A review of the potential human health and environmental risks of two commonly used herbicides (Glyphosate and Triclopyr) in natural areas management.

Conducted for the Sudbury Valley Trustees (SVT)
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This review does not represent the views or policies of the SVT, but rather has served as an excellent reference to SVT for decision-making. This report is a good review of the current science but is not comprehensive, given the overwhelming abundance of articles on this topic.

Executive Summary

Invasive plant species are a considerable challenge to managers of natural areas in Northeastern USA. Controlling invasive species is fundamental to achieving many management goals, especially restoration of natural communities and providing access to trails and features. Most practitioners use a combination of mechanical and chemical control, however, in the majority of cases, some amount of chemical control is essential to success. The primary methods of chemical control include spot applications using foliar spray, cut stem and resprout foliar applications of Triclopyr and/or Glyphosate. Repeated mowing, smothering and hand pulling are common mechanical treatments. Biological control using grazing animals or approved biological control agents are options with varying probabilities of availability or success. The application of glyphosate, in particular, has become highly contentious in recent years. This review includes a summary of existing health and environmental assessments in scientific literature and regulations existing in Massachusetts intended to maximize public and ecological safety while considering the use of these formulations. Also included is an annotated bibliography of literature used in this compilation. In many circumstances, **the use of triclopyr and glyphosate products in accordance with all legal guidelines is an essential low risk practice for successful efforts to control invasive plants in conservation areas.**

Introduction

I used several sources for deriving this compilation. Google Scholar™ searches of glyphosate and triclopyr "toxicity" yielded 40,800 and 4,800 results respectively. Available literature is heavily influenced by information on the effects of agricultural industry practices, including forestry which involve the use of quantities and concentrations of herbicides that are higher than those used by managers of natural areas. My personal library was supplemented by searches of professional stewardship publications including Ecological Restoration, Restoration Ecology, Natural Areas Journal, Biological Invasions, Conservation Biology and other selected journals. Also included were materials provided by Northeast Organic Farming Association (NOFA), the Massachusetts Toxic Reductions Task Force (TRTF) and other sources when applicable. Non peer-reviewed sources were rarely included.

Pesticides are hazardous chemicals. A hazard is anything that has the potential to cause harm. A risk is the likelihood that a hazard will cause harm. Determining risk requires consideration of the toxicity of a

substance and whether, how, and how much a receptor is exposed to a substance. Ecological risk assessment is a **process** that evaluates the likelihood that adverse **ecological** effects may occur or are occurring as a result of exposure to one or more hazardous substances or other stressors. Risk management is the action taken based on consideration of the risk assessment and other information, including the feasibility, impacts, and costs of various management options, and uncertainties inherent in the risk assessment process. It is recognized that ecological and human health effects of pesticides are not fully understood, and some level of risk is typically involved in the use of pesticides.

For the purposes of this review it is important to recognize the difference between risks associated with practices involving products intended for human ingestion and natural areas management practices which provide no pathways for human ingestion except for the risks potentially borne by the herbicide applicators themselves. Evaluations of risks to organisms must include potential pathways to exposure by the organism. The reviewed literature is replete with descriptions of toxicity and risks to organisms without reference to the practical guidelines followed by licensed practitioners. For example, in Relyea's (2005, 2006) often cited "studies" on amphibian mortalities from glyphosate exposure the author used materials and concentrations, including surfactants, that exceeded the application thresholds mandated under federal and state regulations.

Massachusetts Statutes and Regulations

Statutes and regulations in Massachusetts provide multiple layers of protection from human health and environmental harm due to herbicide applications.

For natural areas managers the primary national statutes are the Federal Environmental Protection Agency (EPA) via the Insecticide, Fungicide and Rodenticide Act (FIFRA) https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act which regulates the sale and distribution of pesticides and the Endangered Species Act which requires the EPA to assess the potential effects of materials on endangered and threatened species https://www.epa.gov/laws-regulations/summary-endangered-species-act.

The Massachusetts Pesticide Control Act and regulations https://www.mass.gov/law-library/333-cmr control all aspects of pesticide use, licensing of applicators and products approved for use in the Commonwealth. Approval by the EPA does not confer approval at the state level in Massachusetts. The Department of Agricultural Resources has regulatory jurisdiction over herbicide application in rights-of-way areas. The regulations (333 CMR 11.00) contain provisions for the use of herbicides as part of vegetation management in support of the functioning and use of rights-of-way areas "***while minimizing the potential impacts of herbicides on human health and the environment".*** Specific restrictions exist for the use of herbicides in sensitive areas, which include water supplies, wetlands, state-listed species habitat, inhabited and agricultural areas. The Department maintains a list of herbicides approved for use in sensitive areas.

