Wildfire and Bark Beetle Outbreaks in Lodgepole Pine Forests:

Impacts, Reciprocal Interactions, and Surprises

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Outline

1. Surprises/Lessons from the 1988 Fires in Yellowstone National Park
2. Resistance to an aggressive invasive species in post-fire lodgepole pine forests
3. Interactions of mountain pine beetle and white pine blister rust in YNP
4. Influence of beetle-killed trees on likelihood of active crown fires
5. Advance Regeneration in post-outbreak lodgepole pine forests in SE Wyoming

1. Surprises/Lessons from the 1988 Fires in Yellowstone National Park

- Lodgepole pine may not be the “simple” system that most people think it is!

Photo by J. Vanuga

Turner et al. 2003

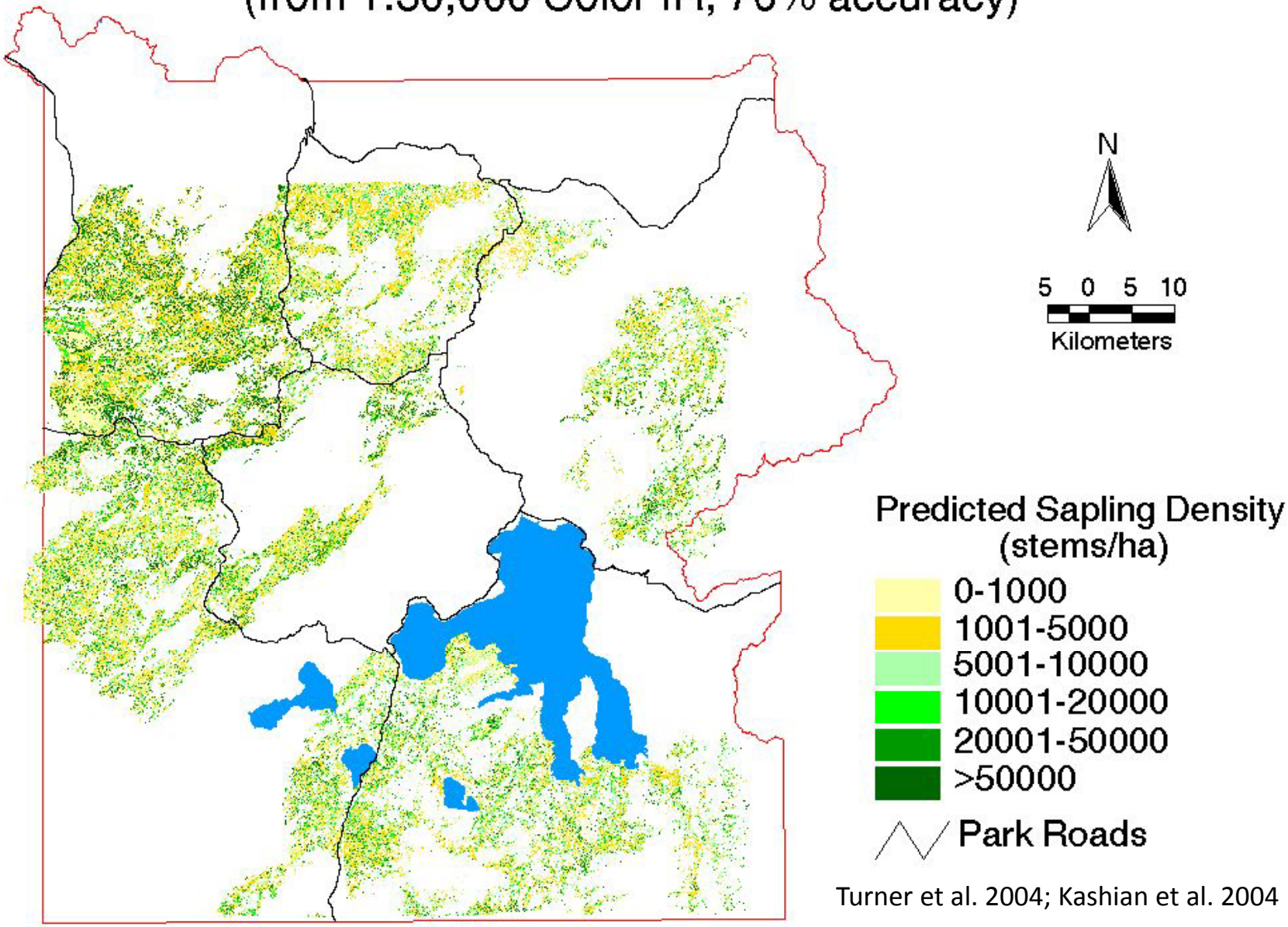
INFLUENCE OF CONE SEROTINY FIRE SEVERITY AND ON POSTFIRE SEEDLING DENSITY

- We knew the importance of cone serotiny in lodgepole pine; however…
- Variability in post-fire seedling establishment across the landscape varied by five orders of magnitude
- Ranged from zero to over 500,000/ha

