# An Epidemic of Needle Cast on Lodgepole Pine in Colorado

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Abstract: An epidemic of needle cast, causing discoloration and defoliation of lodgepole pine, was observed on the Gunnison, White River, and San Isabel National Forests on both sides of the Continental Divide in the southern and central mountains of Colorado. In this general area, most stands were apparently unaffected, but the disease was locally severe. Evidence indicates the epidemic was active for at least four years, from 2008 through 2011. Two species of *Lophodermella* caused the epidemic, *L. montivaga* and *L. concolor*. Generally we found only one species at each site, but in at least one site we found both pathogens. Substantial growth loss of severely infected trees may be expected during the epidemic and for several years afterwards. Mortality is unlikely except for trees that are highly susceptible, small, in suppressed understories, or otherwise compromised.

Key words: Needle cast, epidemic, *Pinus contorta*, *Lophodermella concolor*, *Lophodermella montivaga*

## 1. BACKGROUND

On August 30, 2011, Gerry Chonka (Fire Management Officer, Gunnison Ranger District, GMUG) alerted us to discoloration and defoliation of lodgepole pine (*Pinus contorta*) on the west side of Marshall Pass. Soon thereafter we were able to make additional observations west of Independence Pass on the Aspen-Sopris Ranger District (White River NF), and various areas between those sites on the Gunnison and Salida Ranger Districts (Gunnison and San Isabel NFs).

## 2. OBSERVATIONS

Field sites where needle cast was found are mapped (*Figure 1*) and listed with information on pathogen and symptoms (*Table 1*).

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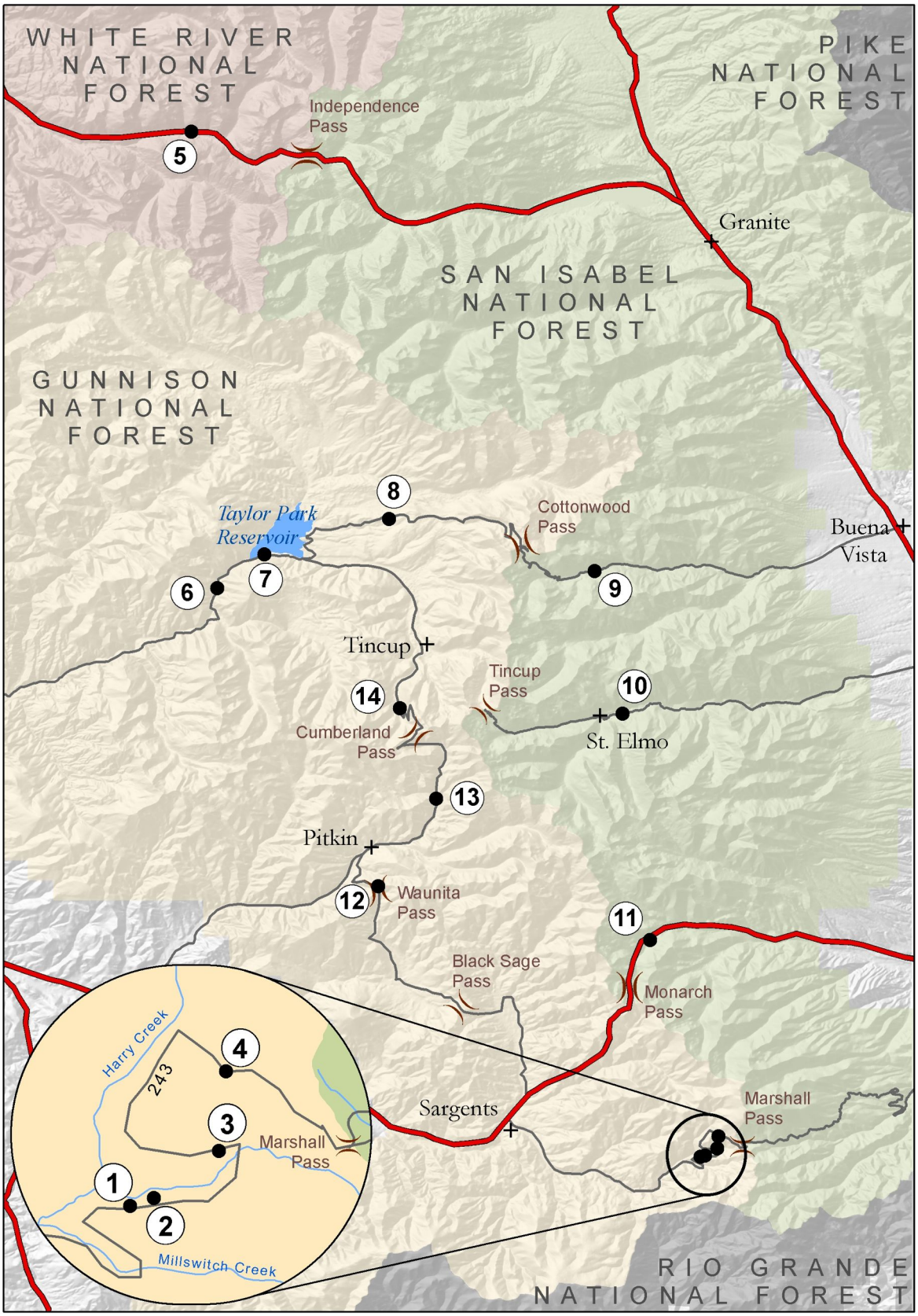


*Figure 1.* Locations of sites where needle cast was found, September 2011.

