ANNALS OF THE UNIVERSITY OF CRAIOVA

Series: ✓*Biology*
✓*Horticulture*
✓*Food products processing technology*
✓*Environmental engineering*

Vol. XXXI (LXVII) - 2026

IMPACT OF MOSQUITO CONTROL ON NON-TARGET ENTOMOFAUNA IN URBAN ECOSYSTEMS

Țucă Ovidiu Andrei[1], Stan Cătălin[1*]
[1*]University of Craiova
* *Correspondence author. E-mail*: st_catalin@yahoo.com

Keywords*: mosquitoes; non-target insects; pyrethroids; Bti; biodiversity*

ABSTRACT

Urban mosquito management is an important public-health intervention, but mosquito suppression occurs within complex urban food webs. Adulticides may expose non-target terrestrial arthropods, whereas larvicides are applied directly to aquatic habitats where mosquito larvae develop. This review summarizes evidence on the ecological effects of pyrethroids, organophosphates, methoprene, Bacillus thuringiensis israelensis (Bti) and spinosad, with emphasis on pollinators, aquatic Diptera, Odonata and trophic interactions. Available evidence indicates that effects are context dependent and are determined by toxicity together with actual exposure. Recent operational-scale evidence suggests low acute risk for non-target arthropods under properly conducted ultra-low-volume applications, while experimental studies have detected effects under some exposure scenarios. Bti treatment can reduce chironomid abundance and emergence and may alter prey-mediated interactions in aquatic and terrestrial food webs. Integrated vector management, source reduction, surveillance and targeted interventions are therefore preferable to indiscriminate insecticide use.

INTRODUCTION

Mosquitoes are ecologically diverse insects, but several urban and peri-urban species are vectors of pathogens affecting humans and animals. Their abundance can also create substantial nuisance. Consequently, mosquito surveillance and control form part of public-health and environmental-management programmes. Current guidance promotes integrated vector management (IVM), in which surveillance, environmental management, biological control and chemical interventions are combined according to local risk and operational need (World Health Organization, 2012, 2024, European Mosquito Control Association, 2024).
The environmental challenge is that mosquito-control interventions operate in multispecies communities rather than in isolated target populations. Ultra-low-volume (ULV) adulticides are intended to contact flying adult mosquitoes, but other arthropods may be present in the treatment area. Larvicides are deliberately applied to aquatic habitats and can therefore expose organisms sharing the same water bodies. Ecological effects depend on the active ingredient, formulation, concentration, exposure route, treatment frequency and susceptibility of the organisms concerned (Zhu et al. 2000, Peterson et al.2006, Boisvert & Boisvert, 2000, Lawler, 2017, Becker et al. 2010).

This review evaluates the evidence for direct and indirect effects of mosquito control on non-target entomofauna and considers the implications for urban ecosystem functioning. Particular attention is given to pollinating and predatory insects, Chironomidae, Odonata and trophic pathways. The purpose is not to characterize mosquito control as inherently harmful, but to identify situations in which environmental exposure may become ecologically relevant and to outline management measures that can reduce unnecessary impacts.

MATERIAL AND METHODS

A narrative literature review was undertaken using peer-reviewed articles, systematic reviews and technical guidance concerning mosquito adulticides, larvicides, non-target organisms and ecosystem effects. Field studies, operational mosquito-control studies, mesocosm experiments and ecological risk assessments were considered. Greater weight was given to systematic reviews and field-realistic or operational studies. Evidence was organized into four categories: direct effects on non-target organisms; indirect effects through prey availability; environmental exposure and transport; and implications for integrated urban mosquito management.

RESULTS AND DISCUSSIONS

MAIN MOSQUITO-CONTROL AGENTS

Adult mosquito control commonly relies on ULV formulations of pyrethroids, while larval control may use insect growth regulators, bacterial larvicides or other insecticidal compounds (World Health Organization, 2024, Becker et al.2010). Pyrethroids act primarily on voltage-gated sodium channels and have broad insecticidal activity. Their environmental relevance is associated with toxicity to many aquatic invertebrates and with the possibility of transport from treated surfaces to water through runoff (Zhu et al., 2000., Liu et al., 2020). Organophosphates such as malathion and naled have also been used for adult mosquito control, although their use varies among jurisdictions (Peterson et al., 2006, Bargar, 2012).

