Herbicide Drift and Chemical Trespass On Natural Landscapes and Habitats

A report to the Illinois Nature Preserves Commission

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Damaged oak canopy, photo credit Martin Kemper

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Kim Erndt-Pitcher was the lead author for the report. Martin Kemper was the lead for data management and analysis.

Cover images: Front cover (left to right, top to bottom): Normal rosinweed, Martin Kemper; Symptoms in rosinweed, Kim Erndt-Pitcher; Normal bluestar, Martin Kemper; Symptoms in bluestar, Martin Kemper; Normal white oak, Martin Kemper; Symptoms in white oak, Martin Kemper; Normal sweet black-eyed susan, Daves Wisconsin Wildflower Photos /FLICKR; Symptoms in sweet black-eyed susan, Kim Erndt-Pitcher; Normal grape, Martin Kemper; Symptoms in grape, Martin Kemper; Normal sugar maple, Martin Kemper; Symptoms in sugar maple, Martin Kemper; Normal post oak, Martin Kemper; Symptoms in post oak, Martin Kemper; Normal redbud, Martin Kemper; Symptoms in redbud, Martin Kemper.

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Executive Summary

Off-target herbicide drift is a major ongoing threat to Illinois' ecosystems, including those protected in the nature preserves system. Yet herbicide trespass has been under-evaluated by state agencies tasked with protecting vulnerable ecosystems. These ecosystems are already under the stressors of climate change, habitat loss, disease, pests, and invasive species. It is critical that Nature Preserves, Land and Water Reserves, and Illinois Natural Areas Inventory sites are protected from herbicide trespass and that high-quality natural communities and the habitats of rare, threatened, and endangered species are prioritized. Illinois Nature Preserves and Land and Water Reserves provide unique legal protections for natural communities of the highest quality, rare plant and animal habitats, and other unique natural features that exist on Illinois' public and private lands.

This report was written to provide the Illinois Nature Preserves Commission (INPC) with background on the legislative framework that is used to regulate pesticides, an overview of the phenomenon of widespread symptoms of herbicide drift, as well as a review, comparison, and summary of the data collected through two of the current monitoring programs which are led by the Illinois Department of Natural Resources (IDNR) and Prairie Rivers Network (PRN). The report concludes with a section on recommendations for future monitoring efforts and how to best protect lands managed by the Nature Preserves Commission.

Monitoring and tissue sampling require significant resources. Current monitoring information is limited in geographic scope due to limited resources such as the number of staff, the capacity of that staff, and the financial resources to support staff time, travel, data management, tissue sampling and analysis, and reporting efforts. These efforts are limited to a handful of relatively small and unconnected initiatives that vary greatly in their purpose and scope. With the exception of minimal coordination and information-sharing between programs, they generally operate independently.

Monitoring efforts led by Prairie Rivers Network have identified symptoms of growth regulator herbicide exposure in over 188 species including 62 species of herbaceous plants, 83 species of trees, and 43 species of shrubs and woody vines. Evidence of both particle and vapor drift have been observed. Monitoring efforts have documented widespread injuries - in yards throughout rural towns, in specialty and non-resistant crops, and on a wide variety of plant species on public and private lands. Due to the geographic distribution of the injuries observed through monitoring efforts over the past four years, and the patterns of those injuries, vapor drift is suspected to be the primary cause of the majority of injuries observed on the landscape.

Singular and repeated exposures to herbicides can stress and weaken plant health making them more susceptible to diseases and pests. Declines in tree health and increased mortality have been observed for several years at locations where herbicide drift has also been observed. Declines in oaks, which appear to be especially affected by early season applications of herbicides, are evident at many monitoring locations. This is especially problematic because tissue sample analyses indicate that multiple exposures are occurring at some locations throughout the growing season. Therefore some oaks (and other species of trees, vines, and herbaceous plants) that are visibly injured by early season herbicide applications also experience exposures later in the season which may have further unseen impacts to plant health and reproduction.

Current monitoring efforts should coordinate and expand data collection efforts in order to efficiently utilize resources and to gain more information on the geographic distribution and severity of herbicide drift to Illinois' valuable natural resources, particularly those protected by or qualifying for Nature Preserve status. Additionally, Illinois needs a comprehensive monitoring program that specifically looks at the ecological impacts of widespread and repeated exposure to herbicide drift. Also included are recommendations to the Illinois Nature Preserves Commission that may help to sufficiently protect Nature Preserves and qualifying sites from the negative impacts of herbicide drift.

Introduction

The purpose of this report is to provide the Illinois Nature Preserves Commission (INPC) with a background and summary of the observed impacts of off-target herbicide drift on INPC protected sites and non-protected but qualifying sites (e.g., Illinois Natural Areas Inventory). This report provides background on the legislative framework that is used to regulate pesticides and an overview of the phenomenon of widespread symptoms of herbicide drift. There are currently five efforts in the state that gather information related to herbicide drift injuries to crop and non-crop plants. This report provides a review, comparison, and summary of the data collected by two of these efforts, which are led by the Illinois Department of Natural Resources (IDNR) and Prairie Rivers Network (PRN). The report concludes with a section on recommendations for future monitoring efforts and how to best protect lands managed by the Nature Preserves Commission.

There is much to learn about the geographic distribution, severity, timing, and long-term ecological implications of one-time and repeated off-target herbicide injury to native species and landscapes. Ecological monitoring that examines the symptoms of off-target herbicide injury to trees and other broadleaf plants is extremely limited regionally and nationally. In fact, there is no known comprehensive ecological monitoring program in Illinois or the Midwest that is documenting the symptoms or short and long-term ecological impacts of off-target herbicide drift.

Current data collection on symptoms of herbicide drift and the documenting or monitoring of injury in Illinois is limited to a handful of relatively small and unconnected efforts. The current programs vary greatly in their purpose and scope. With the exception of a limited amount of coordination and information sharing between programs, they generally operate independently.

Current programs:

Illinois Department of Natural Resources Monitoring (Used by INPC and IDNR staff)

Prairie Rivers Network – Tree and Plant Health Monitoring Program

The Illinois Forestry Association (IFA)

The Illinois Department of Agriculture (IDOA) - Pesticide Complaint Process

Morton Arboretum (MA) -Tissue Sampling

Historically, much of the information collected about herbicide drift injury across the Illinois landscape has been collected by the Illinois Department of Agriculture (IDOA) through a voluntary complaint process which mainly serves the agricultural community. These reports are not intended to assess ecological health, however, but to observe and document injury to crops and plants for regulatory

compliance purposes. In 2018 the current monitoring and tissue sampling efforts were designed and implemented in an effort to better understand the prevalence of symptoms across the state that were largely not represented through the IDOA's Pesticide Misuse Complaint Process.

Legislative Framework

Understanding the issues associated with pesticide drift requires some background knowledge of the applicable laws and regulations governing pesticides, as well as the authorities responsible for their enforcement. This section provides a cursory overview of the relevant laws and regulations necessary for understanding this issue in Illinois and the U.S.

Pesticide manufacturing and use in the U.S. are governed by federal and state laws and regulations. One of the most important federal laws is the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), which grants authority to the US Environmental Protection Agency to regulate the manufacturing and use of all pesticides. The US EPA's Office of Pesticide Programs administers FIFRA [1].

In addition to FIFRA and other federal laws appertaining to pesticides, individual states may have laws addressing pesticides, as well as state agencies that are responsible for administering federal and state pesticide laws and regulations.

In Illinois, the Illinois Pesticides Act, which is administered by the IDOA, is the principal state statute that regulates labeling, distribution, use, application, and disposal of pesticides [2]. The IDOA[1] is responsible for investigating pesticide misuse complaints, determining violations of the Illinois Pesticide Act (Act), and initiating administrative actions based on violations of the Act. The Illinois Environmental Protection Agency (IEPA)[2] is responsible for enforcing provisions of the Act and other Acts that are "intended to protect and preserve the quality of air, water, and guard against unreasonable contamination of land resources." The Illinois Department of Public Health (IDPH)[3] administers the portions of the Act that pertain to the control of pests and vectors that pose threats to human health.

Central to implementation of the Illinois Pesticide Act is the Interagency Committee on Pesticides, which the Act authorizes IDOA to create [2]. The committee has the following members or appointed representatives from the following organizations: the Director of IDOA, the Director of IDPH, the Director of IDNR, the Secretary of the Illinois Department of Transportation (IDOT), the Director of IEPA,

[1] It shall be the duty of the Department of Agriculture to enforce this Act and such provisions of other Acts intended to control the registration, purchase, use, storage and disposal of pesticides, unless otherwise specified in this Section. Also, the Department of Agriculture shall control the purchase and use of pesticides pertaining to the production, protection, care, storage, or transportation of agricultural commodities and to control the use of pesticides applied by agricultural equipment. Also, the Department shall establish and implement an Agrichemical Facility Response Action Program as provided in Section 19.3.

[2] It shall be the duty of the Environmental Protection Agency to enforce such provisions of this Act and other Acts intended to protect and preserve the quality of air, water, and guard against unreasonable contamination of land resources.

[3] It shall be the duty of the Department of Public Health to enforce such provisions of this Act and other Acts intended to control structural pest pesticides, as defined in subparagraph 37 of Section 4, of this Act. It shall be the duty of the Department of Public Health to enforce such provisions of this Act related to vector control, control of pestiferous and disease carrying insects, rodents and other animals, and control of birds and other mammals that may pose a threat to the health of the public.

the President of the University of Illinois or his or her designee representing the State Natural History Survey, and the Dean of the College of Agriculture, University of Illinois.

Section 19 of the Illinois Pesticide Act states that the Interagency Committee on Pesticides (Committee) shall:

- "(1) Review the current status of the sales and use of pesticides within the State of Illinois.
- (2) Review pesticide programs to be sponsored or directed by a governmental agency.
- (3) Consider the problems arising from pesticide use with particular emphasis on the possible adverse effects on human health, livestock, crops, fish, and wildlife, business, industry, agriculture, or the general public.
- (4) Recommend legislation to the Governor, if appropriate, which will prohibit the irresponsible use of pesticides.
- (5) Review rules and regulations pertaining to the regulation or prohibition of the sale, use or application of pesticides and labeling of pesticides for approval prior to promulgation and adoption.
- (6) Contact various experts and lay groups, such as the Illinois Pesticide Control Committee, to obtain their views and cooperation.
- (7) Advise on and approve of all programs involving the use of pesticides on State owned property, state controlled property, or administered by State agencies. This shall not be construed to include research programs, or the generally accepted and approved practices essential to good farm and institutional management on the premises of the various State facilities."

Additionally, the Committee is tasked with conducting "a statewide public education campaign and agriculture chemical safety campaign to inform the public about pesticide products, uses and safe disposal techniques. A toll-free hotline number shall be made available for the public to report misuse cases."

While not a law focused on pesticide use and regulation, the Illinois Natural Areas Preservation Act (INAPA) established the INPC and charges the IDNR and the INPC with the responsibility to protect natural lands and waters[3]. The INAPA enumerates the powers and duties of the IDNR and INPC to carry out this task. The INPA states that it is, "the public policy of the State of Illinois to secure for the people of present and future generations the benefits of an enduring resource of natural areas, including the elements of natural diversity present in the State, by establishing a system of nature preserves, protecting nature preserves and gathering and disseminating information regarding them, providing for appropriate use of nature preserves *that will not damage them*, establishing and maintaining a register of natural areas and buffer areas, *providing certain forms of protection* and control of registered natural areas and registered buffer areas and otherwise *encouraging and assisting in the preservation of natural areas and features*." Sec. 6.07. (e) of the INAPA tasks the Commission with the "protection of registered areas; (f) protection of habitats of endangered, threatened or rare species;..."

Section 17 of the INAPA states that, "All public agencies shall recognize that the protection of nature preserves, buffer areas and registered areas is the public policy of the State and shall avoid the planning of any action that would adversely affect them… If the proposed action is found likely to have an adverse impact on a natural area, the agency shall study the proposed action to determine possible

methods of eliminating or mitigating the adverse impact. Before implementing any action, the agency shall attempt to mitigate or eliminate any adverse impacts in a manner consistent with the planned action. The Department, Commission, or any affected person may seek a writ of mandamus to compel an agency of State or local government to engage in the evaluation and study required by this Section."

The protection of natural areas from herbicide drift damage is a combined function of all of these legislative authorities.

The following sections in this report provide background on the threats posed to natural areas by pesticide drift and information for the Commission to use in order to protect those areas.

Overview of Herbicide Drift

Herbicides are widely used for many reasons, including weed control in agricultural production and lawn care, vegetation control in right-of-ways, and invasive species control. Herbicide drift can and does occur from each of these uses. A major source of herbicide drift in Illinois is the agricultural use of herbicides for weed control. Approximately 75% of Illinois land, or 27 million acres, is dedicated to agriculture and much of this land is dedicated to the production of two crops – corn and soybeans [4].

While herbicides have been in use for decades in agricultural production, their application had typically been limited to early in the season, before sensitive crops emerged and before many wild plants leafed out. However, in the 1990s, glyphosate-resistant seed technologies were developed, changing the weed management strategies used across tens of millions of acres of agricultural land. These technologies meant that glyphosate could be used throughout the growing season on resistant crops. The widespread adoption of glyphosate-resistant crops and the associated changes in weed management practices led to the evolution of glyphosate-resistant weeds.

The adoption of herbicide-resistant plant technologies is now widespread for some commodity crops, including soybeans, canola, corn, cotton, and sugar beets. Most conventional row-crop agriculture operations rely primarily on chemical methods of weed control. Consequently, the agricultural industry is repeatedly updating chemical mixes to combat ever-evolving agricultural weeds. It is estimated that there are over 521 unique cases of herbicide resistance in agricultural weeds worldwide [5].

In an effort to combat the increasing problem of herbicide-resistant agricultural weeds, biotech companies have developed seed technologies that contain new herbicide-resistant traits, allowing for the production of crops that are resistant to multiple herbicides. Therefore, new herbicides and new combinations of herbicides – some of which are highly volatile – can now be applied throughout the growing season, thus increasing the risks of both particle and vapor drift on non-target areas. For example, recently developed herbicide-resistant technologies allow for the mid-season use of the volatile herbicide dicamba over the top (OTT) of growing soybeans and cotton. In addition to pre-planting use of the herbicide, dicamba is now applied when temperatures are higher and the risk of volatilization is enhanced. Figure 1 illustrates the increased use in dicamba after the release of the new formulations of the herbicide in 2017. The use between 2016 and 2017 more than doubles and was largely driven by the OTT use in non-resistant soybeans.

