Terminal branch dieback along Commissary Ridge in the Bridger-Teton National Forest: Investigating white pine blister rust canker ages and rates of expansion

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White pine blister rust (WPBR) is caused by the non-native fungus, *Cronartium ribicola*, a devastating pathogen of North American five-needle pines. Over the past century and a quarter, this pathogen has proven to be one of the most damaging agents of five-needle white pines (Geils et al. 2010; Schoettle et al. 2022) and is the primary factor in the recent ESA listing of whitebark pine (*Pinus albicaulis*, WBP) as threatened in the USA. Whitebark pine is a high-elevation species of western mountain ecosystems that is highly susceptible to WPBR. Since its detection in the Rocky Mountains of Idaho, Montana, and Wyoming around 1926 (McDonald and Hoff, 2001), WPBR has reduced populations of WBP by as much as 70% in some areas including Glacier National Park (Kovalenko pers. comm.). In other areas to the south, WPBR continues to spread and intensify in WBP. White pine blister rust has not yet been detected in several more isolated WBP populations such as some in the Great Basin and has only recently been confirmed on WBP in the southern Sierra (Dudney et al. 2020).

Significant information gaps remain related to the dynamic host-pathogen-environment interactions and factors that influence WPBR infection events and canker expansion in high-elevation systems. Investigations by Kearns et al. (2009) reported that canker expansion rates in limber pine populations in Colorado and Wyoming were consistent across tree and site factors. Their work determined estimates of years since infection based on canker length combined with an adjustment for latency (time between needle infection and visual symptoms). While this information provides a solid baseline for limber pine, to date we know little about this metric in WBP. Knowledge of

Figure 1. A) Count of bud scars to determine the age of the branch internode at the center of the white pine blister rust canker, estimated to be the point of origin into the branch from the infected needle. B) Sample canker with push pins placed at the edges of the active canker. Measurements in future years will be estimated from these margins.

the distribution of canker ages at locations where WPBR is increasing in severity can characterize the frequency of infection events and pinpoint years with favorable environmental conditions.

During the 2021 annual visit to permanent WBP monitoring plots on Commissary Ridge in the southern reaches of the Bridger Teton National Forest, National Park Service field crews noticed extensive terminal branch dieback in WBP stands located on the top and flank of the ridge. Although WPBR damage has been detected in this area at moderate levels over the past 18 years of monitoring, the sudden, wide-spread branch dieback, approximately 15 to 30 cm in length and retaining red needles, was alarming. A follow-up visit later in the season with an interdisciplinary forest health team confirmed that the majority of observed branch mortality was associated with WPBR. Preliminary canker measurements indicated a potential "wave-year" event evidenced by the high frequency of relatively new cankers (mean canker length 5.8 cm (n=19) with canker centers located on branch internodes ranging from 5 to 12 years old). This discovery offered a unique field setting to investigate canker ages (and year of infection by extrapolation), canker expansion rates, and potential wave year detection in a population of heavily infected and easily accessible WBP. As such, in August of 2022, a pilot study was initiated to assess canker expansion rates, canker ages, and occurrence of wave years, and ultimately, improve methods for field studies and gain a better understanding of disease epidemiology.

Methods

A total of 11 WPBR infected WBP were selected that had active cankers (n=25) on intact, live branches. Four of the sampled trees were on top of Commissary Ridge, and the other seven were located on the eastern flank of the ridge. Measurements taken on sampled branch cankers included: length of canker swelling, length of annual growth increments (based on bud scars) from tip of branch to base of canker, and number of annual growth increments with retained needles (for a subset of cankers). Shoot vigor was estimated as the average annual shoot increment length on the same shoot that the canker length was measured. Needles are the points of infection for *C. ribicola*. Assumptions for measurement calculations include that the latent period is 2 years (time from needle infection to visible symptoms or signs of a canker), and branch cankers expand 2 cm per year in this host-pathogen-environment system. Given these assumptions, the estimated canker age in years is half the total canker length including any swelling or bark discoloration (e.g. 1 cm reflects half of annual expansion of a 2 cm canker) plus 2 years (latency). Annual and monthly vapor pressure deficit (VPD; a proxy for humidity) were calculated for the study site. These data were analyzed to determine if conditions conducive for a wave-year event could be detected.