*Table 1.* Locations of observations, map keys, foliage condition, and pathogen identification. Site numbers correspond with numbers in Fig. 1. All identifications are based on field and laboratory (microscopic) examination except for 14, which is based on field examination only. Blanks indicate no data.

| | | | | | Foliage condition in most severely affected trees | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Location | Site # | Pathogen | Elev. | Severity | 2011 | 2010 | 2009 | 2008 | 2007 |
| W of Marshall Pass | 1 | | 9,843 | All ages, widespread | Healthy | Discolored | Some gone | | |
| W of Marshall Pass | 2 | | 10,045 | All ages, widespread | Healthy | Discolored | Some gone | | |
| W of Marshall Pass | 3 | *L. concolor* | 10,253 | All ages, widespread | Healthy | Discolored | Some gone | | |
| W of Marshall Pass | 4 | *L. montivaga* | 10,633 | Severe locally | Discolored | Gone/discol. | Gone | Gone | Healthy |
| W of Independence Pass | 5 | *L. montivaga* | 10,400 | Recently severe, stands have orange hue | Discolored | Gone/discol. | Some gone | Some gone | Some gone |
| Taylor Canyon | 6 | *L. concolor* | 9,163 | Locally severe in small trees or lower branches | Some discol., dwarfed | Gone/discol. | Some gone | Some gone | Some gone |
| Taylor Reservoir | 7 | *L. concolor*? | 9,531 | Severe in small trees, branch dieback | Discol. or dead | Gone/discol. | Some gone | Some gone | Some gone |
| W of Cottonwood Pass | 8 | *L. concolor*? | 10,069 | Mild | Healthy | Healthy | Gone/discol. | | |
| E of Cottonwood Pass | 9 | *L. montivaga* | 10,338 | Isolated trees | Discolored | Gone/discol. | Healthy | Healthy | Healthy |
| St. Elmo | 10 | | 9,944 | Mild to healthy | Healthy | Healthy | Discolored | | |
| E of Monarch Pass | 11 | *L. concolor* | 10,111 | Severe, stands have orange hue | Healthy | Gone/discol. | Often gone | Often gone | |
| W of Monarch Pass | | | | Healthy | | | | | |
| Black Sage Pass | | | | Healthy | | | | | |
| W of Waunita Pass | 12 | | 10,269 | Locally severe | Healthy | Gone/discol. | Gone | Gone | Gone |
| S of Cumberland Pass | 13 | *L. montivaga* | 9,970 | Locally moderate, severe in few trees | Discolored | Gone/discol. | Healthy | Healthy | |
| N of Cumberland Pass | 14 | *L. montivaga* | 10,650 | Moderate in isolated trees | Discolored | Gone/discol. | Healthy | Healthy | |

## 2.1 Marshall Pass

Gerry Chonka's report indicated moderate to severe discoloration/defoliation affecting all size classes of lodgepole pine near the upper end of the Marshall Pass Road, FR 243, with the worst damage above Millswitch Creek in T48, R6E, Section 26. The worst defoliation was estimated to be over 70%.

We visited four sites in that area on Aug. 31, 2011, ranging in elevation from about 9,800 to 10,600 ft. In affected areas, most needles produced in 2010 were already gone or loose, falling, and orange-brown, yellowish or gray. In some cases, 2009 and 2008 needles were completely gone, while 2007 needles were green and tight. This indicates that the epidemic has been active here for four years, beginning in 2008.

At the uppermost site (*Table 1*, *Figure 1*, site 4), current-year (2011) needles were also orange-brown but not loose. Here we found abundant fruiting (reproductive, spore-producing structures) on the 2010 needles (*Figure 2*). Fruiting was raised ridges, elongated to 5 mm or more and coalescing end-to-end, with diffuse black lines generally associated with the ridges. Occasionally, transverse black bands (zone lines) were present at the ends of infected portions of the needles. In the laboratory we identified it as the needle-cast fungus *Lophodermella montivaga*. The specimen was deposited in the herbarium of Forest Health Protection, Gunnison as herbarium #97.

In other sites, the pathogen was either not fruiting or the fruiting had been invaded and replaced by that of a secondary fungus, identified as *Hendersonia pinicola*, and so was unidentifiable. However, we did find one needle with fruiting of *Lophodermella concolor* at site 3.

*Figure 2.* Needles with fruiting of *L. montivaga* are usually gray-tan. Ascomata are seen as raised ridges, coalesced longitudinally, usually with diffuse brownish lines over the ridges. Four needles in the right photo have zone lines, the transverse black bands at the ends of the fruiting areas. From site 4.

## 2.2 Independence Pass

On June 25, 2008, during our Regional Insect and Disease Training, we found heavy infection of *L. montivaga* on several lodgepole pine saplings on the east side of Independence Pass, on the Leadville Ranger District, San Isabel NF (*Figure 3*).

On Sept. 9, 2011, Roy Mask and Tom Eager visited site 5 along Hwy. 82 west of Independence Pass, between Lost Man and Lincoln Gulch Campgrounds, with Jan Burke, Timber Staff Officer of the WRNF. A stretch of a few miles contained many symptomatic trees of all ages, giving the forest an orange-brown hue from a distance. Discoloration appeared most severe on trees approximately 10 feet tall and less. Current-year needles were beginning to fade to yellow. 2010 needles were missing, or where present, appeared orange to red and were falling readily. Among the red 2010 needles were gray needles that had dark fruiting bodies on their surface. The 2009 and 2008 needles were frequently missing. Microscopic study enabled identification of *L. montivaga* (deposited as herbarium #95). However, again we saw that many fruiting bodies had been replaced by secondary fungi.