Figures 1- 4 demonstrate trends in herbicide use for four synthetic systemic herbicides that are widely used in agricultural production. Dicamba and 2,4-D are plant growth regulator herbicides that kill broadleaf plants. Glyphosate and atrazine kill broadleaf plants and grasses. Figure source: U.S. Geological Survey

Figure 1: Dicamba

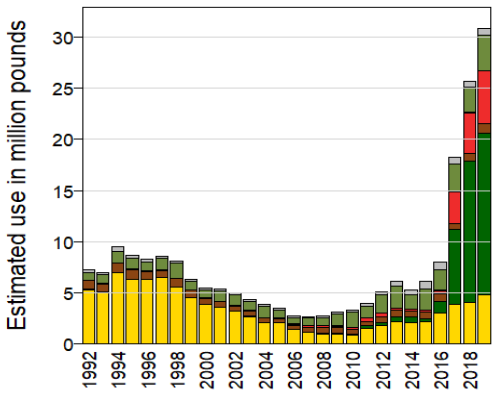


Figure 2: 2, 4-D

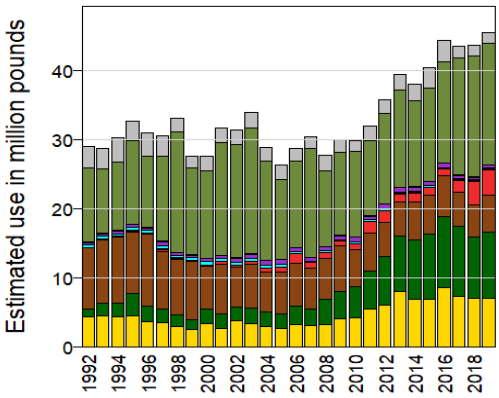


Figure 3: Glyphosate

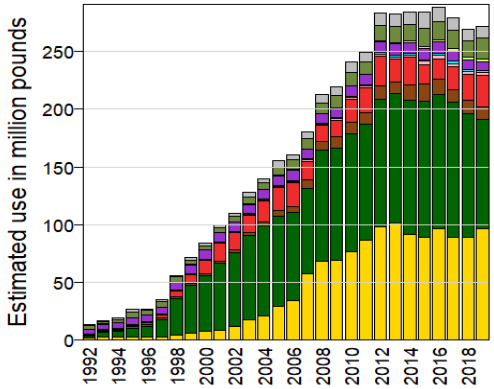
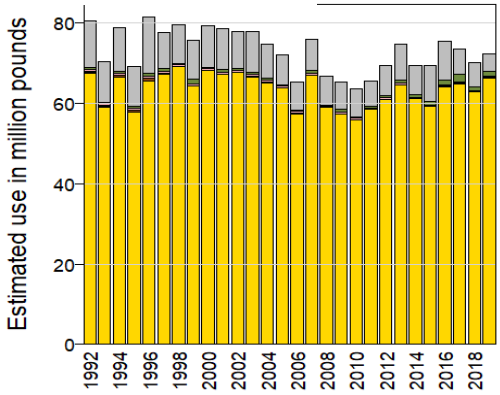
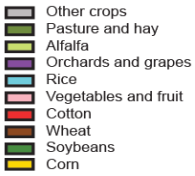


Figure 4: Atrazine





Types of Herbicide Drift

There are two main ways herbicide drift can occur. ***Particle drift*** is the movement of droplets of herbicide solution away from equipment during application; this usually occurs when the applicator applies the herbicide on a windy day. ***Vapor drift*** is the movement of the gaseous form of an herbicide that has volatilized (evaporated) from plant and soil surfaces. Some herbicides can volatilize for days after application and move far away from their target, harming unintended plants. Atmospheric loading describes the volatilization of herbicides from large areas of land that have been sprayed within a similar time frame. High temperatures (of air, leaves, and/or soil), high soil moisture, and low humidity can increase volatilization. Additionally, factors such as tank mixes of multiple herbicides, and the chemical's vapor pressure and pH can influence volatilization. Temperature inversions, or conditions where there is a layer of cool air close to the earth's surface with warmer air above, coupled with high humidity can allow herbicide particles to remain suspended in the air and travel long distances before being deposited on unintended surfaces such as wild plants, landscaping, waterbodies, etc.

Herbicides can be found in ambient air, even in places far removed from potential sources. The long-range transport of herbicides is possible and has been documented for decades [6, 7]. A recent study in Germany examining the types and concentrations of pesticides in ambient air found that pesticides were present at all 49 locations samplers were placed, including the highest mountain in a national park where 13 pesticides were detected. Six pesticides were also detected in devices located within the "Bavarian Forest". Glyphosate was detected in every sample[6].

Two herbicides that are widely used throughout Illinois are the plant growth regulators dicamba and 2,4-D. Both herbicides are known to be volatile, even when applied correctly. Dicamba can begin to volatilize at temperatures in the low 60s and volatility tends to increase as temperatures increase. Both 2,4-D and dicamba can continue to be volatile days after application. Application labels, particularly those for the new formulations of dicamba, are extremely complex and many growers have a limited window of time of when these herbicides can be applied according to label guidelines. When volatilization occurs that results in off-target injury, it is typically impossible to identify the source of injury especially when no misuse of the products was identified.

Both 2,4-D and dicamba can produce visible injury at very low doses. Dicamba can cause leaf cupping and distortion even at 0.005% of the labeled use rate on soybeans. The most common visible symptoms of growth regulator herbicide exposure include leaf curling, cupping, twisting, stunting, discoloration, stem and branch abnormalities, dieback, and fruit delay or abortion (Figure 5, Appendix A).

Figure 5: Examples of symptoms of growth regulator herbicide injury in common native trees.

Flowering dogwood: irregular margins

Post oak: deformed, growth suppressed, chlorosis (yellowing)

Redbud: cupped, curled

Photo credits: Martin Kemper

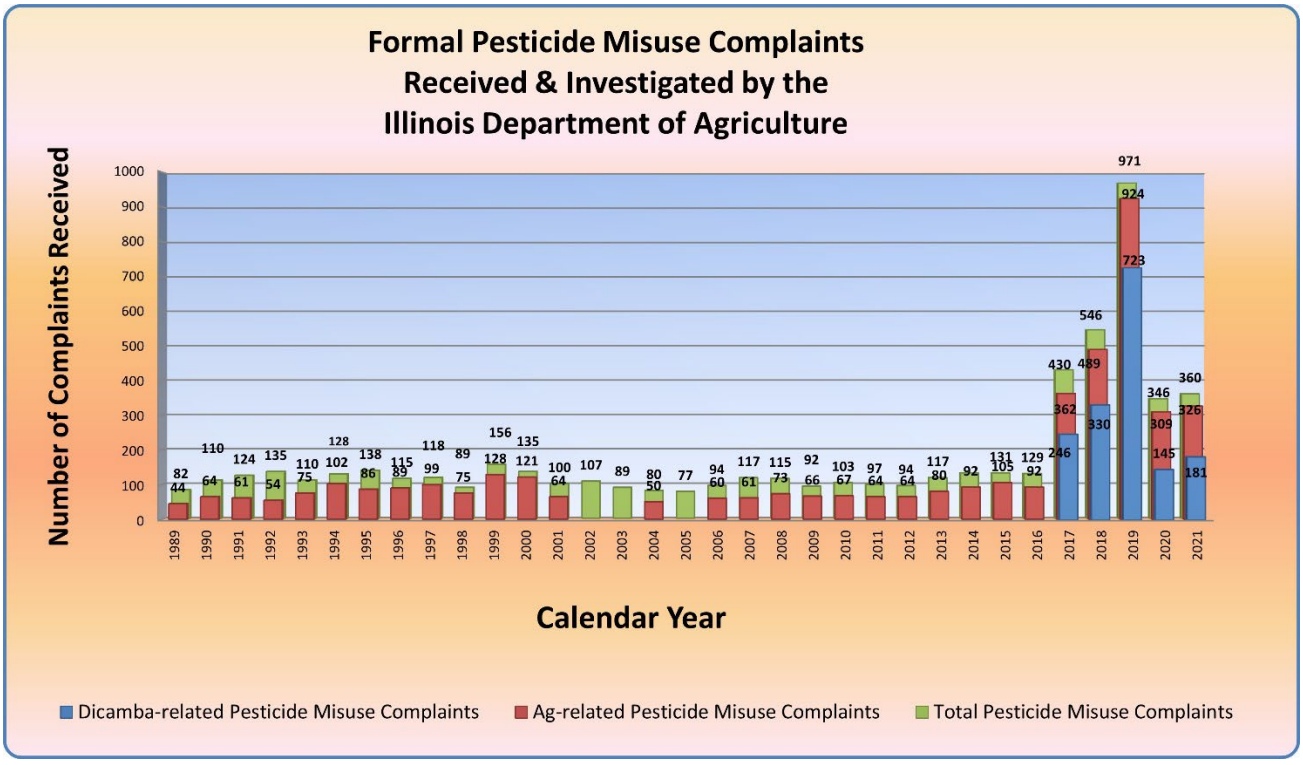
Efforts to Reduce Dicamba Drift

The risk of drift exists with the application of most herbicides. While the herbicide dicamba has been used for decades, the volatility of the herbicide and its tendency to injure non-target broadleaf plants limited its use, mainly to early season weed control, before temperatures and the rate of volatility increased.

In recent years, increased attention has been paid to the off-target impacts to non-resistant soybean varieties caused by the new dicamba products formulated for in-crop (over-the-top – OTT) use. Extensive media reports have highlighted the negative impacts of dicamba drift that many landowners and land managers are confronting and the risks such drift poses to non-target plants. In addition to injuries in non-resistant soybeans, media reports have also highlighted injuries to orchards, organic farms, conservation plantings, public lands, yards, and beekeeping businesses (Appendix B).

Sharp increases in reports of herbicide injury to crops, trees, and private landscaping were documented by state regulatory agencies soon after the release of the new formulations of the herbicide (Figure 6).

Figure 6. Formal Pesticide Misuse Complaints Received by IDOA from 1989 - 2021



Source: Illinois Department of Agriculture
Obtained June 28, 2022

U.S. EPA efforts to reduce off-target injuries to broadleaf plants due to OTT dicamba products include significant label changes, mandatory applicator training, extended buffer requirements, and an additive that was designed to reduce the volatility of the product. Product label requirements now include a downwind buffer of 240 feet between the last treated row of a field and the nearest downwind field edge. Additionally, there is a 57-foot omnidirectional buffer and a 310-foot downwind buffer in fields located in counties that have federally listed threatened and endangered species. [8]

In an effort to reduce the harmful economic and ecological impacts of dicamba drift, the IDOA placed additional rules on the use of the products in Illinois for several years. The additional rules for the 2021 growing season, which are now permanent rules are listed below.

- A pesticide containing dicamba shall not be applied on soybeans if the air temperature in the field at the time of application is over 85 degrees Fahrenheit or if the National Weather Service's forecasted high temperature for the nearest available location for the day of application exceeds 85 degrees Fahrenheit.
- Application on soybeans of a pesticide containing dicamba shall not be made after June 20 of each year.
- Before applying a pesticide containing dicamba on soybeans, the applicator shall consult the FieldWatch sensitive crop registry (https://www.fieldwatch.com) and comply with all associated record-keeping and label requirements.
- Application on soybeans of a pesticide containing dicamba shall not be made if the wind is blowing toward any Illinois Nature Preserves Commission site that is adjacent to the field of application; or an adjacent residential area.

The IDOA noted a reduction in off-target complaints for the 2020 and 2021 growing seasons. While additional restrictions may play a role in the reduction of complaints, it is important to note the majority of formal complaints are crop-related and that many farmers were also proactive and defensively planted dicamba-tolerant seeds on fields they did not intend to spray [9, 10]. This combined with a loss of faith in the reporting process and failure to recognize and/or report injury, likely accounts for a portion of this reduction in formal complaints.

While the modifications made by the IDOA have had some positive influence on the amount of soybean injury occurring on the landscape, the restrictions only apply to formulations of dicamba created for the over the top use in soybeans and cotton. They do not address other formulations of dicamba or other herbicides. And, there are weaknesses even in the OTT dicamba rules. The temperature cut off of 85 degrees does not account for the temperature of plant and soil surfaces, which can often be higher than air temperatures. Nor does the temperature cut off account for the potential for high temperatures in the days following application, which may exceed 85 degrees. The cut-off date of June 20th will likely prevent the use in double-cropping systems; however there are numerous days before June 20th when temperatures exceed 85 degrees and thus conditions will be favorable for increased volatilization.

While the trends in complaints related to soybeans received by IDOA and subsequent regulatory responses have received much attention, monitoring data from a wide variety of uncultivated landscapes including INPC protected sites over the 2020 and 2021 growing seasons have continued to detect significant herbicide exposure events with no detectable downward trends. Additionally, it is important to recognize that the drift as a result from the misuse or volatilization of other herbicides, which do not have cut-off dates, can and does occur throughout the growing season.

The regulatory efforts put in place to better control the documented off-target impacts of the new formulations of dicamba highlight the fact that there is opportunity to make changes and adjustments to herbicide laws and regulations. The extreme amount of injury occurring across the landscape from the use of the new formulations elevated a problem that has been occurring for decades.

Documenting and Reporting Drift (How the complaint process matters.)

IDOA has one process for citizens to report herbicide related injuries to property, the Pesticide Incident Complaint process, which is detailed in the Illinois Pesticide Act rules. Property owners that observe injury can voluntarily submit the Pesticide Incident Complaint Form (Appendix C) to the IDOA. The complaint process is an important tool used to regulate the use of pesticides in Illinois.

Three reasons the complaint process is important are:

1) It is important to make IDOA aware of off-target herbicide related injuries, regardless of whether a known misuse has occurred.
2) The complaint process can uncover instances of misuse that are responsible for observed injury in forest and other non-crop areas that have characteristics of vapor drift exposure.
3) If an investigation into a complaint results in no misuse or violation, but symptoms of herbicide injury exist, then the result is supportive of vapor drift causation.

With an understanding of some of the benefits of the complaint process, it is also important to understand the complexities associated with using a voluntary complaint process for evaluating the efficacy of pesticide regulations. One problematic aspect of the complaint process is that the submission is considered an "allegation of misuse". It is IDOA's responsibility to investigate each submission to determine if misuse was the cause of the injury. Usually, a neighbor, a neighbor's tenant, or a neighbor's pesticide application provider will be the subject of an investigation.

The current reporting process in Illinois was designed to address direct overspray and particle drift due to applicator error and misuse. If a complaint is filed and misuse is found, then enforcement steps are taken. Depending on the nature of the misuse incident, enforcement actions can range from warning letters to fines. All penalties are determined through a point system that is established in the Illinois Pesticide Act. If no misuse is found, the landowner filing the complaint often receives a letter stating that no source or misuse can be identified. The process in Illinois was not designed to evaluate the cause or source of injuries associated with the medium to long-range transport of pesticides associated with vapor drift.

The use of a voluntary pesticide misuse complaint process as a tool for decision making, regulatory action, and gauging the safety of a pesticide is also problematic, and the number of complaints filed should be kept in perspective. It is widely recognized that instances of pesticide injuries to crops are under-reported; injuries to non-crop species such as trees in private residences and forested lands, including natural areas that provide crucial habitat for wildlife, are even more under-reported. The U.S. EPA recently released a report estimating that only 1 out of every 25 instances of pesticide drift is reported across the U.S.[11].

There are many reasons for this under-reporting:

- Owner may be responsible for causing the damage to their own property.
- Intense social pressure against reporting a neighbor's negligence, even if one's own crop or property is damaged.
- Loss of faith in the reporting process.
- Lack of Presence. 1) Many landowners are absentee and cannot directly observe herbicide symptoms. 2) Owners and managers who do live in close proximity often avoid entry into forests

and other natural lands during the growing season when weather and arthropod discomforts are higher.