Methoprene is an insect growth regulator that mimics juvenile hormone and acts mainly on immature mosquitoes. Bti contains bacterial toxins active against susceptible dipteran larvae and is generally more selective than broad-spectrum adulticides. Spinosad is another larvicide with activity against mosquito larvae, but experimental evidence indicates broader effects on some non-target insects than those generally associated with Bti (Boisvert & Boisvert, 2000, Lawler, 2017, Jones &Ottea, 2013).

Table 1 is a screening framework rather than a universal ranking of environmental hazard. Realized ecological risk depends on toxicity together with exposure. Recent operational studies of ULV mosquito control have found no acute deleterious effects across the assessed non-target taxa, while field experiments have produced mixed results, including effects under conditions favoring direct exposure (Peterson et. al., 2026). This distinction between intrinsic hazard and realized field exposure is central to environmental assessment.

Table 1

Principal mosquito-control agents and potential non-target pathways

Agent/group	Main application	Potential non-target organisms	Main ecological concern
Pyrethroids	ULV adulticide	Terrestrial insects; aquatic organisms after runoff	Direct toxicity; deposition and water contamination
Organophos -phates	ULV adulticide	Pollinators and other arthropods	Broad-spectrum neurotoxicity; exposure depends on conditions
Methoprene	Larvicide / IGR	Aquatic invertebrates	Developmental effects in sensitive taxa
Bti	Larvicide	Chironomidae and other Nematocera	Non-target mortality; reduced prey availability
Spinosad	Larvicide	Aquatic and terrestrial insects	Broader effects than Bti in some experimental systems

EFFECTS ON TERRESTRIAL NON-TARGET INSECTS

Pollinators are frequently considered because adulticide aerosols may contact flying insects or treated vegetation. Field studies of honey bees have generally reported limited acute effects under investigated operational conditions. Rinkevich et al. (Rinkevich et al., 2017) found limited effects following truck-based ULV applications, while Pokhrel et al.(Pokhrel et all, 2018) reported no significant differences in honey-bee mortality or colony health after one to three ULV applications in a suburban field setting. A recent Florida study detected mosquito-control residues in hives but no acute honey-bee mortality or effect on colony strength (Barascou et al., 2025).

These findings should not be interpreted as evidence that all applications are harmless. They indicate that exposure conditions are decisive. Night-time treatment, droplet characteristics, rapid atmospheric dispersal and breakdown can reduce the probability that susceptible non-target insects receive a biologically important dose (Peterson et. al., 2026). Conversely, direct exposure, repeated applications, favorable weather for deposition, or treatment of insect-rich habitats can increase environmental relevance.

AQUATIC NON-TARGET ORGANISMS

Larvicides present a different exposure pathway because mosquito larvae share aquatic habitats with many other organisms. The strongest body of evidence concerns Bti. A systematic review by Land et al. (Land et al., 2023) identified consistent negative effects on Chironomidae abundance and emergence, while effects on other response variables were more heterogeneous. Because chironomids can represent a major component of aquatic insect production, their reduction may influence the availability of prey for predatory insects and vertebrates.

Methoprene generally occurs at low concentrations after mosquito-control applications and has limited mobility. The available evidence indicates low risk for most tested organisms at operational concentrations, although some zooplankton, crustacean larvae and small Diptera may be sensitive (Lawler, 2017, Butler, 2010).

Spinosad can have broader effects on aquatic insects in experimental systems (Lawler, 2017, Jones &Ottea, 2013). These findings demonstrate that biological or alternative larvicides should not automatically be considered ecologically neutral.

INDIRECT EFFECTS AND URBAN FOOD WEBS

The ecological importance of mosquito control extends beyond direct mortality. If repeated larviciding reduces the abundance or emergence of non-target aquatic insects, predators may experience changes in prey quantity or composition. Experimental mesocosm research has shown that Bti-induced reductions in chironomid availability can alter interactions involving aquatic predators (Allgeier et al., 2019). In the Camargue, repeated Bti treatment was associated with lower Odonata richness and abundance, illustrating a possible indirect effect on predatory insects (Jakob &Poulin, 2016).

Trophic effects may also extend to terrestrial consumers. Poulin et al. (Poulin et al., 2010) reported changes in prey composition and reproductive parameters of breeding house martins at sites subjected to mosquito control. However, other long-term studies have found limited or no measurable effects on selected birds or invertebrate endpoints (Hanowski et al., 1997a, 1997b, Timmermann &Becker, 2017). Differences in treatment frequency, hydrology, landscape structure, prey communities and study design can explain part of this variability. Therefore, indirect effects should be regarded as plausible and context dependent rather than universal consequences of mosquito control.

