Shahid, M., Singh, U. B., Farah, M. A., & Al-Anazi, K. M. (2024). Phyto-toxicological effect of fipronil to plant seedlings: Assessing germination attributes, root-tip morphology, oxidative stress, and cellular respiration indices. *Pesticide Biochemistry and Physiology*, 205, 106135. https://doi.org/10.1016/j.pestbp.2024.106135.

Spulber, S., Reis, L., Alexe, P., & Ceccatelli, S. (2024). Decreased activity in zebrafish larvae exposed to glyphosate-based herbicides during development – potential mediation by glucocorticoid receptor. *Frontiers in Toxicology*, 6, 1397477. https://doi.org/10.3389/ftox.2024.1397477

Stevens, D., Kramer, A. T., Coogan, M. A., & Sayes, C. M. (2024). Developmental effects of zebrafish (Danio rerio) embryos after exposure to glyphosate and lead mixtures. *Ecotoxicology and Environmental Safety*, 271, 115886. https://doi.org/10.1016/j.ecoenv.2023.115886

Thammatorn, W., Cholewińska, P., Kruangkum, T., & Palić, D. (2024). Aged polyethylene microplastics and glyphosate-based herbicide co-exposure toxicity in Pacific white shrimp (*Litopenaeus vannamei*). *Frontiers in Marine Science*, 11, 1384487. https://doi.org/10.3389/fmars.2024.1384487

Tóth, G., Háhn, J., Szabó, G., Bakos, K., Volner, C., Liang, X., Göbölös, B., Bock, I., Szoboszlay, S., Urbányi, B., Kriszt, B., Kaszab, E., Szabó, I., & Csenki, Z. (2024). In vivo estrogenicity of glyphosate, its formulations, and AMPA on transgenic zebrafish (*Danio rerio*) embryos. *Environmental Pollution*, 342, 123113. https://doi.org/10.1016/j.envpol.2023.123113

Yu, N., Li, J., Chen, Y., Wang, Y., Guo, Z., & Liu, Z. (2024). Glyphosate-based herbicides reduced overwintering population and reproduction of agrobiont spiders. *Journal of Hazardous Materials*, 479, 135782. https://doi.org/10.1016/j.jhazmat.2024.135782

Zhang, Q., Lei, C., Jin, M., Qin, G., Yu, Y., Qiu, D., Wang, Y., Zhang, Z., Zhang, Z., Lu, T., Peijnenburg, W. J. G. M., Gillings, M., Yao, Z., & Qian, H. (2024). Glyphosate disorders soil enchytraeid gut microbiota and increases its antibiotic resistance risk. *Journal of Agricultural and Food Chemistry*, 72(4), 2089-2099. https://doi.org/10.1021/acs.jafc.3c05436

Attachment 1

2024 Annotated Bibliography

Midpeninsula Regional Open Space District
Integrated Pest Management Program

2024
Annotated Bibliography

August 2025

Prepared by:

BOWMAN
1615 5th Street, Suite A
Davis, CA 95616
Contact: Alyssa Nagai or Michael Blankinship
530.757.0941

Prepared for:

Midpeninsula Regional Open Space District
5050 El Camino Real
Los Altos, CA 94022
Contact: Hannah Wallis or Coty Sifuentes-Winter

MIDPENINSULA REGIONAL OPEN SPACE

TABLE OF CONTENTS

1. FUNGICIDES

1.1. Potassium Phosphite Salts

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

2. HERBICIDES

2.1. Aminopyralid

Jones, L. C., Beckley, C., Ransom, C. V., & Prather, T. S. (2024). Fall or spring aminopyralid applications control *Taeniatherum caput-medusae*. *Invasive Plant Science and Management*, 17, 46-54. https://doi.org/10.1017/inp.2024.6

This study examines the effectiveness of aminopyralid herbicide applications in managing medusahead (*Taeniatherum caput-medusae*), an invasive winter annual grass. Researchers conducted field trials in Idaho and Utah, testing sequential fall (pre-emergence) and spring (post-emergence) applications at low (0.09 lb ae/ac) and high (0.18 lb ae/ac) rates. The results indicated that aminopyralid can effectively control medusahead either directly with a fall pre-emergent application or indirectly via reduced seed viability with a spring post-emergent application. Post-emergent applications reduced seed viability by up to 91%, depleting the short-lived seedbank. The study also found that successful control correlated with increased perennial grass cover.

2.2. Clethodim

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

2.3. Clopyralid

Baccin, L., & Moretti, M. L. (2024). Clopyralid applied with sponge wiper for Cirsium arvense control in hops in the western United States. *Crop Protection*, 177, 106518. https://doi.org/10.1016/j.cropro.2023.106518

Baccin and Moretti (2024) evaluated the effectiveness of clopyralid applied via sponge wiper for controlling Canada thistle (*Cirsium arvense*) in Oregon hop production systems. The sponge wiper method significantly reduced herbicide use (by 84%) and cost (by 37%) compared to spraying, without reducing effectiveness. Two applications of clopyralid provided the greatest control, achieving an 88% reduction in biomass, whereas a single application reduced biomass by 68%. Compared to glyphosate, clopyralid provided greater control and did not injure surrounding hops.

Rouhi-Kelarlou, T., Golchin, A., & Soltani Toularoud, A. A. (2024). Ecotoxicological impact of butisanstar and clopyralid herbicides on soil microbial respiration and enzymatic activities. *Chemosphere*, 357, 142029.
https://doi.org/10.1016/j.chemosphere.2024.142029

This study investigates the impact of butisanstar and clopyralid herbicides on soil microbial respiration and enzymatic activities (dose levels 0.8, 1.6, 3.2, and 8 mg ai/10 kg soil). 90-day exposure to either herbicide inhibited microbial respiration and enzymes such as dehydrogenase and catalase while enhancing urease and phosphatase activity, particularly at higher doses. The prolonged persistence of inhibitory effects over the long term suggests that a substantial period is essential for soil microorganisms to adapt to the diverse range of herbicides within the soil matrix.

2.4. Glyphosate

Abe, F. R., Dorta, D. J., Gravato, C., & de Oliveira, D. P. (2024). Elucidating the effects of pure glyphosate and a commercial formulation on early life stages of zebrafish using a complete biomarker approach: All-or-nothing! *Science of the Total Environment, 916*, 170012. https://doi.org/10.1016/j.scitotenv.2024.170012

This study evaluates the effects of glyphosate (0.001 to 100 mg/L) and the glyphosate-based herbicide Roundup Original (0.001 to 10 mg/L) on zebrafish embryos and larvae exposed 3 to 4 hours post-fertilization for up to 144 hours post-fertilization. While both test materials induced oxidative stress and affected motor performance at all exposure levels, Roundup Original showed significantly greater toxicity, including mortality, developmental effects, neurotoxicity, and genotoxicity.

Almirón, A., Lorenz, V., Doná, F., Varayoud, J., & Milesi, M. M. (2024). Epigenetic alteration of uterine leukemia inhibitory factor gene after glyphosate or a glyphosate-based herbicide exposure in rats. *Environmental Toxicology and Pharmacology*, 111, 104564.
https://doi.org/10.1016/j.etap.2024.104564

This study evaluates the potential epigenetic effects of glyphosate (3.8 mg/kg) and the glyphosate-based herbicide MAGNUM SUPER II on reproductive health in pregnant rats exposed via diet from gestation day 9 through lactational day 21. Decreased expression of the leukemia inhibitory factor gene was observed in both treatment groups, which could adversely affect embryo implantation.

Almirón, A., Lorenz, V., Varayoud, J., Durando, M., & Milesi, M. M. (2024). Perinatal exposure to glyphosate or a commercial formulation alters uterine mechanistic pathways associated with implantation failure in rats. *Toxics*, 12(8), 590.
https://doi.org/10.3390/toxics12080590

This study evaluates the effects of glyphosate (3.8 mg/kg) and the glyphosate-based herbicide MAGNUM SUPER II on reproductive health in pregnant rats exposed via diet from gestation day 9 through lactational day 21. Effects on uterine function and reduced expression of implantation-related genes were observed in both treatment groups.

Anarghou, H., Malqui, H., Ihbour, S., Laaroussi, M., Essaidi, O., Fetoui, H., Bouhrim, M., Najimi, M., & Chigr, F. (2024). Impact of glyphosate-based herbicide exposure through maternal milk on offspring's antioxidant status, neurodevelopment, and behavior. *Naunyn-Schmiedeberg's Archives of Pharmacology*, 397, 6591-6609. https://doi.org/10.1007/s00210-024-03035-5

This study assesses the neurodevelopmental and behavioral effects of Roundup exposure in offspring when pregnant/lactating mice consume treated drinking water (25 mg/L or 50 mg/L) from gestation day 0 until postnatal day 21. Observed effects included oxidative stress, changes in parent and pup social behavior, and delayed pup development.