Tinker et al. 1994; Turner et al. 1997; Turner et al. 2003; Schoennagel et al. 2003

1998 Lodgepole Pine Sapling Density

(from 1:30,000 Color IR, 76% accuracy)



Turner et al. 2004; Kashian et al. 2004

Summary of selected post-88 data

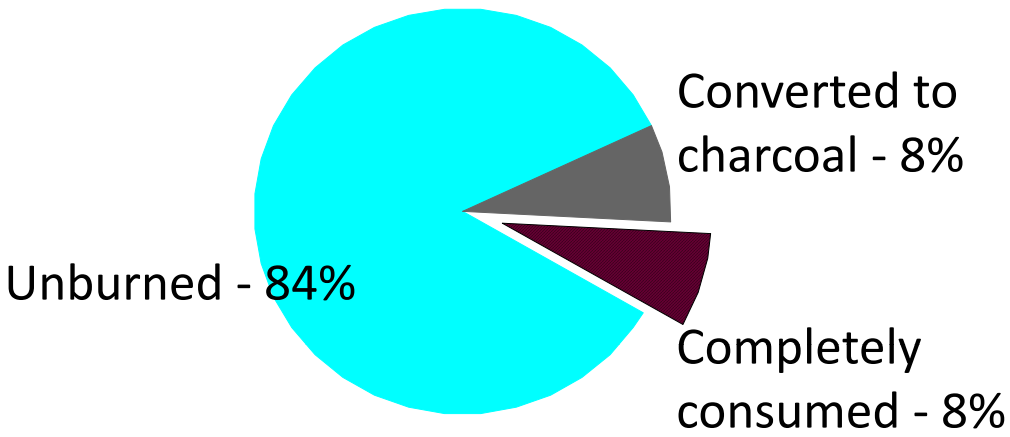
	Range	Mean	Median
Seedling Density (Seedlings/ha)	0-535,000	19,932	3,099
Total ANPP (Mg/ha/yr)	0.035-15.1	12.8	1.9
Total LAI (m^2/m^2)	0.083-6.9	0.80	0.27

Turner et al. 2004

Plant species diversity continued to increase in many of the burned stands during the first several years following the fire