- Lack of information and awareness. Off-target herbicide injuries are occurring in places that are well-removed from agricultural fields, certainly beyond the distance of recommended setbacks and buffer zones. Many landowners and land managers are not aware of or on the lookout for potential symptoms. This lack of awareness results in a failure to look for symptoms that are otherwise readily observable or a misattribution of symptoms to disease or pest injuries if they are observed.

Because complaints are narrowly tied to misuse investigations, they represent a limited tool for addressing injuries associated with vapor drift, regardless if an investigation is carried out or not. This is due primarily to the long distance transport volatile herbicides can undergo.

It is valuable to recognize that the majority of the complaints being received by IDOA are also crop-related. Millions of acres of non-resistant soybeans have been reported injured each year throughout the Midwest since the new formulations of dicamba were released [11, 12]. However, there are currently no estimates available for the acreage of vulnerable wild plants injured by off-target movement of dicamba over this time period. The recent rise in herbicide injuries to native plant communities is occurring when funding for many state and federal ecological monitoring programs is low. Many agencies are also understaffed and do not have the resources to perform the level of ecological monitoring that is needed in order to evaluate the health of ecosystems injured by herbicide drift. These same ecosystems are also under the threats of habitat loss, climate change, increased pesticide use, invasive species, disease, and pest pressures.

Ecological Implications of Widespread Drift

Impacts to plant communities

Off-target herbicide injuries to native trees and other plants have been occurring for as long as herbicides have been used. Numerous resources and handbooks on tree and plant health address the complexities associated with identifying the potential symptoms of herbicide drift [13]. Before the creation of glyphosate-resistant crops, herbicide drift injury to native plants from the use of agricultural herbicides largely occurred early in the growing season as a result of pre-planting weed control. Many trees and other plants are at the sensitive stages of bud-swell and leaf emergence during these early spring application periods and are therefore susceptible to drift-related injuries.

However, the widespread adoption of glyphosate-resistant weed technologies added significant risks for native plant communities. The increased and continued use of glyphosate (Figure 3), from early spring to mid-season application, pose additional risks to wild plants and the wildlife that depend on their existence in agricultural landscapes. Studies performed in Iowa attributed the reduction of in-field populations of milkweed, an obligate host plant for the monarch butterfly, to the widespread adoption of glyphosate-resistant cultivars and the post-emergent application of the herbicide [14].

In recent years there have been widespread reports of broadleaf trees and plants with injuries symptomatic of herbicide exposure in Illinois. These injuries are largely, but not exclusively, due to drift from agricultural lands. Failures to abide by label instructions, the overall increased use of dicamba, 2,4-D, and other herbicides to combat herbicide-resistant weeds, and the use of volatile herbicides over the top of resistant crops all contribute to off-target injuries to trees and other plants.

The increased media reports as well as data collected by monitoring efforts that document off-target herbicide injuries, underscore the fact that herbicide drift is causing injury far beyond mandatory buffer zones for OTT dicamba products [15-18]. Many injuries are also likely the result of pre-planting weed control, the use of 2,4-D, and the use of older formulations of dicamba or other herbicides in products with shorter or no buffer zone restrictions.

The incidence of injuries to native trees, shrubs, and other plants is likely much higher than is documented through the pesticide misuse complaint process and the limited monitoring efforts that currently exist. The use of herbicides, particularly volatile herbicides, for early season and pre-planting weed control and throughout the growing season for in-crop weed control threatens a wide array of flowering broadleaf plants. Many, if not all, plant communities in Illinois are also facing the additional threats of habitat and biodiversity loss, insect pressures, disease, pollution, invasive species, and climate change.

The stress plants experience from exposure to herbicide drift is a major ecological concern and a threat multiplier of the aforementioned stressors. The stress of repeated exposure to herbicide drift can weaken trees, making them more susceptible to disease and pests. Trees that have experienced multiple exposures to growth regulator herbicides can exhibit decreased canopy cover, reduced plant vigor, and even death [19]. Herbicide drift from 2,4-D or dicamba can cause severe injuries such as branch dieback and arrested development in trees [20]. Depending on the developmental stage during exposure, growing conditions, and overall plant health, many annual and perennial herbaceous plants can "grow out of" visible symptoms of herbicide exposure. However, studies of woody perennial species have shown symptoms of injury remain visible long after exposure [21]. Symptoms in woody perennial species can remain for the entire growing season and may be observed in fallen leaves. Little is known about how repeated herbicide drift impacts seed viability; the quality and quantity of nuts, fruits, pollen, and nectar production; root and vascular health; growth, or other factors related to plant health.

Oaks appear to be of particular concern when examining the ecological impacts of herbicide drift on ecosystem health throughout the Midwest. They are keystone species in Illinois' hardwood forests and are important economically as well. Monitoring efforts and anecdotal evidence of oaks injured by herbicide drift have raised concerns about the impacts to tree health and longevity. Injuries to white oak seedlings exposed to 1%, 10%, and 25% of label use rates of 2,4-D and dicamba during the leaf unfolding stage varied. Injuries included leaf cupping, strapping with parallel venation, and initial leaf cupping followed by the death of the growing point. Acetochlor and metolachlor inhibit the growth of seedling shoots and are both widely used as pre-emergent herbicides in the spring. Exposure to acetochlor + atrazine or metolachlor during the leaf unfolding stage caused tatters, another symptom frequently associated with herbicide drift [22].

Not all plants respond to herbicide exposure the same way and there are many factors that influence a plant's ability to recover, including species sensitivity, exposure rate, frequency of exposure, life-stage, climatic stressors, and overall plant health. Some species are considered extremely sensitive to herbicides, experiencing harm at a tiny fraction of the label application rate [23]. Several native species, including elderberry, pin oak, and Eastern redbud, are very sensitive to dicamba and 2,4-D, exhibiting visible symptoms at 1/200 label application rates. Ornamental fruit and nut tree species have different sensitivities to dicamba and 2,4-D [21]. However, the same study found that all 18 species examined showed sensitivity to drift rates of 2,4-D and dicamba. Plants can also have different responses to common combinations of herbicides. Some plants can be less affected by exposures of mixtures of

herbicides such as the common combination of glyphosate and dicamba [23], while others can be more affected [21, 24].

The health and preservation of rare, threatened, and endangered species are also of concern. The increased use of volatile herbicides and the use of new combinations of herbicides throughout the growing season to combat herbicide-resistant weeds presents a real threat to rare, threatened, and endangered plant species, plant communities, and the animals that depend on them. In a memo recently released by the U.S. EPA regarding the status of over-the top dicamba use, the agency stated that, "There have also been more than 290 incidents reported in counties where additional restrictions were implemented to prevent off-field exposures to endangered species and critical habitat. The Agency is not aware of any "take" where an endangered species or critical habitat has been harmed. However, these incidents suggest the possibility that a "take" could occur" [11].

It is valuable to recognize that many nature preserves and Illinois Natural Areas Inventory sites with listed species are in proximity to agricultural lands. Currently, there are 432 Nature Preserves and Land and Water Reserves that at least partially contain a listed species and there are 1,723 Endangered and Threatened records that are at least partially within a Nature Preserve or Land and Water Reserve. Of the 489 species that are listed as threatened or endangered in Illinois, 394 exist at least partially within a Nature Preserve or Land and Water Reserve.

Herbicide drift can impact native plants in numerous ways. Studies have demonstrated that low levels of dicamba and glyphosate can negatively impact the reproduction of wild plants [23, 25]. Additionally, plants that are in reproductive stages during a drift event can have impaired fertility [26]. Simulated drift levels of 1% of the field application rate of dicamba have been found to delay, reduce, or suppress the flowering of wild plants and reduce pollinator visitation [25]. Wild plants growing near treated crop fields are at risk of sublethal to lethal injury from particle and vapor drift of many herbicides. Depending on the severity, timing, and the number of exposures, the consequences for native plant populations, including rare and keystone species, could be great. Repeated exposures of agrichemicals to non-target plants can be additive and synergistic [27].

Impacts to wildlife

Multiple drift events during a single growing season are likely to have a greater effect on the floral and tissue resources diverse plant communities provide, thus having a greater impact on wildlife that depend on them. Single exposures each year for several consecutive years may also have deleterious effects on plant health, leading to impacts that could ripple through food webs.

Stressors such as invasive species, insecticide use, habitat loss, pollution, and climate change are also contributing to declines in invertebrate populations worldwide [28, 29]. Off-target herbicide injuries to plants can have significant and easily overlooked impacts on native invertebrate populations. Herbicide drift injuries to wild plant communities increases stress on invertebrate populations and could have cascading impacts on other wildlife and ecosystem functions.

Wildlife may be exposed to herbicides and other pesticides by direct contact through drift or by consuming contaminated plant and floral resources. As with many plant species, the toxicity of an herbicide to invertebrates or other wildlife can vary widely based on multiple factors including the chemical(s) in question; the rate, timing, duration, and frequency of exposure; and the health of that individual.

Dicamba and 2,4-D herbicides and their inactive ingredients can have lethal and sublethal effects on non-target beneficial insects [30]. Other invertebrates are likely to experience negative effects associated with exposure to herbicides. A recent meta-analysis revealed that bees chronically exposed to glyphosate experienced increased mortality [31]. Declines in forage quantity and quality can also impact invertebrate communities [32].

Environmental changes that negatively impact the quantity, quality, and diversity of floral resources can have developmental and physiological impacts on bees, potentially impacting the health of individual bees or colonies [33-35]. Bees that gather nectar and pollen which is low in quality, and therefore provides lower nutrition, may have reduced fitness and survival. Additionally, due to reduced floral resources as a result of off-target drift, bees may need to fly greater distances to find nectar and pollen, therefore increasing physical stress and risk of predation.

Loss of or shifts in food resources, food quality, or habitat can also affect other wildlife, causing them to travel greater distances for resources, which increases their risk of mortality and requires more energy. Changes in host plant quality can influence reproductive strategies in invertebrates including egg size, egg resource allocation, and nutrition quality for developing young [36]. Largescale changes in agricultural lands have been identified as indicators for declines in bird species [37]. Insectivorous birds and other predators may also be negatively impacted by shifts in insect declines related to resource losses associated with herbicide drift [36, 38].

This report is not intended to provide a comprehensive literature review on the impacts of herbicide drift on wild plant and animal populations. While new studies are published each year that examine the impacts of herbicide exposure to native species, significant gaps remain in our understanding of an individual species or an ecosystem's ability to recover from singular or multiple exposures to herbicide drift. Applying the knowledge which is gained through scientific studies to the observations made through monitoring and reporting efforts is critical.

The current reporting system administered by the IDOA does not provide the information necessary to properly understand and evaluate the extent of drift exposures — particularly of vapor drift — to protected lands. Nor is it designed to assess the environmental impacts associated with vapor drift. As designed, it is unable to protect cultivated and wild plants from unreasonable harm associated with vapor drift.

The limited monitoring that is currently being performed indicates that the issue of herbicide drift injury to native plant populations is widespread and could have deleterious effects on the health of these ecosystems. Additionally, the current monitoring efforts do not provide the wide range of information necessary for a comprehensive understanding of the ecological implications of widespread drift, nor are they robust enough to provide an adequate assessment of the geographic distribution of drift injuries, or the severity of those injuries throughout the state. Nevertheless, current monitoring efforts highlight the fact that injuries are occurring at a much broader scale than what complaint reports indicate and they provide valuable information that can lead to a greater understanding of the impacts repeated herbicide exposures have on species.

Overview of Monitoring Information

The current efforts that examine and document potential exposure to off-target herbicide drift vary greatly in the details they capture and the way that information can be utilized. When comparing monitoring programs it is important to consider the intent of the programs. With the exception of the monitoring and sampling that PRN performed on some state lands and/or INAI sites and injury reports that were passed along to the Department of Agriculture, data and information have not been proactively shared between the programs.

As with many field studies, there are several limitations with monitoring and tissue sampling data, and it is important to recognize them. One of the most limiting factors associated with all efforts aimed at better understanding herbicide drift is resources. All of the efforts that are currently underway are limited by staff and volunteer availability and financial resources. Proper monitoring and data entry, travel to visit sites, data management and analysis, tissue sampling and analysis all take considerable time and financial resources.

There is a certain level of subjectivity in the monitoring data, as is common in rapid ecological assessments. It is impossible to entirely remove subjectivity in field settings. However, in an effort to minimize subjectivity, both IDNR and PRN provided training opportunities for staff and volunteers. Prairie Rivers Network also has a webpage where forms, informational videos, and a photo library of symptoms can be found. The majority of the monitoring and sampling for PRN's Tree and Plant Health Monitoring Program was performed by a handful of highly trained and experienced volunteers. Numerous IDNR and INPC staff also participated in trainings and have an excellent understanding of the issue.

The Illinois Department of Natural Resources and the Illinois Nature Preserves Commission

IDNR developed a monitoring and reporting program to document the presence and extent of off-target exposures to the State's land resources and natural areas that could be attributed to drift or volatilization from agricultural herbicide application on surrounding lands. This includes sites within the Illinois Nature Preserves System, which is an important component of the program because the INPC and IDNR have a statutory responsibility to protect these sites under state law. The monitoring information collected to date has largely focused on identifying the presence of symptoms at sites with the goal of better understanding their prevalence and submitting reports associated with potential misuse to the Illinois Department of Agriculture.

Prairie Rivers Network – Tree and Plant Health Monitoring Program

The Tree and Plant Health Monitoring Program formally began in the spring of 2018 and is intended to be used as a rapid assessment of the presence of symptoms of herbicide injury at a location. Specific information is gathered at each site in an effort to gain a better understanding of the geographical distribution of symptoms, species impacted, frequency, and severity of symptoms of growth regulator herbicide drift impacting trees, native plant communities, and crops that are not herbicide-resistant. This program also collects leaf tissue samples from trees at sites monitored for analysis of herbicide residue. Due to the lack of awareness on this issue, the program was also developed to educate the public, land managers, and decision-makers on the widespread phenomenon of symptoms of herbicide drift in trees and other plants and to demonstrate the need for more monitoring and meaningful efforts that greatly reduce off-target injuries to plants.

The Illinois Department of Agriculture

The IDOA does not monitor. They are tasked with administering the Illinois Pesticide Act. The IDOA's voluntary pesticide misuse complaint process allows growers and landowners to report symptoms of off-target pesticide drift. The agency investigates complaints submitted. If misuse or off-label use of a pesticide occurred that resulted in the injury of crops, livestock, people, or property, enforcement actions in accordance with the Illinois Pesticide Act may be taken.

Additional monitoring information

The Morton Arboretum

The Morton Arboretum was funded through a multi-year, multi-state grant to collect tissue samples of trees that are symptomatic of herbicide drift. They did not perform monitoring at sites where samples were collected. The intent of the grant was to document the extent of herbicide drift damage on woody plants (i.e. trees and shrubs) on state lands through tissue sampling. Where possible, samples were taken in cooperation with IDNR district foresters and natural resource managers. The samples were submitted to the South Dakota State University (SDSU) diagnostic lab for growth regulator herbicide analysis. Results from the tissue analysis were reported to the affected parties (i.e. district foresters and natural resource managers) and the IDOA was kept apprised of the results. No further action was taken regarding the leaf tissue analysis results. Samples taken each year were from a very small subsample of trees with reported damage associated with locations requested from IDNR district foresters and natural resource personnel.