Andersson, F., Barthelemy, S., & Cederlund, H. (2024). An investigation of spray drift deposition of glyphosate from an herbicide spraying train and its potential impact on non-target vegetation and railway ditches. *Science of the Total Environment*, 956, 177208. https://doi.org/10.1016/j.scitotenv.2024.177208

This study evaluates the extent of glyphosate (Roundup Ultra) spray drift from herbicide-spraying trains and its effects on non-target vegetation and railway ditches. Spray deposition decreased rapidly with distance, falling from 1800 g a.e./ha (1.6 lb/ac) to approximately 5 g/ha (4.5 mg/ac) within 1 meter (3.3 feet) of the application area. Vegetation within 0.35 to 1.4 meters (1.1 to 4.6 feet) of the sprayed track showed measurable impact, though effects were minimal beyond 1.5 meters (4.9 feet). Despite concerns over drift, glyphosate concentrations in railway ditches remained below environmental quality standards.

Aslam, S., Arslan, M., & Nowak, K. M. (2024). Microbial activity, community composition, and degraders in glyphosate-spiked soil are driven by glycine formation. *Science of the Total Environment*, 907, 168206. https://doi.org/10.1016/j.scitotenv.2023.168206

This study investigates how glyphosate and its degradation products – aminomethylphosphonic acid (AMPA), glycine, and sarcosine (all dosed at 50 mg/kg soil for 75 days) – affect soil microbial activity and composition. Findings suggest that glyphosate degradation primarily leads to glycine formation, which in turn enhances soil microbial activity and alters microbial community dynamics rather than glyphosate itself. Gram-negative bacteria were identified as primary degraders, while Gram-positive bacteria, actinobacteria, and fungi played secondary roles in utilizing degradation byproducts. Of the compounds studied, AMPA was the most persistent throughout the experiment.

Bao, Y., He, X., Zhai, Y., Shen, W., Jing, M., Liu, Y., Yang, H., & Chen, L. (2024). Effects of glyphosate-based herbicide on gut microbes and hepatopancreatic metabolism in Pomacea canaliculata. *Ecotoxicology and Environmental Safety*, 280, 116549. https://doi.org/10.1016/j.ecoenv.2024.116549

This study examines the effects of 96-hour Roundup (6 mg/L or 18 mg/L) exposure on the freshwater golden apple snail (*Pomacea canaliculata*) gut microbiota and hepatopancreatic metabolism. Results showed reduced gut microbiome diversity and impacts to metabolic pathways (e.g., lipid, amino acid, and glucose metabolism), particularly at the high dose, which could weaken the snail's immune and adaptive capacities.

Battisti, L., Potrich, M., Abati, R., Sampaio, A. R., Libardoni, G., Costa-Maia, F. M., Berte, E. A., Martinez, C. B. R., & Sofia, S. H. (2024). Toxicity of glyphosate herbicides formulated for Africanized *Apis mellifera Linnaeus*, 1758 (Hymenoptera: Apidae). *Ecotoxicology and Environmental Safety*, 287, 117247. https://doi.org/10.1016/j.ecoenv.2024.117247

This study evaluates the lethal and sublethal effects of the glyphosate-based herbicide Roundup Transorb R on honeybees under laboratory conditions. Using acute (48 hours) and chronic (144 hours) exposure bioassays, the researchers found that chronic oral exposure to Roundup Transorb R significantly increased honeybee mortality and damaged the midgut epithelium following exposure to 75% or 100% of the manufacturer's recommended dose. Acute oral exposure reduced walking ability, though no effects were observed on mortality, vertical displacement, flight resumption, or following acute or chronic contact exposure.

Bellot, M., Carrillo, M. P., Bedrossiantz, J., Zheng, J., Mandal, R., Wishart, D. S., Gómez-Canela, C., Vila-Costa, M., Prats, E., Piña, B., & Raldúa, D. (2024). From dysbiosis to neuropathologies: Toxic effects of glyphosate in zebrafish. *Ecotoxicology and Environmental Safety*, 270, 115888. https://doi.org/10.1016/j.ecoenv.2023.115888

This study explores the neurotoxic effects of glyphosate (0.3 µg/L or 3 µg/L) on zebrafish, focusing on gut microbiome alterations and their connection to brain function. Researchers found that 14-day glyphosate exposure led to gut dysbiosis, increased serotonin and dopamine levels, and heightened anxiety-like behavior in zebrafish.

Bortolon Ribas, E., Dal-Pont, G. C., Centa, A., Bueno, M. O., Cervini, R., Silva Ogoshi, R. C., & Locatelli, C. (2024). Effects of low concentration of glyphosate-based herbicide on genotoxic, oxidative, inflammatory, and behavioral markers in *Danio rerio* (Teleostei and Cyprinidae). *Biochemistry Research International*, 2024, 1542152. https://doi.org/10.1155/2024/1542152

This study evaluates the effects of low concentrations of the glyphosate-based herbicide Shadow (50, 250, and 500 µg/L) on zebrafish over a 96-hour exposure period. Results showed a reduction in antioxidant enzyme activity in the liver and brain, along with an increase in micronuclei formation in the blood at the highest glyphosate concentration. The inflammatory marker IL-1β was inhibited, suggesting the potential for immunosuppressive effects. Behavioral tests did not reveal significant differences between exposed and control groups. Based on these results, there is potential for zebrafish exposure to Shadow to induce oxidative and genotoxic stress, particularly in liver tissue.

Chávez-Reyes, J., Gutiérrez-Reyes, C. D., Hernández-Cuellar, E., & Marichal-Cancino, B. A. (2024). Neurotoxicity of glyphosate: Focus on molecular mechanisms probably associated

with alterations in cognition and behavior. ***Environmental Toxicology and Pharmacology*****, 106, 104381. https://doi.org/10.1016/j.etap.2024.104381**

This theoretical and non-systematic review explores the neurotoxic effects of glyphosate and glyphosate-based herbicides, integrating both preclinical (rodent models) and clinical studies. Preclinical studies report anxiety, memory deficits, and behavioral changes in rodents, often at doses higher than typical environmental exposures. Clinical evidence is sparse, with some reports of depression, Parkinsonism, and cognitive impairment, but no definitive causal links established.

Chianese, T., Trinchese, G., Leandri, R., De Falco, M., Mollica, M. P., Scudiero, R., & Rosati, L. (2024). Glyphosate exposure induces cytotoxicity, mitochondrial dysfunction, and activation of ERα and ERβ estrogen receptors in human prostate PNT1A cells. ***International Journal of Molecular Sciences*****, 25(13), 7039. https://doi.org/10.3390/ijms25137039**

This study investigates the endocrine-disrupting effects of glyphosate on human prostate cells at low (3.5×10^{-4} M) and high (3.5×10^{-3} M) doses following 24-hour exposure. Researchers observed that glyphosate exposure induces cytotoxicity, mitochondrial dysfunction, and nuclear translocation of estrogen receptors ERα and ERβ, even at low doses. Western blot and immunofluorescence analyses revealed that glyphosate disrupts hormonal signaling pathways and triggers apoptosis, potentially interfering with prostate cell function.

Cresto, N., Courret, M., Génin, A., Martin, C. M. P., Bourret, J., Sakkaki, S., de Bock, F., Janvier, A., Polizzi, A., Payrastre, L., Ellero-Simatos, S., Audinat, E., Perroy, J., & Marchi, N. (2024). Continuous low-level dietary exposure to glyphosate elicits dose and sex-dependent synaptic and microglial adaptations in the rodent brain. ***Environmental Pollution*****, 345, 123477. https://doi.org/10.1016/j.envpol.2024.123477**

This study investigates the neurophysiological effects of continuous dietary exposure to glyphosate at acceptable daily intake (ADI) and no observed adverse effect level (NOAEL) concentrations (0.5 mg/kg/day and 50 mg/kg/day, respectively) in mice. Male mice in the high dose exposure group showed the most pronounced effects, which included reduced neurotransmitter release probability, novel object recognition, and synaptic plasticity, as well as increased microglial reactivity and synaptic density.

