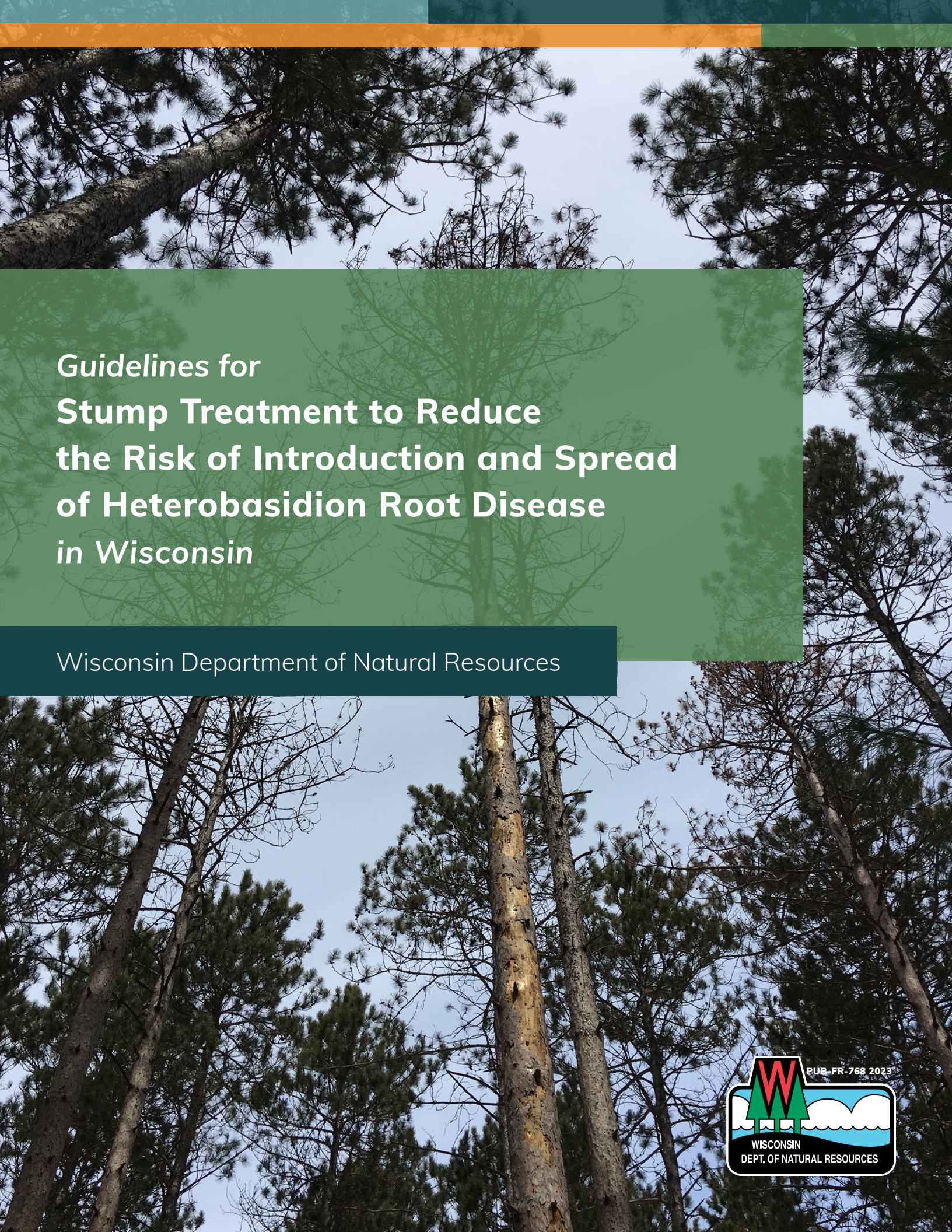

Guidelines for

Stump Treatment to Reduce the Risk of Introduction and Spread of Heterobasidion Root Disease *in Wisconsin*

Wisconsin Department of Natural Resources

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WISCONSIN
DEPT. OF NATURAL RESOURCES

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HRD guidelines are one tool used to help ensure healthy forests for current and future generations of Wisconsin citizens.

Chapter 1

Introduction

Heterobasidion root disease (HRD), caused by the fungus *Heterobasidion irregulare*, is a serious disease of conifers.

The disease was formerly known as annosum root rot and Fomes root rot. The HRD pathogen attacks trees' bark, cambium and sapwood. Diseased trees will exhibit reduced height, shoot and diameter growth, with thin and yellowish foliage. Trees will often die. The pathogen can become established in a stand after wind disseminates fungal spores that land on fresh cut stumps. Once established, *H. irregulare* will grow into the stumps, and spread underground to kill root systems of neighboring trees. The disease can impact future stands, including regeneration, as it remains on a site for many years.

Stump treatment can be performed manually using a backpack sprayer (blue dye is added as a visual cue to ensure acceptable coverage).

Pesticide solution is applied on fresh cut stumps through a spray nozzle attached on a fixed head processor (blue dye is added as a visual cue to ensure acceptable coverage).

Originally described during the 1870s, HRD was reported in the northeastern United States by the early 1900s. HRD was confirmed in many eastern states in the 1950s and 1960s. In Wisconsin, the disease was first confirmed in Adams County in 1993. Since then, the disease has been found in other counties (Figure 1, Page 5).

Preventive pesticide treatments can be applied to fresh cut stumps at the time of harvest to prevent spores from germinating, thereby suppressing growth of the fungus into the stump. Costs are associated with these treatments. Stump treatment can be performed through a spray attachment on a processor or manually using a backpack and hand sprayer. More information on treatments can be found in Chapter 5.8. Additionally, information about pesticides currently registered and available for use as preventive stump treatments in Wisconsin can be found at the HRD landing page on the DNR website. Currently, there are no curative treatments to eliminate the HRD pathogen from a stand once it is infested. Preventing disease introduction is the best approach.

Although both conifer and hardwood trees can be infected, coniferous trees appear to be much more susceptible to the disease. Currently in Wisconsin, HRD is most commonly found affecting red pines and white pines in plantation settings. On overstory trees, HRD symptoms and signs have been observed on jack pines, red pines and white pines, and white spruce and Norway spruce. HRD has also affected the following species growing in the understory: red pine, jack pine, white pine, balsam fir, white spruce, eastern red cedar, oaks (both red and white), black cherry and buckthorn. Of these species, mortality resulting from the disease in Wisconsin has been observed, or is suspected, among the conifers. Mortality of hardwood species has not been documented in Wisconsin.

Pesticide solution is applied on fresh cut stumps through a perforated sawbar on a dangle head processor at the time of harvesting (blue dye is added as a visual cue to ensure acceptable coverage).

Stump infection is the most common pathway of introduction of *H. irregulare* to new locations in Wisconsin. After a stump is colonized, the pathogen moves underground to nearby residual trees through root contact. Mortality of diseased residual trees typically starts to appear 3-8 years after a thinning operation is performed. As the fungus moves underground to neighboring trees, growth of those trees will begin to decrease, foliage will become thin, and often they will eventually die. In this way, the fungus moves outward from the point of infection, creating an ever-expanding pocket of dead trees. The fungus produces a fruit body near the soil line of a colonized tree or a stump. Since the fungus can persist in wood and on a site for many years, control is very difficult after a stand is infested. Therefore, prevention of this disease is very important.

In HRD infested stands, healthy trees surrounding each infection center are harvested to capture wood value.

SCOPE OF THE GUIDELINES

Mortality caused by HRD in a mature white pine plantation.

Since HRD can persist on a site for many years, control is very difficult after a stand is infested.

The HRD guidelines are designed to help property managers and landowners determine whether the preventive pesticide treatment should be used to reduce the risk of introduction and spread of *H. irregulare* at the time of harvest in a pine and/or spruce stand. The guidelines should also be used by foresters and loggers to help communicate with property managers and landowners about the pesticide treatment option. These guidelines were developed to be scientifically-sound, based on currently available scientific information, and operationally-practical in the field.