*Figure 3.* Lodgepole pine shoot on the east side of Independence Pass, photographed June 25, 2008, when bud had broken and needles were beginning to expand. 2007 needles were nearly all infected by *Lophodermella montivaga* and had heavy fruiting. 2006 needles were all missing and presumably had been heavily infected and cast in 2007.

## 2.3 Taylor Canyon and Cottonwood Pass

On Sept. 15, we scouted a variety of lodgepole pine areas on the Gunnison and Salida Ranger Districts to assess how continuous the damage was between Marshall and Independence Passes. In upper Taylor Canyon, above Lottis Creek Campground (site 6), needle cast was locally heavy, especially on small trees and the lower portions of taller trees. Many affected shoots carried only 2011 needles (*Figure 4*), and fruiting was found on the 2010 needles that remained. Here the macro- and microscopic characters fit *L. concolor*. Near Taylor Reservoir (site 7), the disease affected a smaller proportion of trees, but in those it was more severe, with all needle cohorts affected in some understory trees, leading to branch dieback and imminent mortality. Current-year discoloration noted here may have been early twig dieback. Samples were tentatively identified as *L. concolor*. Higher up, on the west side of Cottonwood Pass (site 8), areas of mild disease were found. The 2010 and 2011 needles were healthy, suggesting that it had not been active here after 2009. In 2009 needles, fruiting was again tentatively identified as *L. concolor*.

On the east side of Cottonwood Pass (site 9), we found several isolated trees up to 30' tall that had heavily affected, yellow to orange current-year needles. The 2010 needles were orange to gray or gone, and we identified *L. montivag*a fruiting on those needles.

*Figure 4.* Saplings with severe infection by *L. concolor* in upper Taylor Canyon and near Taylor Reservoir (sites 6 and 7), holding only current-year needles.

## 2.4 St. Elmo area

Along Chaffee County Road 162 from the Mt. Princeton Hot Springs as far as St. Elmo, the lodgepole pine appeared generally healthy. Near St. Elmo (site 10), some individuals carried only two years' needles: 2011 and 2010 needles were healthy, but 2009 needles were discolored and loose with blackish fruiting, and there were no older needles. This may have been older, inactive needle cast such as found on the west side of Cottonwood Pass.

## 2.5 Monarch Pass

On the east side of Monarch Pass, needle cast was severe and widespread near the Madonna Mine (site 11). South of the highway, the mature lodgepole forest had a distinct orange tinge. On the north side, where we could examine trees closely, only 2011 needles were uniformly healthy. The 2010 needles were generally either gone or loose and discolored with fruiting; 2009 and 2008 needles were mostly gone. Microscopic examination allowed identification of *Lophodermella concolor* (Forest Health Protection, Gunnison, herbarium #110).

No needle cast was observed on the west side of Monarch Pass.

## 2.6 Black Sage Pass

Relatively few lodgepole pine were encountered on this route; they appeared generally unaffected.

## 2.7 Waunita Pass

The few lodgepole stands on the east side of Waunita Pass appeared unaffected. On the west side, lodgepole pine is in extensive, pure stands. Stands of young lodgepole were found with various symptoms (site 12). 2011 needles were healthy. 2010 needles were gone or discolored with fruiting. Trees in the worst-affected area were missing all older foliage, meaning they carried only current-year foliage. Samples were not collected.

## 2.8 Cumberland Pass

Most lodgepole appeared generally healthy north of Pitkin, but approaching Cumberland Pass from the south, one stand had a somewhat orange hue (site 13). Several trees near the road had current-year foliage almost all discolored, indicating very heavy infection this year (*Figure 5*). 2010 needles were already gone or discolored/dead with some fruiting. Collections were identified in the laboratory as *L. montivaga*.

On the north side, almost all the lodgepole pine appeared healthy. A few individuals had discolored 2011 needles and 2010 needles that were loose and discolored with fruiting (site 14). Older foliage was healthy. Based on field observations only, we identified the pathogen as *L. montivaga*.

*Figure 5.* Discoloration of current-year needles at site 13. Some older needles are gray with fruiting of *L. montivaga*.

# 3. THE NEEDLE CASTS

## 3.1 Basic biology and disease cycles

Diseases categorized as needle casts have the following features:

1. The pathogens infect conifer needles, which die prematurely and are usually dropped or "cast" earlier than they otherwise would be.
2. They have only one infection period per year. The disease cycle from one infection to the next requires a full year or multiple years.
3. Most of the pathogens are in the family Rhytismataceae (formerly Hypodermataceae), order Rhytismatales, and have similar morphological features.

The two pathogens identified here are among the most virulent of the group (Boyce 1961, Minter 1993). They both infect current-year needles, *L. concolor* in June-July and *L. montivaga* in July-September (*Figure 6*). In the case of *L. montivaga*, needles discolor orange to brown quickly, as early as one month after infection. Needles infected by *L. concolor* discolor in early spring of the following year. Fruiting bodies develop on the needles and ripen in time for the respective infection period. If conditions are moist for long enough when fruiting bodies are ripe, spores are forcibly shot into the air. Needles begin falling soon after.

Infection is dependent on a period of continuously wet leaf surfaces when the fruiting is mature and ready to sporulate. Infection is reportedly most severe in in cool valleys and at the confluence of streams where mists and fogs are common (Mielke 1956). Heavy precipitation is not required, but continuous wetness, such as drizzle, fog, and overcast, even for just a day, can be ideal. When conditions are suitable, mature fruiting bodies open by a longitudinal slit. Inside is a layer of spore-producing tissue. Spores are shot into the air sequentially when the slit is open.