The Illinois Forestry Association

The Illinois Forestry Association (IFA) has fielded reports from private landowners with concerns and firsthand experience with tree damage resulting from off-target herbicide drift for several years. In 2021, the IFA developed an online form that allows landowners to submit pictures and information on symptoms associated with suspected herbicide injury to their trees. This reporting form is not accusatory in nature but exists to capture data that could be important to mitigating this issue in the future. The IFA aims to share this information with forestry agencies, nonprofits and other professionals so that we can all collectively learn more about the magnitude of this issue in Illinois.

Summary of Monitoring Information and Discussion

The two main efforts which monitor for symptoms of herbicide injury in non-target plants are PRN's Tree and Plant Health Monitoring Program and the IDNR's monitoring program, which is also used by INPC staff. While communication between programs has occurred over the past several years, there was no formal coordination between PRN and IDNR during the development of monitoring efforts prior to 2022. Both programs have had improvements and refinements made since their inception.

Due to the nature of the data collected by the state and the modifications that were made to the program over the years, considerable time was dedicated to organizing and verifying the data collected. However, due to differences between the two programs, a comprehensive analysis and comparison of the results is beyond the scope of this report.

The design of the IDNR reporting form for the monitoring seasons prior to 2022 presented challenges when examining the data. Several fields, including site name, visit number, species affected, and site description were fill-in-the-blank. Various field personnel interpreted and used these fields in

significantly different ways. In addition, without a standardized method of naming sites, recording locations monitored within a site, species monitored, and symptoms expressed by each species, it is often difficult to glean meaningful information about the location, spatial characteristics, pattern, severity, and species affected by herbicide drift. Considerable time was spent clarifying site names, site type (Nature Preserve, Land and Water Reserve, etc.), and County of Injury. The types of injuries reported on individual species cannot be determined and was not feasible for this report.

In many of the reports, particularly those that did not report injury, it was difficult to determine the size of the area monitored and if staff walked through the site or just observed the location from a vehicle. Some reports that listed no injury were entered as a group into the database, rather than individual reports.

Comparison of Programs Which Record Herbicide Drift Exposures

Table 1 compares key components of all monitoring and tissue sampling efforts that are currently in place. As stated previously, the intent of the individual programs varies widely, which also limits the ability to combine the information that is being gathered. There are inconsistencies throughout each category and across all efforts. Some categories such as site name, county, number of visits per year, species observed, symptoms observed, and the estimated number of individuals within species expressing symptoms could be documented in each effort with minimal added effort on the part of the recorder/monitor.

During the 2022 calendar year, PRN and IDNR collaborated to make improvements to monitoring forms. The two programs now have considerable overlap in the type and specificity of the data they collect. Some coordination between staff on the monitoring of specific portions of the state has also occurred.

Table 1 compares key components of all current monitoring and tissue analysis efforts that aim to document symptoms of herbicide drift injury to non-target plants.

Table 1. Comparison of Herbicide Drift Injury Monitoring & Tissue Analysis Efforts					
	PRN Monitoring and Tissue Analysis	**IDNR/INPC Monitoring and Tissue Analysis**	**IDOA Misuse Reporting**	**Morton Arboretum Tissue Analysis**	**IFA Monitoring**
Consistent site naming among observers and across years	Yes	No	NA	No	NA
GPS coordinates	Yes	Yes	Yes	No	Yes
County	Yes	No	Yes	No	Yes
Years of monitoring	4	4	4 + (Complaint records only) *	NA	1
Multiple visits to site/year	Yes	Yes – but difficult to determine	NA	NA	NA
Size of area monitored/sampled	Yes	No	Yes/inconsistent	No	No
Lists species impacted at site	Yes – drop-down	Fill in – inconsistent method of naming	None in summaries	No	Fill-In
Estimated # individuals/species impacted	Yes	No	No	NA	No
Estimated % trees w/ symptoms	No	Yes	No	NA	No
Estimated % herbaceous plants w/ symptoms	No	Yes	No	NA	No
Photos of symptoms	Yes	Yes	Not requested	Some	Yes
Symptom severity rating	Yes	No	No	No	No
Estimated distance to nearest potential source	Yes, for most sites	No	No	No	No
Notes section for additional information	Yes	Yes	Not in summaries	Yes	Yes
Cutoff date for monitoring and reporting	No	Yes	No monitoring/No complaint cutoff	No monitoring/No sampling cutoff	No
Monitoring for tissue samples	Yes	No	Site visit is performed by staff	No	No
Tissue sampling protocol	Yes	No**	Unknown	No	NA
Tissue analysis	Yes	Yes**	At some locations	Yes	No

* 4 years of IDOA annual Misuse Enforcement Report records were obtained via FOIA
** In 2021 PRN assisted in collection of samples at INPC locations. INPC paid for the analysis of these samples.

Monitoring Findings – Species Impacted and Severity of Symptoms

Tables 2 and 3 provide a summary of the data collected through the PRN Tree and Plant Health Monitoring Program. The purpose of these tables is to provide information on the extent and severity of symptoms documented, as well as the species in which symptoms have been observed. The PRN monitoring efforts documented symptoms of growth regulator herbicide injury in a total of 188 species including 62 species of herbaceous plants, 83 species of trees, and 43 species of shrubs and woody vines (Appendix D).

At the INPC sites that were monitored through the PRN Tree and Plant Health Monitoring Program, Eastern redbud, several species of oaks, and boxelder were the most frequently reported tree species with symptoms (Table 2). It is important to note that due to staff and volunteer availability, the majority of the sites PRN monitored were located in the southern third of the state.

Table 2 shows the 20 most frequently reported species from INPC and non-INPC sites that were recorded in the PRN database.

Table 2. 20 Most Frequently Reported Species – PRN Monitored Sites		
Scientific Name	**Common Name**	**Frequency of Locations with Symptoms 2018-2021**
Cercis canadensis	Eastern Redbud	221
Quercus velutina	Black Oak	209
Quercus stellata	Post Oak	203
Quercus alba	White Oak	203
Toxicodendron radicans	Poison Ivy	172
Acer negundo	Box Elder	169
Quercus palustris	Pin Oak	163
Quercus rubra	Red Oak	160
Quercus imbricaria	Shingle Oak	158
Carya spp.	Hickory	141
Ulmus spp.	Elm	141
Celtis occidentalis	Hackberry	131
Prunus serotina	Wild Black Cherry	94
Vitis spp.	Grape	82
Platanus occidentalis	Sycamore, Buttonwood	81
Quercus macrocarpa	Bur Oak	78
Fraxinus spp.	Ash	78
Cornus florida	Flowering Dogwood	77
Diospyros virginiana	Persimmon	69
Quercus marilandica	Blackjack Oak	65

Oaks appear to be particularly affected by growth regulator herbicides. They are among the most frequently observed species with symptoms in the PRN monitoring program. Numerous sites PRN has monitored over the past four years show declines in the health of several species of oaks including post, white, black, blackjack, and pin. Oaks are a keystone species in Illinois hardwood forests in which they provide important food resources for wildlife and serve as valuable host plants to hundreds of species of Lepidoptera. They are important economically as well.

Table 3 provides a summary of observations made of oak species at INPC sites. Data was collected by PRN volunteers and INPC staff from 2018 to 2021. At large sites, where there were numerous individuals of a single species, the number of symptomatic individuals was estimated during the walk through of that site. For small sites, or sites that had a small number of individuals of a certain species, each symptomatic individual was recorded. PRN has used a rating system to evaluate the severity of visible

symptoms in trees and plants. Symptoms were rated between zero and ten according to the scale below. A rating of 10 was reserved for trees that leafed out and then died or appeared to be dying. Examples of each category can be found in Appendix E.

0 = No symptoms
1, 2 = Slight symptoms
3, 4 = Light symptoms
5, 6 = Moderate symptoms
7, 8 = Severe symptoms
9, 10 = Extreme symptoms

Table 3. Oak Injury Data for PRN Monitored INPC and non-INPC Sites – All years

Scientific Name	Common Name	Highest Av Injury	Lowest Av Injury	Av Injury	Number of Locations with Injury	Locations Rated with Injuries Greater than 5	Est. Number of Individuals with Symptoms
Quercus stellata	Post Oak	5.3	2	3.4	203	129	5324
Quercus alba	White Oak	5	1.2	2.9	203	108	3494
Quercus velutina	Black Oak	4.6	1.8	3.1	209	101	2714
Quercus nigra	Water Oak *	4	2.8	3.4	5	2	35
Quercus rubra	Red Oak	3.9	1.8	2.8	160	50	1095
Quercus acutissima	Sawtooth Oak*	3.8	2	2.9	8	2	29
Quercus marilandica	Blackjack Oak	3.8	2.4	3.1	65	16	607
Quercus pagoda	Cherrybark Oak	3.8	2	2.9	14	3	88
Quercus macrocarpa	Bur Oak	3.6	2	2.8	78	21	461
Quercus palustris	Pin Oak	3.6	1.6	2.5	163	39	1585
Quercus bicolor	Swamp White Oak	3.3	1.4	2.3	52	13	607
Quercus phellos	Willow Oak	3.3	3.1	3.1	7	1	9
Quercus imbricaria	Shingle Oak	3.2	1.6	2.2	158	23	1613
Quercus lyrata	Overcup Oak	3.2	2.2	2.7	10	1	44
Quercus shumardii	Shumard Oak	3.1	1.4	2.2	17	4	91
Quercus muehlenbergii	Chinkapin Oak	2.7	1.8	2.1	46	3	161
Quercus falcata	Southern Red Oak	2	1.8	1.8	4	0	7
Quercus coccinea	Scarlet Oak	1	1	1	1	0	1

*Denotes adventive species
Note: Locations were only counted once a year. Multiple visits to a site were excluded

Comparison of Two Monitoring Reports from IDNR

Table 4 below provides examples of two reports that were submitted to the IDNR monitoring program. Several columns of information have been removed from this table in order to maintain the anonymity of the site and staff. Information in the columns was simplified for presentation. Both reports were performed by the same staff person and both reports were filed to the department before the 2021 cutoff date for reporting.

Both reports document symptoms in a wide variety of plants at State Natural Areas. The percentages of trees damaged at both sites is 50% or greater. Symptoms are consistent between both sites and are listed as yellowing, bleaching, small size, irregular margins, thickened tissue, and cupping. Both locations note secondary growth in trees is occurring and report that while insect damage is present, it does not resemble the symptoms of herbicide drift. One difference between the sites appears to be where the observations were made. The observations at Site A were made along the main road that goes through the site, while Site B has observations along the field edge and throughout the area. While there are differences in the reports and the extent of the injuries reported, the information presented leads one to question why Site A was not reported to IDOA and Site B was.

Table 4. Comparison of Two IDNR Monitoring Reports

Monitoring Details	Site A	Site B
Reported to IDOA	No	Yes
Observation date	6/15/2021	7/7/2021
County	Pope	Johnson
Site type	State Natural Area	State Natural Area
% trees damaged	75%	50%
% plants damaged	25%	75%
Multiple species damaged	Yes	Yes
Leaf discoloration	Yellowing, bleaching	Yellowing, bleaching, light green, spotted
Dieback of actively growing regions or death?	No	No
Canopy dieback	Yes	No
Leaf distortion	Small, irregular margins, thickened tissue	Small, thickened tissue, irregular margins
Leaf cupping	Margins cupped up and down	Margins cupped up and down
Secondary growth	Yes	Yes
Insect or disease damage	Yes	Yes
Does insect damage resemble chemical drift damage?	No	No
Oak tatters?	No	No
Oak light in color, lacking leaves?	Yes	Yes
General description of injury	Across range of species including chinkapin oak, ash, elm, black oak, red mulberry. Mature, canopy individuals with somewhat thin foliage. Damage includes cupping of leaves and epinasty. Wingstem shows some deformation, twisting, and yellowing where there is new growth.	Species include black walnut, ash, persimmon, box elder, red oak, sweetgum, elm, black cherry, shingle oak, hickory. All sizes exhibit damage.
Is there a pattern/gradient to the injury?	Observations made solely from main road through site.	Moderate to severe along west boundary adjacent to existing soybean field, but damage observed throughout.
Photos of injury	5 submitted	13 submitted

Table 5 provides a summary of all pesticide complaints submitted to IDOA and ensuing misuse actions for 2018-2021. The reports submitted by the IDNR and the actions taken on those reports are also listed. It is important to note that the IDNR system has a growing season cut-off date for field submission of reports that will be considered for forwarding to IDOA. IDOA does not have a cut-off date for accepting reports. Additionally, PRN data indicate symptoms of herbicide exposure, in trees especially, are readily observable throughout the growing season.

Field staff submitted 259 reports of injury in the years 2018-2021 through the IDNR reporting system. IDOA reported receiving 103 complaints from IDNR over the same time period. We were not able to determine the reasons some reports were not reported to IDOA. There may have also been additional observations of injury made by staff that were not reported due to the cutoff date.

Table 5. IDOA Complaints and Ensuing Misuse Actions 2018-2021									
Year	**Total # of Complaints Received by IDOA**	**Total # of Complaints Deemed Misuse Cases[1]**	**Total # of Complaints Submitted After Aug. 1**	**# of Misuse Determinations After Aug. 1**	**Last Date Misuse**	**% Misuse (all cases)**	**INDR Data - Monitored Locations with Damage**	**% Misuse Cases from IDNR Pesticide Injury Reports to IDOA**	**Misuse Actions (IDNR referrals)**
2018	547	280	111	51	9-Nov	51%	26	3 of 13[2] = 23%	3 Wrn Ltr
2019	972	271	666	139	5-Dec	28%	50	3 of 28 = 11%	1 Wrn Ltr, 2 Fine
2020	347	123	99	19	9-Nov	35%	61	0 of 35 = 0%	none
2021[3]	234	78	29	4	11-Nov	33%	80	0 of 27 = 0%	none
Total	2100	752	905	213		avg = 36%	217	avg = 6%	avg = 1.5/yr

[1] Type of misuse is not recorded in IDOA summary data.

[2] Damage was not determinable in any of the 26 monitoring reports in the IDNR data for 2018, but cross reference with PRN and IDOA data indicate 13 reports (complaints) were submitted to IDOA.

[3] IDOA data for 2021 is through the end of March 2022 - some misuse case and outcomes not yet recorded. However, all listed IDNR cases were closed.

The number of voluntary complaints received by IDOA for the years 2018-2021 are summarized in Table 5. The total number of IDOA misuse actions for the four years included in the table above resulted in 15 advisory letters, 559 warning letters, and 273 fines. The average fine amount was $735. The total number of misuse actions are greater than the number of misuse cases because a misuse case may generate more than one action regarding one or more applicators. Complaint numbers spiked sharply in 2018 and 2019 due to dicamba related complaints, then decreased in 2020 and 2021. As discussed previously, some of this decrease in complaints can be attributed to the increase in applicator training requirements, changes the manufacturer made to the label, and the Illinois-specific additional restrictions that were placed on the use of over the top dicamba products. However, as previously stated, defensive planting of dicamba tolerant soybeans and failure to report due loss of faith in the reporting system or social pressures likely also contributed to these declines in complaints. While overall complaint numbers declined from 2019 to 2021 the percentage of misuse determinations remained similar from 2019 onward.