The HRD guidelines do not address landscape-level management issues or the management of actively-expanding HRD pockets. However, when a pine/spruce harvest is planned, consideration of the potential impact of HRD on adjacent stands is encouraged. In addition, proper handling of *H. irregulare*-colonized wood will reduce the risk of long-distance spread of the pathogen. Recommended Best Management Practices (BMPs) for stands infested with HRD can be found in Appendix A; links to information about the management of stands affected by HRD are available in Appendix D. Interested individuals are encouraged to discuss stand-specific options with foresters and/or forest health staff.

The HRD guidelines are not prescriptions for managing pine/spruce or regenerating pine/spruce. The silvicultural prescription should come from other sources, such as the Wisconsin DNR Silviculture Handbook. The HRD guidelines are to be used in conjunction with these other sources for sustainable forest management.

USING THE GUIDELINES

The stump treatment guidelines for the prevention of HRD are used for forest management activities on state lands managed by DNR (DNR lands), and are recommended on County Forests and private lands. Treatment of pine and/or spruce stumps of merchantable size is recommended under certain conditions described in the guidelines. Information about HRD is available at the DNR website's HRD landing page. Contact a forester and/or forest health staff for more information about the disease and consultation.

HOW TO USE THE HRD GUIDELINES

The HRD guidelines are divided into chapters, based on the location of the stand being managed and detection of HRD in the stand:

- **Chapter 2:** If HRD is not present in the stand AND the stand is NOT within 25 miles of a confirmed HRD stand
- **Chapter 3:** If HRD is not present in the stand AND the stand IS within 25 miles of a confirmed HRD stand
- **Chapter 4:** If HRD is present in the stand

Guidelines rationale and additional background information can be found in Chapter 5.
Relevant section(s) are indicated after the symbol "👉".

Figure 1 shows the HRD locations (dark blue points) in Wisconsin (and one location in Minnesota near the state border), with 25-mile buffer zones (pale blue shading). Spores will be more abundant in stands that are closer to a site where *H. irregulare* is present (👉 Chapter 5.1). This map should be consulted at the time of timber sale establishment. The map in the HRD guidelines is updated annually on Jan. 1 and is good through the end of the year (Dec. 31). Additionally, an online version of the map is updated throughout the year, and is available online at the HRD landing page at the DNR website. The HRD guidelines allow users to continue to refer to the map in the HRD guidelines until the "good through" date expires. The HRD guidelines give users a choice of following the map in the HRD guidelines until the end of the year or using the up-to-date map that appears online. If new HRD locations are added to the map, and the stand is now within 25 miles of known HRD locations, there will be a one-year grace period for implementation of the guidelines on DNR lands. If it is practical, implementation of the guidelines is encouraged as soon as new HRD locations are added.

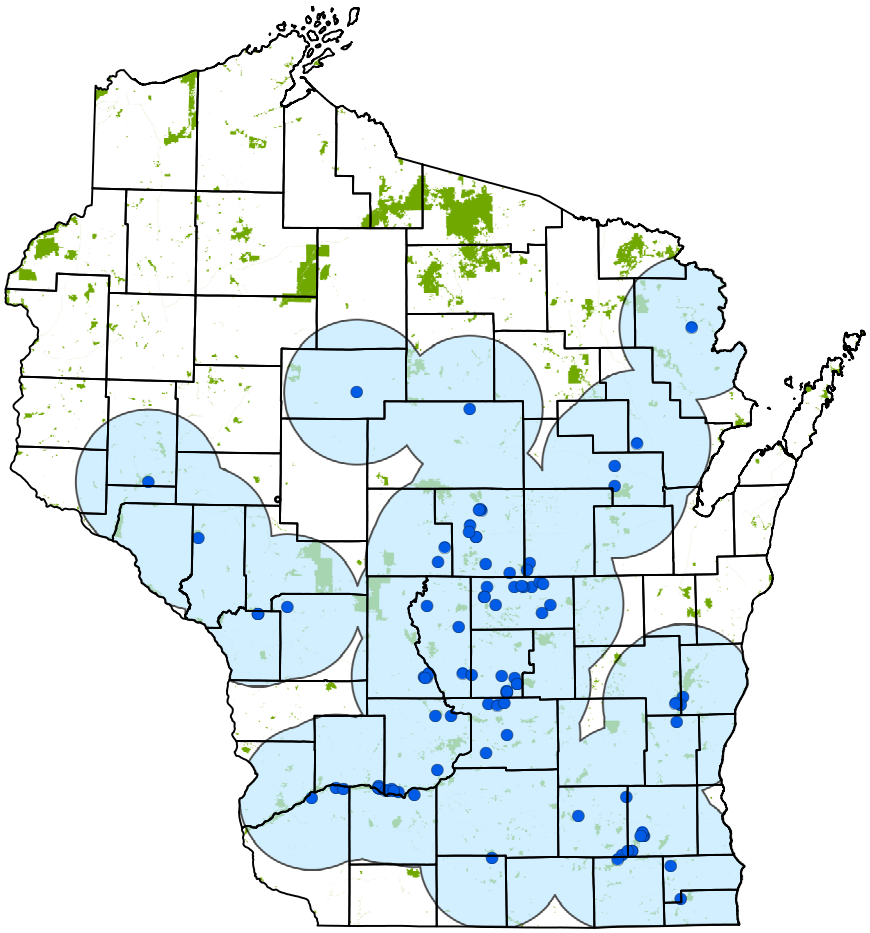


Figure 1: HRD locations in Wisconsin and Minnesota, with 25-mile buffers
Map creation date: Jan. 1, 2024
Map good through: Dec. 31, 2024
Note: A 6-mile buffer map is found in Appendix C.

In addition to general recommendations for preventive stump treatment, the HRD guidelines also include specific situations as Exceptions and Modifications when treatment may not be necessary. It is up to property managers/landowners to decide whether they prefer to use any of the Exceptions or Modifications. It is important to read the entire document before making a management decision about whether stump treatment should be conducted in a stand. For more information on Exceptions and Modifications listed in each chapter, read Chapter 5: Guidelines Rationale and Background Information.

Before a timber sale is established, it is extremely important to examine the stand for signs and symptoms of HRD.

Fruit bodies of H. irregulare may be small and similar to the shape of popcorn.

Fruit bodies of H. irregulare may decay before growing again.

Fruit bodies of H. irregulare may be found at the base of an infected stump.

Fruit bodies of H. irregulare may be found at the base of an infected tree.

DIFFERENCES BETWEEN EXCEPTIONS AND MODIFICATIONS — DOCUMENTATION REQUIREMENTS

If any of the Exceptions or Modifications apply to your stand, you may choose not to apply the preventive stump treatment. You should consider the potential impact to the stand and adjacent stands due to HRD if you choose not to use a preventive stump treatment at the time of harvest and *H. irregulare* were to infest the stand.