Both glyphosate and triclopyr are approved under the Sensitive Areas Materials List https://www.mass.gov/service-details/rights-of-way-sensitive-area-materials-list. Natural Areas management plans within priority habitats regulated under regulations of the Massachusetts Endangered Species Act require approval by the Massachusetts Natural Heritage & Endangered Species Program https://www.mass.gov/service-details/regulatory-maps-priority-estimated-habitats.

Surfactants are additives that reduce waste and non-target impacts by improving herbicide ability to adhere to plant tissues. As inactive ingredients surfactants are not subject to regulation in many states.

However, in Massachusetts, DAR approved surfactants have been added to the sensitive areas materials list (Wijnja 2010)

The Massachusetts Pesticide Control Act expressly prohibits regulation of herbicides by municipal government boards and authorities. The Massachusetts Supreme Judicial Court has reinforced this prohibition as local control confounds the intent of Federal and State statutes.

How do triclopyr and glyphosate herbicides work?

Among the dozens of available products, glyphosate and triclopyr are two of the most commonly used herbicides for natural areas management because of their modes of action and their low levels of persistence. Glyphosate is absorbed by leaves and stems of plants and inhibits certain amino acid processes and pathways. Essentially a metabolic disruptor targeting amino acids found only in plants. See http://npic.orst.edu/factsheets/archive/glyphotech.html#mode and https://www.mass.gov/doc/glyphosate-2011pdf/download for summaries.

Similarly, triclopyr is a synthetic hormone related to a naturally occurring auxin. Absorbed by living tissues plant growth is disrupted http://www.npic.orst.edu/factsheets/triclopyrgen.html#howwork, https://www.mass.gov/doc/triclopyr-2011pdf/download.

The review process for approval of sensitive area materials, in place since 1987, is described here: https://www.mass.gov/service-details/herbicide-review-process-for-sensitive-areas-in-rights-of-way

Both are non-selective and neither works on all target invasive plants equally.

These modes of action must be compared with the much riskier and environmentally damaging neonicotinoids, widely used insecticides that are known to be devastating to native pollinators and honey bees.

Bees, monarchs and other pollinators

Native bees and introduced honey bees are the focus of great concern for conservationists because their declines signal a threat to some fundamental ecosystem services that effect human interests more severely than some other taxa. Recent reports of a global collapse of insect numbers increase the magnitude of the significance of any potential detriments caused by the application of triclopyr and glyphosate. Repeated searches failed to produce credible documentation of mortality to bees. Several papers (Zhu et al. 2015, Balbuena et al 2014, McPhail 2018) provided weak correlations between bee functions but mortality of individuals and population level impacts have not been documented.

Monarch butterfly larvae feed exclusively on milkweeds. When herbicide applications target all non-crop plants in an agricultural landscape, milkweeds are eliminated and monarch populations decline. Unless managers are targeting milkweed there is no connection between focused invasive plant control and monarch butterfly declines.

Mycorrhizae

Helander et al (2018) and Zaller (2014) Examined glyphosate effects on mycorrhizal functions in industrial application settings and found some disruptions of activity.

Aquatic Invertebrates and Fish

Labels for glyphosate and triclopyr products include standard testing results (see product labels). In addition, Robichaud 2020 studied aquatic biota effects for three years of glyphosate applications for Phragmites control and found "The direct, over-water application of Roundup Custom® with Aquasurf® to control invasive P. australis does not pose a toxicological risk to aquatic biota."

Risk Assessment

Most management decisions for natural areas managers involve assessments of risks to environmental and visiting public health. The location, densities and intensities of use, for example, help determine the benefits and detriments of trail establishment and maintenance. Several federal and state agencies apply formal risk assessment protocols to decisions about using herbicides to meet management goals. This topic will be more thoroughly explored in the development of policies but see https://www.fs.fed.us/foresthealth/protecting-forest/integrated-pest-management/pesticide-management/pesticide-risk-assessments.shtml for instructions and discussions on risk evaluation and management.

Source: beginners guide to Hazard and risk https://www.tes.com/lessons/arpxXTnKO15_YQ/7f-hazards-and-risks

Human Health

There are widespread reports of linkages between cancers such as non-Hodgkins lymphoma and glyphosate exposure. Huge court settlements have been rendered based on assumptions of a causal linkage between glyphosate applicators and cancers. Scientific evidence for a causal relationship is lacking or contradictory. Several papers are included in the annotated bibliography and literature cited sections. Most notably the highly influential book Whitewash (Gillam 2018) provides no scientific basis for a causal linkage between glyphosate and non Hodgkins lymphoma yet has been influential in several court cases. See https://biofortified.org/2018/02/hogwash-review-whitewash-carey-gillam/ for a more emphatic dismissal of the contents of this book. However, Zhang et al, 2019 concluded "Overall, in accordance with evidence from experimental animal and mechanistic studies, our current meta-analysis of human epidemiological studies suggests a compelling link between exposures to Glyphosate Based Herbicides and increased risk for NHL."