Of the 103 complaints IDOA reported receiving from IDNR from 2018-2021, 94% (97 of 103) of all cases and 100% of recent cases were closed by IDOA with no misuse findings or subsequent actions. Beyond reporting misuse actions (e.g., advisory letters, warning letters, fines), IDOA does not summarize findings regarding actual causation of injuries. Misuse and causation, as previously noted, are not necessarily linked.

IDOA records indicate that of the approximately 100 complaint cases IDOA reported receiving from IDNR from 2018-2021, it took tissue samples to determine the presence of specific herbicides in two instances - 2% of the time. This compares to an average tissue sample rate for other complaint cases reported to IDOA during 2018-2020, of approximately 7% (2018-2020 data).

Tissue Sampling

Tissue samples are an important part of identifying specific sources of off-target herbicide injury. There are numerous factors that can impact the length of time that pesticide residues remain at a detectable level in leaf tissue. These factors include (but are not limited to) the pesticide in question, weather, plant species, rate of exposure(s), and interactions of more than one pesticide from either the mix applied to nearby field(s) or from contact with other sources of particle or vapor drift. Normally tissue samples are taken with no knowledge of the source, rate, or timing of herbicide exposures to the plants being sampled. Nor is there typically any way to identify if the exposures detected originate from a single or multiple sources. Despite these limitations, important inferences can be made from sets of tissue samples when spatial, temporal, chemical, and/or other patterns emerge.

Because of the predominant symptoms observed, analysis for growth regulator herbicides was prioritized in all years for tissue samples collected by both PRN and IDNR/Morton Arboretum. The herbicides analyzed did vary by program and year.

PRN Tissue Sampling (PRN/INPC)

Tree leaf tissue samples were collected by PRN for the Tree and Plant Health Monitoring Program. PRN staff and volunteers also assisted INPC staff in the collection of tissue samples on INPC sites. The same analysis protocols and handling procedures were followed during all years for all samples collected by PRN (Appendix F). Samples were kept in a cooler until they could be frozen. Frozen samples were packaged in coolers with ice packs and shipped overnight or next-day to the lab. Samples were shipped early in the week to ensure they arrived prior to the weekend.

None of the samples collected by PRN or INPC staff were taken from areas where there was evidence of chemical weed control use in the surrounding turf or surfaces directly around the trees. Tissue samples collected were taken from sites with a low likelihood of particle drift. All tissue samples were collected from trees and the majority of the samples were collected from oaks. Some trees were sampled multiple times a year. In these cases, samples were typically taken 2-4 weeks apart.

Sampled trees usually were typical in symptom expression compared to other individuals of the same species at the sample location. Symptoms and severity ratings were recorded for all sampled individuals. Sample sites varied in estimated distance to the closest potential sources of drift which were primarily cropland.

IDNR/Morton Arboretum Tissue Sampling

The Morton Arboretum collected tissue samples for IDNR with the assistance of field staff, interns, landowners, and Arboretum staff. There was no formal protocol or standardized data recording for collections. Samples were kept in a cooler on ice until they could be frozen. Frozen samples were packaged in coolers with ice packs and shipped overnight or next-day to the lab. From 2018-2021 analysis varied from 1-4 herbicides.

All Tissue Analysis Results

Table 6 provides a summary of all tissue samples collected by IDNR, INPC, and PRN.

Table 6. IDNR, INPC, and PRN Tissue Sample Summary 2018-2021									
	IDNR processed			INPC & PRN processed			Totals All Samples		
Chemical	# Samples	# Positive	Location Data: # Positive/ # Sampled	# Samples	# Positive	Location Data: # Positive/ # Sampled	# Samples	# Positive	% Positive
2,4-D	86	75	27 of 27	72	55	24 of 31	158	130	82
dicamba	134	74	26 of 38	72	21	20 of 31	206	95	46
2,4-D & dicamba	86	40	15 of 27	72	14	9 of 31	158	54	34
atrazine	nt	nt		5	4	3 of 4	5	4	80
metolachlor	nt	nt		5	3	3 of 4	5	3	60
triclopyr	86	20	10 of 27	72	0	0 of 31	158	20	13
picloram	86	1	1 of 27	72	0	0 of 31	158	1	1
clopyralid	64	1	1 of 20	72	0	0 of 31	136	1	1
quinclorac	64	1	1 of 20	44	0	0 of 22	136	1	1
nt = no test									

It is important to note that multiple samples were taken at many of the sample locations. Hence there are more samples than sampled locations. Some of the differences in chemical detections between IDNR and PRN likely reflect the fact that some IDNR tissue samples originate from state property located along field edges where root uptake and/or particle drift could result in increased residue levels and hence longer windows for detections. Several of the samples taken by PRN are serial samples taken from the same site throughout the growing season. This was done in order to better understand the type and number of exposures occurring during the growing season.

All samples were analyzed for residues of dicamba. There was a mix-up at the lab in 2020 with the samples collected and analyzed for the Morton Arboretum and those samples were only analyzed for dicamba that year. 2,4-D was the most frequently detected herbicide among the herbicides for which tissues were analyzed and may remain detectable in leaf tissue for longer periods of time than other herbicides. Dicamba was the second most common herbicide detected in samples. Dicamba is known to have a shorter window for detection in leaf tissue. Numerous samples contained detectable levels of both dicamba and 2,4-D. Triclopyr, metolachlor, atrazine, picloram, clopyralid, and quinclorac were also detected.

Tissue Analysis Results for INPC Locations

Samples taken on lands managed by the state were analyzed for a variety of herbicides over the years with a consistent focus on growth regulator herbicides. A few samples collected by PRN were also analyzed for pre-emergent herbicides. Results are shown for the herbicides that were detected in leaf samples analyzed (Table 7). The lowest detectable concentrations of herbicides (or limit of detection) varied between 0.001 and .005 PPM for all herbicides, depending on laboratory capabilities.

Table 7 provides tissue analysis results for INPC locations. Tree leaves were collected according to PRN's tissue sampling protocol.

Table 7. Tissue Analysis Results for INPC Locations: Summary 2018-2021

Chemical	IDNR Processed			INPC - PRN Processed[1]			Totals (all samples)		
	# Samples	# Positive	Location data: # Positive/ # Locations	# Samples	# Positive	Location data: # Positive/ # Locations	# Samples	# Positive	% Positive
2,4-D	18	17	6 of 6	15	11	9 of 11	33	28	85
dicamba	40	32	11 of 13	15	3	3 of 11	55	35	64
2,4-D & dicamba	18	16	6 of 6	15	3	3 of 11	33	19	58
atrazine	nt	nt	--	1	0	0 of 1	1	0	0
metolachlor	nt	nt	--	1	0	0 of 1	1	0	0
triclopyr	18	3	2 of 6	15	0	0 of 11	33	3	9
picloram	18	0	0 of 6	15	0	0 of 11	33	0	0
clopyralid	9	0	0 of 2	15	0	0 of 11	24	0	0
quinclorac	9	0	0 o 2	15	0	0 of 11	24	0	0

1 INPC - PRN processed = some INPC samples were collected by PRN

Monitoring and Tissue Analysis of the State Champion Post Oak

The PRN monitoring program has collected multiple leaf tissue samples per growing season over several consecutive years from selected sites. This was done in an attempt to better understand the types and frequency of herbicide exposures occurring to species of concern. One such location and tree is the State Champion Post Oak located in Washington County. With the permission of the landowners, leaves from this tree have been collected and analyzed for herbicide residues 12 times between 2018 and 2021 (Table 8). Monitoring of this tree on 5/15/2022 found level 5 injury. Monitoring was again conducted on 6/14/2022, and level 6 injury was observed. Tissue samples were taken on both occasions, but have not yet been analyzed. Thirty-five post oaks monitored at the same location on these dates in 2022 averaged level 6 symptom severity with a range of 3-8. Symptoms were rated according to PRN's symptom ranking described above. The data collected indicate the state champion tree and the other trees in this stand are receiving multiple exposures of more than one herbicide within and across growing seasons. The health of the State Champion Post Oak has declined over this time period with dieback, epicormic branching, and thin canopy evident. Several nearby smaller mature post oaks have died or been removed due to the hazard their weakened conditions presented over the same time period. Appendix G contains photos of symptoms for each year of monitoring.

Table 8. Tissue Analysis Results for the State Champion Post Oak – PRN Tissue Sampling Program 2018-2021								
Sample Date	**% Foliage Affected**	**Symptom Severity[1]**	**Indicative Leaf Symtoms[2]**	**2,4-D ppb**	**Dicamba ppb**	**Atrazine ppb**	**Metolachlor ppb**	**Independent Exposure[3]**
10-Jul-18	76%-100%	6	curled or cupped, epinasty, twisted, deformed, and/or stunted	0	0	nt	nt	no detection
14-May-19	75%-100%	4	curled or cupped, epinasty, twisted, deformed, and/or stunted	35	0	nt	nt	yes
27-May-19	75%-100%	5	curled or cupped, twisted, deformed, and/or stunted	78	0	nt	nt	yes
05-Jul-19	75%-100%	5	curled or cupped, epinasty, twisted, deformed, and/or stunted	36	5	nt	nt	yes
18-Jul-19	75%-100%	5	curled or cupped, epinasty, twisted, deformed, and/or stunted	37	5	nt	nt	nd
24-May-20	76%-100%	5	curled or cupped, epinasty, twisted, deformed, and/or stunted	28.5	0	nt	nt	yes
18-Jun-20	76%-100%	5	curled or cupped, epinasty, twisted, deformed, and/or stunted	27.1	3.24	2.5	0	yes
11-Jul-20	76%-100%	5	curled or cupped, epinasty, irregular margins, twisted, deformed, and/or stunted	23.5	4.07	nt	nt	yes
02-Aug-20	76%-100%	5	curled or cupped, irregular margins, epinasty, twisted, deformed, and/or stunted	45.9	0	nt	nt	yes
22-May-21	76%-100%	5	curled or cupped, epinasty, twisted, deformed, and/or stunted	140	0	24.3	27	yes
27-Jun-21	76%-100%	4	curled or cupped, sideways, upside down, or drooped (epinasty), twisted, deformed, and/ or stunted	75.3	0	nt	nt	nd
28-Aug-21	76%-100%	5	curled or cupped, sideways, upside down, or drooped (epinasty), twisted, deformed, and/or stunted	42.6	0	nt	nt	nd

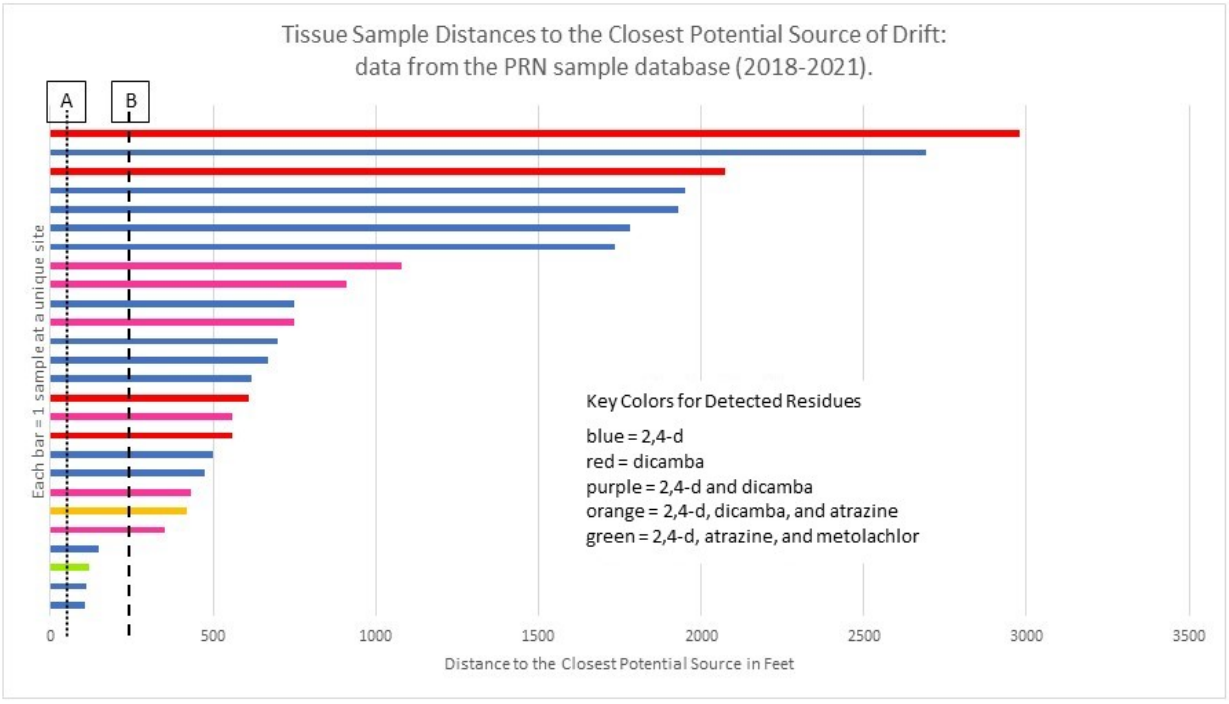
[1] Symptom Severity Rating on a scale of 0-10 (0 = normal, 10 = foliage death)
[2] Indicative Symptoms = Symptoms indicative of herbicide exposure
[3] Independent Exposure means sample characteristics indicate new or additional exposure since previous samples; nd = not determinable from residue level; nt = not tested for that herbicide
Note: ppb = part per billion

Estimated Distances to Closest Potential Source

In PRN's Tree and Plant Health Monitoring Program, distances to the nearest potential source of drift were estimated using visual observations and satellite imagery. Both known and unknown sources of drift were accounted for in these calculations. Potential sources included: rights of way where broadleaf vegetation control occurred, golf courses, row crop agricultural fields, pastures without broadleaf plants, and landscaping without broadleaf plants. If areas could not be inspected first-hand and satellite imagery was used to identify land use, then a conservative approach was used in assuming broadleaf weed control occurred in an area and thus was counted as a closest potential source.

Figure 7 illustrates distances to the nearest potential source for one tissue sample taken from each of the sites PRN sampled over a four year period. Some sites were sampled multiple times a year and every year. In order to illustrate that dicamba is moving beyond the mandatory buffer zone, samples that contained detectable levels of the herbicide were selected. Samples with 2,4-D, and more than one herbicide were also intentionally selected to demonstrate that other herbicides are also moving long distances at rates that can cause injuries in trees. The dotted line A represents the omni-directional 57 foot buffer for the application of the new formulations (OTT) of dicamba for counties with federally listed threatened and endangered species. The dashed line B represents the 240 foot standard downwind buffer that is required for all applications of dicamba in Illinois. The majority of herbicide detections are occurring outside the recommended buffer requirements for dicamba, which are also among the most stringent requirements for any herbicide that is currently widely used.

Figure 7.



Key to Buffer Lines (apply only to OTT dicamba)
A = 57 foot omni-directional buffer for counties with federally listed species
B = 240 foot standard downwind buffer

Note: one sample positive for 2,4-d and dicamba at 7200 feet omitted from chart

Conclusions & Recommendations

Conclusions

Throughout Illinois, major investments have been made by private landowners and local, state, and federal agencies to protect and restore natural communities and habitats of native plant and animal species. Some of these areas also provide additional protection for soil and water quality, important baseline information for monitoring environmental quality, opportunities for scientific research, and nature-based outdoor recreation. Illinois nature preserves and land and water reserves are among the most important elements of that investment. They can provide unique legal protection for natural communities of the highest quality, habitats for rare plants and animals, and other unique natural features that exist on Illinois' public and private lands. And they provide many additional, critically-important environmental and scientific benefits.