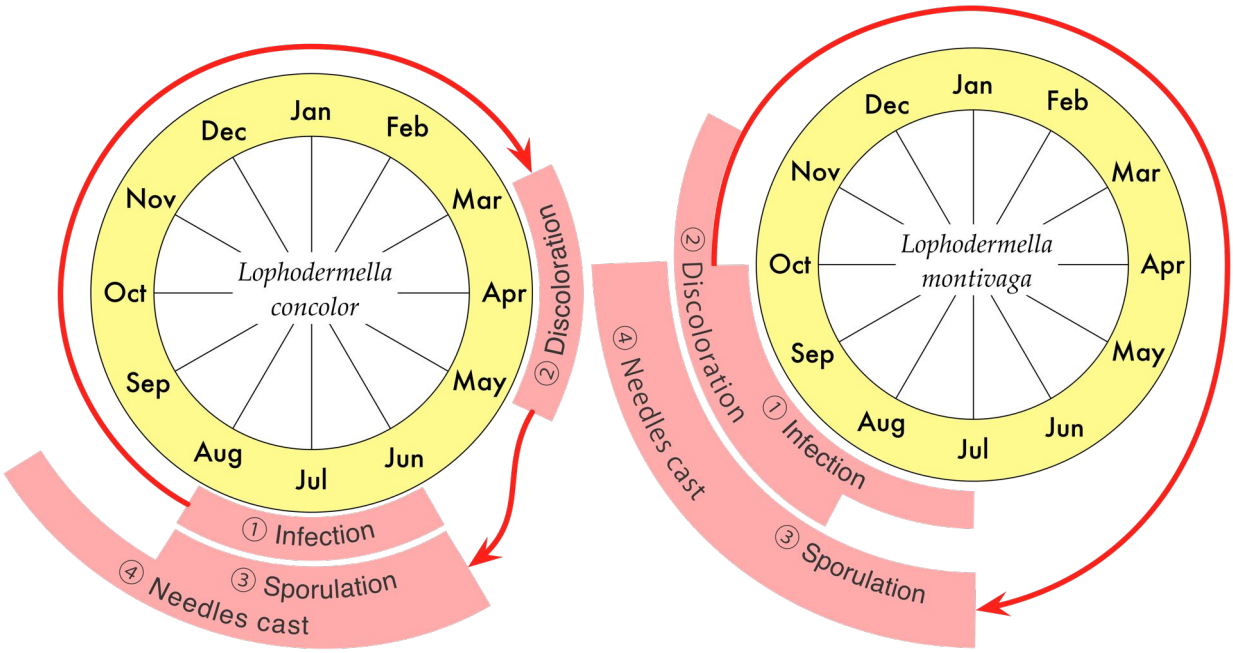


*Figure 6.* Disease cycles of the two pathogens. Disease cycles are based on data in the literature (see Appendix), but are not known precisely and time periods are approximate.

The airborne spores are long and covered with a sticky sheath. If they impact a needle, they stick to it. If conditions remain moist, the spore germinates and the fungus penetrates the needle surface and begins to grow inside.

## 3.2 Effects on trees

Both of these needle casts can lead to nearly complete defoliation when conditions are conducive for several successive years. With *L. concolor*, if infection occurs before needles are fully expanded, needles may remain dwarfed (Darker 1932). Small trees and those in the understory may be affected throughout their height, but taller overstory trees are mostly infected in the lower crown except under very conducive conditions. In trees that are highly susceptible, suppressed, off-site, or in very dense stands, twig and branch dieback and even mortality can occur (Darker 1932, Minter 1993).

Needle casts can cause substantial growth loss. A study in Oregon found significant growth effects of a closely related pathogen, *Lophodermella morbida*, on off-site ponderosa pine (Harvey 1976). Comparing trees that had been severely infected for a few years with nearby relatively healthy trees, and correcting for prior growth, diseased trees had 33% less height growth and 15% less radial growth. In Scotland, *Lophodermella sulcigena* (very close to and perhaps identical with *L. montivaga*) was first noticed in a 10-yr old Corsican pine plantation in 1970. By the end of 1975, diseased trees had 59% less volume and were 20% shorter than healthy trees. (Mitchell *et al.* 1976).

Several factors may moderate the impact of needle casts. (*i*) Weather may not be suitable for spore dispersal and infection during the period when fruiting is mature. (*ii*) Resistance can vary greatly among families of lodgepole pine. (*iii*) Secondary fungi (effectively hyperpathogens) can increase during an epidemic. These fungi invade the fruiting bodies of the needle-cast fungi and replace them with their own reproductive structures. In some of our samples, nearly every fruiting body we examined had been invaded by secondary fungi. This substantially reduces inoculum available to infect new needles.

# 4. CONCLUSIONS AND RECOMMENDATIONS

This epidemic appears to have been active since 2007 or 2008. We examined an area that extends about 60 miles along the Continental Divide; it may extend farther north or south. The epidemic is spotty, with locally heavy infection extending up to several square miles, but separated by larger areas with little or no infection. These areas of heavier infection may remain moist longer at the critical times of year, or they may have more susceptible genotypes of lodgepole pine than other areas.