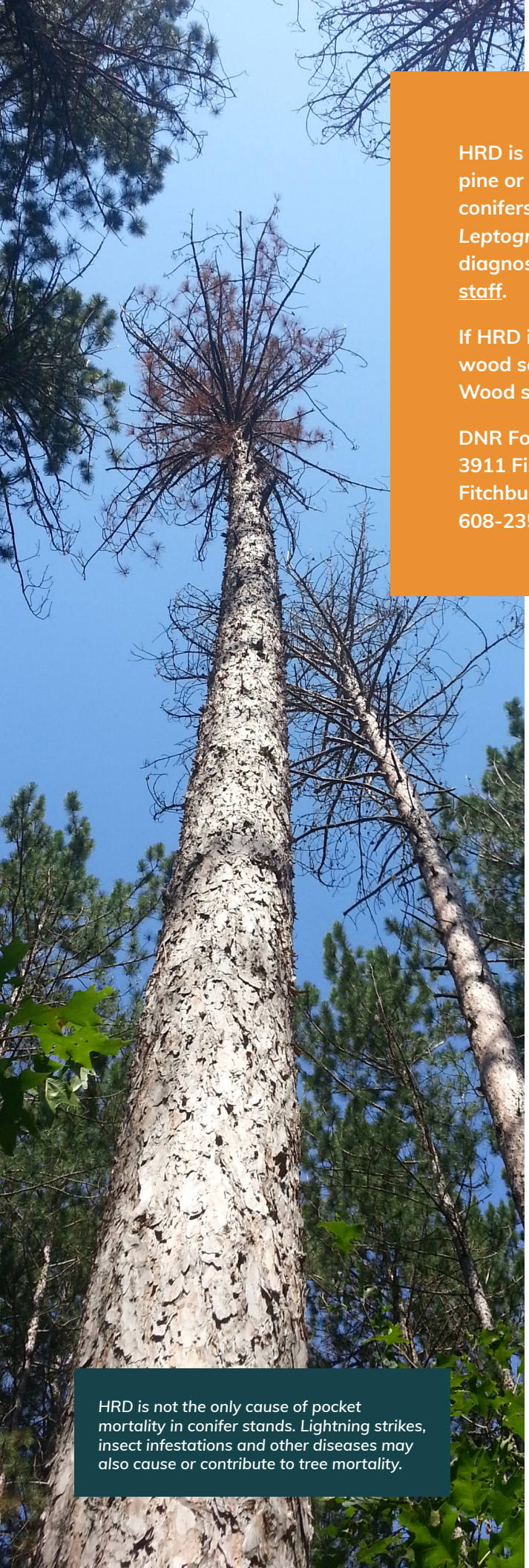
Please note that there are differences between Exceptions and Modifications. Exceptions are considered relatively common and are straightforward to apply. No detailed justification is needed to apply the Exceptions. However, a short explanation of which Exception was used should be included in the timber sale documentation. Modifications are considered to be stand-specific, and consultation with a forester and/or forest health staff in your area is recommended to assess applicability.

Justification for Modifications should be documented and included in the normal approval process for harvesting. For public lands, justification for using a Modification must be included in Form 2460-001 (Timber Sale Notice and Cutting Report). For Managed Forest Law and Forest Crop Law lands, it should be included in Form 2450-032 (Cutting Notice and Report of Wood Product). If the Exception/Modification requires a change in these forms, justifications should be added accordingly.

HOW TO SURVEY FOR HRD IN A STAND

Before a timber sale is established, it is extremely important to examine the stand in an effort to detect HRD. Look for a pocket of dead trees and fading trees (those with thinning crowns). If *H. irregulare* infected the stumps at the time of the previous thinning, these symptoms will begin to appear 3-8 years after that thinning. HRD also attacks understory conifer regeneration, so look for dead or fading regeneration. The number of HRD pockets in a stand can vary widely. Look for characteristic fruit bodies of *H. irregulare* at the base of dead/fading trees and old stumps from previous thinnings, as well as symptomatic understory conifers.

Fruit bodies may be buried among soil and duff layers, so move the duff layer from immediately around the base of the tree or old stump to adequately look for them. Fruit bodies are most commonly observed in the fall, but can be found any time of the year. Young fruit bodies look like popcorn and are firmly attached to the stump, tree, or root. Under favorable environmental conditions, fruit bodies grow into bracket-shaped or shelf-like fungi, which feel leathery (not hard) and remain attached to the stump, dead tree, or root. These shelf forms are sometimes perennial but can disintegrate quickly. Fruit bodies vary in color but are usually light to dark brown above and white to tan below. Fruit bodies found below the duff layer or soil may be completely white.



HRD is not the only cause of pocket mortality in conifer stands. Lightning strikes, insect infestations and other diseases may also cause or contribute to tree mortality.

HRD is not the only disease that creates a pocket of mortality in a pine or spruce stand. For example, similarly appearing groups of dying conifers can be caused by insects and associated root disease fungus, *Leptographium* species, or lightning strikes. If you need assistance diagnosing the causal agent, contact a forester and/or forest health staff.

If HRD is suspected but no fruit bodies are found, consider collecting wood samples from the base of dead trees for laboratory assessment. Wood samples can be sent to:

DNR Forest Health Lab
3911 Fish Hatchery Rd.
Fitchburg, WI 53711
608-235-7532

Presence of the HRD pathogen is confirmed in the lab. One method is to grow H. irregulare on a nutrient agar plate.

PESTICIDE APPLICATION LAW

The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) oversees Chapter ATCP 29 of the Wisconsin Administration Code (Pesticide Use and Control). The law states that individuals that make commercial for hire pesticide applications are considered commercial pesticide applicators, and must become certified in the appropriate Wisconsin Commercial Pesticide Applicator Certification Category. To certify, each individual must purchase a category specific training manual from the UW PAT, and then pass the DATCP certification exam. Certification is valid for five years. Once certified the individuals need to obtain an annual individual commercial pesticide applicator license. A business that makes commercial for hire pesticide applications must have an annual pesticide application business license. The business must employ certified and licensed pesticide applicators.

Individuals making applications to property they or their employer own or control, and who receive no compensation beyond normal wages, are not required to be certified or licensed when a non-Restricted Use Pesticide (RUP) is used.

Chapter 2

If HRD is not present in the stand AND the stand is NOT within 25 miles of a confirmed HRD stand

Recommendation: Treatment of pine and spruce stumps is considered unnecessary because there is a large distance between the stand and known locations of HRD. However, it is possible that HRD is present in areas where the disease has not been confirmed.

If you choose to harvest during April 1-Nov. 30 without stump treatment, consider the potential impact to the stand (and subsequent impact on adjacent stands) if HRD were to develop in the stand. It is important to note that there are no treatments to eradicate the pathogen after it infests a stand.

Exceptions: None
Modifications: None

A healthy spruce stand provides habitat for a variety of wildlife — including spruce grouse, a threatened bird in Wisconsin.

Chapter 3

If HRD is not present in the stand AND the stand IS within 25 miles of a confirmed HRD stand

Recommendation: If harvesting occurs from April 1-Nov. 30, preventive stump treatment on pine and spruce is recommended if more than 50 percent of the stand is pine and/or spruce. The minimum tree size for treatment is merchantable size. No treatment is required from Dec. 1-March 31. Harvesting without preventive stump treatment can be considered April 1-Nov. 30 under certain conditions listed as Exceptions or Modifications in this chapter.

It is possible that *H. irregulare* is present in a stand where the disease has not been confirmed. If you choose to harvest during April 1-Nov. 30 without stump treatment, consider the potential impact to the stand and subsequently to adjacent stands if HRD were to develop in the stand. It is important to note that there are no treatments to eradicate the pathogen after it infests a stand.

Note: Regarding site preparation following a harvest: There is currently no evidence that mechanical site preparation has ever contributed to introduction or increase/decrease of HRD in the Lake States. Thus, pesticide treatment is recommended during harvesting, regardless of a plan for mechanical site preparation. When a conifer site is regenerated to conifers, it is recommended that site preparation and re-planting be delayed for 2 years to reduce the risk of damage by pales weevils (*Hylobius pales*), and this practice may help reduce the risk of HRD as well.

Preventive stump treatment with a registered pesticide may not be needed during prolonged unusually cold weather or deep snow cover outside the winter period (outside of December 1 – March 31) (see Modification 1).

EXCEPTIONS

1. It is the final harvest and the future desired stand will be less than 50 percent pine and/or spruce combined. 👉 Ch. 5.2

2. It is the final harvest, and pine and/or spruce is not an important part of the future stand. 👉 Ch. 5.2

MODIFICATIONS

1. Unusual weather patterns. Examples of unusual weather conditions include but are not limited to: 👉 Ch. 5.3

   - Prolonged, unusually warm weather during the winter period (Dec. 1-March 31). Treatment may be recommended.
   - Prolonged, unusually cold weather outside the winter period (outside of Dec. 1.-March 31). Treatment may not be necessary.
   - Deep snow cover (at least 12 inches) outside of the winter period (outside of Dec. 1-March 31). Treatment may not be necessary.

2. FOR NON-DNR LANDS ONLY — The stand is between 6 and 25 miles from a known infestation and you have a greater tolerance for risk.