Results

We saw what appeared to be first- or second-year fruiting cankers on shoot increments ranging in age from 4 to 14 years old, suggesting that needles of all ages can serve as points of infection. On average, needles were retained on shoots for 9 years. Furthermore, we found no relationship between canker length and age of the stem section at the center of the canker (data not shown). Mean branch canker length at the top of Commissary Ridge was 6.4 cm and was 11.6 cm on the lower flank of the ridge. The data suggested that canker expansion varied with shoot vigor (Fig. 2). The mean estimated years since infection was 5.2 and 7.8 years, on the ridge and below, respectively. Trees on the ridge appeared to experience a recent infection wave that did not occur below the ridge (Fig. 3) if the assumptions of our analyses hold true. However, our preliminary explorations of VPD did not detect any obvious episodes with conditions conducive for a wave-year event in the Commissary Ridge area.

Discussion

Preliminary results from data collected in 2022 highlight the need for continued repeat observations over a longer period. Canker expansion rates can be tracked on a yearly basis with simple measurements from marked cankers, while additional data collection will improve assumptions on how canker expansion rates are influenced by shoot vigor, effects of site (tree position on the ridge), and tree age (mature versus younger). Our findings show that WBP needles can be retained for up to nine years at these locations and needles of all ages appear to remain susceptible and serve as in-

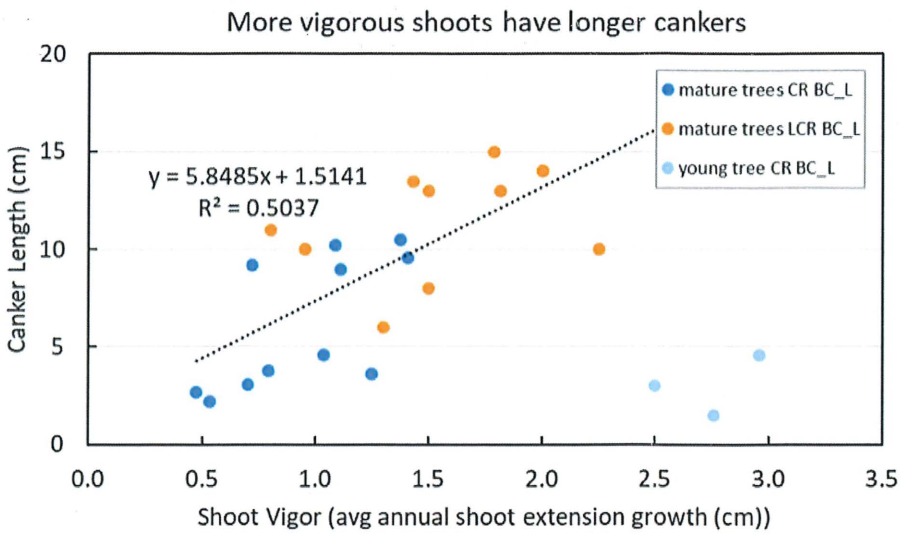

Figure 2. Relationship between shoot growth (vigor) and canker length. Shoot vigor was estimated as the average annual shoot increment length over the past 9-10 years on the same shoot canker length was measured. Cankered shoots from mature whitebark pine trees at Commissary Ridge (dark blue; CR) and the lower flank of Commissary Ridge (orange; LCR) were measured and one young tree (light blue) at Commissary Ridge. Note that shoots of mature trees at the lower site generally grew more per year than those on the Ridge.

