Termite Feeding on Aspen and Pine Stakes on a High Elevation Sagebrush-Steppe Rangeland in Southeastern Idaho

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Abstract. An indigenous subterranean termite, *Reticulitermes tibialis* Banks, fed on quaking aspen (*Populus tremuloides* Michx.) and loblolly pine (*Pinus taeda* L.) stakes in prescribed burn and non-burned field plots on an established sagebrush-steppe rangeland restoration study site on Red Mountain, southeastern Idaho, expanding the known distribution of the 'arid-land subterranean termite' species. Aspen and pine stakes in the plots as part of a 5-year wood-decay study were unexpectedly damaged by termites. Groups of 25, 15-cm-long stakes were placed horizontally on the soil surface, and groups of 25, 20-cm-long stakes were vertically inserted to a depth of 20 cm into the soil. Aspen stakes were more damaged by feeding termites than were pine stakes. Stakes inserted into soil sustained greater termite feeding and decay damage compared with stakes on the soil surface. During the first 4 years of the study, wood mass loss caused by termite feeding on stakes exceeded loss from decay. Losses from termite feeding and microbial decay were similar by the 5th year. Differences in termite feeding damage on aspen stakes were compared with pine stakes in prescribed burn and non-burned plots. Stakes in prescribed burn plots had more mass loss than those in non-burned plots.

Introduction

Sagebrush-steppe rangelands encompass thousands of hectares in several areas across the western United States. These rangelands support diverse plant communities, including several species of sagebrush (*Artemisia* spp. L.) and many grasses and forbs (Blaisdell et al. 1982, Miller and Rose 1999, Johnson 2004). Naturally occurring range fires are commonly associated with sagebrush-steppe ecosystems. Widespread prescribed burning as a vegetation management and restoration technique is used to improve habitat for birds and other wildlife (Fernandes et al. 2003). Whereas fire directly impacts the ecology and health of sagebrush-steppe habitats, there is a paucity of information about foraging and feeding behavior by subterranean termites in these ecosystems. Fire can change the amount of woody material on the soil surface and mass of dead roots, thereby

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altering soil properties and affecting ground-dwelling insects. Changes in wood quantity affect wood-feeding insects such as subterranean termites (Hanula et al. 2012).

A 5-year study on Red Mountain in southeastern Idaho evaluated progressive decay severity on groups of 15-cm-long wooden stakes on the soil surface ('surface stakes') and similar groups of 20-cm-long stakes vertically inserted into the soil ('mineral soil stakes'; top end level with the soil surface) in prescribed burn sagebrush-steppe habitat restoration plots and adjacent non-burned 'check' plots. Subterranean termites were feeding in the plots, damaging quaking aspen (*Populus tremuloides* Michx.) and loblolly pine (*Pinus taeda* L.) stakes being evaluated for microbial decay. Termite activity was not expected at the high-elevation, cold winter climate location (winter soil temperature: –2°C at 1-cm depth). Summer daytime air temperatures averaged 12°C (SNOTEL 2010). Termite species foraging in the plots were identified and their impact on wooden stakes evaluated. Differential influence of prescribed burn sites compared with non-burned sites on termite occurrence and feeding was evaluated.

Materials and Methods

Study Site. The southeastern Idaho study site was on the southwestern and northeastern slopes of Red Mountain (42° 25' 64.5" N – 111° 06' 37.5" E) on the Targhee-Caribou National Forest, Bear Lake County, ~25 km northeast of Montpelier, ID. Elevations were 2,100 to 2,200 m AMSL, with some plots on a 35° (NE) site aspect and others on a 215° (SW) site aspect with a 6-8% slope. For a habitat-restoration study, two treatments were established in 2004: (1) prescribed burn areas, and (2) non-burned areas. To minimize impact to the soil surface, prescribed burns were conducted during spring.