To be precise, this is really two epidemics, because two species of needle-cast fungi are involved. This may be unusual, and we are not aware of published reports of this. However, the fungi are very similar in moisture requirements. Weather patterns that favor infection during June-July for *L. concolor* may also favor infection during July-September for *L. montivaga*. Unknown ecological differences may account for their apparent spatial segregation.

Depending on management objectives, needle casts may or may not be a management concern. The most common and widespread effect on trees will be growth reduction, which is likely to be an issue mostly where timber production is the primary emphasis.

Direct control of needle casts in our forest environments is neither practical nor desirable. Fungicides are sometimes used for direct control of needle casts in settings such as very high-value timber plantations, landscaping and Christmas trees.

In managed stands, where disease management is desirable, long-term, silvicultural approaches are most practical and effective:

1. Even-aged management reduces disease severity by avoiding the conducive conditions in understories, where needles stay wet longer and infection is more likely.
2. Similarly, keeping stand density low can reduce severity of the disease. Dense stands, where crown closure occurs early, tend to stay wet for a long time.
3. Finally, resistance and site factors can be used for long-term disease management by focusing forest management in areas less prone to disease. If lodgepole pine is planted, selection of resistant seed sources is one approach. Where natural regeneration is the normal practice, as in the Rocky Mountain Region, observations during an epidemic such as this can show which areas remain healthy, either because of resistant genotypes or nonconducive site factors. Management efforts that are focused in such areas are likely to be more successful in the face of future needle-cast epidemics.

# 5. APPENDIX – IDENTIFICATION OF *LOPHODERMELLA* SPECIES ON LODGEPOLE PINE

*The information in this appendix is provided to summarize the literature on identification and to help in identification of these fungi.*

The genus *Lophodermella* is distinguished from related genera on conifer needles by the following features: (*i*) ascomata produced below the host hypodermis; (*ii*) ascospores clavate with a mucilaginous sheath, often becoming septate at maturity; (*iii*) needles infected the year they are formed and usually cast the following year; (*iv*) ascomata not extending most of the needle length in solid black lines as in the *Lirula* complex, and; (*v*) asci wide compared to those in the *Lophodermium* complex (Darker 1967).

There are two or three species of *Lophodermella* on lodgepole pine in the southern Rocky Mountains, and they can be difficult to distinguish. Although in the literature there are fairly clear morphometric distinctions among the species, in practice there can be a confusing array of measurements of a specimen, some of which fit one species and some another. Sizes of microscopic features can vary substantially during development and depending on mounting medium. It can be difficult to find a specimen that is ideally mature but not spent. Also, secondary fungi often invade ascomata and impede microscopic identification.

For example, Johnson (1993) reported an epidemic of *L. concolor* on lodgepole pine in the Red Sandstone/Piney River analysis area on the White River National Forest. That same summer, there was correspondence with a mycologist regarding *Lophodermella* specimens from Colorado. The mycologist was having difficulty identifying the specimens based on measurements. Three were identified as *L. montivaga* and one tentatively as *L. concolor*.

In communication with David Minter (Centre for Agricultural Bioscience International), an authority on the group, it appeared that he considered macroscopic characters as most determinative. Symptoms in autumn can also be very helpful, since only *L. montivaga* can cause discoloration of current-year needles.

Below we provide a collation of the descriptions of the fungi from the literature, along with our notes on the most useful distinguishing features.

## 5.1 *Lophodermella concolor* (Dearn.) Darker

*Lophodermella concolor* usually can be distinguished by the following combination of characters:

1. Current-year needles not discolored, but some cohort of older needles partly discolored and/or missing. (Lack of current-year discoloration is only helpful in autumn, when *L. montivaga* can discolor current-year needles)
2. No distinctly raised, more or less distinctly brown, long ridges that are coalesced longitudinally, on previous-year needles. However, there may be unrelated streaks and blotches of browning on the needle. Ascomata generally blend in with the color of the needle and may be hard to find.
3. Ascomata very short, < 1 mm, ellipsoid, may be slightly sunken at maturity.
4. Microscopic characters:
    a. ascospores ranging wider than 5 µm
    b. ascomata usually ≤ 0.4 mm wide
    c. ascoma lower wall usually < 20 µm thick

**Ascomata** (hysterothecia). (Minter 1993) on brown dead areas which later become paler, on both sides of needles, at first slightly darker than leaf surface and more waxy, later the same color, at maturity depressing the needle surface slightly, inconspicuous, 0.4–0.8 × 0.28–0.44 mm. Beneath

one or two layers of hypodermal cells, some of which are tanned, mesophyll beneath also tanned. Upper and lower walls colorless, both about 10-15 µm thick.

(Darker 1932) Hysterothecia at first seated on dead tawny areas which later fade to a pale buff, hysterothecia at first slightly darker than the leaf surface and more waxy in appearance, later concolorous with the leaf surface, following the stomatal lines, at maturity forming shallow depressions, inconspicuous, amphigenous, 0.4-0.8 × 0.28-0.44 mm; hysterothecia in cross section subhypodermal, 0.20-0.28 mm deep; basal plectenchyma colorless, 10-15 µm thick; covering layer of epidermis and hypodermis 20-30 µm thick and colorless compact plectenchyma 10-15 µm thick, occasionally a layer of host parenchyma and fungus tissue up to 30 µm thick covers over the hysterothecium; hymenium 135-200 µm thick.

(Funk 1985) ascoma much shorter than that of *L. montivaga*.

**Paraphyses.** (Darker 1932) about as long as the asci, occasionally becoming variously expanded at the tips into spore-like proliferations. (Minter 1993) about as long as the asci, often wider at the base.