Cunha Ignácio, A., dos Reis Guerra, A. M., de Souza-Silva, T. G., do Carmo, M. A. V., & de Almeida Paula, H. A. (2024). Effects of glyphosate exposure on intestinal microbiota, metabolism, and microstructure: A systematic review. ***Food & Function*****, 15, 7757-7781. https://doi.org/10.1039/d4fo00660g**

This systematic review analyzes the impact of glyphosate and its formulations on gut microbiota, intestinal microstructure, and metabolism in animal models (primarily laboratory rodents, bees, cows, and various aquatic species). Findings suggest that glyphosate exposure induces intestinal dysbiosis, which leads to an increase or decrease in specific bacterial groups, as well as causing structural and morpho-functional changes in the gut epithelium in some animal models. At the metabolic level, glyphosate-based herbicides adversely affected lipid and energy metabolism, the circulatory system, cofactor and vitamin metabolism, and replication, repair, and translation processes. The authors indicate that these alterations could lead to intestinal and systemic diseases such as Crohn's disease and Alzheimer's disease, though human relevance remains uncertain.

da Silva Durante, L., Hollmann, G., & Nazari, E. M. (2024). Impact of exposure to glyphosate-based herbicide on morphological and physiological parameters in embryonic and larval development of zebrafish. *Environmental Toxicology*, 39(3), 1822-1835. https://doi.org/10.1002/tox.24024

This study evaluates the effects of exposure to Roundup WG (0.065 mg/L and 6.5 mg/L) on zebrafish embryos (3 to 6 hours post-fertilization) and larvae (3 to 6 days post-fertilization) following 72-hour exposure. Results showed increased mortality, reduced spontaneous movement in embryos, altered heartbeats, and morphological defects such as pericardial edema and caudal curvature at the lower concentration. Decreased cell proliferation and increased apoptosis in exposed embryos and larvae was also observed.

Dinep-Schneider, O., Appiah, E., Dapper, A., Patterson, S., Vermulst, M., & Gout, J.-F. (2024). Effects of the glyphosate-based herbicide Roundup on C. elegans and S. cerevisiae mortality, reproduction, and transcription fidelity. *Environmental Pollution*, 356, 124203. https://doi.org/10.1016/j.envpol.2024.124203

This study examines the effects of Roundup Weed and Grass Killer Concentrate Plus (0.1%, 1%, and 5% solution) on the model organisms *Caenorhabditis elegans* (a nematode) and *Saccharomyces cerevisiae* (yeast). Roundup exposure increased mortality and reduced reproduction in both species, even though *C. elegans* lacks the shikimate pathway targeted by glyphosate. Additionally, Roundup exposure significantly elevated transcription errors in yeast, particularly C-to-U and G-to-A substitutions, suggesting oxidative stress as a potential mechanism of toxicity.

Drechsel, V., Krais, S., Peschke, K., Ziegler, M., Köhler, H.-R., & Triebskorn, R. (2024). Glyphosate- and aminomethylphosphonic acid (AMPA)-induced mortality and residues in juvenile brown trout (*Salmo trutta f. fario*) exposed at different temperatures. *Environmental Sciences Europe*, 36(30). https://doi.org/10.1186/s12302-024-00857-1

This study investigates the bioconcentration and toxicity of glyphosate and its major metabolite, AMPA, in juvenile brown trout (*Salmo trutta f. fario*) at different temperatures. Researchers exposed fish to varying concentrations of glyphosate (56, 560, or 5,600 µg/L), Roundup LB Plus (equivalent to 5,600 µg/L glyphosate), and AMPA (3,666 µg/L) over two to four weeks at 7°C and 15°C. Mortality rates and estimated bioconcentration factors were higher at 15°C than at 7°C, as well as for Roundup LB Plus compared to glyphosate and AMPA. 10-month-old fish also showed lower mortality than 6-month-old fish.

Evalen, P. S., Barnhardt, E. N., Ryu, J., & Stahlschmidt, Z. R. (2024). Toxicity of glyphosate to animals: A meta-analytical approach. *Environmental Pollution*, 347, 123669. https://doi.org/10.1016/j.envpol.2024.123669

This meta-analysis systematically evaluates the effects of glyphosate and glyphosate-based herbicides on animal health using data from 121 studies comprising 1,282 observations. Findings indicate that glyphosate is generally sub-lethally toxic to animals, with aquatic organisms exhibiting greater sensitivity than terrestrial ones. Notably, toxicity did not follow a dose-dependent pattern, suggesting potential non-linear effects. The study also identifies widespread publication bias, suggesting that studies showing negative effects might be overrepresented while non-significant results could be underreported.

Fernandes Farder-Gomes, C., Grella, T. C., Malaspina, O., & Nocelli, R. F. C. (2024). Exposure to sublethal concentrations of imidacloprid, pyraclostrobin, and glyphosate harm the behavior and fat body cells of the stingless bee *Scaptotrigona postica. *Science of the Total Environment*, 907, 168072. https://doi.org/10.1016/j.scitotenv.2023.168072**

This study examines the sublethal effects of the insecticide imidacloprid (0.3 mg/L), the fungicide pyraclostrobin (1.5 mg/L), and glyphosate (7 mg/L in sucrose solution) on the stingless bee (*Scaptotrigona postica)* following 48-hour oral exposure. All tested chemicals caused reduced walking distance and velocity. Sublethal doses of glyphosate were associated with morphological and physiological alterations in the fat body cells, including increased apoptosis, suggesting potential effects on detoxification and metabolic processes. No immune suppression was seen following glyphosate exposure.

Fernandes Farder-Gomes, C., de Oliveira, M. A., Malaspina, O., & Cornélio Nocelli, R. F. (2024). Exposure of the stingless bee *Melipona scutellaris* to imidacloprid, pyraclostrobin, and glyphosate, alone and in combination, impairs its walking activity and fat body morphology and physiology. *Environmental Pollution*, 348, 123783. https://doi.org/10.1016/j.envpol.2024.123783

This study investigates the sublethal effects of the insecticide imidacloprid (0.081 mg/L), the fungicide pyraclostrobin (1.5 mg/L), and glyphosate (7 mg/L), both individually and in combination, on the stingless bee (*Melipona scutellaris)* following 48-hour oral exposure. Pesticide exposure, alone and in combination, reduced walking activity, altered fat body cell structure, and induced oxidative stress, apoptosis, and immune suppression.

Flach, H., Pfeffer, S., Dietmann, P., Kühl, M., & Kühl, S. J. (2024). Glyphosate formulations cause mortality and diverse sublethal defects during embryonic development of the amphibian *Xenopus laevis*. *Chemosphere*, 367, 143624. https://doi.org/10.1016/j.chemosphere.2024.143624

This study investigates the effects of four different glyphosate formulations (Glyphosat TF, Durano TF, Helosate 450 TF, and Kyleo) on South African clawed frog (*Xenopus laevis)* embryos exposed from the 2-cell stage to NF-stage 44/45 (tadpole stage) (approximately 14-day exposure duration). Adverse effects varied by formulation, with sublethal exposure leading to reduced eye and head size, impaired heart morphology, and altered cardiac gene expression. Kyleo (27.9% glyphosate and 32% 2,4-D) caused both the highest mortality rates (96% mortality at the 10 mg/L dose level) and embryo defects at the lowest concentration (0.01 mg/L) compared to the other products tested. Glyphosate alone did not cause mortality at the highest dose tested (100 mg/L). The researchers concluded that co-formulants, not glyphosate alone, are likely responsible for the observed mortality and morphological defects.

Hembach, N., Drechsel, V., Sobol, M., Kaster, A.-K., Köhler, H.-R., Triebskorn, R., & Schwartz, T. (2024). Effect of glyphosate, its metabolite AMPA, and the glyphosate formulation Roundup® on brown trout (*Salmo trutta f. fario*) gut microbiome diversity. *Frontiers in Microbiology*, 14, 1271983. https://doi.org/10.3389/fmicb.2023.1271983

This study investigates the effects of glyphosate (56, 560, or 5,600 µg/L), its primary metabolite AMPA (3,666 µg/L), and Roundup LB Plus (560 or 5,600 µg glyphosate/L) on the gut microbiome of juvenile brown trout following a 3-week exposure. Reduced microbial diversity was observed following all treatments, with the strongest impacts seen in younger fish with more diverse microbiomes. Pathogen colonization was also increased in younger fish. No consistent impact on shikimate pathway gene expression by glyphosate was seen, suggesting that glyphosate exposure may indirectly affect fish health by altering microbial balance.