Before prescribed burns, approximate percentages of scattered, patchy ground-cover consisted of interspersed mixtures of little sagebrush (*Artemisia arbuscular* Nutt.; 35%), mountain big sagebrush (*Artemisia tridentata* Nutt. var. *pauciflora* Winward and Goodrich; 30%), prairie Junegrass (*Koeleria macrantha* [Ledeb.] J. A. Schultes; 20%), bluebunch wheatgrass (*Agropyron spicatum* Pursh.; 20%), basin wild rye (*Elymus cinereus* Scribn. and Merr; 10%), yellow rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt.; 5%) and mountain snowberry (*Symphoricarpos oreophilus* A. Gray; 1%). Patchy mixtures of scattered forbs including lesser rushy milkvetch (*Astragalus convallarius* Greene; <5%), lupine (*Lupinus sericeus* var. *asotinensis* [Phillips] Hitchc.; <5%), Jones' fleabane (*Erigeron jonesii* Cronquist; 10%), aster (*Symphyotrichum* spp. Nees; 5%), helianthella (*Helianthus uniflorus* Nutt.; 5%), and common yarrow (*Achillea millefolium* L.; 1%) were growing on the study areas. Several grasses interspersed across the study areas were Idaho fescue (*Festuca idahoensis* Elmer; 25%), bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) Á. Löve; 5%), western wheatgrass (*Pascopyrum smithii* [Rydb.] Á. Löve; 5%), Kentucky bluegrass (*Poa pratensis* L.; 3%), and New Mexico feathergrass (*Hesperostipa neomexicana* [Thurber ex J. M. Coulter] Barkworth; 5%) (Blaisdell et al. 1982, Miller and Rose 1999, Johnson 2003, Johnson 2004, Cook et al. 2009, Dumroese et al. 2015)

Soil was fine, mixed Pachic Agricryoll with conglomerate and sandstone as parent material. The coarse fraction was 20-35%, with the fine fraction classified as loam (Soil Survey Staff 2003). Mean annual air temperature was ~1.5°C, with summer daytime air temperatures averaging 12°C and winter soil temperature –2°C at 1-cm deep. Mean annual precipitation was ~78 cm (SNOTEL 2010).

Termite Identification. Subterranean termites were collected into labelled glass vials containing 90% EtOH and brought to a laboratory for identification and genetic processing. Termite soldiers were collected from stakes on the surface and in mineral soil in prescribed burn and non-burned plots and identified morphologically using standard taxonomic keys (Banks 1946, Gleason and Koehler 1980, Scheffrahn and Su 1994, Brown et al. 2005). Also, soldiers and workers were molecularly identified to species using polymerase chain reaction (PCR) protocols. Termite identification was validated by DNA sequencing and using BLASTn searches on GENBANK. Smith et al. (2010) described the analytical procedures.

Stake Evaluation. Aspen and pine stakes were originally installed to be an index of surface and below-ground impacts of prescribed burning on soil microbes. A detailed description of stake preparation was provided by Jurgensen et al. (2006). During 2004, 600 wood stakes were installed in three replications in each of two treatments (prescribed burn and non-burned 'check'). In each treatment and replication, 25 (2.5 x 2.5 x 15 cm) stakes of each wood species were placed horizontally on the soil surface, and 25 (2.5 x 2.5 x 20 cm) stakes were inserted vertically into the mineral soil. Two subplots were in each replication and main plot. Each year, five stakes of each wood species from each location were collected from prescribed burn and non-burned plots and evaluated for decay and termite damage.

Using stake dimensions, a visual measurement of depth, width and length of wood loss from termite feeding was used to estimate the percentage of stake cross-section (volume) loss, and categorized as: 0% (none), >0−5% (superficial), >5−25%, >25−50%, >50−75%, and >75%. All stakes were cleaned of soil and debris, then oven-dried at 105°C for 48 hours and weighed. Each field stake oven-dry mass was compared with its pre-installation initial dry mass to determine individual and cumulative mass loss caused mainly by termites (no visible decay loss although some decay may have been hidden), decay only (no termite damage),