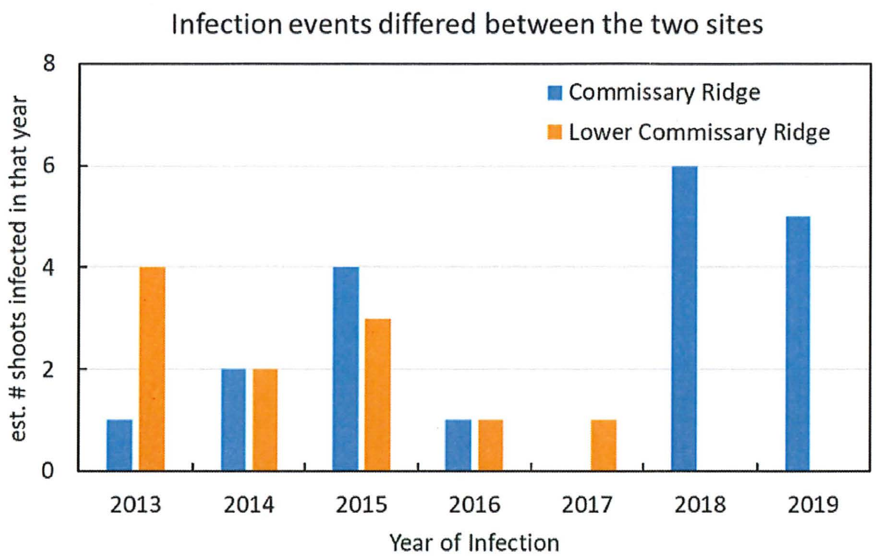

Figure 3. Numbers of white pine blister rust cankers on whitebark pine shoots estimated to have been infected in each year from 2013 to 2019, by tree location (blue indicates trees at the top of Commissary Ridge and orange indicates trees below the ridge.

fection points. Our interpretation of evidence for a wave year event on the ridge is influenced by our assumption of a two-year latent period and an annual expansion rate of two cm per year. Additional data to test these assumptions are warranted and underway. Detection of wave-year events is complicated as environmental conditions favorable for infection may be difficult to tease out by examining means over time and space. Commissary Ridge is positioned to the west and runs parallel to a narrow, mesic valley bottom where morning fog is seasonally common (Shanahan, pers comm). Ribes species are abundant and particularly dense along the small, southerly flowing stream on the east side of the valley. Local drivers of the observed patterns of infection on Commissary Ridge may be related to topographic features, the abundance of host species, and the mesic setting. We will continue to investigate environmental factors at different scales in relation to canker age estimates that suggest years with high frequencies of new infections.

Estimating the year of infection an WBP is complicated because the species routinely retains seven or more needle cohorts per shoot and information on susceptibility by needle age is lacking (Schoettle, pers comm). For example, if only 1-year-old needles could be infected, we could simply equate the age of the cankered stem section with the year of infection;

however, if needles of all ages can be infected, we cannot make that assumption. Hence the need to age cankers and gain more information on the infection probability of needles of different ages, the latent period between infection and visible symptoms, and annual canker growth. Our data suggests that needles of all ages may serve as points of infection; measurement of additional shoots, especially at first signs of canker development, may improve our confidence in this finding. Experimental studies will be needed to better understand mechanisms that determine latency. Annual remeasurement of the pinned cankers will improve our estimates of canker growth rates and possible factors affecting growth. The Commissary Ridge site presents an opportunity to collect data to increase our understanding of canker expansion, infection years, and the epidemiology of this important pathosystem in high elevation 5-needle pines.

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References

Geils BW, Hummer KE, and Hunt RS. 2010. White pines, Ribes, and blister rust: a review and synthesis. *Forest Pathology* 40: 147–185.

Dudney JC, Nesmith JC, Cahill MC, CribbsJE, Duriscoe, DM, Das AJ, Stephenson NL, and Battles JJ. 2020. Compounding effects of white pine blister rust, mountain pine beetle, and fire threaten four white pine species. *Ecosphere* 11, e03263.

Kearns HSJ, Jacobi WR, and Geils BW. 2009. A method for estimating white pine blister rust canker age on limber pine in the central Rocky Mountains. *Forest Pathology* 39: 177–191.

McDonald GL and Hoff RJ. 2001. Blister rust: an introduced plague. In, Whitebark pine communities: ecology and restoration. Tomback, D.F., Arno, S.F., Keane, R.E., eds. Island Press, Washington, DC. pp. 193-220.

Schoettle AW, Burns KS, McKinney ST, Krakowski, J, Waring KM, Tomback DF, and Davenport M, 2022. Integrating forest health conditions and species adaptive capacities to infer future trajectories of the high elevation five-needle white pines. *Forest Ecology and Management.* 521: 120389.