THE HAZARD–EXPOSURE DISTINCTION

A major conclusion from recent evidence is that environmental risk cannot be inferred from toxicity alone. Many adulticides are intrinsically toxic to arthropods, but operational ULV applications may produce relatively low exposure of non-target populations because treatments are conducted at night, droplets are small and rapidly disperse, and insecticide concentrations decline after application (Peterson et. al., 2026). In contrast, an organism positioned directly in the aerosol path, or a sensitive aquatic organism exposed to a larvicide, can experience a substantially different exposure scenario.The spatial distribution of aerosolized compounds is also influenced by local meteorological conditions and atmospheric-dispersion processes, a principle addressed in pollutant-dispersion modelling studies (Buzatu, 2010).

For urban environmental management, the relevant question is therefore not simply whether a compound is toxic to insects, but whether the planned application creates a meaningful exposure of non-target populations. This approach supports site-specific risk assessment and avoids both extremes: assuming that every mosquito treatment causes widespread biodiversity loss or assuming that non-target effects are impossible.

IMPLICATIONS FOR URBAN ENVIRONMENTAL MANAGEMENT

The evidence supports an integrated management sequence: surveillance and mapping of mosquito breeding sites; source reduction; targeted larval control; careful selection and timing of adulticides when justified; and monitoring of both mosquito populations and selected non-target indicators. Wetlands, ponds, urban streams and pollinator-rich green spaces require particular attention because they may contain sensitive communities or conservation-relevant taxa. Within the local urban context of Craiova, previous studies have documented particulate-matter

pollution and the use of independent sensor networks for air-quality monitoring (Gavrilescu et al., 2013; Buzatu & Dodocioiu, 2022). Such experience with environmental monitoring can also support the design of integrated surveillance programs for mosquito-control interventions.

Monitoring programs should record active ingredient, formulation, dose, application method, treated area, weather conditions and treatment frequency. Where repeated treatments occur, sentinel observations of pollinators, aquatic macroinvertebrates and predatory insects can provide useful evidence of environmental change. Such a framework is consistent with the integrated vector-management approach recommended for sustainable mosquito control (World Health Organization, 2012, 2024; European Mosquito Control Association, 2024) and with general principles of environmental protection (Gavrilescu& Buzatu, 2014).

CONCLUSIONS

Mosquito control is an important component of urban public-health management, but it takes place within complex ecological networks. Available evidence demonstrates that non-target effects are possible, particularly for susceptible aquatic Diptera and for food-web components affected indirectly by repeated larviciding. At the same time, operational-scale studies indicate that properly conducted ULV applications do not necessarily produce measurable population-level effects in all non-target taxa. Environmental risk is therefore conditional rather than universal.

The preferred environmental-management strategy is integrated vector management based on surveillance, source reduction, targeted larviciding, careful selection and timing of adulticides, and post-treatment ecological monitoring. The objective should not be the elimination of insects from urban environments, but the selective management of mosquito populations while maintaining biodiversity and ecosystem functions.

REFERENCE

Allgeier, S., Friedrich, A., Brühl, C.A., 2019. Mosquito control based on Bacillus thuringiensis israelensis (Bti) interrupts artificial wetland food chains. Science of the Total Environment, 686, 1173–1184.

Barascou, L., Rawn, D., Qualls, W.A., Oliva, D., Prouty, C., Kozuch, M., Kleckner, K., Ellis, J.D., Jack, C., 2025. The effects of mosquito larvicides and adulticides applied via truck-mounted and aerial spray on western honey bees (Apis mellifera) in Florida, USA. Chemosphere, 392, 144741.

Bargar, T.A., 2012. Risk assessment for adult butterflies exposed to the mosquito control pesticide naled. Environmental Toxicology and Chemistry, 31(4), 885–891.

Becker, N., Petrić, D., Zgomba, M., Boase, C., Madon, M.B., Dahl, C., Kaiser, A., 2010. Mosquitoes and Their Control. 2nd ed. Heidelberg: Springer.

Boisvert, M., Boisvert, J., 2000. Effects of Bacillus thuringiensis var. israelensis on target and nontarget organisms: A review of laboratory and field experiments. Biocontrol Science and Technology, 10(5), 517–561.

Butler, M., Ginsberg, H.S., LeBrun, R.A., Gettman, A., 2010. Evaluation of nontarget effects of methoprene applied to catch basins for mosquito control. Journal of Vector Ecology, 35(2), 372–384.

Buzatu G.-D. 2010. Aspects concerning modeling of the air pollutants dispersion. Research Journal of Agricultural Science, 42, 3, 457-463.