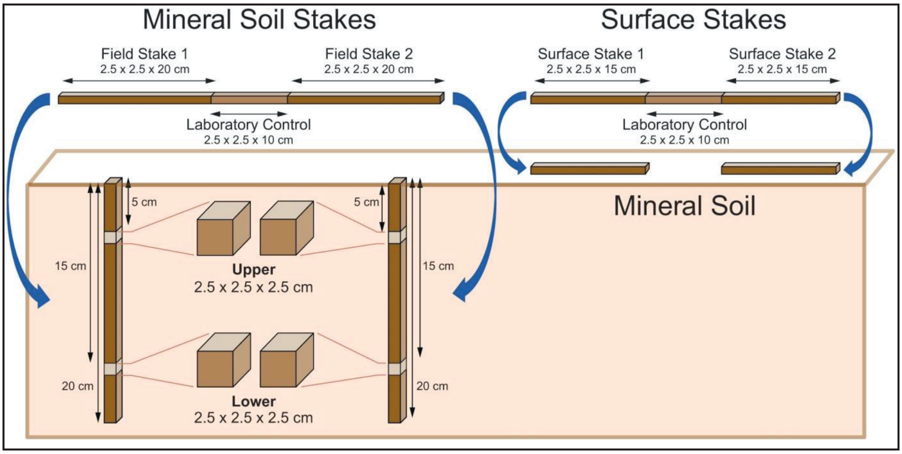

Fig. 1. Stake layout installed horizontally on the soil surface or vertically inserted into mineral soil. Laboratory control sections used for decayed wood and sound wood comparisons (Courtesy Jurgensen et al. 2020).

or obvious decay and termite damage combined for each wood type and field placement (surface or vertically inserted in mineral soil) (Table 1; Figs. 1, 2).

Linear regression was used to evaluate termite feeding on stakes over time and calculate regression formulas (Microsoft 2010). PROC GLM (SAS 2003) was used for analyses of variance for sampling dates (2005-2009), prescribed burn or non-burned, and wood stakes on the surface or in mineral soil.

Results and Discussion

Mass Loss. Subterranean termites fed on aspen and pine stakes on the surface and in mineral soil in prescribed burn and non-burned plots, causing varying amounts of loss of wood mass. Generally, cross-section losses from aspen and pine stakes on the dry soil surface were significantly less compared with stakes in mineral soil ($P \leq 0.01$, Table 1).

When termites were present, mass losses from termite feeding on aspen stakes in mineral soil exceeded loss from decay during the first 4 years, but both termite feeding and decay losses combined were similar by the 5th year, demonstrating that termites are active in recycling dead wood on sagebrush-steppe rangeland (Fig. 2). Overall, aspen stakes were more damaged by feeding and mass loss than were pine stakes ($P \leq 0.01$; Table 1, Fig. 3).

Termite feeding damage was more severe on aspen and pine stakes in mineral soil in prescribed burn compared with non-burned plots. Fewer pine and aspen stakes on the soil surface were damaged by termites compared with those in mineral soil (Table 1). Loss of wood mass of aspen stakes always exceeded that of

Table 1. Number of Stakes Damaged by Termites and Percentage (%) of Stake Cross-section Loss in Prescribed Burn and Non-burned Plots (Study Installed 2004)

Stake and plot type[1]	2005	2006	2007	2008	2009	Total damaged
Pine surface						
Burned	0 (0%)	0 (0%)	1 (<5%)	2 (<5%)	3 (<5%)	6
Non-burned	0 (0)	0 (0)	0 (0)	3 (<5-15)	4 (<5-15)	7
Pine buried						
Burned	1 (<1)	1 (<5)	5 (<5-35)	5 (<5-50)	5 (5-75)	17
Non-burned	1 (<1)	0 (0)	1 (<5)	1 (1-15)	1 (5-15)	4
Aspen surface						
Burned	0 (0)	1(15-25)	2 (35-50)	4 (5->75)	2 (25-75)	9
Non-burned	0 (0)	0 (0)	1 (15-25)	2 (15-75)	3 (25-75)	6
Aspen buried						
Burned	6 (5-35)	7(5-75)	5 (5-75)	6 (15->75)	2 (50->75)	26
Non-burned	0 (0)	1(25-35)	1 (15-25)	0 (0)	2 (5-25)	4

[1]Each plot and type had a duplicate group of 25 stakes for each year, with each set remaining in its plot until the year it was collected and evaluated. For example, groups of stakes collected in 2009 were in their plots for 5 years.