   If the stand is within 6 miles of a known infestation, the risk of introduction is high and DNR recommends the use of preventive stump treatment. But, as you move further away from a known infestation, the risk is reduced and based on your tolerance for risk you may decide preventive treatment is not necessary. A map that shows known HRD stands with 6-mile buffers is found in Appendix C. On DNR lands, a buffer of 25 miles is used.

   Note: Risk tolerance for DNR lands was decided at the Division of Forestry leadership level as a policy decision.

3. The stand is near final harvest (within 10 years) AND the regeneration plan for the stand will be less than 50 percent pine and/or spruce combined or pine and/or spruce will not be an important component of the regeneration plan after the final harvest. 👉 Ch. 5.2

4. Salvage harvesting. If a stand is exposed to high potential loss on residual trees, due to a natural disaster or multiple forest health issues, the stand may need to be harvested quickly to capture wood value. Although efforts should be made to arrange preventive stump treatment, under this type of emergency salvage harvesting, arrangement of pesticide application at harvest may not be practical.

A pesticide application on fresh cut stumps at the time of harvesting is an effective tool for HRD prevention.

Chapter 4

If HRD is present in the stand

Note: DNR currently maintains the locations of confirmed HRD-affected stands. If you suspect HRD in your stand, please contact forest health staff for confirmation and consultation.

Recommendation: If harvesting occurs from April 1-Nov. 30, preventive stump treatment on pines and spruce is recommended if more than 50 percent of the stand is pine and/or spruce. The minimum tree size for treatment is merchantable size. No treatment is required from Dec. 1-March 31. Harvesting without preventive stump treatment can be considered April 1-Nov. 30 under certain conditions listed as Exceptions or Modifications in this chapter.

If you choose to harvest during April 1-Nov. 30 without stump treatment, consider the potential impact to the stand and subsequently to adjacent stands. It is important to note that there are no treatments to eradicate the pathogen after it infests a stand.

Note: Rgarding site preparation following a harvest: There is currently no evidence that mechanical site preparation has ever contributed to introduction or increase/decrease of HRD in the Lake States. Thus, pesticide treatment is recommended during harvesting, regardless of a plan for mechanical site preparation. When a conifer site is regenerated to conifers, it is recommended that site preparation and re-planting be delayed for two years to reduce the risk of damage by pales weevils. This practice may help reduce the risk of HRD as well.

A pocket caused by HRD. Please report all HRD infestations in Wisconsin to DNR Forest Health staff.

EXCEPTIONS

1. It is the final harvest and the future desired stand will be less than 50 percent pine and/or spruce combined ☛ Ch. 5.2

2. It is the final harvest, and pine and/or spruce is not an important part of the future stand. ☛ Ch. 5.2

3. HRD is widespread in the stand ☛ Ch. 5.5 Stump treatment will help prevent new infestations but will not stop the movement of *H. irregulare* through root systems that are already colonized. Expect some additional infection through root contact and root infection. If stumps are not treated at the time of harvest, there may be additional stump infection following deposition of windborne spores.

Harvesting without preventive stump treatment with a registered pesticide may be an option to consider if HRD is widespread in the stand (see Exception 3).

MODIFICATIONS

1. Unusual weather patterns. Examples of unusual weather conditions include but are not limited to: ☛ Ch. 5.3

   - Prolonged, unusually warm weather during the winter period (Dec. 1-March 31). Treatment may be recommended.
   - Prolonged, unusually cold weather outside the winter period (outside of Dec. 1-March 31). Treatment may not be necessary.
   - Deep snow cover (at least 12 inches) outside of the winter period of Dec. 1-March 31. Treatment may not be necessary.

Harvesting without preventive stump treatment may be justified if a conifer stand is impacted by a natural disaster and a salvage harvest needs to occur quickly (see Modification 4).

2. The stand is near final harvest (within 10 years) AND the regeneration plan for the stand will be less than 50 percent pine and/or spruce combined; or pine and/or spruce won't be an important component of the regeneration plan after the final harvest. ☛ Ch. 5.2

3. A long-term economic analysis demonstrates that treatment is not economically practical, and that not treating is still suitable to meet all long-term objectives for the stand. ☛ Ch. 5.7

4. Salvage harvesting. If a stand is exposed to high potential loss on residual trees due to a natural disaster or multiple forest health issues, the stand may need to be harvested quickly to capture wood value. Although efforts should be made to arrange preventive stump treatment, under this type of emergency salvage harvesting, arrangement of pesticide application at harvest may not be practical.

Chapter 5

Guidelines rationale and background information

5.1 | Long-distance spread of *H. irregulare* and buffer radius

Spores of *Heterobasidion* species are produced from fruit bodies and disseminated by wind. Because they are small, even light air currents carry the spores easily. Although spores may be carried over hundreds of miles, it has been estimated that more than 99 percent of spores deposit within 300 feet of the spore source. However, the remaining 1 percent, while a small percentage, still represents hundreds of thousands of spores per day from one large fruit body. Spores may also be spread on logging equipment or by movement of colonized wood, but there is lack of research on spread by these means.

Spores of H. irregulare are produced from the lower surface of fruit bodies and disseminated by wind. The spore-producing surface is white and porous.

It is evident that the number of spores decreases as the distance from a spore source increases. However, research results on the long-distance dissemination of HRD spores can be complicated and somewhat contradictory, as noted in the next few paragraphs about the findings of various researchers.

A spore trap quantifies airborne spore density. Photo courtesy of Eric Otto, University of Minnesota

A recent spore trapping survey conducted in Quebec (Berube et al., 2017) found that spore density was highest in the infested stand and rapidly declined to approximately 20 percent of its density at one mile away. Spore density dropped to approximately 10 percent and was similar at 3, 15, and 87 miles distant from the known infested stand, and may represent background level. The viability of airborne spores may vary between 1 percent and 5 percent.

It is not known how many spores are needed to infect a freshly cut stump. Berube et al. noted that previous studies indicated a deposition rate of approximately 356 spores per 12-inch stump over 6 weeks may be necessary to initiate infection, whereas the number of spores they detected at 0.3 miles from an infested stand was less than 1 spore per 12-inch stump over 6 weeks.

The study concluded that although it is unlikely that local spores pose an added risk of infection more than 3 miles away, low background spore load is high enough to be responsible for long-distance introduction of the disease, and long-distance airborne spore dispersal remains the most important constant source of infectious *H. irregulare* in Quebec.

A review paper by Garbelotto and Gonthier (2013) summarized the results of studies performed in regions as diverse as Fennoscandia, the Alps, and Mediterranean forests. These studies indicated effective spore dispersal to be between 0.06 and 0.77 miles. They noted that although spores have been reported to travel long distances, there is increasing evidence of a geographically limited range of effective, viable dispersal of spores.

Laflamme and Bussierers (2017) summarized the history of HRD in Canada in their research leaflet. In 1967, a spore sampling operation in New Brunswick revealed that viable airborne spores from *Heterobasidion* species were present in the air, although the disease had not yet been identified in New Brunswick forests. In fact, the closest known source of inoculum of infection was more than 60 miles away, in Maine. In 1989, the first case of HRD in Quebec was discovered approximately 25 miles from the Larose Forest in Ontario, where HRD had been confirmed. This historical information serves as evidence that natural long distance spread of *H. irregulare* can occur in Eastern forests.

Microscopic image of H. irregulare with spores at the tip.

Although not common, fruit bodies of H. irregulare can be formed more than one foot from the soil line of an infected tree.

Gonthier et al. (2014) summarized impacts of the pathogen following a single introduction of *H. irregulare* to Italy through infected wood during World War II. The European species of *Heterobasidion* (*H. annosum*) was already native in their forests, but the introduction of the new species changed the dynamics of the disease and allowed them to track the spread of *H. irregulare*. They noted that the rate of spread of *H. irregulare* has been estimated to be at least 0.8 miles per year. In this case, available habitats (forest stands) were extremely fragmented in the infestation area. In Italy, the zone of infestation distance was set within 6 miles of any confirmed infestation sites, and the buffer zone was set within 50 miles of confirmed infestation sites. The zone of infestation was set based on both confirmed infestations and on the range of effective dispersal of airborne *H. irregulare* spores, and the buffer zone was based on the presumed distance at which effective dispersal of *H. irregulare* is minimized. The treatment of stump surfaces within the buffer zone is required in Italy.