Off-target herbicide drift – trespass - is a major, yet still poorly evaluated ecological threat to Illinois' ecosystems, including those protected in the nature preserves system. These ecosystems are already under the stressors of climate change, habitat loss, disease, pests, and invasive species. It is critical that Nature Preserves, Land and Water Reserves, and Illinois Natural Areas Inventory Sites are protected from herbicide trespass and that high-quality natural communities and the habitats of rare, threatened, and endangered species are prioritized.

Evidence of both particle and vapor drift have been observed. However, herbicide trespass, particularly from vapor drift as a result of the widespread use of volatile herbicides, knows no boundaries and threatens both private and public lands. Monitoring efforts have documented widespread injuries - in yards throughout rural towns, in specialty and non-resistant crops, and on a wide variety of plant species on public and private lands. However, due to the geographic distribution of the injuries observed through monitoring efforts over the past four years, and the patterns of those injuries, vapor drift is suspected to be the primary cause of the majority of injuries observed on the landscape.

Singular and repeated exposures to herbicides can stress and weaken the condition of individual plants making them more susceptible to diseases and pests. Declines in tree health and increased mortality have been observed for several years at locations where herbicide drift has also been observed. Declines in oaks, which appear to be especially affected by early season applications of herbicides, are evident at many monitoring locations. This is especially problematic because tissue sample analyses indicate that multiple exposures are occurring at some locations throughout the growing season. Therefore, oak trees (and other species of trees, vines, and herbaceous plants) that are visibly injured by early season herbicide applications are also subject to repeated exposures which may have further unseen impacts to plant health and reproduction.

Repeated exposures to herbicides from either particle or vapor drift could result in loss of individual plants at a location, declines in regeneration, and increased pest pressures and disease rates in populations (especially oak), ultimately resulting in threats to ecosystem function. Without proper recognition and documentation of the presence of symptoms of herbicide exposure in areas of concern, functional abnormalities and health issues are likely being overlooked or misattributed and therefore going unaddressed.

The majority of the monitoring information collected over the past four years has focused on trees. It can be more challenging to observe symptoms of injury in herbaceous plants. The symptoms expressed by individual species and the impacts individual species experience are often poorly understood. Symptoms of herbicide injury may become less obvious in herbaceous plants as they continue to grow, making exposure diagnosis difficult.

Due to the complex community composition, staggered blooming and reproductive periods, and the types of wildlife that depend on those species for host plants and forage resources, multiple exposure events could have serious but unseen impacts on ecosystems that are comprised mainly of herbaceous plants, such as prairies and glades. Managed honeybee colonies have been used for understanding the environmental stressors native bee and other pollinator species may be experiencing. In recent years, apiary losses have been attributed to declines in forage quality and quantity as a result of herbicide drift[39]. This raises questions on the impacts to native bee populations. The potential shifts in the quality and quantity of forage for native bees, or how herbicide exposure is impacting native bee populations throughout Illinois, warrants more attention. There is a great need for ecological monitoring that examines the impacts of repeated herbicide drift on native floral resources and the associated impacts on the health of wild bees.

Monitoring and tissue sampling take significant resources, including finances, manpower, and time. The current monitoring information is limited in geographic scope due to limited resources such as the number of staff, the capacity of that staff, and the financial resources to support staff time, travel, data management, tissue sampling and analysis, and reporting efforts. However, it is important to note that the locations and species represented in the monitoring observations examined in this report are not all-inclusive of the locations, species, or plant types that had observable symptoms. Many of the individuals that we spoke with observed injuries at substantially more locations than they had the opportunity and/or permission to monitor. Rather, the magnitude and frequencies of reported injuries in this report are the result of constraints on both volunteers and professional staff resources. It is also clear from cross-referencing monitoring results among observers that some observers are not sufficiently trained to recognize herbicide related injuries. For example, some professional staff remarked during training sessions hosted by PRN that plants with even significant levels of injury looked “normal” in their experience. This highlights the widespread appearance of these symptoms across the landscape over time.

The information provided by monitoring programs is desperately needed in order to fill the gaps in information that are not provided to regulatory agencies through the voluntary complaint process. Much of the current enforcement and regulatory efforts are based on a predication of misuse. In cases involving agricultural uses, investigations and enforcement are prompted after pesticide exposure and/ or injury occurs via property owners’ complaints reported to IDOA. This process was designed to address applicator error and particle drift. The IDOA’s pesticide misuse complaint process is not a replacement for ecological monitoring, nor was it designed to address the current issues related to volatility, where injury occurs despite no technical “misuse” on the part of the applicator. Only a small percentage of the injury reports that were submitted to IDOA by IDNR were found to be caused by applicator error or misuse. The remaining cases, where no misuse was found and no action was taken, suggest volatilization and drift.

As mentioned previously, it is widely recognized that only a small percentage of plant injuries symptomatic of herbicide exposure are reported to IDOA as complaints and that the reasons for this are numerous and complex. Overall, the pesticide misuse complaint process has many shortcomings that limit its ability to serve as a reliable and trustworthy tool for gauging the severity, geographic range, and

frequency of pesticide-related injuries resulting from both legal use and illegal misuse. Given the widespread use of pesticides on the landscape and the recent rise in use of highly volatile herbicides such as 2,4-D and dicamba across the agricultural landscape the effectiveness of the complaint process in protecting the environment from unreasonable harm is in question.

The additional restrictions and rules that have been placed on the over the top use of the new formulations of dicamba highlight that there are other measures that can be taken by regulatory agencies to further protect the people and environment of Illinois from unreasonable harm caused by pesticide drift. Therefore, it is reasonable to assume that restrictions could be placed on other herbicides that trespass and cause harm to critical habitats such as Nature Preserves and Land and Water Reserves.

Perhaps surprisingly, it has been PRN's experience that the presence of widespread and even severe herbicide injury to plant communities goes largely unnoticed by the general public. Outdoor enthusiasts, land owners and land managers, and even veteran biologists often do not see symptoms until trained to do so, and until time is taken to actively examine plant foliage.

One impediment to recognition is proximity. Even severe symptoms are difficult to identify through casual distant observations of the landscape, for example, as one is driving. Even in parks and our own backyards, symptoms are often at distances that prohibit easy identification and are in positions where humans typically do not look – up into canopies of trees.

Another impediment is understanding. Many individuals simply are not able to differentiate normal from abnormal foliage. When abnormalities are observed, an even smaller percentage are able to connect injury to herbicide exposure.

Educating the public to inspect for and recognize symptoms is important. But that need is highest for individuals and agencies that have direct responsibility for or special interests in environmental safety and public health related to pesticides. Text, graphics, and various media that illustrate injury are necessary tools to expand awareness and characterize conditions, but there is no substitute for in-person contact. Experiencing an entire forest that demonstrates symptoms is the most effective tool to promote awareness that can result in action.

Recommendations

The recommendations for this report are separated into three main sections. The first provides general suggestions for the improvement of current monitoring and tissue sampling efforts and suggestions for the creation of new monitoring efforts. The second provides recommendations for a comprehensive monitoring program for the state which would help inform sound regulatory decisions and scientific studies that would not only benefit Illinois, but much of the U.S. and other countries that are also experiencing pesticide drift. The third is a set of recommendations specifically for the INPC. These recommendations should not be viewed as directives but as suggestions of ways to provide stronger protections for INPC protected and qualifying sites.

Section 1: The Expansion of Current Monitoring Efforts

The INPC has recognized the high potential risk of herbicide drift, particularly vapor drift (chemical trespass), to INPC protected sites and INAI sites and the need for continued monitoring and analysis of the threat parameters and potential risk reduction and/or mitigation of damages. Throughout the development of this report, PRN and IDNR have worked to make modifications to their existing monitoring programs that will improve data collection and facilitate collaboration and information sharing between efforts, which include monitoring at nature preserves and land and water reserves. We recommend that regular communication occurs between all monitoring efforts in order to coordinate improvements and changes to monitoring methods and to ensure that resources are being used wisely and efforts are coordinated as much as is reasonable.

It is important to recognize that much of the injury occurring to Nature Preserves and other monitored sites appears to be the result of vapor drift, as is indicated by the lack of enforcement actions taken on pesticide complaints filed by IDNR. These injuries, and those that are occurring across the state on both private and working lands, threaten the health of people and wildlife in Illinois. The existing voluntary pesticide complaint process was not designed to identify or address injuries associated with vapor drift. This underscores the urgent need for the expansion of current monitoring and tissue sampling programs. The information collected by monitoring efforts should be used to inform the INPC, IEPA, IDOA, and the Interagency Committee on Pesticides of the severity, geographic distribution, and ecological threats posed by herbicide drift.

Ideally, coordination and planning among agencies that employ increased public resources as well as enhanced public - private partnerships should be developed. An emphasis should include a division of labor and, especially, information sharing.

Improve, Expand, and Coordinate Monitoring Efforts

We recognize that agency and partner organization staff are often limited in their capacity to perform new tasks. However, by increasing the involvement of properly-trained agency staff, friends groups, volunteers, and NGO staff, some of these constraints can be alleviated.

Individual monitoring programs will likely have different objectives. However, developing consistency in critical data collection is highly desirable and can contribute to and supplement data collected by a larger, comprehensive monitoring effort. All data to be recorded should be selected with the end product in mind and staff/volunteers should be well trained and have a specific monitoring protocol to follow. This will help ensure that critical data is collected and that it is consistent and usable across monitoring platforms.

Desirable Consistencies in Data Collection Across Programs Include:

- Data collection limited to individuals trained in symptom identification and which have demonstrated adequate skills in plant species identification.
- GPS points marking the outer borders of the area monitored.
- A minimum of 5 species should be monitored at each site.
- Species monitored should be from different habitat layers at the site whenever possible (ground, understory, and canopy).
- Species monitored at each location should vary in plant type and species. Photographs should be taken of each species monitored that document symptoms observed.
- Photographs should be named using a consistent method that includes date, site, species, photo number.
- Monitoring for all programs should occur throughout the growing season and into late summer. (Late season applications of herbicides, particularly of glyphosate, occur and cause lasting injury to plant communities.)
- In order to reduce resources spent on verifying and cross referencing data, whenever possible, it is recommended that standardized lists (e.g., in drop-down or check box lists in e-forms) be used for most repetitive data categories including:
    - The site name of a monitoring location
    - The site type of a monitoring location
    - The county of a monitoring location
    - Description of how an area was monitored (e.g., walked trail, walked grid, walked roadway, drove roadway etc.)
    - Names of species observed with symptoms (scientific name recommended)
    - Symptoms observed for each species
    - An estimate of the number of individuals for each species showing symptoms
- Consistent or cross-referenceable rating system(s) to characterize severity of symptoms on a species basis.
- Community level measures, when used, should use standard vegetation measures like cover (e.g., % cover of canopy trees with symptoms in forest/woodland communities).

** The IDNR has made significant changes to the 2022 monitoring form, many of which include the above recommendations.*

Improve, Expand, and Coordinate Tissue Sampling Efforts

The tissue sampling programs are perhaps even more limited in their scope due to the costs of analysis and shipping. However, they are an important aspect of a monitoring program and help verify the causes of symptoms observed at a site and characterize specific chemical exposures. Current programs could certainly be made more robust with increased funding.

There is still a lack of understanding of exposures and impacts to INAI sites. Serial sampling could be performed at a select few of these sites. Additionally, sampling could be expanded to include more herbaceous plants. However, all programs and efforts could benefit and more meaningful information could be gleaned from tissue sample data from increased coordination within and between programs

To ensure broad priorities are met, and to reduce unnecessary redundancies and associated costs, monitoring efforts throughout the state should coordinate tissue sampling to the extent possible. This could include sharing and leveraging resources associated with sample acquisitions, processing, shipping, and laboratory analyses, all of which can be costly.

Resource and opportunity costs can be high, therefore rigorous standardized protocols that minimize contamination issues are needed for sample collection and handling. In addition, the value of tissue sampling equally depends on the quality of data associated with individuals, species, date, specific location, and landscape context of sampled specimens. Protocols which prompt recording important data in consistent formats amenable to analysis should be a priority.

Some Options for Increasing Capacity and Coordination Include:

- Seek cost reductions at private labs, and/or request IDOA (or other state supported lab) to process samples from IDNR/INPC sites free or at cost).
- Programs collectively identify priority species (e.g., specific trees and forbs) and focus a percentage of samples on those species.
- Programs collectively identify priority areas where serial sampling would be most beneficial. Factors to consider during selection include: proximity to potential source types, priority habitats, species of concern, and history of exposures.
- Programs identify, train, and use "volunteer" resources (e.g., friends groups, student interns) to assist tissue sample acquisition.

Section 2: A Comprehensive Monitoring Program for Illinois

In addition to swift and meaningful action that addresses the threats herbicide drift poses to Illinois Nature Preserves and Land and Water Reserves, Illinois needs a comprehensive ecological monitoring program that examines the impacts of off-target herbicide injury to plant life. This program should assess the frequency, severity, and geographic distribution of off-target herbicide exposure events and the overall impacts to and health of exposed areas. The information gathered should highlight the species most frequently reported with visible symptoms and provide insight on the impacts herbicide exposure has on community and population parameters such as plant reproduction and growth, shifts in species composition, and plant pollinator impacts and responses. An effort should also focus on the less visible effects on plant health such as photosynthesis, growth, nutrient transport, etc. Ideally, one emphasis would include the health of INPC protected properties.

Program Needs

The comprehensive monitoring program should have an advisory team that is charged with setting the priorities of the monitoring program. Advisory team members should include IDOA, IEPA, INHS, & IDPH to define/consolidate the extent of environmental threat from vapor drift.

While individual efforts may continue, there is a need for a coordinated effort that examines the larger ecological impacts associated with repeated exposures to herbicide drift. Ideally there would be a central location for data storage and data management, cooperation between research institutions and field staff, and data and information sharing.