Buzatu G.-D., Dodocioiu A. M. 2022. Air quality study in Craiova municipality based on data provided by uRADM independent sensor network. Annals of the University of Craiova, Biology, Horticulture, Food Products Processing Technology, Environmental Engineering, 27 (63), 99-106.

European Mosquito Control Association, 2024. EMCA Guidelines for Mosquito Control in Built-up Areas in Europe. Strasbourg: EMCA. Available at: https://www.emca-online.eu/emca-guidelines-for-mosquito-control-in-built-up-areas-in-europe (accessed 30 September 2026).

Gavrilescu E., Buzatu G.-D. 2014. Elemente fundamentale de protecţia mediului. Edit. Sitech, Craiova, pp. 333.

Gavrilescu E., Buzatu G.-D., Popescu S.M. 2013. Air pollution by particulate matter (PM10) in Craiova municipality. Bulletin of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture, 70, 2, 439-440.

Hanowski, J.M., Niemi, G.J., Lima, A.R., Regal, R.R., 1997a. Effects of two mosquito control agents on growth and reproduction of red-winged blackbirds (Agelaius phoeniceus). Journal of the Minnesota Academy of Science, 62(1), 3–6.

Hanowski, J.M., Niemi, G.J., Lima, A.R., Regal, R.R., 1997b. Response of breeding birds to mosquito control treatments of wetlands. Wetlands, 17(4), 485–492.

Jakob, C., Poulin, B., 2016. Indirect effects of mosquito control using Bti on dragonflies and damselflies (Odonata) in the Camargue. Insect Conservation and Diversity, 9(2), 161–169.

Jones, O.M., Ottea, J., 2013. The effects of spinosad on Culex quinquefasciatus and three nontarget insect species. Journal of the American Mosquito Control Association, 29(4), 346–351.

Land, M., Bundschuh, M., Hopkins, R.J., Poulin, B., McKie, B.G., 2023. Effects of mosquito control using the microbial agent Bacillus thuringiensis israelensis (Bti) on aquatic and terrestrial ecosystems: A systematic review. Environmental Evidence, 12, 26.

Lawler, S.P., 2017. Environmental safety review of methoprene and bacterially-derived pesticides commonly used for sustained mosquito control. Ecotoxicology and Environmental Safety, 139, 335–343.

Peterson, R.K.D., Kennedy, T.E., Strand, J.R., 2026. Risk determination for non-target arthropods from outdoor space applications of mosquito adulticides. Journal of Medical Entomology, 63(3), tjag090.

Peterson, R.K.D., Macedo, P.A., Davis, R.S., 2006. A human-health risk assessment for West Nile virus and insecticides used in mosquito management. Environmental Health Perspectives, 114(3), 366–372.

Pokhrel, V., DeLisi, N.A., Danka, R.G., Walker, T.W., Ottea, J.A., Healy, K.B., 2018. Effects of truck-mounted, ultra-low volume mosquito adulticides on honey bees (Apis mellifera) in a suburban field setting. PLoS ONE, 13(3), e0193535.

Poulin, B., Lefebvre, G., Paz, L., 2010. Red flag for green spray: Adverse trophic effects of Bti on breeding birds. Journal of Applied Ecology, 47(4), 884–889.

Rinkevich, F.D., Margotta, J.W., Pokhrel, V., Walker, T.W., Vaeth, R.H., Hoffman, W.C., Fritz, B.K., Danka, R.G., Rinderer, T.E., Aldridge, R.L., Linthicum, K.J., Ottea, J.A., Healy, K.B., 2017. Limited impacts of truck-based ultra-low-volume applications of mosquito adulticides on mortality in honey bees (Apis mellifera). Bulletin of Entomological Research, 107(6), 724–733.

Timmermann, U., Becker, N., 2017. Impact of routine Bacillus thuringiensis israelensis (Bti) treatment on the availability of flying insects as prey for aerial feeding predators. Bulletin of Entomological Research, 107(6), 705–714.

World Health Organization, 2012. Handbook for Integrated Vector Management. Geneva: World Health Organization.

World Health Organization, 2024. Compendium of WHO and other UN guidance in health and environment, 2024 update. Geneva: World Health Organization. ISBN 978-92-4-009538-0.

Zhu, Q., Yang, Y., Zhong, Y., Lao, Z., O'Neill, P., Hong, D., Zhang, K., Zhao, S., 2020. Synthesis, insecticidal activity, resistance, photodegradation and toxicity of pyrethroids (A review). Chemosphere, 254, 126779.