**Asci.** (Darker 1932, Minter 1993) subcylindric, 120–225 × 15–17 µm (rarely up to 21 µm broad in fresh material per Darker).

**Ascospores.** (Darker 1932, Minter 1993) lower half tapering to an acute base, 45–60 × 6–8 µm. (Funk 1985) 45–60 × 4–8 µm.

**Zone lines.** (Minter 1993) not observed

**Phenology.**

- Sporulation and infection of current-year needles – June-July (Minter 1993, Sinclair 2005). June-July (Millar 1986)
- Symptoms – reddish-brown in March and April of year following infection, becoming straw colored and falling during summer (Minter 1993). May/June (BC Forest Practices Branch). After 9 months [which would be March-April) (Millar 1986).
- Needles cast – Needle-cast occurs 12-14 months after initial infection at, or slightly before maturation of the ascomata (Minter 1993). After 12-14 months (Millar 1986). Millar states, regarding casting before maturation:

  > "Darker (1932) stated that needles of *P. banksiana*, infected by *L. concolor*. are cast after 1 year at, or slightly before, maturation of the hysterothecia. Other workers have generally found only empty ascocarps, or ascocarps colonized by secondary fungi, on cast needles. *Lophodermella* seems to be adapted to sporulating on the tree, close to the new susceptible tissue, and shedding of immature ascocarps must be assumed to be due to other causes."

**Damage.** "*Hypodermella concolor* causes such severe blighting that after one or two years of heavy defoliation the tips of the twigs are killed and the whole branch may eventually die." Needles may be dwarfed (Darker 1932).

**Notes.** May be followed by *Hendersonia pinicola* (Millar 1986, Minter 1993) and *Hemiphacidium longisporum* (Millar 1986).

## 5.2 *Lophodermella montivaga* Petrak

In our area, if any of the following characters are present, along with the basic characters of *Lophodermella*, the species is almost certainly *L. montivaga*:

1. Current-year needles discolored (only observable in fall/early winter, and of course only if those needles were infected)

2. Previous-year or sometimes older needles with distinctly raised, often more or less distinctly brown, long ridges that are coalesced longitudinally, sometimes (although interrupted) for much of the length of the needle.
3. Zone lines (transverse, blackish bands) on occasional needles.
4. Microscopic:
    a. ascoma lower wall tends to be thick, >20 µm
    b. ascospores tend to be small, generally < 4 x 50 µm
    c. ascomata range > 0.5 mm wide (measured in the compound microscope) (Note: Minter (1993) gives only the superficial dimensions, not the cross-sectional width)

**Ascomata** (hysterothecia). (Minter 1993) on both sides of 1-yr old needles, on mostly terminal discolored areas, brown, grayish brown or dark gray, waxy appearance when moist, raising surface of the needle, often coalescing longitudinally, 0.75–8 × 0.28–0.4 mm. Beneath tanned hypodermal cells. Upper wall colorless or pale brown. Lower wall colorless, 20-30 µm thick, becoming up to 40 µm thick at sides.

(Darker 1932) Hysterothecia scattered, on sordid areas mostly terminal on one year old needles, discolored brown in lip region, waxy when moist, 0.28-0.4 × 0.75-8 mm; lips inconspicuous; hysterothecia in cross-sectional view subhypodermal, 0.42-0.63 mm wide (including triangular wedges of plectenchyma which extend under the epidermis at edges of hysterothecia), 0.22-0.25 mm deep; basal plectenchyma 24-30 µm thick, becoming thicker along sides of hysterothecia (up to 40 µm); covering layer of epidermis and hypodermis 25-32 µm thick and colorless plectenchyma layer 30-33 µm thick; hymenium 108-150 µm thick.

(Funk 1985) ascoma much longer than that of *L. concolor*.

**Paraphyses.** (Darker 1932, Minter 1993) unbranched, up to 150 × 1 µm. [in our specimens, paraphyses were rarely this narrow]

**Asci.** (Minter 1993) clavate to almost cylindrical, 120–160 × 12–15 µm. (Darker 1932) Asci elongated, clavate, 8-spored, 120-160 x 12-15 µm.

**Ascospores.** (Darker 1932, Funk 1985, Minter 1993) 40-50 × 3-4 µm.

**Zone lines.** (Minter 1993) brown, broad, diffuse, occasional at the interface between dead and live needle tissue.

**Phenology.**

- Sporulation and infection of current-year needles – July to October (Minter 1993). July-September (Sinclair 2005). July-September in table, July-October in text (Millar 1986).
- Symptoms – In Colorado the first symptoms have been reported in September (Minter 1993). "Lesions appear after one month" (Sinclair 2005). "After 1 month" in table; "First symptoms appear in September in Colorado" in text (Millar 1986).
- Needles cast – summer (Sinclair 2005).

**Notes.** (Minter 1993) May be N. American form of *L. sulcigena* (Staley's unpublished key indicates he wondered if they were the same), also resembles *L. morbida*.

## 5.3 *Lophodermella cerina* (Darker) Darker

Staley (1964) did not list this pathogen, originally described from California, among the conifer foliage diseases of Colorado. He did put it in an unpublished key (1976) to species in the southern Rockies and Great Basin, but did not list lodgepole pine as a host. However, Hunt & Ziller (1978) and Minter (1993) did list lodgepole as a host. If lodgepole is a host in our area, it appears to be uncommon. If it does occur, it should be recognizable by the spores, which are longer and, relative to the length, narrower than those of the other species.