Houssou, A. M., Lokonon, T. F., Koussovi, G., Adjahouinou, D. C., Cocan, D., & Montchowui, E. (2024). Biological effects of glyphosate and emamectin benzoate-based pesticides on the freshwater prawn (*Macrobrachium macrobrachion*) juveniles. *Water, Air, & Soil Pollution*, 235, 803. https://doi.org/10.1007/s11270-024-07602-7

This study evaluates the acute and chronic toxicity of the glyphosate-based herbicide SUNPHOSATE-G and the emamectin benzoate-based insecticide EMACOT on juvenile freshwater prawn (*Macrobrachium macrobrachion)*. Emamectin benzoate had severe impacts on molting success, weight gain, and overall survival, while glyphosate exhibited relatively lower toxicity at environmental concentrations. However, high glyphosate doses (27.98 mg/L) still affected growth parameters.

Hsiao, Y.-C., Johnson, G., Yang, Y., Liu, C.-W., Feng, J., Zhao, H., Moy, S. S., Harper, K. M., & Lu, K. (2024). Evaluation of neurological behavior alterations and metabolic changes in mice under chronic glyphosate exposure. *Archives of Toxicology*, 98, 277-288. https://doi.org/10.1007/s00204-023-03622-0

This study investigates the neurological and metabolic effects of chronic glyphosate exposure in mice, focusing on potential disruptions to the gut-brain axis. Mice were exposed to glyphosate through drinking water at two concentrations (1.75 mg/kg and 175 mg/kg/day) over six months. Behavioral tests showed minimal alterations, while metabolomic analysis showed localized disruption to the gut metabolome in a dose-dependent manner. However, serum metabolites remained largely unchanged, suggesting that glyphosate-induced gut microbiota disruption does not significantly impact systemic neurotoxicity. The study concludes that even high doses of glyphosate do not strongly impair neurobehavioral function.

Huang, Y., Huang, Q., Zhou, K., Luo, X., Long, W., Yin, Z., Huang, Z., & Hong, Y. (2024). Effects of glyphosate on neurotoxicity, oxidative stress, and immune suppression in red swamp crayfish, *Procambarus clarkii*. *Aquatic Toxicology*, 275, 107050. https://doi.org/10.1016/j.aquatox.2024.107050

This study investigates the sublethal effects of 96-hour Roundup exposure (5 mg/L, 10 mg/L, or 20 mg/L) in red swamp crayfish (*Procambarus clarkii)*. The authors found that Roundup exposure resulted in dose-dependent neurotoxicity, oxidative stress, and immune suppression in *P. clarkii*, with the highest dose (20 mg/L) causing the most significant effects.

Klátyik, S., Simon, G., Oláh, M., Takács, E., Mesnage, R., Antoniou, M. N., Zaller, J. G., & Székács, A. (2024). Aquatic ecotoxicity of glyphosate, its formulations, and co-formulants: Evidence from 2010 to 2023. *Environmental Sciences Europe, 36*(22). https://doi.org/10.1186/s12302-024-00849-1

This review summarizes the ecotoxicological effects of glyphosate and glyphosate-based herbicides on aquatic ecosystems identified in studies published between 2010 and 2023. The authors found that glyphosate alone shows limited toxicity to many aquatic species while glyphosate-based herbicides and co-formulants (e.g., surfactants such as polyethoxylated tallow amine (POEA)) are often significantly more toxic that glyphosate itself. While many studies report acute and sublethal effects on algae, crustaceans, fish, and amphibians, more research is needed on bioaccumulation and chronic exposure effects. The primary mechanism for adverse effects in aquatic plants and animal organisms appears to be oxidative stress.

Klátyik, S., Takács, E., Barócsi, A., Lenk, S., Kocsányi, L., Darvas, B., & Székács, A. (2024). Hormesis, the individual and combined phytotoxicity of the components of glyphosate-based formulations on algal growth and photosynthetic activity. *Toxics, 12*(4), 257. https://doi.org/10.3390/toxics12040257

This study assesses the effects of 72-hour exposure to glyphosate, the glyphosate-based herbicides Roundup Classic and Medallon Premium, and the co-formulants polyethoxylated tallow amines (POEA) and alkyl polyglucosides (APG), on algal growth and photosynthetic activity. While the sensitivity of green algae and cyanobacteria species differed widely, formulated herbicides (especially Roundup Classic with POEA) were significantly more toxic than their isolated components, with co-formulants contributing significantly to toxicity. Both Roundup Classic and POEA, but not glyphosate alone, were associated with impacts to photosynthetic activity even at low concentrations. POEA in particular showed much greater toxicity compared to glyphosate alone.

Langarica-Fuentes, A., Straub, D., Wimmer, B., Thompson, K., Nahnsen, S., Huhn, C., Kleindienst, S. (2024). Subtle microbial community changes despite rapid glyphosate degradation in microcosms with four German agricultural soils. *Applied Soil Ecology*, 198, 105381. https://doi.org/10.1016/j.apsoil.2024.105381

This study investigates the degradation of glyphosate and its effects on soil microbial communities in four agricultural soils from Germany (Braunerde silty clay, Parabraunerde silt loam, Parabraunerde silt clay, and Braun Redzina silty clay loam). Using microcosm experiments, the authors applied glyphosate at 15 mg/kg and monitored degradation over 56 days. Results showed that glyphosate degraded rapidly (60-85% by day 7 and >99% degraded in most soils by day 56), but AMPA persisted longer (up to 20.7% at Day 56). Despite rapid degradation, microbial community composition and abundance remained largely unchanged. The authors acknowledged that the sorption/desorption dynamics of glyphosate with the soil matrix can heavily influence its bioavailability.

Ma, C., Gu, G., Chen, S., Shi, X., Li, Z., Li-Byarlay, H., & Bai, L. (2024). Impact of chronic exposure to field level glyphosate on the food consumption, survival, gene expression, gut microbiota, and metabolomic profiles of honeybees. *Environmental Research*, 250, 118509. https://doi.org/10.1016/j.envres.2024.118509

This paper studies the effects of chronic oral exposure to glyphosate (5 mg/kg) on honeybee (*Apis mellifera*) health over a 10-day period. The authors saw a ~15% reduction in sugar consumption and survival probability in glyphosate-exposed bees. Additionally, gene expression related to immunity, metabolism, and longevity was altered, though no significant changes were observed in gut microbiota diversity.

Marins, K., Bianco, C. D., da Silva, A. H., & Zamoner, A. (2024). Maternal exposure to glyphosate increased the risk of adverse neurodevelopmental outcomes in rodent offspring: A systematic review. *Environmental Pollution*, 363, 125086. https://doi.org/10.1016/j.envpol.2024.125086

This systematic review evaluates whether maternal exposure to glyphosate or glyphosate-based herbicides during pregnancy and lactation adversely affects neurodevelopment in rodent offspring. The authors concluded that prenatal glyphosate exposure disrupts neurotransmitter systems, oxidative stress responses, and brain architecture in rodents. Twenty-seven studies were assessed as part of this review.

Mathias, F., Estienne, A., Ramée, C., Lefort, G., Piégu, B., Chahnamian, M., Froment, P., & Dupont, J. (2024). Chronic dietary exposure to a glyphosate-based herbicide alters ovarian functions in young female broilers. *Poultry Science*, 103, 103767. https://doi.org/10.1016/j.psj.2024.103767

This study examines the effects of chronic dietary exposure to the glyphosate-based herbicide Gallup Super 360 on metabolism and ovarian function in young female broilers. Over a 25-day period, broilers were fed diets containing doses corresponding to one-eighth and one-third of the no observed adverse effect level (NOAEL) defined by the European Food Safety Authority (EFSA) (13 mg/kg/day and 34 mg/kg/day, respectively). Results indicated dose-dependent reductions in food intake, body weight, and fattening, alongside increased oxidative stress and ovarian weight. Decreased steroid secretion and dose-dependent reduction in sex hormone production was also seen. Interestingly, the authors found that the more Gallup Super 360 the food contained, the less the broilers consumed. Potential rationale for the reduced food intake includes that Gallup Super 360 gave the food an unpleasant taste or produced a feeling of satiety.

Mazuryk, J., Klepacka, K., Kutner, W., & Sharma, P. S. (2024). Glyphosate: Hepatotoxicity, nephrotoxicity, hemotoxicity, carcinogenicity, and clinical cases of endocrine, reproductive, cardiovascular, and pulmonary system intoxication. *ACS Pharmacology & Translational Science*, 7(5), 1205-1236. https://doi.org/10.1021/acsptsci.4c00046

This review synthesizes data from preclinical animal studies, in vitro experiments, and clinical case reports that have reported toxicological impacts of glyphosate and glyphosate-based herbicides on various organ systems including the liver, kidneys, blood, endocrine system, reproductive organs, cardiovascular system, and lungs. The authors conclude that the studies demonstrate harmful impacts of glyphosate and its co-formulants on the gut microbiome, gastrointestinal tract, liver, kidney, and endocrine, as well as reproductive, and cardiopulmonary systems, whereas carcinogenicity of these herbicides remains controversial.