Section 3: Recommendations to INPC Commissioners

- **It is recommended the Commission request that IDNR perform a thorough evaluation on the impact of repeated herbicide drift (particle and vapor) events to INPC sites. Monitoring reports have identified multiple years of repeated herbicide injuries at INPC protected sites. These repeated injuries threaten the health of these areas. The information from the IDNR studies would be used to inform the Commission on how to best protect these sites.**

- **It is recommended the Commission submit this report to IDOA, IEPA, and the Interagency Committee on Pesticides and invite them to work with the INPC to take immediate steps to address the injuries occurring to Nature Preserves, Land and Water Reserves, and Illinois Natural Areas Inventory sites that are being injured as a result of particle and vapor drift.**

- **It is recommended the Commission request that the Interagency Committee on Pesticides, perform a statewide public education campaign that educates the public on the issue of off-target herbicide drift and how and where to report symptoms.**

- **It is recommended the Commission request that all monitoring data and tissue analyses results be shared with IEPA, IDOA, and the Interagency Committee on Pesticides. This information could provide these regulatory and advisory bodies with much needed information and resources to better protect INPC sites from further harm.**

- **It is recommended the Commission require misuse complaints to be sent to IDOA for injuries documented on all publicly owned INPC properties and all privately owned properties the landowner has given permission to report. Reports for INPC sites should be submitted to IDOA regardless of when observations were made and even when symptoms of insect or disease are present along with symptoms of herbicide injury.**

- **It is recommended the Commission facilitate field visitations to affected sites for higher level technical and administrative staff of agencies and organizations with focused interest and legal responsibility for environmental health and public safety associated with pesticides.**

- **It is recommended the Commission engage with the Interagency Committee on Pesticides on the issue of vapor drift and the regulatory complexities involved. In parallel with the Federal role in pesticide management, to recommend that the Interagency Committee on Pesticides request that IEPA take an active role in studying herbicide drift, particularly vapor drift, and its impacts on natural landscapes.**

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Appendix A

Typical Symptoms of Growth Regulator Herbicide Injury

Hackberry: chlorosis (yellowing)

Black oak: deformed, growth suppressed

Post oak: twisted, deformed

White oak: strapping

Wild grape: irregular margins

Redbud: curled, cupped

Credit: PRN 2018 – 2019 Tree and Plant Health Report
Photos: Martin Kemper

Appendix B: Media Stories

1. How Monsanto And Scofflaw Farmers Hurt Soybeans In Arkansas, August 1, 2016
2. Public Interest Groups, Farmers File Lawsuit Challenging Monsanto's Toxic Pesticides, January 23, 2017
3. A Final Report on Dicamba-injured Soybean Acres, October 30, 2017
4. Arkansas Defies Monsanto, Moves to Ban Rogue Weedkiller, Sepember 22, 2017
5. A Wayward Weedkiller Divides Farm Communities, Harms Wildlife, October 7, 2017
6. Monsanto Attacks Scientists After Studies Show Trouble for Weedkiller Dicamba, October 26, 2017
7. Report of the 2017 State of Arkansas Dicamba Task Force Meetings, September 21, 2017
8. These Citizen-regulators in Arkansas Defied Monsanto. Now They're Under Attack, February 14, 2018
9. Local Courts Lift Arkansas Weedkiller Ban, Creating Chaos, April 18, 2018
10. Bayer's Weed-Killing Future Targeted in Appeal of EPA Approvals, August 30, 2018
11. A Drifting Weedkiller Puts Prized Trees At Risk, September 27, 2018
12. Despite a Ban, Arkansas Farmers are Still Spraying Controversial Weedkiller, October 9, 2018
13. The EPA Says Farmers Can Keep Using Weedkiller Blamed For Vast Crop Damage, November 1, 2018
14. Halloween Night Tricks: Monsanto's Xtendimax Weed-Killer Re-approved, Despite Continuing Rampant Drift Damage, November 1, 2018
15. Is Fear Driving Sales Of Monsanto's Dicamba-Proof Soybeans?, February 7, 2019
16. Illinois Tightens Dicamba Restrictions as State and Company Officials Grapple with Complaints, March 19, 2019
17. As Weeds Outsmart The Latest Weedkillers, Farmers Are Running Out Of Easy Options, April 11, 2019
18. States Worry Dicamba Data Falling on Deaf Ears at EPA, June 3, 2019
19. Rainy Spring May Wash Out Dicamba Pesticide Analysis, July 1, 2019
20. Farmers, Conservationists Challenge Approval of Monsanto's Crop-damaging Dicamba Pesticide, August 14, 2019
21. Despite Federal, State Efforts, Dicamba Complaints Continue, August 31, 2019
22. What Bayer Says About Dicamba, October 2, 2019
23. 'Dicamba fatigue': State Regulators Anticipate More Off-Target Damage from Bayer's Controversial Herbicide in 2020, December 17, 2019
24. Weedkiller Complaints Skyrocket Among Illinois Farmers, December 22, 2019
25. Monsanto, BASF Lose Bid to Stop Peach Farm's Herbicide Case, January 2, 2020
26. No Jail for Farmer in Dicamba Misuse, January 4, 2020

27. Roundup Ruled the Farm, Now Its Maker Has a Challenger, January 6, 2020
28. EPA Documents Show Dicamba Damage Worse Than Previously Thought, October 29, 2020
29. EPA and Bayer Had Close Contact in 2020 Reinstatement of Dicamba, October 7, 2021
30. Republicans Criticize Recent EPA Regs: EPA Actions on Ag Pesticides Draw Rebuke from Republican Legislators, November 23, 2021
31. Florida Gardening: Twigs Falling From Oak Trees May Be Caused by Lawn Weed Treatment, April 14, 2021
32. New Dicamba Lawsuits: Texas Grape Growers, Arkansas Honey Producer Sue Over Dicamba Injury, June 4, 2021
33. Eastern Arkansas Faces Potential 650,000 to 800,000 Acres of Dicamba Damage, July 15, 2021
34. 650,000 Acres of Soybeans Damaged by Dicamba this Summer, State Estimates, July 19, 2021
35. Dicamba Diagnosis Refresher: Cupped Soybeans and Dicamba: Scientists Dispel Common Myths, July 15, 2021
36. Herbicide Injury on the Rise: Battle Lines Drawn as Dicamba Injury Surfaces Once Again, July 21, 2021
37. A Drift-prone Weedkiller Still Damages Crops and Trees, Despite Attempts to Stop It, July 23, 2021
38. EPA Eyes Dicamba Injury: EPA in Search of Dicamba Injury Reports as it Reviews the Spray Season, September 14, 2021
39. EPA Doesn't Promise Dicamba Use in 2022, October 7, 2021
40. Why Many Minnesota Farmers Are Facing an Early 2022 Dicamba Application Cutoff Date, December 13, 2021
41. EPA Examines Information on Dicamba Damage to Determine Regulatory Path Forward, December 15, 2021
42. EPA Details Dicamba Damage: EPA Publishes Dicamba Damage Report, But Says Label Changes Unlikely in 2022 Season, December 21, 2021
43. Off-target Dicamba Damage in 2021 May Be the Worst Year Yet in the Upper Midwest, August 2, 2021
44. Dicamba Lawsuit Revived: Court Asked to Kickstart Lawsuit to Vacate Dicamba Registrations, January 7, 2022
45. Iowa, Minnesota Get More Restrictive Dicamba Labels, March 16, 2022
46. Dicamba Herbicide Damage Could Hurt the Texas Hill Country Wine Industry, April 8, 2022

Appendix C

PESTICIDE INCIDENT COMPLAINT FORM INSTRUCTIONS

The complaint form on the reverse side of this page is provided to assist in the submittal of information associated with an alleged pesticide misuse complaint. Please provide as much information as possible about the incident. Feel free to attach additional pages to the complaint form if needed.

The Department's responsibility is to investigate a pesticide misuse complaint, determine whether any violations of the Illinois Pesticide Act have occurred and initiate any administrative actions deemed necessary based upon a detected violation. The Department's responsibility does not include the offering of assistance in the pursuit of damage reimbursement.

This complaint form must be received by the Department within 30 days of the incident or within 30 days of when the damage associated with the incident was first noticed, pursuant to 8 IAC 250.200. Complaints received by the Department after this 30-day period will be kept on file at the Department but no investigation or administrative action will be pursued.

Copies of the Department's completed complaint investigation file, including any analytical sample results, will only be provided in response to a request submitted under the Freedom of Information Act. In most cases, a copy of a complaint investigation file will not be released until after an investigation has been completed, any potential enforcement action has been taken, and the case has been closed. If you wish to receive a copy of the investigation file related to your complaint, please send a written request addressed to the Freedom of Information Office, Illinois Department of Agriculture, State Fairgrounds, PO Box 19281, Springfield, IL 62794-9281.

Please return the completed form to the address listed below. If you prefer to FAX your complaint form, the Department's FAX number is (217)524-4882. If you have any questions regarding pesticide regulations, the complaint investigation process or other related issues, please feel free to contact the Illinois Department of Agriculture, Bureau of Environmental Programs at (800)641-3934 or (217)785-2427.

Illinois Department of Agriculture
Bureau of Environmental Programs
State Fairgrounds PO Box 19281
Springfield, Illinois 62794-9281

PLEASE PRINT INFORMATION CLEARLY:

Complainant Information: - Mailing

Today's Date: _____

Name: _____

Address: _____

City, State, Zip: _____

County: _____

Home Telephone Number: _____ Work: _____

Cellular Telephone Number: _____ Email: _____

Complaint Information:

Location of Damage - address/county: _____

Date of Incident: _____ Time: _____ Date Noticed Damage: _____ Time: _____

Applicator type involved (check one): ☐ Commercial Company; ☐ Farmer; ☐ Homeowner; ☐ Other

Name of applicator (if known): _____

Company Name (if known): _____

Address: _____

_____

Telephone Number: _____ County: _____

Method of application (please check): ☐ Ground or ☐ Aerial; ☐ Liquid spray or ☐ Granular

Weather information: _____

Chemical involved (if known): _____

Specific nature of the complaint:

(If more space is needed, attach a separate sheet to this form)

Signature _____

Date: _____

Witness Information (other than complainant):

Name: _____ Telephone number: _____

Address: _____

_____

IMPORTANT NOTICE: This State Agency is requesting disclosure of information that is necessary to accomplish the statutory purpose as outlined under the 415 ILCS 60/1 through 28. Failure to provide this information shall prevent this form form being processed. This form has been approved by the State Fors Management Center IL-406-1280 (1-94)

Appendix D
Complete Lists of Species Demonstrating Symptoms

PRN Tree and Plant Health Monitoring Program
2018-2021

Coefficient of Conservatism (CC value) is a value assigned (0-10) to native species that indicates the likelihood that it is part of a stable and relatively undisturbed natural community.

Low CC value species are ubiquitous, even in disturbed environments.

High CC value species are less common and largely require relatively undisturbed or native remnant habitats with significant ecological integrity.

* = Adventive species

Forbs				
Scientific Name	**Common Name**	**Type**	**CC**	**Family**
Amsonia tabernaemontana	Willow Amsonia, Blue Dogbane	P-Forb	6	Apocynaceae
Asclepias hirtella	Tall Green Milkweed	P-Forb	6	Asclepiadaceae
Aster anomalus	Blue Aster	P-Forb	8	Asteraceae
Aster azureus	Sky-blue Aster	P-Forb	7	Asteraceae
Aster drummondii	Drummond's Aster	P-Forb	3	Asteraceae
Aster laevis	Smooth Aster	P-Forb	8	Asteraceae
Aster novae-angliae	New England Aster	P-Forb	4	Asteraceae
Aster patens	Late Purple Aster	P-Forb	6	Asteraceae
Aureolaria flava	Smooth False Foxglove	P-Forb	8	Orobanchaceae
Baptisia lactea	White False Indigo	P-Forb	6	Fabaceae
Boehmeria cylindrica	False Nettle	P-Forb	3	Urticaceae
Boltonia asteroides	False Aster	P-Forb	5	Asteraceae
Campanula americana	American Bellflower	A-Forb	4	Campanulaceae
Capsicum	Pepper	A-Forb	0	Solanaceae
Cirsium altissimum	Tall Thistle	P-Forb	3	Asteraceae
Dasistoma macrophylla	Mullein Foxglove	P-Forb	7	Scrophulariaceae
Desmodium cuspidatum	Bracted Tick Trefoil	P-Forb	6	Fabaceae
Desmodium glutinosum	Pointed Tick Trefoil	P-Forb	3	Fabaceae
Desmodium perplexum	Perplexing Tick Trefoil	P-Forb	0	Fabaceae
Erechtites hieracifolia	Fireweed, Pilewort	A-Forb	2	Onagraceae
Erigeron philadelphicus	Marsh Fleabane	P-Forb	3	Asteraceae
Eupatorium rugosum	White Snakeroot	P-Forb	2	Asteraceae
Eupatorium serotinum	Late Boneset (L. Thoroughwort)	P-Forb	1	Asteraceae
Eupatorium sessilifolium	Upland Boneset	P-Forb	8	Asteraceae
Hackelia virginiana	Stickseed	P-Forb	1	Boraginaceae
Helianthus divaricatus	Woodland Sunflower	P-Forb	5	Asteraceae
Helianthus mollis	Downy Sunflower	P-Forb	7	Asteraceae
Hibiscus laevis	Halberd-leaved Rose Mallow	P-Forb	4	Malvaceae
Hibiscus lasiocarpus	Hairy Rose Mallow	P-Forb	5	Malvaceae
Laportea canadensis	Wood Nettle	P-Forb	2	Urticaceae
Liatris pycnostachya	Prairie Blazing-star	P-Forb	6	Asteraceae

Liatris squarrulosa	Southern Blazing-star	P-Forb	8	Asteraceae
Lobelia inflata	Indian Tobacco	P-Forb	4	Campanulaceae
Monarda bradburiana	Monarda, Bradbury Monarda	P-Forb	5	Lamiaceae
Monarda fistulosa	Wild Bergamot	P-Forb	4	Lamiaceae
Parthenium integrifolium	Wild Quinine, Am. Feverfew	P-Forb	8	Asteraceae
Penstemon digitalis	Foxglove Beard-tongue	P-Forb	4	Scrophulariaceae
Phytolacca americana	Pokeweed	P-Forb	1	Phytolaccaceae
Pycnanthemum tenuifolium	Slender Mountain Mint	P-Forb	4	Lamiaceae
Rudbeckia hirta	Black-eyed Susan	P-Forb	2	Asteraceae
Rudbeckia subtomentosa	Fragrant Coneflower	P-Forb	5	Asteraceae
Scrophularia marilandica	Figwort	P-Forb	4	Scrophulariaceae
Silene stellata	Starry Campion	P-Forb	6	Polemoniaceae
Silphium integrifolium	Rosinweed	P-Forb	5	Asteraceae
Silphium laciniatum	Compass Plant	P-Forb	5	Asteraceae
Silphium perfoliatum	Cup Plant	P-Forb	4	Asteraceae
Silphium terebinthinaceum	Prairie-dock	P-Forb	4	Asteraceae
Smilacina racemosa	False Solomon's Seal	P-Forb	4	Liliaceae
Solidago buckleyi	Buckley's Goldenrod	P-Forb	8	Asteraceae
Solidago caesia	Bluestem Goldenrod	P-Forb	7	Asteraceae
Solidago canadensis	Canada Goldenrod	P-Forb	1	Asteraceae
Solidago rigida	Rigid Goldenrod	P-Forb	4	Asteraceae
Solidago speciosa	Showy Goldenrod	P-Forb	7	Asteraceae
Solidago ulmifolia	Elm-leaved Goldenrod	P-Forb	5	Asteraceae
Stachys tenuifolia	Smooth Hedge Nettle	P-Forb	5	Lamiaceae
Thalictrum revolutum	Waxy Meadow Rue, Skunk M. R.	P-Forb	5	Ranunculaceae
Verbesina alternifolia	Yellow Ironweed, Wingstem	P-Forb	4	Asteraceae
Verbesina helianthoides	Yellow Crownbeard	P-Forb	6	Asteraceae
Vernonia missurica	Missouri Ironweed	P-Forb	5	Asteraceae
Veronicastrum virginicum	Culver's Root	P-Forb	6	Scrophulariaceae
Zizia aurea	Golden Alexanders	P-Forb	7	Apiaceae