Modification 2 in chapter 3 of these guidelines was adopted based on the recent research data that demonstrated that the number of spores decreases as the distance from a spore source increases, and the definition of zone of infestation that has been implemented in Italy. Users of the guidelines should note that it is possible that HRD is present in a stand where the disease has not been confirmed.

5.2 | HRD hosts in Wisconsin

In Wisconsin, both conifer and hardwood trees can be infected by HRD. However, conifer trees appear to be much more susceptible to HRD. Currently HRD is most commonly found in red and white pines in a plantation setting. On overstory trees, the disease has been observed on jack, red and white pines, and on white and Norway spruce. HRD has been found on the following species growing in understory: red pine, jack pine, white pine, balsam fir, white spruce, eastern red cedar, oaks (both red and white), black cherry and buckthorn. Of these species, mortality by the disease in Wisconsin has been observed, or is suspected, only on conifers. Prior research in other states and countries has shown that Scots (Scotch) pine is susceptible to HRD; however, it has not been confirmed on Scots pine in Wisconsin. Mortality of hardwood species has not been documented in Wisconsin.

Fruit bodies of H. irregulare at the base of an understory black cherry.

Fruit bodies of H. irregulare on a spruce stump.

In a summary publication, Laflamme and Bussierers (2017) noted that experiments in Ontario plantations revealed that the stumps of jack pine could be colonized by *H. irregulare*. Ohno et al. (2017) found that the pathogen was frequently observed on discs of tamarack, red pine and white spruce that were placed at a radial distance of approximately 3 feet around stumps bearing *H. irregulare* fruit bodies. In contrast, the pathogen was not seen, or only rarely seen, on discs of northern white cedar, eastern hemlock and balsam fir. In another test, weight loss due to decay in root wood artificially inoculated with *H. irregulare* was greatest for red pine (23.2 percent), followed by tamarack (19.1 percent), white spruce (12.3 percent), northern white cedar (9.7 percent), hemlock (7.8 percent) and balsam fir (1.3 percent).

5.3 | HRD spore production

It is known from early research that HRD fruit bodies produce spores when temperatures are at or above 32°F and cease when temperatures reach 100°F. Most often, spores are produced between 41°F and 90°F.

In a study conducted in central Wisconsin (Stanosz et al., 2016), relatively fewer viable spores were disseminated from HRD fruit bodies during periods of coldest winter temperatures. However, viable spores were detected at temperatures of 23°F to 32°F. Other studies have shown spores being produced at 18°F. Yet, it is not known if spores produced at these temperatures can germinate and infect stump surfaces.

5.4 | HRD infection and stem wounds

Infection via stem wounds is not considered a major source of new infestation. Stem wounds of conifers are mostly infected by fungi other than *Heterobasidion* species. There is no evidence that stem wounds on pine can become infected naturally. An artificial inoculation study concluded that infection of stem wounds is unlikely to occur unless a tree is extremely stressed.

Infection via stem wounds is very uncommon.

The frequency of infection and subsequent pathogen colonization is correlated with the size, depth of the wound and growth rate of the tree. Smaller trees have developed smaller root systems and dying roots can be quickly decomposed and colonized by other fungi, making small-diameter trees a lower risk of infection and spread of the disease to nearby trees. So, although small understory trees occasionally break during harvest, they do not appear to be a major risk factor for new infestation.

Currently HRD is most commonly found in conifer plantations.

5.5 | Factors affecting disease incidence and severity

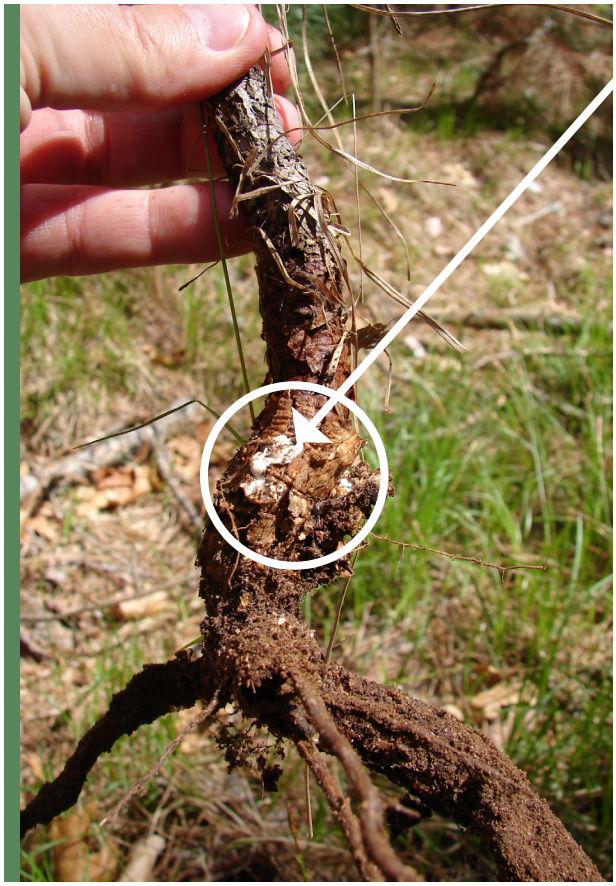
Incidence: The incidence of HRD can be impacted by a variety of factors, including distance to HRD infestations (👉 Ch. 5.1), stump susceptibility, temperature (👉 Ch. 5.3), prevailing winds, tree species involved (👉 Ch. 5.2), stump size and presence of enough spores to lead to infection of the stump. Infection probability is proportional to the density of airborne spores deposited on fresh cut stumps.

How long a stump is susceptible (at risk for new infection) depends on host, site, and season; however, susceptibility rarely exceeds one month because of changes in the chemistry of nutrients available on stump tops and to competition by other microorganisms.

Severity: Damage caused by *Heterobasidion* species is generally high on fertile soils and on sand soils with low organic matter content. Damages caused by the pathogen are generally greater on former agricultural lands and former pastures than on forest soils.

Depending on soil properties, the fungus may either directly colonize the bark of live roots (in low-pH soils) or grow under the outer bark scales (in high-pH soils). The growth under the outer bark scales may result in significantly higher fungal expansion rates because of the lack of an active host defense response. *Garbelotto* and *Gonthier* (2013) noted in their review that an acceleration of secondary growth of the *Heterobasidion* species and an increase in tree-to-tree transmission through root contacts were documented in the roots of felled trees, where lack of an active host response resulted in a much greater colonization of the root layer. This indicates there are situations that can enhance pocket expansion.

Currently, HRD is most commonly found in plantations. This may partly be due to frequent root contacts or grafts, ease of recognizing HRD in these stands, shorter intervals between cutting, and/or the lack of other competing organisms on former agricultural soils. Studies of natural ecosystems have shown HRD may be less damaging than in managed forests, but root disease pathogens still have roles in affecting species composition, stand density, and structure through creation of canopy gaps. In addition, some native fungi (such as *Phlebiopsis gigantea*) compete against *Heterobasidion* species, but little is known about their relative abundances and importance in preventing HRD in Wisconsin.



Fruit bodies of H. irregulare at the base of a red pine seedling.

5.6 | Impact of HRD on regeneration

Colonized stumps from previous harvests can impact the subsequent generation of trees, as they serve as both a source of vegetative growth and spore-bearing conks. A large stump colonized by *Heterobasidion* species can continue to harbor the pathogen and be a source of pathogen spread for decades after felling.

In the southeastern United States, loss of seedlings planted after harvest of an infested stand is estimated to be less than 5 percent. In the higher temperatures of the southern United States, survival time of the pathogen in colonized host materials may be much shorter than in Wisconsin.