Mazuryk, J., Klepacka, K., Kutner, W., & Sharma, P. S. (2024). Glyphosate: Impact on the microbiota-gut-brain axis and the immune-nervous system, and clinical cases of multiorgan toxicity. *Ecotoxicology and Environmental Safety*, 271, 115965. https://doi.org/10.1016/j.ecoenv.2024.115965.

This article reviews how glyphosate may affect the microbiota-gut-brain axis and its links to gut dysbiosis, neurodevelopmental disorders, immune suppression, and neurotoxicity based on data from animal studies, in vitro experiments, and human case reports on acute poisoning. The authors acknowledge that despite numerous pre-clinical reports demonstrating the harmful impacts of glyphosate, glyphosate surfactants, and glyphosate-based herbicides on animals, relevance to humans remains uncertain. Further, the authors indicate that glyphosate-based herbicides are primarily pathogenic because of the surfactants (e.g., POEA) and heavy metals that display higher toxicity than glyphosate alone.

McQueen, J. P., Gendron, E. M. S., Solon, A. J., Bueno de Mesquita, C. P., Hufft, R. A., Shackelford, N., Suding, K. N., Schmidt, S. K., & Porazinska, D. L. (2024). Glyphosate-based restoration of a degraded grassland threatens soil health and the diversity of nematode communities. *Soil Biology and Biochemistry*, 191, 109350. https://doi.org/10.1016/j.soilbio.2024.109350

This study examines the long-term effects of Roundup ProMax use in grassland restoration on soil health. Potential effects on nematode community diversity and structure were assessed by applying Roundup ProMax at different frequencies (2 applications per year for four years or 5 applications per year for two years followed by 2 applications per year for two years) to experimental plots in Colorado. An application rate of 5 lb/ac via truck hand sprayer was used for the first and fifth applications and 0.65 lb/ac via backpack was used for other applications. Results showed reduced nematode diversity, altered community composition, and decreased ecological stability as well as impacts that extended to other trophic levels, particularly fungivores and root associates, particularly in plots receiving the highest rates herbicide.

Mitton, G. A., Corona, M., Alburaki, M., Iglesias, A. E., Ramos, F., Fuentes, G., Vázquez, M. M., Mitton, F. M., Chan, P., Ruffinengo, S. R., & Maggi, M. D. (2024). Synergistic effects between microplastics and glyphosate on honey bee larvae. *Environmental Toxicology and Pharmacology*, 111, 104550. https://doi.org/10.1016/j.etap.2024.104550

Researchers analyzed honeybee larvae survival, weight, gene expression, oxidative stress markers, and immune system responses after exposure to different concentrations of microplastics and their combination with glyphosate (5 mg/L). While microplastics alone did not cause significant toxicity, the combination of microplastics (500 mg/L and 1,000 mg/L dose groups) with glyphosate led to decreased survival rates and larval weight. Glyphosate alone reduced weight and induced oxidative/immune changes. These results indicate that co-exposure to environmental microplastics and glyphosate can potentiate toxicity during larval development in bees.

Motta, E. V. S., de Jong, T. K., Gage, A., Edwards, J. A., & Moran, N. A. (2024). Glyphosate effects on growth and biofilm formation in bee gut symbionts and diverse associated bacteria. *Applied and Environmental Microbiology*, 90(8). https://doi.org/10.1128/aem.00515-24

Motta et al. (2024) demonstrated that specific strains of the honeybee gut microbiota and other diverse animal- and plant-associated bacterial strains can form biofilms *in vitro* and that glyphosate and glyphosate-based herbicide formulations (Roundup PROMAX) have variable impacts on their growth and biofilm formation. In some cases, these impacts correlated with the ability of glyphosate to inhibit EPSPS, while others showed unexpected resistance or even enhancement of biofilm production. Glyphosate exhibited dose-dependent effects while Roundup PROMAX exhibited more variable effects which were often hormetic (biphasic).

Nanthanawat, P., Insuwan, W., Prasatkaew, W., Nanuam, J., Meemon, P., & Thanomsit, C. (2024). Adverse effects of glyphosate-based herbicide on hatching rate, morphological alterations, and acetylcholinesterase (AChE) expression in golden apple snail eggs. *Aquatic Toxicology*, 277, 107162. https://doi.org/10.1016/j.aquatox.2024.107162

In this study, researchers examined the impact of the formulated herbicide Glyphosate (2 to 10 mL/L) on golden apple snail (*Pomacea canaliculata*) eggs, focusing on hatching rates, morphological abnormalities, and acetylcholinesterase (AChE) expression as potential biomarkers for toxicity. Results showed a dose-dependent decrease in hatching rates and significant developmental abnormalities, including shell deformations and disrupted organogenesis. Reduced AChE expression and alteration in protective biochemical compounds was also observed.

Negrini Ferreira, L. M., Hrncir, M., de Almeida, D. V., Bernardes, R. C., & Lima, M. A. P. (2024). Climatic fluctuations alter the preference of stingless bees (Apidae, Meliponini) towards food contaminated with acephate and glyphosate. *Science of the Total Environment*, 952, 175892. https://doi.org/10.1016/j.scitotenv.2024.175892

Negrini Ferreria et al. (2024) evaluated how temperature fluctuations influence the foraging preferences of the stingless bee (*Plebeia lucii*) when exposed to food containing the glyphosate-based herbicide Roundup Original DI (31.3 mg ai/L) alone and in combination with the acephate-based insecticide Cefanol. The authors found that at higher temperatures, bees preferred food containing a mixture of both agrochemicals or uncontaminated food, whereas at lower temperatures, they showed a preference for food laced with a single agrochemical. The study suggests that foragers do not actively avoid contaminated food.

Ojiro, R., Ozawa, S., Zou, X., Tang, Q., Woo, G.-H., & Shibutani, M. (2024). Similar toxicity potential of glyphosate and glyphosate-based herbicide on cerebellar development after

maternal exposure in rats. *Environmental Toxicology*, 39(5), 3040-3054. https://doi.org/10.1002/tox.24163

This study investigates the developmental neurotoxicity of glyphosate and the glyphosate-based herbicide Turnout Liquid Agent on the cerebellar development of rat offspring following maternal dietary (1.5 or 3% in the diet) or drinking water (1%) exposure from gestation day 6 to postnatal day 21. Findings suggested that Turnout Liquid Agent, and glyphosate alone to a lesser extent, disrupts normal cerebellar development. Effects were largely reversible by adulthood. The authors note that these results were based on extremely high doses of glyphosate compared to human exposure levels.

Palberg, D., Kaszecki, E., Dhanjal, C., Kisiała, A., Morrison, E. N., Stock, N., & Emery, R. J. N. (2024). Impact of glyphosate and glyphosate-based herbicides on phyllospheric Methylobacterium. *BMC Plant Biology*, 24(119). https://doi.org/10.1186/s12870-024-04818-x

This study describes the effects of glyphosate and the glyphosate-based herbicides WeatherMax and Transorb on *Methylobacterium*, a genus of plant-associated bacteria known to promote plant growth and stress tolerance. The researchers tested the sensitivity of 18 *Methylobacterium* strains to and found that nearly all strains exhibited sensitivity to the formulated products. Glyphosate alone did not significantly impact bacterial growth unless combined with polysorbate-20 (Tween20), a surfactant that increases membrane permeability. Surfactants like Tween20, even when non-toxic alone, amplified glyphosate toxicity.

Pochron, S. T., Sasoun, S., Maharjan, S., Pirzada, W. U., Byrne, S., Girgis, M., Jacobellis, M. A., Mitra, J. A., Miranda, A. S., Gelder, G. V., & Khan, S. (2024). Toxicity of a common glyphosate metabolite to the freshwater planarian (*Girardia tigrina*). *Sustainability*, 16(842). https://doi.org/10.3390/su16020842

This study explores the ecological impacts of aminomethylphosphonic acid (AMPA), the primary degradation product of glyphosate, on the freshwater planarian (*Girardia tigrina*). The researchers assessed the effects of AMPA exposure on planarian survivorship, regenerative capacity, and locomotion over 7- and 14-day periods at high and low concentrations (3.1 µg/L and 0.02 µg/L, respectively). The findings indicate that while short-term exposure to AMPA does not significantly affect planarian health, prolonged exposure may impair regeneration, particularly in tail segments.