Shrubs and Vines				
Scientific Name	**Common Name**	**Type**	**CC**	**Family**
Amorpha fruticosa	False Indigo Bush	Shrub	6	Fabaceae
Ampelopsis cordata	Raccoon Grape	W-Vine	2	Vitaceae
Bumelia lanuginosa	Chittam Wood	Shrub	10	Sapotaceae
Campsis radicans	Trumpet Creeper, T. Vine	Shrub	2	Bignoniaceae
Ceanothus americanus	New Jersey Tea	Shrub	8	Rhamnaceae
Celastrus scandens	American Bittersweet	W-Vine	2	Celastraceae
Cephalanthus occidentalis	Buttonbush	Shrub	4	Rubiaceae
Cornus drummondii	Rough-leaved Dogwood	Shrub	2	Cornaceae
Cornus obliqua	Pale Dogwood, Silky, Blue Fr	Shrub	4	Cornaceae
Cornus racemosa	Gray Dogwood	Shrub	2	Cornaceae
Corylus americana	Hazelnut	Shrub	4	Betulaceae
Elaeagnus umbellata	Autumn Olive*	Shrub	0	Eleagnaceae
Euonymus	Burning Bush*	Shrub	0	Celastraceae
Euonymus atropurpurea	Wahoo, Burning Bush	Shrub	5	Celastraceae
Hydrangea arborescens	Wild Hydrangea	Shrub	6	Hydrangeaceae
Hypericum prolificum	Shrubby St. John's Wort	Shrub	6	Hypericaceae
Ilex decidua	Swamp Holly	Shrub	6	Aquifoliaceae
Lindera benzoin	Spicebush	Shrub	5	Lauraceae
Menispermum canadense	Canada Moonseed	W-Vine	4	Menispermaceae
Parthenocissus quinquefolia	Virginia Creeper	W-Vine	2	Vitaceae
Ptelea trifoliata	Wafer Ash, Hoptree	Shrub	4	Rutaceae
Rhubus	Blackberry	Shrub	2	Rosaceae
Rhus aromatica	Fragrant Sumac	Shrub	4	Anacardiaceae
Rhus copallina	Dwarf Sumac	Shrub	3	Anacardiaceae
Rhus glabra	Smooth Sumac	Shrub	1	Anacardiaceae
Rosa multiflora	Multiflora Rose*	Shrub	0	Rosaceae
Rosa setigera	Prairie Rose	Shrub	5	Rosaceae
Rubus allegheniensis	Common blackberry	Shrub	2	Rosaceae
Rubus flagellaris	Common Dewberry	Shrub	2	Rosaceae
Rubus occidentalis	Black Raspberry	Shrub	2	Rosaceae
Sambucus canadensis	Elderberry, Common Elder	Shrub	2	Caprifoliaceae
Smilax	Greenbriar	W-Vine	3	Smilacaceae
Staphylea trifolia	Bladdernut	Shrub	5	Staphyleaceae
Symphoricarpos orbiculatus	Coralberry	Shrub	1	Caprifoliaceae
Syringa vulgaris	Lilac*	Shrub	0	Oleaceae
Toxicodendron radicans	Poison Ivy	W-Vine	1	Anacardiaceae
Vaccinium pallidum	Lowbush Blueberry	Shrub	7	Ericaceae
Viburnum	Viburnum	Shrub	4	Caprifoliaceae
Viburnum lentago	Nannayberry	Shrub	4	Caprifoliaceae

Viburnum opulus	European High Bush Cranberry*	Shrub	0	Caprifoliaceae
Viburnum prunifolium	Black Haw	Shrub	4	Caprifoliaceae
Vitis	Grape	W-Vine	3	Vitaceae
Weigela	Weigela*	Shrub	0	Caprifoliaceae

Trees			
Scientific Name	**Common Name**	**CC**	**Family**
Acer negundo	Box Elder	1	Aceraceae
Acer rubrum	Red Maple	5	Aceraceae
Acer saccharinum	Silver Maple	1	Aceraceae
Acer saccharum	Sugar Maple	4	Aceraceae
Aesculus glabra	Ohio Buckeye	5	Sapindaceae
Ailanthus altissima	Tree-of-heaven*	0	Simaroubaceae
Amelanchier arborea	Shadbush, Juneberry	7	Rosaceae
Asimina triloba	Pawpaw	4	Annonaceae
Betula nigra	River Birch	4	Betulaceae
Broussonetia papyrifera	Paper Mulberry*	0	Moraceae
Carya aquatica	Water Hickory	10	Juglandaceae
Carya cordiformis	Bitternut Hickory	4	Juglandaceae
Carya glabra	Pignut Hickory	5	Juglandaceae
Carya illinoensis	Pecan	6	Juglandaceae
Carya laciniosa	Kingnut Hickory	7	Juglandaceae
Carya ovata	Shagbark Hickory	4	Juglandaceae
Carya texana	Black Hickory	8	Juglandaceae
Carya tomentosa	Mockernut Hickory	6	Juglandaceae
Castanea mollissima	Chinese Chestnut*	0	Fagaceae
Catalpa	Catalpa	0	Bignoniaceae
Celtis laevigata	Sugarberry	5	Ulmaceae
Celtis occidentalis	Hackberry	3	Ulmaceae
Celtis tenuifolia	Dwarf Hackberry	7	Ulmaceae
Cercis canadensis	Eastern Redbud	3	Fabaceae
Cornus florida	Flowering Dogwood	5	Cornaceae
Crataegus	Hawthorn	3	Rosaceae
Crataegus mollis	Red Haw, Downy H.	2	Rosaceae
Crataegus viridis	Green Hawthorn	5	Rosaceae
Diospyros virginiana	Persimmon	2	Ebenaceae
Foresteria acuminata	Swamp Privet	6	Oleaceae
Fraxinus	Ash	4	Oleaceae
Gingko biloba	Gingko*	0	Ginkgoaceae
Gleditsia triacanthos	Honey Locust	2	Fabaceae
Gymnocladus dioicus	Kentucky Coffee Tree	6	Fabaceae

Juglans nigra	Black Walnut	4	Juglandaceae
Koelreuteria paniculata	Golden-Rain Tree*	0	Sapindaceae
Liquidambar styraciflua	Sweet Gum	6	Hamamelidaceae
Liriodendron tulipifera	Tulip Poplar	5	Magnoliaceae
Maclura pomifera	Hedge Apple*	0	Moraceae
Magnolia	Magnolia*	0	Magnoliaceae
Malus	Crabapple*	0	Rosaceae
Malus domestica	Apple*	0	Rosaceae
Morus alba	White Mulberry*	0	Moraceae
Morus nigra	Black Mulberry*	0	Moraceae
Morus rubra	Red Mulberry	4	Moraceae
Nyssa sylvatica	Sour Gum	7	Nyssaceae
Ostrya virginiana	Hop Hornbeam	4	Betulaceae
Platanus occidentalis	Sycamore, Buttonwood	3	Platanaceae
Platanus x acerifolia	London Plane Tree*	0	Platanaceae
Populus deltoides	Cottonwood	2	Salicaceae
Populus heterophylla	Swamp Cottonwood	8	Salicaceae
Prunus	Cherry - Plum	0	Rosaceae
Prunus persica	Peach*	0	Rosaceae
Prunus serotina	Wild Black Cherry	1	Rosaceae
Pyrus calleryana	Ornamental Pear*	0	Rosaceae
Quercus acutissima	Sawtooth Oak*	0	Fagaceae
Quercus alba	White Oak	5	Fagaceae
Quercus bicolor	Swamp White Oak	7	Fagaceae
Quercus coccinea	Scarlet Oak	7	Fagaceae
Quercus falcata	Southern Red Oak	6	Fagaceae
Quercus imbricaria	Shingle Oak	2	Fagaceae
Quercus nigra	Water Oak*	0	Fagaceae
Quercus lyrata	Overcup Oak	7	Fagaceae
Quercus macrocarpa	Bur Oak	5	Fagaceae
Quercus marilandica	Blackjack Oak	6	Fagaceae
Quercus muehlenbergii	Chinkapin Oak	5	Fagaceae
Quercus pagoda	Cherrybark Oak	5	Fagaceae
Quercus palustris	Pin Oak	4	Fagaceae
Quercus phellos	Willow Oak	7	Fagaceae
Quercus rubra	Red Oak	5	Fagaceae
Quercus shumardii	Shumard's Oak	7	Fagaceae
Quercus stellata	Post Oak	5	Fagaceae
Quercus velutina	Black Oak	5	Fagaceae
Rhamnus caroliniana	Carolina Buckthorn	7	Rhamnaceae
Robinia pseudoacacia	Black Locust	1	Fabaceae

Salix	Willow	3	Salicaceae
Sassafras albidum	Sassafras	2	Lauraceae
Tilia americana	American Linden, Basswood	5	Malvaceae
Ulmus alata	Winged Elm	5	Ulmaceae
Ulmus americana	American Elm	5	Ulmaceae
Ulmus pumila	Siberian Elm*	0	Ulmaceae
Ulmus rubra	Slippery Elm, Red Elm	3	Ulmaceae
Vaccinium arboreum	Farkleberry	6	Ericaceae

Appendix E

Examples of PRN Symptoms Ratings

0 = Normal Leaves, No Injury

1, 2 = Slight symptoms

3, 4 = Light symptoms

5, 6 = Moderate symptoms

7, 8 = Severe symptoms

9, 10 = Extreme symptoms

Credit: PRN 2018 – 2019 Tree and Plant Health Report
Photos: Martin Kemper

Appendix F

Plant Tissue Sampling Form for Herbicide Residue Testing - page 1 of 2

Sample ID _____

Site ID:_____ County:_____ Date: _____

Observer Name: _____ City: _____

Phone #_____ e-mail:_____

Witness Name(s):_____

Pre-Collection: Plant Species (one only): _____ Number Sampled: _____

Record injury data for the sampled species on page 2 of this form. Complete a Tree & Plant Health Monitoring Report (TPHMR) form if additional affected species are present and monitored (recommended).

TPHMR completed for additional monitored species: No Yes Date: _____

Label outside of 1 gal. ziplock bag with: *sample ID, species, date,* & *collector initials* (with Sharpie)

Label clean shop towel with: *sample ID, species, date, & collector initials*

Clean cutting tools before sampling Date _____ Time _____ Initial_____

Put on clean nitrile gloves Date _____ Time _____ Initial_____

Start Collection: Collect one gallon leaves; place in ziplock bag (keep out of sun)

Date_____ Time_____ Initial_____

Photograph typical sample of leaves on shop towel - add time labeling to towel

Date_____ Time_____ Initial_____

Complete Collection: Seal bag Date_____ Time_____ Initial_____

Refrigerate on returning from field if shipping in less than 72 hours (otherwise place in freezer)

Indicate which: freezer / refrigerator Date_____ Time_____ Initial_____

Documentation and Shipping:

Fill out and copy *lab submission form*, ensure site (sample) ID and all other data conform with 1) *this form* and 2*) monitoring form* Date_____ Time_____ Initial_____

Remove sample from storage and place *lab submission form* in a separate pint size ziplock bag and attach to outside of sample bag Date_____ Time_____ Initial_____

Ship **on freezer packs** overnight express, next day delivery, preferably early in week (not over weekend)

Date_____ Time_____ Initial_____

Tree and Plant Health Monitoring Report Short Form + Supplemental Data Sample ID _____

Site ID:_____ Subunit:_____ County:_____ Date: _____

Observer: First Name:_____ Last Name:_____ Witness Name(s) _____

	Sampled Individual(s)		Additional Monitored Individual(s) [1]		GPS Points in Relation to Potential Drift Source[2] (parts may need to be completed later)	
Common (or scientific) name			----------		Nearest for Sampled N_____ W_____ Nearest Pot. Source N_____ W_____ Distance (ft) _____	Farthest for Sampled N_____ W_____ Farthest Pot. Source N_____ W_____ Distance (ft) _____
Number observed (approx OK for monitored)						
% foliage affected: 1-25, 26-50, 51-75, 76-100						
Average and range of injury						
SYMPTOMS – Mark "X" if Present	Present?	Notes (and rating for each sampled individual if >1) below	Present?	Notes and ratings below		
Leaves: curled or cupped						
sideways, upside down, or drooped						
irregular margins						
strapped						
tattered						
twisted, deformed, and/or stunted					Nearest for Monitored N_____ W_____ Nearest Pot. Source N_____ W_____ Distance (ft) _____	Farthest for Monitored N_____ W_____ Farthest Pot. Source N_____ W_____ Distance (ft) _____
veins bleached and/or parallel						
Shoots: elongated, coiled, and/or bent						
growth suppressed and deformed						
Leaves: chlorotic (yellowed)						
necrotic (brown/black areas)						
2nd growth						
Trees: epicormic branching						
dieback						
death						

[1] Original data here unless a separate Tree and Plant Health Monitoring Report (TPHMR) form has been completed. In that case, transfer data for the sampled species from the TPHMR form here. [2] Enter GPS points as decimal degrees. Choose any point in area when entering TPHMR on-line.

GPS Data Source(s): _____ **Also: If a separate TPHMR Report was not completed, record the following data:**

Visit Planned? [ ] yes [ ] no Visit #:____ **Layers:** Check for affected layers, strikethrough if layer is absent: [ ] Overstory [ ] Understory [ ] Ground layer

[ ] LARGE (>1 acre) Type: _____ (e.g., upl. forest) Approx: sampled acres ____ affected acres ___

[ ] SMALL (<1 acre) Type: _____ (e.g., yard, school, park) Approx. # trees affected _____ **Eliminated onsite sources? Y N**

Evidence of Particle Drift? Y N Injury Pattern Gradient Present? Y N Adjoining Land Use/Additional Notes: _____

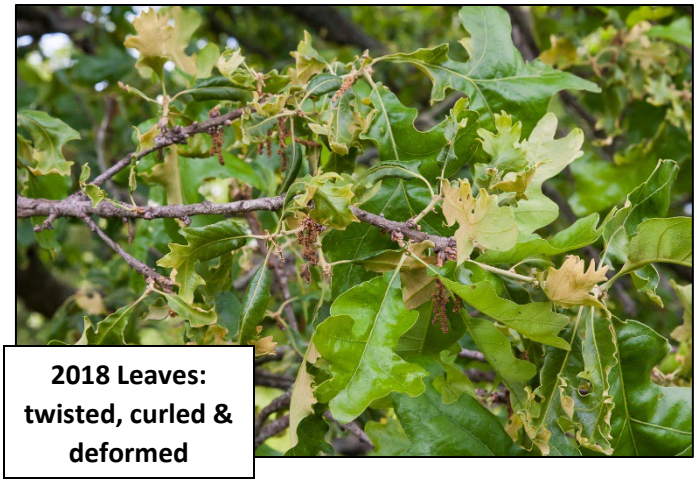
_____

Appendix G

Symptoms documented during PRN monitoring and tissue sampling efforts.

State Champion Post Oak

2017 Leaves: twisted, curled & deformed



2018 Leaves: twisted, curled & deformed

2019 Leaves: twisted, curled, deformed, stunted, & chlorosis

2020 Leaves: twisted, curled, deformed, & chlorosis

2021 Leaves: twisted, curled & cupped

2022 Leaves: twisted, curled, deformed

Photo credits: Martin Kemper