A study was conducted in the Lake States to evaluate natural regeneration on stands with HRD in 2017. Surveys on 49 pockets in 31 stands in Wisconsin and Michigan found overall adequate regeneration with “desirable” tree species, mainly hardwood species. Although white and red pine composed 18 percent of the total regeneration, transmission of HRD to white pine advance regeneration was repeatedly observed. The study concluded that in sites where invasive species and conifers are the dominant regeneration, the invasive species are expected to eventually fill the gaps (M. Demchik, University of Wisconsin-Stevens Point, Personal Communication).

Mortality of understory white pine and balsam fir caused by HRD.

5.7 | Economic analysis of preventive treatment

Costs are associated with the pesticide and labor/equipment needed for treatments to prevent HRD. An economic analysis for a specific stand weighs the reduction in yield due to HRD against the monetary cost of the treatment. An analysis is conducted using a regional pine or spruce growth model. Additional factors that should be considered include;

- Site index
- Number of trees per acre
- Price per cord and price per thousand board feet (MBF)
- Planting costs per acre
- Rotation age
- Thinning timings and number of thinnings
- Discount rate
- Percent loss due to HRD
- Treatment cost per cord

Due to the number of factors considered in an economic analysis, results are very specific to a stand based on local timber markets, treatment costs and stand conditions.

HRD pocket

5.8 | Types and efficacy of pesticides for prevention of HRD

The pesticide is applied in an aqueous solution on fresh cut stumps (blue dye is added as a visual cue to ensure acceptable coverage).

There are currently two different types of pesticides approved in Wisconsin to prevent HRD from infecting fresh cut stumps within a stand:

The borate compound Cellu-Treat™: This chemical formulation acts as a wood preservative and barrier to prevent infection by the pathogen on fresh cut stumps. It is a wettable powder that dissolves in water. Effectiveness of borate compounds in preventing stump infection has been demonstrated in more than 80 published papers (Pratt, 1996).

Biological Control Agent (RotStop®C): Contains spores of a naturally occurring wood decay fungus, *Phlebiopsis gigantea*, in a wettable powder that is applied as an aqueous mixture. Decades of field studies and experience in commercially managed forests in Europe and North America demonstrate effectiveness of *P. gigantea*. This fungus is known to occur within conifer forests of Wisconsin, but its relative abundance and distribution is not known and may be too limited to naturally prevent development of HRD.

Both materials that are currently available for stump treatment for HRD in Wisconsin are applied in water. Therefore, treatment is not feasible during periods of cold temperatures. Based on the spore dissemination data obtained in Wisconsin (👉 Ch. 5.3) and operational practicality, these guidelines do not require treatment from Dec. 1-March 31.

Spray solution containers are stowed in a storage box on a processor.

5.9 | Conifer resources in Wisconsin

LOCATION OF CONIFER RESOURCES

About one-third of all pine volume (Table 1 and Figure 2) is located in northeast Wisconsin; another third is located in central Wisconsin. Northwest Wisconsin contains about 26 percent of all pine volume. The southeast and southwest portions combine to make up only about 10 percent of the total volume. A total of 83 percent of all other conifer species (other than pine) is located in the northern regions (Table 1 and Figure 3).

Table 1. Volume (in milliona of cubic feet) of growing stock by species and region of the state. (2016 FIA Data)

Species	Statewide	Northeast	Northwest	Central	Southwest	Southeast
Pines	**3,782**	**1,290**	**972**	**1,167**	**210**	**144**
Percent All pines		**34 percent**	**26 percent**	**31 percent**	**6 percent**	**4 percent**
E white pine	1,817	615	397	577	127	101
red pine	1,739	619	498	497	82	43
Jack pine	226	55	77	93	0	1
Conifers	**2,423**	**1,222**	**798**	**167**	**29**	**207**
Percent all conifers		**50 percent**	**33 percent**	**7 percent**	**1 percent**	**9 percent**
N white-cedar	715	362	176	38	0	138
E hemlock	453	282	114	34	0	23
balsam fir	417	202	200	13	0	3
tamarack	322	138	134	40	1	9
white spruce	256	107	100	19	12	17
black spruce	199	122	73	4	0	0
Scotch pine	23	5	0	13	4	1
Norway spruce	20	4	0	3	2	11
E redcedar	17	0	0	2	10	5
Total	**6,205**	**2,511**	**1,769**	**1,333**	**239**	**352**

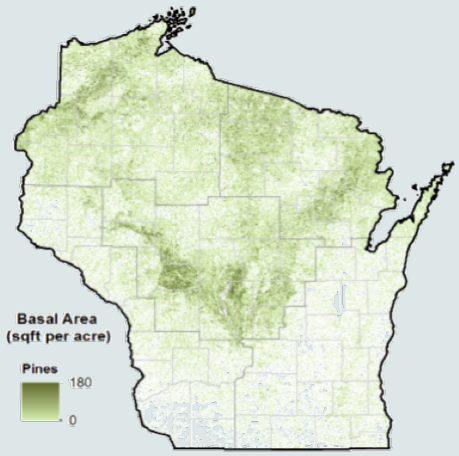


Figure 2: Basal area of pines (square feet per acre)

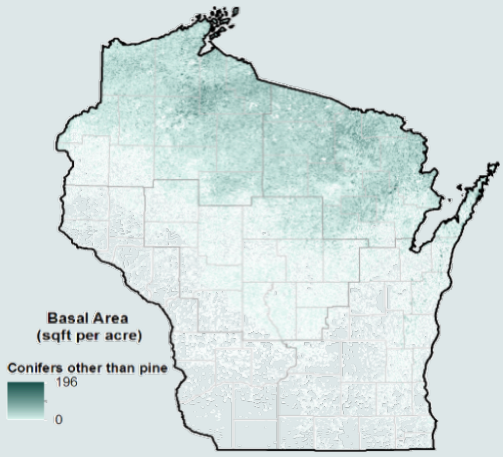


Figure 3: Basal area of conifers other than pine (square feet per acre)

Forest Type	Total (thousand acres)	
	Natural	Planted
Jack pine	221	52
Red pine	154	630
E white pine	405	121
Total pine	**779**	**803**
Percent total	**49 percent**	**51 percent**
E hemlock	88	0
Balsam fir	201	10
White spruce	60	38
Black spruce	323	3
Tamarack	380	4
N white-cedar	327	2
Total conifer	**1,379**	**57**
Percent total	**96 percent**	**4 percent**
Total	**2,163**	**860**

PLANTATIONS VS. NATURAL STANDS

There are about 3 million acres occupied by pine and other conifer forest types in Wisconsin (Table 2). About half of this acreage is pine; half is other conifer types. Less than 30 percent of the total conifer acreage is planted and most of this is red pine (80 percent of all red pine in Wisconsin is planted). Almost all non-pine conifer acreage is natural (96 percent). Most white pine (77 percent) and jack pine (81 percent) occur in natural stands.

Table 2. Area of timberland (thousand acres) by pine and conifer forest type and stand origin (natural vs. artificial regeneration).

CONIFER OWNERSHIP

Almost two-thirds of all pine volume is privately owned in Wisconsin; the remaining one-third is publicly owned (State, Federal, or County/Municipal). Other conifers follow a similar pattern, with 62 percent in private ownership and 38 percent publicly owned.

Table 3. Net volume of growing-stock trees (at least 5 inches dbh.), in million cubic feet. (2017 FIA Data)

Species	Federal	State	County and Municipal	Private	Statewide
Pines	**445**	**347**	**619**	**2,559**	**3,970**
Percent all pines	**11 percent**	**9 percent**	**16 percent**	**64 percent**	**100 percent**
eastern white pine	154	194	254	1,334	1,936
red pine	256	136	312	1,084	1,788
jack pine	35	16	53	141	246
Other conifers	**395**	**202**	**344**	**1,548**	**2,490**
Percent other conifers	**16 percent**	**8 percent**	**14 percent**	**62 percent**	**100 percent**
northern white-cedar	117	59	84	480	740
eastern hemlock	64	47	37	317	464
balsam fir	74	29	63	261	428
tamarack (native)	39	24	53	217	332
white spruce	57	19	50	131	257
black spruce	45	20	50	90	206
Scotch pine	0	0	0	24	24
Norway spruce	0	3	7	12	21
eastern red cedar	0	1	0	17	18
Total all pines and other conifers	**840**	**549**	**963**	**4,107**	**6,460**

AGE CLASS AND FUTURE OF PINE RESOURCES

The volume of pines has increased significantly in the last two decades.