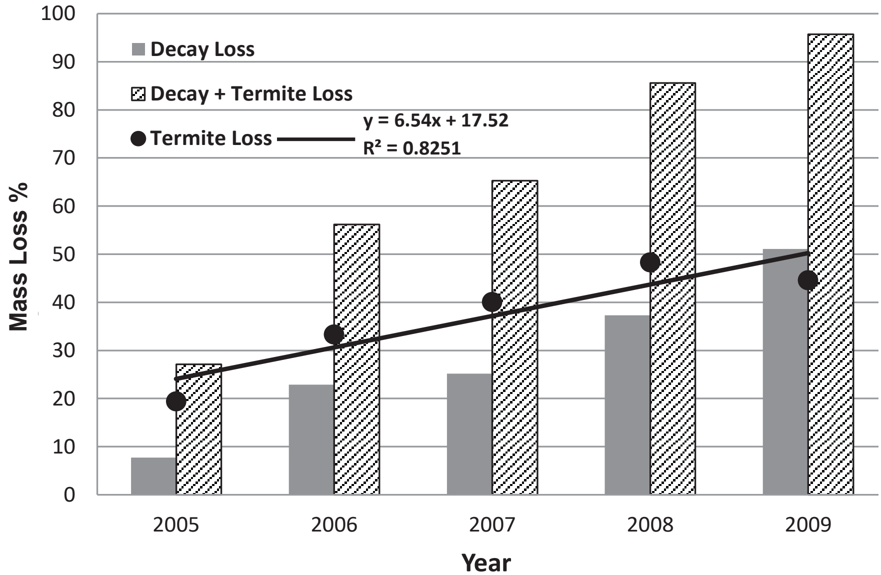

Fig. 2. Increasing percentage of dry mass loss caused by decay, termite feeding, or decay and termite feeding combined on stakes in mineral soil in prescribed burn plots. For example, where termites were feeding on stakes in mineral soil during 2005, an additional 20% mass loss occurred compared with decay alone. The slanted line represents mass loss due to termite feeding.

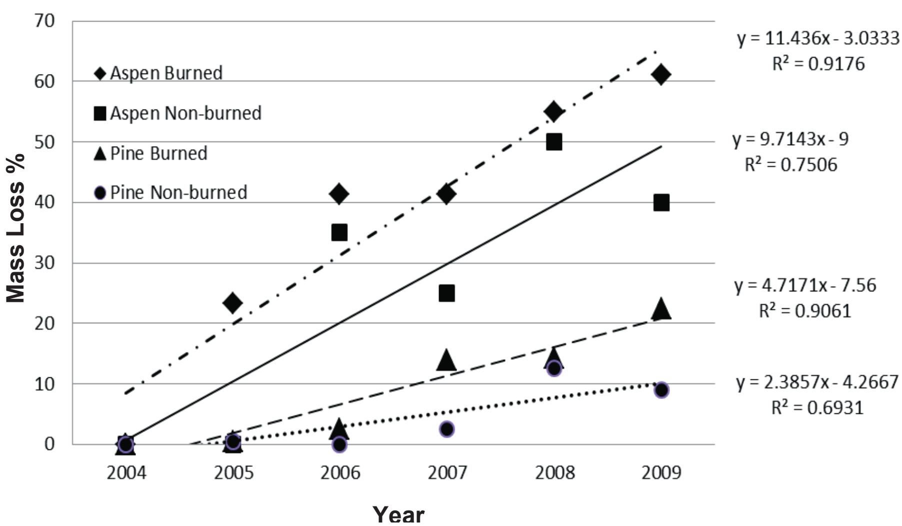

Fig. 3. Average percentage of combined mass loss from termite feeding on aspen and pine stakes on the surface and in mineral soil in prescribed burn and non-burned check plots. Aspen mass loss always exceeded pine mass loss ($P \leq 0.01$).

pine stakes, demonstrating subterranean termites preferred aspen for food. Termites damaged a total of 45 aspen stakes (surface and mineral soil) compared with 34 pine stakes (Table 1, Fig. 3).

During the 5-year study, mean combined mass loss from aspen stakes on the surface and in mineral soil increased from 5 to 72%, greater than the combined mass loss of 2 to 22% from pine stakes on the surface and in mineral soil in prescribed burn and non-burned plots (Fig. 3). For aspen stakes in mineral soil that were damaged by termite feeding and decay, mass loss was approximately double that of decay from microbial activity in mineral soil. Aspen stakes were 20% consumed by termite feeding after 1 year in mineral soil, increasing to 48 and 45% after 4 and 5 years, respectively (Fig. 2). Mean mass loss on the surface increased from 2 to 32% for aspen stakes compared with 1 to 7% for pine stakes.