Pompermaier, A., Alves, C., Chagas, F. B., Tamagno, W. A., Bridi, C., Ferreira, G. F., Hartmann, P. A., & Hartmann, M. (2024). Effects of glyphosate-based herbicide exposure in early developmental stages of *Physalaemus gracilis*. *Scientific Reports*, 14, 25652. https://doi.org/10.1038/s41598-024-76338-5

Pompermaier et al. (2024) assessed morphological, physiological, behavioral, and biochemical responses in weeping frog (*Physalaemus gracilis)* tadpoles exposed to various concentrations of Roundup Original Mais (100, 350, and 700 µg a.i./L) over 7 days. The results indicated significant adverse effects, including impaired anti-predatory behavior, morphological anomalies, increased acetylcholinesterase activity, and oxidative stress.

Schleicherová, D., Pastorino, P., Pappalardo, A., Nota, A., Gendusa, C., Mirone, E., Prearo, M., & Santovito, A. (2024). Genotoxicological and physiological effects of glyphosate and its metabolite, aminomethylphosphonic acid, on the freshwater invertebrate *Lymnaea stagnalis*. *Aquatic Toxicology*, 271, 106940. https://doi.org/10.1016/j.aquatox.2024.106940

This study evaluates the genotoxic and physiological effects of glyphosate and its primary metabolite AMPA on *Lymnaea stagnalis*, a freshwater snail. Snails were exposed to increasing concentrations (0.0125 to 0.5 mg/L) of glyphosate, AMPA, and a mixed solution of both in a 1:1 ratio over four weeks. Results indicated that both glyphosate and AMPA induced genotoxic and physiological damage in snails, with AMPA showing comparable or higher toxicity than glyphosate. Combined exposures (glyphosate + AMPA) increased certain genotoxic endpoints but did not demonstrate strong synergistic effects.

Silveira Moraes, J., Ballesteros, M. L., Hued, A. C., Bonifacio, A. F., Azambuja, T. G., Vaz, B. S., & Gaspar Martins, C. M. (2024). Glyphosate and its formulated product Roundup Transorb R® affect locomotor activity and reproductive and developmental parameters in Jenynsia lineata fish: An intergenerational study. *Chemosphere*, 362, 142541. https://doi.org/10.1016/j.chemosphere.2024.142541

In this study, adult neotropical fish (*Jenynsia lineata)* were exposed to environmentally relevant concentrations of glyphosate and the glyphosate-based product Roundup Transorb R (65 µg/L) for 21 days and impacts on reproduction and offspring development were assessed. Results showed that both pure and formulated glyphosate can cause significant reproductive and developmental toxicity in fish, including reduced male sexual behavior, reduced female breeding, increased embryonic death, and morphological abnormalities in offspring. Additionally, parental glyphosate exposure influenced locomotor activity of offspring, with pure glyphosate causing hyperlocomotion and Roundup Transorb R causing hypolocomotion.

Singh, R., Shukla, A., Kaur, G., Girdhar, M., Malik, T., & Mohan, A. (2024). Systemic analysis of glyphosate impact on environment and human health. *ACS Omega*, 9(6), 6165-6183. https://doi.org/10.1021/acsomega.3c08080

This review provides a summary of glyphosate’s environmental and health impacts, highlighting its widespread use in agriculture. The authors discuss glyphosate’s persistence in soil and water systems, its role in the development of herbicide resistance in weeds, and its potential effects on non-target organisms, including humans. The authors also present information on studies linking glyphosate exposure to oxidative stress, endocrine disruption, and neurotoxicity, as well as its controversial classification as a possible carcinogen.

Solomon, J., Gutierrez-Reyes, C. D., Chávez-Reyes, J., Onigbinde, S., Marichal-Cancino, B. A., López-Lariz, C. H., Beck, M., & Mechref, Y. (2024). Neuroglycome alterations of hippocampus and prefrontal cortex of juvenile rats chronically exposed to glyphosate-based herbicide. *Frontiers in Neuroscience*, 18, 1442772. https://doi.org/10.3389/fnins.2024.1442772

This study examines the neurotoxic effects of chronic exposure to the glyphosate-based herbicide Rival (100 mg glyphosate/kg body weight/day) on the glycome profile of the hippocampus and prefrontal cortex in juvenile rats. Female rats exhibited impaired object recognition memory, while male rats showed no significant cognitive deficits. Although glycomic changes were identified, no mechanistic pathway analysis was performed linking glycan alterations to functional or behavioral deficits.

Spulber, S., Reis, L., Alexe, P., & Ceccatelli, S. (2024). Decreased activity in zebrafish larvae exposed to glyphosate-based herbicides during development – potential mediation by glucocorticoid receptor. *Frontiers in Toxicology*, 6, 1397477. https://doi.org/10.3389/ftox.2024.1397477

This study investigates the neurodevelopmental effects in zebrafish (*Danio rerio*) larvae exposed to environmentally relevant concentrations of Roundup Transorb (5 to 10 mg/L). The findings reveal that GBH exposure significantly reduced spontaneous activity and impaired responses to environmental stimuli, while pure glyphosate had minimal effects.

Stevens, D., Kramer, A. T., Coogan, M. A., & Sayes, C. M. (2024). Developmental effects of zebrafish (*Danio rerio*) embryos after exposure to glyphosate and lead mixtures. *Ecotoxicology and Environmental Safety*, 271, 115886. https://doi.org/10.1016/j.ecoenv.2023.115886

This study assesses the combined effects of glyphosate (0.001 to 10 mg/L) and lead acetate (0.5 to 4 mg/L) on the development of zebrafish embryos. The results showed that individual exposures to glyphosate and lead delayed hatching and increased coagulation rates, with stronger effects observed in co-exposure scenarios.

Thammatorn, W., Cholewińska, P., Kruangkum, T., & Palić, D. (2024). Aged polyethylene microplastics and glyphosate-based herbicide co-exposure toxicity in Pacific white shrimp (*Litopenaeus vannamei*). *Frontiers in Marine Science*, 11, 1384487. https://doi.org/10.3389/fmars.2024.1384487

This study investigates the combined toxicity of aged polyethylene microplastics (32 to 500 µm in size, ~408 pieces/g feed) and the glyphosate-based herbicide Roundup Flex 480 (20 or 200 mg glyphosate/kg feed) on Pacific white shrimp (*Litopenaeus vannamei*) following 96-hour exposure. Exposure to the formulated product significantly reduced acetylcholinesterase (AChE) activity and altered oxidative stress markers. While microplastics alone had minor effects, combined exposure appeared to modulate the toxicity of the formulated product by altering AChE concentration and immune gene expression. These finding suggest that microplastics may influence glyphosate bioavailability and toxicity in aquatic organisms.

Tóth, G., Háhn, J., Szabó, G., Bakos, K., Volner, C., Liang, X., Göbölös, B., Bock, I., Szoboszlay, S., Urbányi, B., Kriszt, B., Kaszab, E., Szabó, I., & Csenki, Z. (2024). *In vivo* estrogenicity of glyphosate, its formulations, and AMPA on transgenic zebrafish (*Danio rerio*) embryos. *Environmental Pollution*, 342, 123113. https://doi.org/10.1016/j.envpol.2023.123113

This study evaluates the estrogenic effects of glyphosate, its primary metabolite AMPA, and various glyphosate-based herbicides (Dominator Extra 680 SL, Fozat 480, Roundup Mega, and Total) on zebrafish embryos following 5-day exposure to concentrations ranging from 0.35 to 2.8 mg glyphosate/L. Results showed that exposure to environmentally relevant concentrations of glyphosate, AMPA, and glyphosate-based herbicides can cause morphological deformities and hormonal disruptions. Notably, different products exhibited different toxicity profiles, with Roundup Mega and Dominator Extra 680 SL exposures causing the highest rate of morphological deformities.

Vázquez, D. E., Verellen, F., & Farina, W. M. (2024). Early exposure to glyphosate during larval development induces late behavioral effects on adult honey bees. *Environmental Pollution*, 360, 124674. https://doi.org/10.1016/j.envpol.2024.124674

This study examines the long-term behavioral effects in adult nurse honeybees following 72-hour exposure to glyphosate during larval development. Honeybee larvae reared in vitro were orally exposed to 70 µg glyphosate/L and those reared in-hive were exposed to 700 µg glyphosate/L, with ingestion by larvae documented using an indicator dye. Larval exposure to glyphosate caused late behavioral effects in adult bees, including reduced sensitivity to sucrose, impaired locomotion, and learning deficits. The authors note that it is unknown if these physiological and cognitive effects reverse with age.