Red Pine: The volume of red pine has increased significantly since 1996. This volume increase has occurred almost exclusively in sawtimber-sized trees. Models project increased volume over the next 30 years, due to increasing numbers of trees entering large size classes. The number of saplings has decreased in the last 20 years, suggesting that red pine volume may diminish in the future.

White Pine: The white pine resource has doubled in volume in the last two decades. The number of trees in all size classes has increased significantly, indicating that white pine should remain a major species in future forests. Models indicate a sharp increase in volume over the next 40 years.

Jack Pine: Since 1983, both the volume and rate of growth of jack pine have decreased significantly. The number of poles and sawtimber trees has decreased by 33 to 40 percent since 1996. Seedling numbers have decreased at a greater rate than any other species. Volume of jack pine is predicted to decrease by two-thirds over the next 40 years.

RELEVANT LITERATURE

Berube JA, Potvin A, Stewart D. 2017. Importance of local and long-distance *Heterobasidion irregulare* aerial basidiospore dispersal for future infection centers in thinned red pine plantations in Quebec. *The Forestry Chronicle.* 93(3):241-245

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Ohno K, Myers LJ, Smith DR, Clausen CA, Mausel D, Stanosz GR. 2017. Conifer species influence *Heterobasidion irregulare* sporulation on stem discs exposed to natural inoculum and root wood decay in soil-block tests. *For. Path.* E12381. https://doi.org/10.1111/efp.12381

Stanosz G, Cram M, Coyle D, Haugen L. 2018. Heterobasidion Root Disease in Eastern Conifers. Forest Insect & Disease Leaflet 76. USDA Forest Service, Northeastern Area State and Private Forestry, Newtown Square, PA. 16p.

Stanosz G, Smith D, Juzwik J. 2016. Seasonal availability of inoculum of the Heterobasidion root disease pathogen in central Wisconsin. *Can. J. For. Res.* 46:1076-1080 (2016)

Woodward S, Stenlid J, Karjanlainen R, Huttermann A. 1998. *Heterobasidion annosum*: Biology, ecology, impact and control. Wallingford, UK: CABI. 589 pp. This is a 23-chapter book that provides a single-source summary drawing from over 2000 research papers.

Appendix A

Generally accepted forestry management practices

1. Start the thinning/harvesting with healthy/non-infested portions of the stand, and then move to infested areas.

2. During thinnings or salvage operations, it is recommended that dead trees and the bottom 8 feet of stems of trees that show dieback, thinning and/or yellowing of the foliage (fader trees) and trees with *H. irregulare* fruit bodies be utilized as soon as possible from April through November. If colonized portions of diseased trees sit for long periods in a log yard, they can produce fruit bodies and spores to increase the risk of new infestations in that area.

When harvesting a stand with HRD, start the thinning/harvesting in healthy/non-infested portions of the stand.

3. To capture the value of wood from trees that will die from HRD before the next thinning entry, seemingly healthy trees outside the pocket (within 35 to 65 feet from the perimeter of the last faders) could be harvested. It is estimated that the pathogen spreads through roots approximately 3.5-6.5 feet per year, which gives an estimated expansion of 35 to 65 feet during the 10 years between thinnings. Removing these healthy trees around a pocket will not be effective in preventing or delaying the further spread of the disease through root connections or by root contact.

4. A clearcut harvest of the stand may be considered if the infestation is extensive (many pockets or pockets that are coalescing).

5. Cleaning logging equipment (tires, cutting head, etc.) with pressurized water prior to leaving the harvest site may help minimize the risk of the spread of *H. irregulare* to a new location.

   Note: The significance of equipment contamination on the long-distance spread of this pathogen is unknown. However, spores of the pathogen have been reported to survive in dry soil for 1 year or longer. Because harvesting equipment can wound stems and roots, and the fungus can infect trees through wounds, washing at least the contacting parts of the equipment before entering areas not yet infested is a cautious approach.

Clean logging equipment (tires, cutting head, etc.) with pressurized water prior to leaving HRD infested stands to minimize the risk of the spread of H. irregulare to a new location.

Appendix B

Dichotomous decision/exception key chart

1. **Is HRD in the stand?**
   No – go to 2
   Yes – go to 9

2. **Is the stand within 25 miles of a known infestation?**
   No – no treatment recommendations
   Yes – go to 3

3. **Do pine and/or spruce make up more than 50 percent of the stand?**
   No – no treatment recommendations
   Yes – go to 4

4. **Is this an intermediate thinning or is it the final rotation?**
   Intermediate thinning – go to 5
   Final rotation – go to 6

5. **Will thinning occur from April 1-Nov. 30?**
   No – no treatment is required Dec. 1-March 30.
   Yes – treatment recommended. For Exceptions and Modifications, see Chapter 3

6. **Is the future stand less than 50 percent pine and/or spruce combined?**
   No – go to 7
   Yes – treatment may not be necessary (Exception 3.1)

7. **Are pine and/or spruce important components of the future stand?**
   No – treatment may not be necessary (Exception 3.2)
   Yes – go to 8

8. **Will harvesting occur from April 1-Nov. 30?**
   No – no treatment is required Dec. 1-March 30.
   Yes – treatment recommended, for Exceptions and Modifications see Chapter 3

9. **Is HRD widespread in the stand?**
   No – go to 10
   Yes – treatment may not be necessary (Exception 4.3)

10. **Do pine and/or spruce make up more than 50 percent of the stand?**
    No – no treatment recommendations
    Yes – go to 4

11. **Is this an intermediate thinning or is it the final rotation?**
    Intermediate thinning – go to 12
    Final rotation – go to 13

12. **Will thinning occur from April 1-Nov. 30?**
    No – no treatment is required Dec. 1-March 30.
    Yes – treatment recommended, for Exceptions and Modifications see Chapter 3

13. **Is the future stand less than 50 percent pine and/or spruce combined?**
    No – go to 14
    Yes – treatment may not be necessary (Exception 4.1)

14. **Are pine and/or spruce important components of the future stand?**
    No – treatment may not be necessary (Exception 4.2)
    Yes – go to 15