"*Hypodermella cerina* is similar in general appearance to *Hypodermella concolor*. Its hysterothecia, however, are more lens-shaped in cross section and are less deeply seated in the host tissue. The asci are considerably broader in *H. cerina* and its ascospores are more nearly filiform than those of *H. concolor*. Both species are strongly parasitic and in some localities control measures would be warranted." (Darker 1932).

**Ascomata** (hysterothecia). (Minter 1993) on paler or waxy or dirty-looking areas on both sides of otherwise reddish-brown needles, same color as leaf surface or grayish, indistinct outline, slightly raised, 0.6–2.75 × 0.3–0.63 mm. Beneath tanned hypodermal cells. Upper wall brown, 10-24 μm thick, lower wall colorless, 15-30 μm thick.

**Paraphyses.** (Minter 1993) threadlike, 180–200 × 1–3 μm.

**Asci.** (Minter 1993) narrowly saccate, tapering to apex, 160–225 × 17–21 μm.

**Ascospores.** (Minter 1993) 68–78 × 3–3.5 μm.

**Zone lines.** (Minter 1993) not observed.

**Phenology.**

- Sporulation and infection of current-year needles – Spring (Minter 1993, Sinclair 2005).
- Symptoms – Beginning that autumn. (Minter 1993, Sinclair 2005). Autumn (Millar 1986).
- Needles cast – After 1-2 years (Millar 1986).

**Notes.** (Minter 1993) May be followed by *Hendersonia acicola*.

## 5.4 Characters common to all species

**Hysterothecia.** Subhypodermal: beneath the cuticle, epidermis, and hypodermal cells. Hypodermal cells are "tanned" in *L. cerina* and *L. montivaga*, can be in *L. concolor*.

**Paraphyses.** Colorless, smooth, thin-walled, septate, apex slightly swollen.

**Asci.** Ripening sequentially, thin-walled.

**Ascospores.** Colorless, thin-walled, aseptate, clavate, with a mucilaginous sheath.

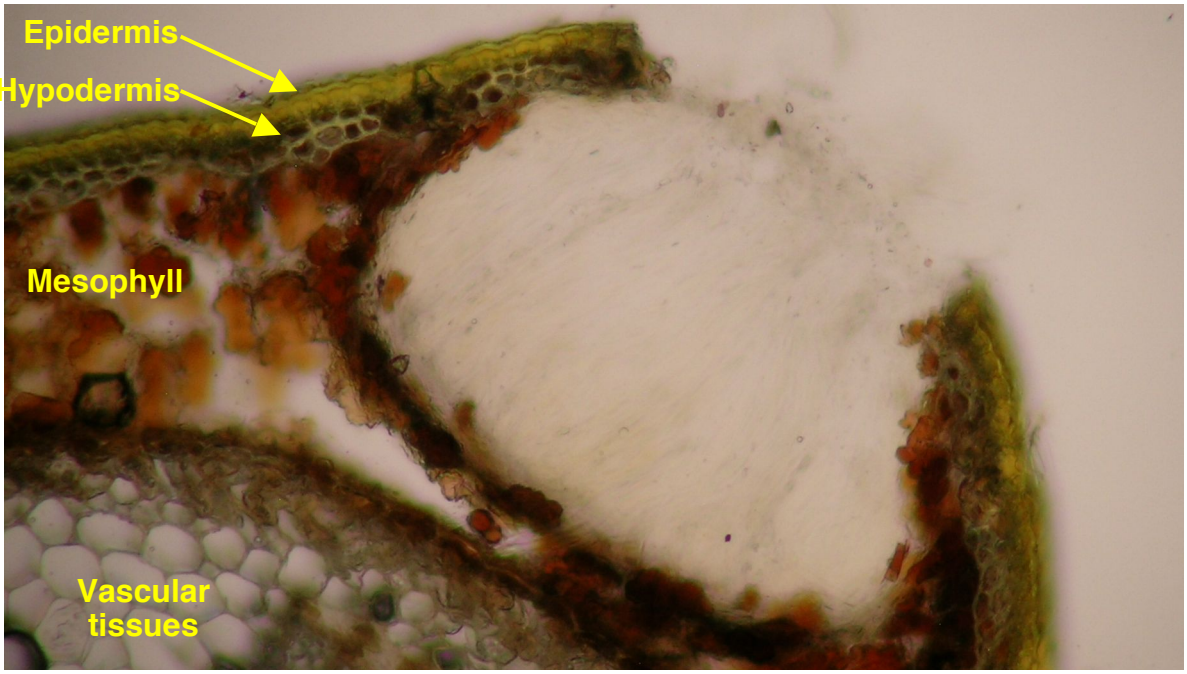


*Figure 7.* Cross section of ascoma of *L. concolor* from site 6. The ascoma is below the epidermis and hypodermis, which are not strongly pigmented. It is deeply seated, with little mesophyll separating it from the vascular tissues of the needle. The darkening of the ascoma wall is due to secondary fungi.