Wang, X., Wu, K., Mo, J., & Huang, W. (2024). Developmental toxicity of glyphosate, its formulations, and AMPA in non-target organisms: Insights from zebrafish embryos and larvae. *Journal of Hazardous Materials Advances*, 16, 100516. https://doi.org/10.1016/j.hazadv.2024.100516

This review comprehensively examines the developmental toxicity of glyphosate, glyphosate-based herbicides, and AMPA in non-target organisms based on 33 studies of glyphosate-exposed zebrafish embryos and larvae. The authors summarize reports of glyphosate-induced disruptions in brain development, cardiovascular abnormalities, immune system alterations, impaired energy metabolism, skeletal malformations, and endocrine interference. The authors raise concerns about potential bioaccumulation and chronic exposure risks for ecosystem and human health. Although the exact molecular mechanisms of toxicity remain unclear, oxidative stress, mitochondrial dysfunction, and endoplasmic reticulum stress are suggested as key drivers of toxicity.

Wang, C., Zhang, H., Wang, J., Sprecher, B., & Lin, S. (2024). Glyphosate (Roundup) as phosphorus nutrient enhances carbon and nitrogen accumulation and up-regulates phosphorus metabolisms in the haptophyte *Isochrysis galbana*. *Science of the Total Environment*, 913, 169715. https://doi.org/10.1016/j.scitotenv.2023.169715

This study tested the ability of the haptophyte *Isochrysis galbana* to utilize glyphosate as a phosphorus nutrient source and its subsequent effects on cellular metabolism. Researchers found that *I. galbana* can directly uptake glyphosate and use it as a sole phosphorus source, albeit with lower efficiency than inorganic phosphate. Glyphosate-grown cells exhibited increased carbon and nitrogen accumulation and altered metabolic pathways, including up-regulated phosphorus and nitrate/nitrite transport mechanisms.

Wood, L. J., Botten, N., Fredeen, A. L., & Werner, J. R. (2024). Glyphosate-based herbicide contributes to nutrient variability in forest plants. *Frontiers in Forests and Global Change*, 7, 1463454. https://doi.org/10.3389/ffgc.2024.1463454

Wood et al. (2024) studied the long-term effects of glyphosate-based herbicides (VisionMax and GlySil) on nutrient concentrations in forest plants including willow (*Salix* sp.), red osier dogwood (*Cornus sericea*), and fireweed (*Chamaenerion angustifolium*). Herbicide applications resulted in significant but not necessarily consistent or predictable alterations to nutrient availability in the plant species studied. Fireweed and dogwood seemed to show greater changes in nutrients due to treatment in the shorter term (year 1), whereas willow showed greater changes over the long-term (year 12). Out of the nutrients analyzed, boron, calcium, magnesium, and nickel were individually significant in predicting areas treated with VisionMax or GlySil.

Yan, B., Luo, L., Zhang, Y., Men, J., Guo, Y., Wu, S., Han, J., & Zhou, B. (2024). Detrimental effects of glyphosate on muscle metabolism in grass carp (*Ctenopharyngodon idellus*). *Aquatic Toxicology*, 276, 107122. https://doi.org/10.1016/j.aquatox.2024.107122

This study assesses the effects of 14-day glyphosate exposure (1, 10, or 100 µg/L) on the muscle metabolism of grass carp (*Ctenopharyngodon idellus*) using biochemical and metabolomic analyses. Glyphosate reduced total antioxidant capacity and vitamin E levels while increasing oxidative stress markers. Key pathways affected were amino acid and nucleotide metabolism, particularly at the 100 µL dose.

Yu, N., Li, J., Chen, Y., Wang, Y., Guo, Z., & Liu, Z. (2024). Glyphosate-based herbicides reduced overwintering population and reproduction of agrobiont spiders. *Journal of Hazardous Materials*, 479, 135782. https://doi.org/10.1016/j.jhazmat.2024.135782

This study examines the effects on overwintering survival, reproduction, and oxidative stress responses of the agrobiont wolf spider (*Pardosa pseudoannulata*) following exposure to the glyphosate-based herbicide Nongxingwang in Chinese paddy fields. Compared to the one-time effect of mechanical weeding, Nongxingwang application resulted in impacts to the spider population that persisted throughout the entire overwintering. Survivors showed reduced fecundity and increased oxidative stress. The study also found that weeds treated with Nongxingwang contributed to prolonged herbicide exposure, potentially exacerbating its impact on spiders.

Zhang, Q., Lei, C., Jin, M., Qin, G., Yu, Y., Qiu, D., Wang, Y., Zhang, Z., Zhang, Z., Lu, T., Peijnenburg, W. J. G. M., Gillings, M., Yao, Z., & Qian, H. (2024). Glyphosate disorders soil enchytraeid gut microbiota and increases its antibiotic resistance risk. *Journal of Agricultural and Food Chemistry*, 72(4), 2089-2099. https://doi.org/10.1021/acs.jafc.3c05436

Zhang et al. (2024) evaluates the impact of glyphosate on the soil-dwelling worm *Enchytraeus crypticus* following 14-day exposure to 1 mg glyphosate/kg dry soil. While survival was rarely affected, glyphosate exposure was associated with oxidative stress, shifts in digestive enzyme activity, and less diverse gut microbial composition. It was also associated with a temporary increase in the abundance of antibiotic-resistant genes and mobile genetic elements; however, effects were minimal by the end of the 14-day exposure.

Zhi-Xiang, D., Wan-Li, L., Xi-Jie, L., Jia-Li, L., Jun, Z., Chong-Hui, Z., Qi, H., Zhe, C., Yuan, C., Hong-Mu, Z., Jun, G., & Wen-Li, T. (2024). Glyphosate exposure affected longevity-related pathways and reduced survival in Asian honey bees (*Apis cerana*). *Chemosphere*, 351, 141199. https://doi.org/10.1016/j.chemosphere.2024.141199

This study investigates impacts to the survival and molecular pathways of Asian honeybees (*Apis cerana)* exposed to glyphosate. Acute 48-hour oral exposure to glyphosate resulted in 20% mortality at 4 g glyphosate/L. Higher concentrations of glyphosate (2 to 20 g glyphosate/L) to were associated with decreased body weight while there was no significant change in food consumption at the low concentrations tested (5 to 500 mg glyphosate/L).

2.5. Imazapyr

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

2.6. Triclopyr

Álvarez, F., Arena, M., Auteri, D., Batista Leite, S., Binaglia, M., Castoldi, A. F., Chiusolo, A., Colagiorgi, A., Colas, M., Crivellente, F., De Lentdecker, C., De Magistris, I., Egsmose, M., Fait, G., Ferilli, F., Gouliarmou, V., Halling, K., Herrero Nogareda, L., Ippolito, A., ... Villamar-Bouza, L. (2024). Peer review of the pesticide risk assessment of the active substance triclopyr (variant triclopyr-butotyl). *EFSA Journal*, 22, e8177. https://doi.org/10.2903/j.efsa.2024.8177

This article presents the European Food Safety Authority’s (EFSA) peer review conclusions on the risk assessment of triclopyr-butotyl (triclopyr BEE), based on evaluations by the Rapporteur Member State (Poland) and Co-Rapporteur (Hungary), under the EU regulatory framework. The conclusions were reached on the basis of the evaluation of application of triclopyr BEE on established pasture and non-recreational amenity grassland (field use). Proposed maximum residue levels (MRLs) for various agricultural commodities are presented.

Bertoni, Í., Sales, B. C. P., Viriato, C., Peixoto, P. V. L., & Pereira, L. C. (2024). Embryotoxicity induced by triclopyr in zebrafish (*Danio rerio*) early life stage. *Toxics*, 12(255). https://doi.org/10.3390/toxics12040255

This study evaluates the effects on zebrafish embryos following 144-hour exposure to sublethal triclopyr concentrations (0.1, 0.26, 1.3, 2.6, and 13 mg/L). Triclopyr exposure exhibited significantly delayed egg hatchability at the 13 mg/L dose level and reduced yolk sac absorption at all dose levels. Additionally, zebrafish larvae exposed to 13 mg/L triclopyr exhibited uninflated swim bladders, and those exposed to 2.6 mg/L showed less swimming activity in dark phases of the simulated light/dark cycle of 14/10 hours.

3. INSECTICIDES

3.1. D-trans Allethrin

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

3.2. Diatomaceous Earth

Demirozer, O., Bulus, I. Y., Yanik, G., Uzun, A., & Gosterit, A. (2024). Does diatomaceous earth (DE) cause mortality on *Apis mellifera* and *Bombus terrestris? Journal of Apicultural Research*, 63(4), 778-784. https://doi.org/10.1080/00218839.2022.2146343

This study evaluates the potential toxicity of four commercial diatomaceous earth formulations (Bio, Demite, Detech, and Detech WP) on honeybees (*Apis mellifera*) and bumble bees (*Bombus terrestris*) following contact exposure. Results indicated that all tested products were classified as "harmless" (Class 1) to honeybees and bumble bees at field-use concentrations (maximum field dose of 0.9 g/ft^2) according to the International Organization for Biological Control toxicity scale (<25% mortality).