Stakes in mineral soil were more damaged by termites than were stakes on the soil surface (Table 1). Stakes in mineral soil were exposed to more water, cooler temperatures in summer months and warmer temperatures in winter months. The moderated soil conditions were conducive to termite foraging and microbial proliferation, leading to greater damage to stakes in mineral soil compared with stakes exposed to drier, often hotter or colder more variable microclimate on the surface (Elkins et al. 1986, Nash and Whitford 1995, Li and Su 2008).

When stakes were damaged by termites during the study, average mass loss from damage to aspen always exceeded loss to pine. However, 3 years after installation, numbers of aspen and pine stakes damaged by termites were similar (combined surface and mineral soil) although mass and cross-section losses to aspen continued to exceed those from pine stakes ($P = 0.01$; Table 1, Fig. 3). For example, by the 2nd-year evaluation, only one of five aspen stakes on the surface in prescribed burn plots was damaged by termites, sustaining 15 to 25% cross-section loss, while no pine stakes on the surface were damaged by termites. Contiguous surface stakes with no termite damage had 2.4 to 12% dry mass loss only from microbial decay, demonstrating that after termites locate stakes, damage progression can become severe in a few months (Table 1; Figs. 2, 3).

By the 2nd year, 15 aspen stakes (surface and mineral soil) were damaged by termites in prescribed burn and non-burned plots, while only three pine stakes in mineral soil were damaged by termites. Loss from feeding damage for aspen stakes in mineral soil varied from 5 to >75% of their cross-section. The combined number of aspen stakes on the surface and in mineral soil that were damaged by termites in prescribed burn plots exceeded the number in non-burned plots during the first 4 years, with the trend leveling by the end of the 5th year (Table 1). Cross-section loss for decay alone or decay and termites combined in prescribed burn plots significantly exceeded loss in non-burned plots ($P \leq 0.01$).

By the 5th year, a combined total of 35 aspen stakes on the surface and in mineral soil in prescribed burn plots were more damaged by termites compared with 10 aspen stakes (surface and mineral soil) from non-burned check plots. Termites seemed to forage more actively in prescribed burn plots. Although fewer pine than aspen stakes were damaged by termites, the greatest number of pine stakes damaged by termites were those in mineral soil in prescribed burn plots. During the study, more pine stakes in mineral soil were damaged by termites than were those on the soil surface (Table 1, Fig. 3).

Termites. Termites in pine and aspen stakes were identified morphometrically using a stereo-microscope with computerized measurement software, and also molecular protocols (Banks 1946, Gleason and Koehler 1980, Scheffrahn and Su 1994, Brown et al. 2005, Smith et al. 2010). On aspen and pine stakes from each location, soldier and worker castes were identified as the 'arid-land subterranean termite' (Snyder 1954, Weesner 1965), *Reticulitermes tibialis* Banks 1920, indigenous to the US Midwest, Great Plains and Northwestern and Pacific Coast states. This is the first record of *R. tibialis* on Red Mountain, ID.

Termite soil excavation and tunneling affect organic matter content and distribution of soil nutrients and porosity (Elkins et al. 1986, Nash and Whitford 1995). Termite tunneling also influences soil bulk density as excavated materials are moved between soil horizons (Li and Su 2008). Redistribution of soil influences plant diversity and viability, and plant biomass and wood accumulation in and on the soil surface, thereby influencing termite foraging (Mando and Stroosnijder 1996, Mando et al. 1999).

Because subterranean termites move vertically between soil horizons, they escape range fires by tunneling downward (Nutting and Jones 1990, Jouquet et al. 2003, Brown et al. 2005, Brown et al. 2009, Morris et al. 2016). Termites contribute to normal background CO_2 and CH_4 flux from soil, affecting soil-dwelling microbe ecology and energy cycles (Konemann et al. 2016). Impacts on sagebrush-steppe rangeland ecosystem soil and plant ecology need additional study.

Subterranean termites inhabiting the Red Mountain study site were adapted to live in high-altitude, sagebrush-steppe rangeland with harsh winter conditions of sub-freezing temperatures and deep snowfall. Results also demonstrated that fire management practices influence occurrence and distribution of subterranean termites in fire-impacted soil, and prescribed burning affected termite foraging and feeding activities in sagebrush-steppe rangeland in southeastern Idaho.

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