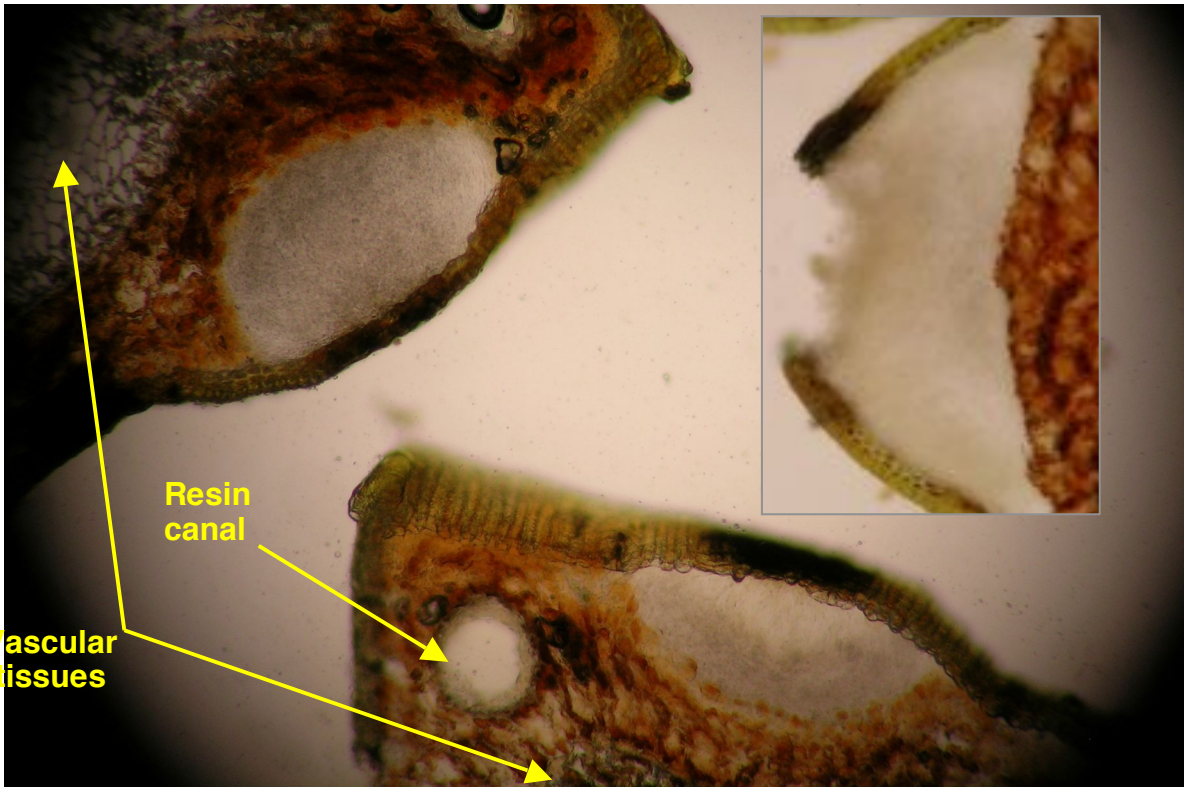


*Figure 8.* Intact, immature ascomata of *L. montivaga* from site 9. The epidermis and hypodermis are darkened over the center of the ascomata. Ascomata do not extend as deeply as those of *L. concolor*, being separated from the vascular tissues by more mesophyll. The inset shows a closer view of one from site 13, where the epidermis and hypodermis have ruptured and can be seen more clearly

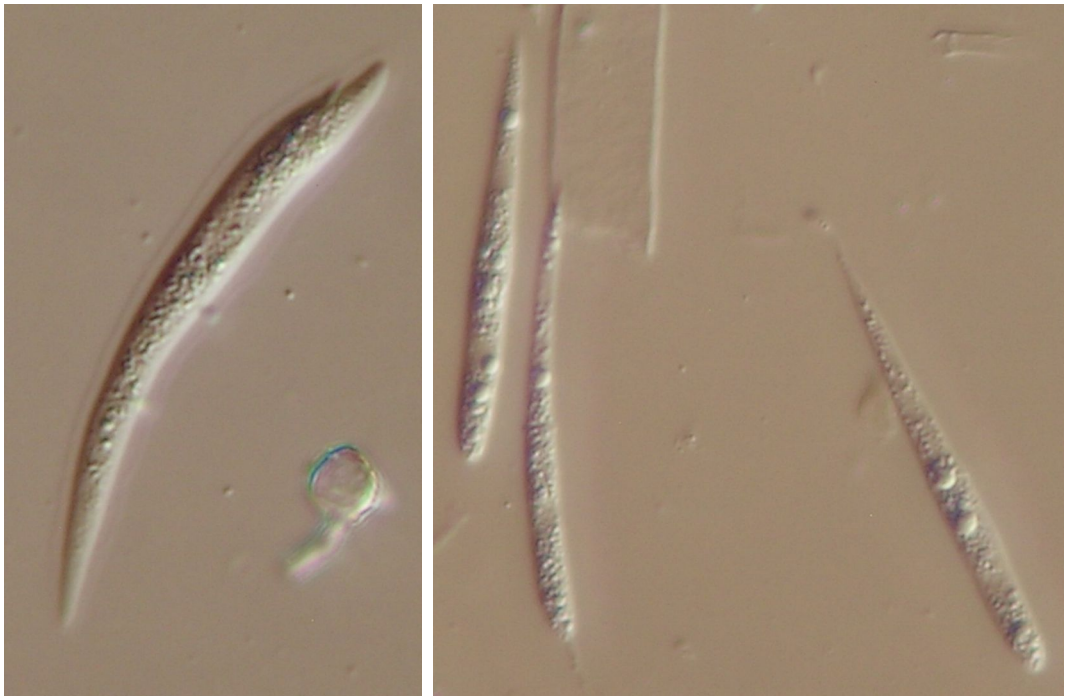

*Figure 9.* Ascospores of *L. concolor* (left, from site 11) are usually more broadly clavate than those of *L. montivaga* (right, from site 4). The sticky mucilage sheath can be seen around the spore of *L. concolo*r.

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