3.3. Fipronil

da Silva Gomes, S., da Silva, J. F., Padilha, R. M. O., de Vasconcelos, J. V. A., Negreiros Neto, L. G. d., Marrs, J. A., & Cadena, P. G. (2024). Behavioral effects of the mixture and the single compounds carbendazim, fipronil, and sulfentrazone on zebrafish (*Danio rerio*) larvae. *Biomedicines*, 12(1176). https://doi.org/10.3390/biomedicines12061176.

This study assesses the behavioral effects of the fungicide carbendazim, the insecticide fipronil, and the herbicide sulfentrazone – both individually and in mixtures (carbendazim: 0.20 mg/L individually, 0.10 mg/L in binary mixtures, or 0.060 mg/L in ternary mixture; fipronil: 0.05 mg/L individually, 0.025 mg/L in binary mixtures, or 0.017 mg/L in ternary mixture; sulfentrazone: 0.20 mg/L individually, 0.10 mg/L in binary mixtures, or 0.025 mg/L in ternary mixture) – on zebrafish (*Danio rerio*) larvae following 6-day exposure. Exposure to sulfentrazone caused the most significant behavioral disruptions, followed by fipronil and carbendazim. Fipronil-exposed larvae showed higher immobility and reduced swimming speed and distance. Combined exposures were associated with synergistic responses that affected speed, distance covered, and optomotor response.

de Oliveira, D., Tadei, R., Triques, M. C., Goulart, B. V., Montagner, C. C., Espíndola, E. L. G., & de Menezes-Oliveira, V. B. (2024). Fipronil risk assessment in tropical soils: Relevant concentrations cause high risk to the edaphic community. *Water, Air, & Soil Pollution*, 235(123). https://doi.org/10.1007/s11270-024-06925-9.

This study assesses the ecological risk of the fipronil-based insecticide Regent in tropical soils, focusing on its impact on soil invertebrates from various phylogenetic classes or subclasses

(Collembola- springtails, Acari- mites and ticks, and Oligochaeta- worms). Even at recommended application rates, fipronil exposure caused high risk to soil invertebrates in tropical soils; however, toxicity was variable between species. The authors concluded that risk assessments based on a single species such as the earthworm are likely to underestimate the broader risk to soil diversity.

Farder-Gomes, C. F., Miranda, F. R., Fernandes, K. M., Bernardes, R. C., Bastos, D. S. S., de Oliveira, L. L., Martins, G. F., & Serrão, J. E. (2024). Exposure to low-concentration fipronil impairs survival, behavior, midgut morphology, and physiology of *Aedes aegypti* larvae. *Chemosphere*, 358, 142240. https://doi.org/10.1016/j.chemosphere.2024.142240.

This study investigates the effects of low concentrations of the fipronil-based insecticide Tuit Florestal on Egyptian mosquito (*Aedes aegypti)* larvae following 24-hour exposure. The study highlights fipronil's potential as a mosquito larvicide.

Mamboungou, J., Fernandes, É. K. K., Vieira, L. G., & Rocha, T. L. (2024). Hazardous fipronil insecticide effects on aquatic animals' health: Historical review and trends. *Science of the Total Environment*, 954, 176334. https://doi.org/10.1016/j.scitotenv.2024.176334.

This review discusses the ecotoxicity of fipronil on aquatic animals, summarizing data on exposure conditions, biomarkers, and toxic effects. Fipronil is highly toxic to aquatic invertebrates and induces sublethal oxidative stress, genotoxicity, neurotoxicity, and morphological changes in aquatic organisms, particularly arthropods, mollusks, amphibians, fish, and turtles. Environmental conditions (pH, temperature) and formulation additives influence the toxicity of fipronil to aquatic organisms.

Moreira, R. A., González, M. P., Dias, M. A., Ogura, A. P., Mena, F., Montagner, C. C., Espíndola, E. L. G., Blasco, J., Parra, G., & Araújo, C. V. M. (2024). Ecological consequences when organisms avoid a contaminated environment: A study evaluating the toxicity of fipronil. *Science of the Total Environment*, 926, 171480. https://doi.org/10.1016/j.scitotenv.2024.171480.

This study examines the behavioral responses of the water flea (*Daphnia magna)* to fipronil contamination using the Heterogeneous Multi-Habitat Assay System (HeMHAS). After a 48-hour pre-exposure to sublethal concentrations of fipronil, water fleas preferentially moved toward less contaminated areas, demonstrating an ability to detect and avoid toxic environments. However, fipronil exposure impaired swimming ability, reducing total distance traveled.

Ogura, A. P., Dias, M. A., Marestoni, I. F., Bernegossi, A. C., Felipe, M. C., Montagner, C. C., & Espíndola, E. L. G. (2024). Chemical and ecotoxicological assessment of the uptake of pesticides 2,4-D and fipronil by free-floating aquatic macrophytes. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-024-06287-z

This study evaluates the uptake of the herbicide 2,4-D and fipronil by three species of free-floating aquatic macrophytes (*Salvinia auriculata*, *Eichhornia crassipes*, and *Pistia stratiotes*). Bioaccumulation, translocation, and the impact of these pesticides on aquatic ecosystems were assessed through chemical analyses and ecotoxicological bioassays. Macrophytes accumulated fipronil primarily in roots, while 2,4-D translocates to shoots. However, the plants did not significantly reduce pesticide concentrations or ecotoxicity.

Provase, M., Schmitz Boeing, G. A. N., Tsukada, E., Salla, R. F., & Abdalla, F. C. (2024). Impact of environmental concentrations of fipronil on DNA integrity and brain structure of *Bombus atratus* bumblebees. *Environmental Toxicology and Pharmacology*, 110, 104536. https://doi.org/10.1016/j.etap.2024.104536.

This study investigates the neurotoxic and genotoxic effects of environmentally relevant fipronil concentrations on the neotropical bumblebee (*Bombus atratus)*. Using the comet assay and morphological analysis, researchers found that exposure to 2.5 and 3.5 µg/g fipronil for 96 hours caused genotoxic and structural damage in brain cells of the test organisms. Based on these results, exposure to sublethal concentrations of fipronil could impact cognitive functions of bumblebees.

Shahid, M., Singh, U. B., Farah, M. A., & Al-Anazi, K. M. (2024). Phyto-toxicological effect of fipronil to plant seedlings: Assessing germination attributes, root-tip morphology, oxidative stress, and cellular respiration indices. *Pesticide Biochemistry and Physiology*, 205, 106135. https://doi.org/10.1016/j.pestbp.2024.106135.

This study investigates the phytotoxic effects of fipronil on chickpea and mung bean seedlings, evaluating its impact on germination, root-tip morphology, oxidative stress, and cellular respiration. Higher fipronil concentrations (200-300 mg/L) significantly reduced seedling survival, root-shoot elongation, and vigor indices. Microscopic analysis showed morphological distortion in root tips, increased oxidative stress markers (e.g., proline, malondialdehyde), and DNA damage, highlighting the potential for cytotoxic and genotoxic in plants exposed to high doses of fipronil.

Shahid, M., Singh, U. B., Farah, M. A., & Al-Anazi, K. M. (2024). Short-term responses of identified soil beneficial-bacteria to the insecticide fipronil: Toxicological impacts. *World Journal of Microbiology and Biotechnology*, 40, 403. https://doi.org/10.1007/s11274-024-04203-8.

This study investigates the toxicological effects of fipronil (10 to 150 mg/L) on soil-beneficial bacteria (*Rhizobium leguminosarum*, *Azotobacter salinestris*, and *Serratia marcescens)* following 2- to 8-day exposure. Results showed that fipronil has the potential to disrupt key functions of soil-beneficial bacteria such as nitrogen fixation, phosphate solubilization, and plant growth regulation, particularly at higher doses.

3.4. Indoxacarb

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

3.5. Phenothrin

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

3.6. Prallethrin

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

3.7. S-Hydroprene

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

3.8. Sodium Tetraborate Decahydrate (Borax)

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

4. RODENTICIDES

4.1. Cholecalciferol

No relevant publications released in 2024 which focused on one or more of the following research areas were found for this chemical: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.

5. ADJUVANTS

No relevant publications released in 2024 which focused on one or more of the following research areas were found for adjuvants used by the District: biodiversity, water quality, soil health, wildlife, efficacy and effectiveness, human health and safety, and drift and effects on non-target species.