Tracking 54,000 applicators over periods ranging from five to fourteen years, Andreotti et al (2018) found no statistical correlation with cancer development and applicators but left long-term high-level exposure conclusions to further analyses.

In January 2020 the EPA released the results of its glyphosate review as required by Federal law: https://www.epa.gov/sites/production/files/2020-01/documents/glyphosate-interim-reg-review-decision-case-num-0178.pdf. The agency opted to renew licenses for glyphosate products and found no evidence of glyphosate causing cancer when used according to label directions.

Analytical Methods

One reason for the extreme disparity in conclusions about the environmental and human health implications of glyphosate use is the application of meta-analysis. Borenstein (2009), Chang (2016) and

Rothstein (2005) all warn about the high potential for bias and false conclusions if meta-analyses are not conducted with caution.

Triclopyr

Antunes-Kenyon and Kennedy, 2004 in a report to the Massachusetts Pesticide Board drew several conclusions:

"Given the maximum expected environmental concentrations of 2.5 ppm, the rapid degradation in treated water, and the lack of bioaccumulation, there are negligible risks to avian species, including those whose diet might consist primarily of aquatic vegetation treated with triclopyr."
"Studies reviewed show that triclopyr acid is practically non-toxic to small mammals on an acute oral basis."
"Both triclopyr acid and triclopyr TEA are practically non-toxic to freshwater fish on an acute basis."
"Garlon 4 (triclopyr BEE) shows significantly greater toxicity to Xenopus Laevis embryos as compared to Garlon 3 (triclopyr TEA) (Perkins, 2000). Observations and data indicated a trend of increased Release® (triclopyr BEE) toxicity to amphibians under decreased pH. The combination of Release® and pH was not deemed to be teratogenic (tumor inducing)."

Durkin (2002) found no evidence of neurotoxicity, endocrine disruption or other toxic effects of triclopyr or glyphosate.

Best Management Practices

Though risks of applications of glyphosate and triclopyr to environmental and human health appear to be low, land managers generally elect to reduce using these products to the extent possible.

Application methods

A more thorough discussion of application methods will be included in a policy discussion where different techniques are evaluated for efficiency and success while reducing the volume of herbicide used.

Broadcast application. When herbicides are used non-selectively where invasive monocultures are the target.

Spot applications include foliar and cut stump treatments where individual or small clusters of invasive plants are selected for treatment. Cutting a stem and applying herbicide directly to the cut surface is a highly selective form of application. Cut stem may also refer to cutting of hollow stem plants such as Phragmites australis and dripping herbicide into the hollow stem.

Alternatives to herbicide applications include mechanical, biological and the use of organic non-regulated materials.

Mechanical treatments include mowing, excavating, hand pulling or using levers (weed wrench, uprooters). Early infestations containing lower (countable) numbers of stems may be controlled with these methods but are impractical for larger, well established infestations.

Plants often store carbohydrates in below ground root and rhizomes. Repeated cutting and removal can eventually result in control of some infestations. Mike Bald's "Got Weeds" https://choosewiselyvt.wordpress.com/got-weeds/website chronicles the results of using alternatives to herbicides to control invasive plants. Burning with propane torches can be used to kill the above ground portion of a plant. Success rates of these methods are uneven because invasive plant propagules include

both seeds and vegetative reproduction via plant fragments. Mechanical treatments that leave behind root and rhizome debris may result in increasing the infestation when the plants recover.

Biological controls include grazing animals or biocontrol agents requiring testing and approval by the US Department of Agriculture's Animal, Plant Health Inspection Service (APHIS). Other than some beetles for the control of purple loosestrife no biological control agents are available for most of the most problematic invasive plants in New England. Grazing by goats can be expensive and goats do not discern between desirable and undesirable plants but in some circumstances may be an effective tool for managing invasive plants https://ohiostate.pressbooks.pub/sciencebitesvolume2/chapter/chapter-1/, Carreiro (2020).

Goats are capable of both controlling some invasive plants and spreading invasive plant seeds. A recent study (Marchetto et al 2020) reported low survival of common buckthorn (*Rhamnus cathartica*) seeds after digestion by goats. Grazing may be viewed as a form of repeated cutting with variable effects on below ground portions of plants. Grazing animals do not discern between desirable and undesirable plant species and care must be taken to avoid impacts to protected species and other species of conservation concern.

Unregistered herbicides (often referred to as "organic")

Herbicides composed of materials not regulated by EPA or DAR include salt solutions, borax and various vinegars and oils. Most achieve cosmetic or temporary results.

Pelargonic acids and cinnamon and clove oils have had some promising results (Carreiro 2020) with some species in the mid-west but not those most frequently targeted in our region such as Bittersweet and porcelain berry. Trials with these species may begin in 2020 (Polatin pers. communication). These applications were five times as expensive and were at least a third greater in labor intensity than traditional herbicide applications.