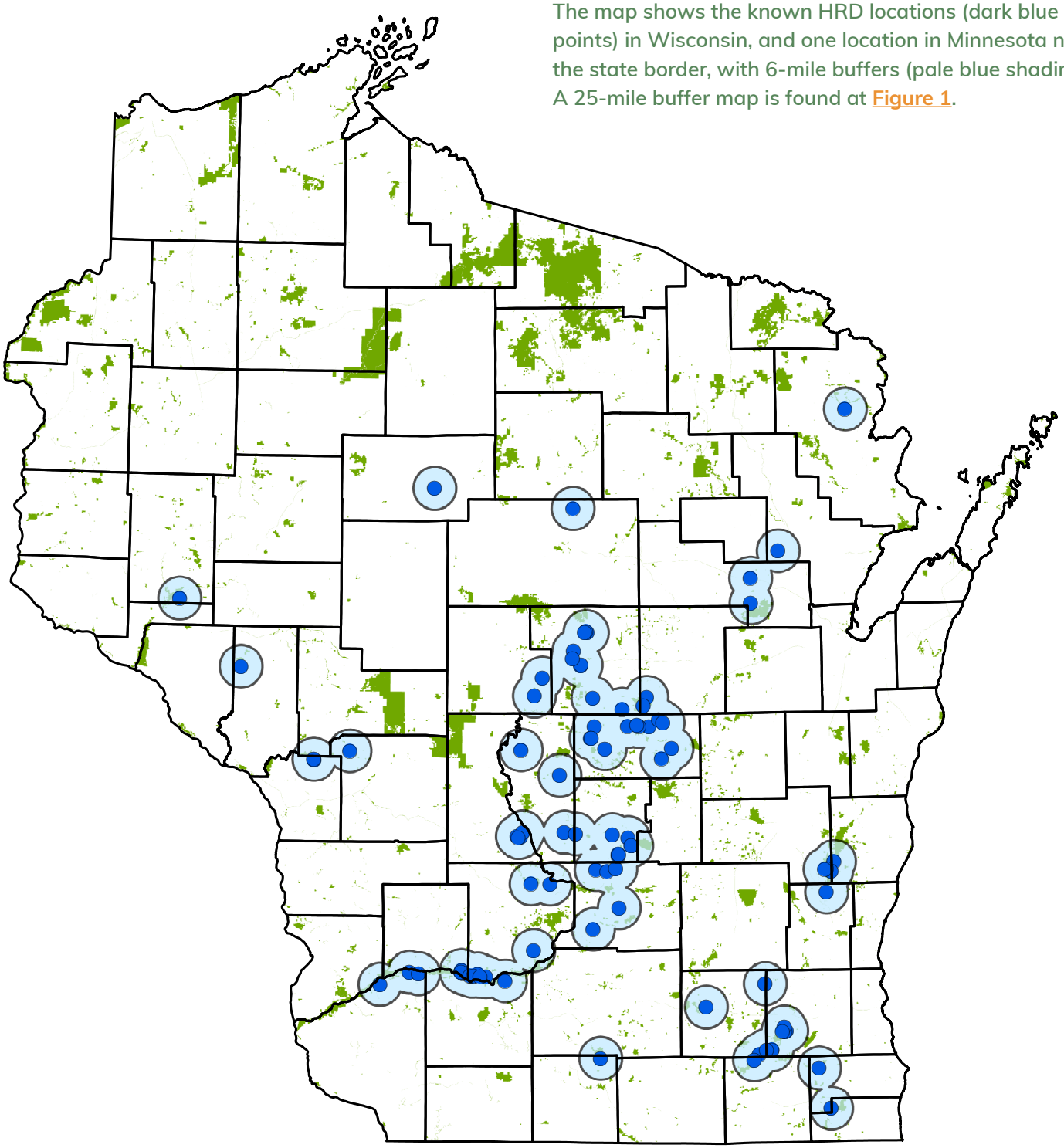
15. **Will harvesting occur from April 1-Nov. 30?**
    No – no treatment is required Dec. 1-March 30
    Yes – treatment recommended, for Exceptions and Modifications see Chapter 4

*NOTE – there may be some additional situations in which you do not need to treat stumps during a harvest. These are noted as Modifications in Chapters 3 and 4.

Appendix C

6-mile buffer map

The map shows the known HRD locations (dark blue points) in Wisconsin, and one location in Minnesota near the state border, with 6-mile buffers (pale blue shading). A 25-mile buffer map is found at Figure 1.



Appendix D

Resources

GENERAL INFORMATION

- Wisconsin DNR Division of Forestry
- Wisconsin foresters — Forestry Assistance Locator
- Wisconsin DNR Forest Health specialists
- Wisconsin DNR Managed Forest Law
- Wisconsin County Forests
- Consulting Foresters

HETEROBASIDION ROOT DISEASE

- Wisconsin DNR HRD landing page
- FIDL 76 Heterobasidion Root Disease in Eastern Conifers

FOREST RESOURCE

- Wisconsin's Forest Resources [PDF]

HANDBOOKS/GUIDELINES

- Wisconsin DNR Forest Management Guidelines
- Wisconsin DNR Silviculture Handbook

Fruit bodies of H. irregulare at the base of an infected red pine.

Appendix E

Glossary

Cambium
A layer of meristematic cells, lying parallel to the surface of a stem or root, which undergo cell divisions to produce secondary tissues.

Coalesce
Come together and form a whole.

Conk
Fruit body, usually of a polypore wood-decay fungus, formed on tree stumps, roots, branches, trunks or occasionally on lumber. Usually they are spongy to hard, become large when mature and persist for one or more years.

Conifer
Tree usually bearing a cone.

Dieback
Progressive death of twigs or branches, from the tips toward the base.

Duff layer
Moderately to highly decomposed leaves, needles, fine twigs, and other organic material found above the mineral soil surface.

Exception
Situations that can be applied to harvest without stump treatment in these guidelines. Exceptions are considered relatively common and are straightforward to apply. No detailed justification is needed to apply Exceptions.

Fader
A tree that is showing dieback and/or yellowing of the foliage. Foliage may be thin, or tufted at the tips of branches.

Fruit body
A complex, multicellular fungal structure that contains or bears spores. HRD fruit bodies may be small and "popcorn-like," or may take the form of a shelf fungus.

Infected
A host plant in which a pathogen has completed the process of penetration and is now established within that plant.

Infested
An area or stand occupied by a pathogen, insect or other pest.

Modification
Situations that can be applied to harvest without stump treatment in these guidelines. Modifications are considered to be stand-specific, and consultation with a forester and/or forest health staff is recommended to assess applicability. Justification for Modifications should be documented and included in the normal approval process for harvesting.

Pathogen
An organism or agent capable of causing disease in a particular host or range of hosts.

Perennial
Lasting several years.

Pesticide
(1) any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, (2) any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant, and (3) any nitrogen stabilizer. (https://www.govinfo.gov/content/pkg/USCODE-2013-title7/html/USCODE-2013-title7-chap6-subchapII-sec136.htm)

Pocket
An irregular opening in the forest due to mortality of trees in a cluster. It often expands as additional trees die.

Residual trees
Trees remaining after a thinning or final harvest.

Root contact
Point at which roots of one tree touch the roots of another tree, which can allow *H. irregulare* to move from tree to tree underground. Grafting of roots is not required for *H. irregulare* in one root to infect the root of another tree.

Spore
A one to many-celled, microscopic reproductive body in bacteria, fungi, and some lower plants; may be sexually or asexually produced and of a wide variety of sizes, shapes, colors, and origins.

Stand
1: A contiguous group of trees sufficiently uniform in species composition, structure, and age-class distribution, and growing on a site of sufficiently uniform quality, to be considered a relatively homogeneous and distinguishable unit. 2: A contiguous group of similar plants.

Understory
The vegetation that is growing below an upper canopy.

Appendix F

Contributors

The stand-level HRD guidelines were originally implemented in May 1, 2013. In 2017 and 2018, the HRD guidelines were thoroughly reviewed and updated. The HRD guidelines were developed by evaluating multiple areas, including recent research findings, using experience gained in implementation of the HRD guidelines, and applying economic considerations.

HRD guidelines were revised in 2018 with the help of the following groups:

- A stakeholder Advisory Committee – representatives from affected stakeholder groups, including industry, government, landowners, and non-profit groups.
- The Technical Team – representatives from forestry programs within DNR.

ADVISORY COMMITTEE

Becky Gray (Facilitator)	DNR-Division of Forestry
Nancy Bozek	Representation: Non-Industrial, Private Land
Linda Haugen	Representation: USDA Forest Service
Tom Hittle	Representation: Industrial Land Managers
Jeff Kante	Representation: Society of American Foresters
Joe Kies	Representation: Paper and Pulp Industries
Scott Koerner	Representation: Timber Producers
Juris Repsa/Ben Preston	Representation: Timber Industries
Mike Sieger	Representation: WI DNR State Lands
Dave Spaude	Representation: County Forests
Glen Stanosz	Representation: University of Wisconsin-Madison
Sue Swanson	Representation: WI DNR Managed Forest Law Lands
Joel Wagenaar	Representation: Consulting Foresters

TECHNICAL TEAM (WDNR DIVISION OF FORESTRY)

Julie Ballweg

Todd Lanigan

Kyoko Scanlon

Tom Shockley/Adam Wallace

Linda Williams

A healthy red pine stand generates revenue from timber production as well as habitat and shelter for wildlife.

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