Turner et al. 1997; Turner et al. 2003

Much less coarse wood was consumed by severe fires than was previously believed



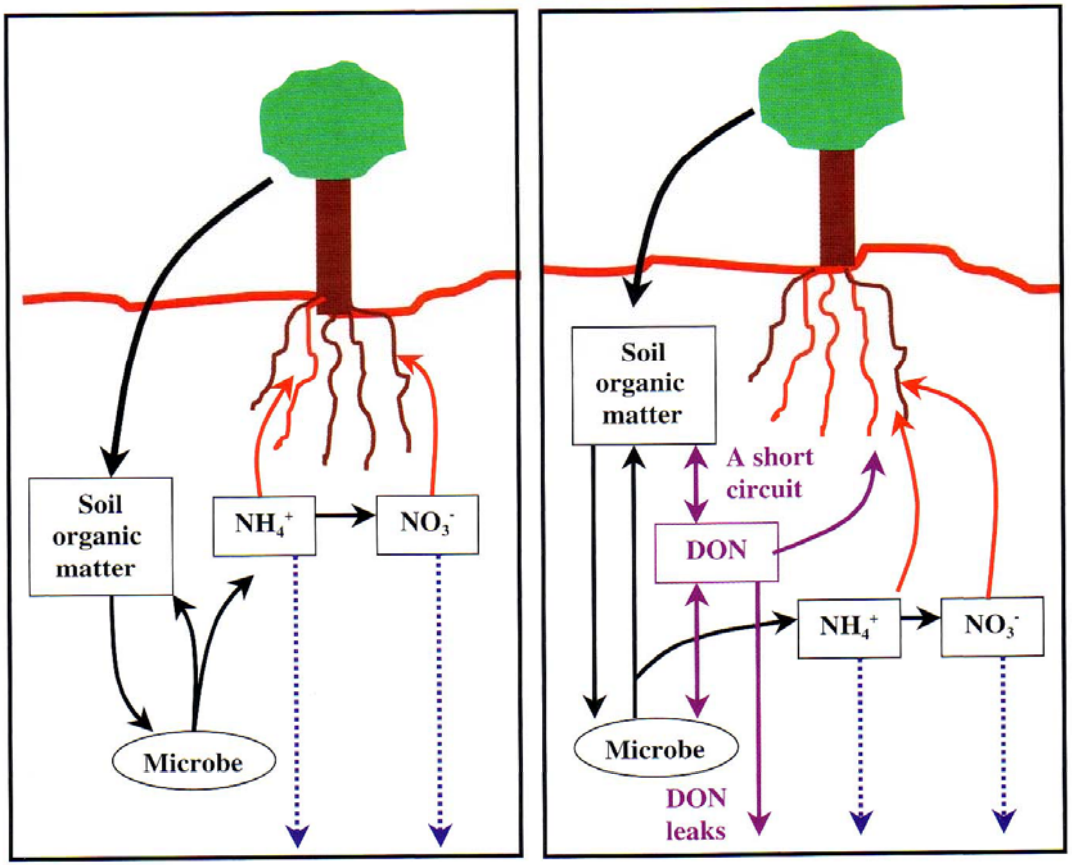
Tinker and Knight 2000

- Rare episode of Aspen establishment by seed (or was it rare???)
  - Seedlings established nearly park wide;
  - Many were several kilometers from the nearest seed source
  - Most will likely not grow into mature trees
  - Role of coarse wood in aspen recruitment is not well understood

Turner et al. 2003; Romme et al. 1997; Romme et al. 2005

A New Picture of N cycling!

- We asked if post-fire lodgepole pine take up organic nitrogen?
- YES! Intact glycine was measured in saplings after injection into soils.



Turner, Romme, Smithwick, and Tinker, Unpublished data

2. Plant community resistance to an aggressive invasive species in post-fire lodgepole pine forests

- Canada thistle
  - Native to Eurasia
  - Accidentally introduced into US in early 1600s
  - By 1954, noxious weed in 43 states in US

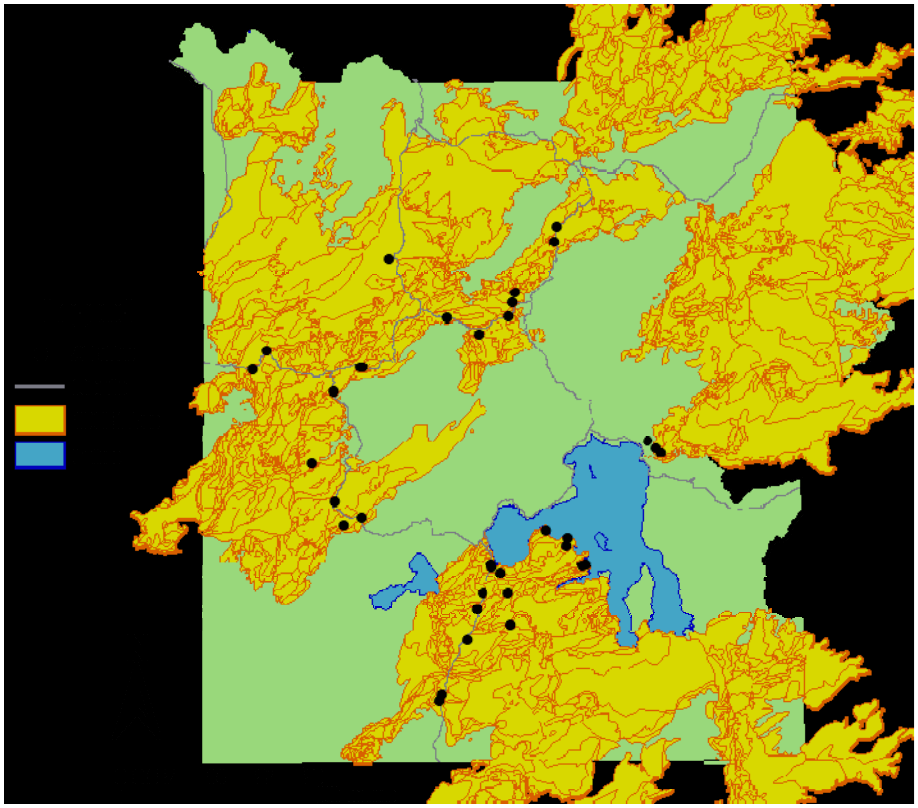
Photos of Canada thistle in burned forests of YNP by Brianna Wright

Canada thistle & Fire

- Fire can promote establishment & spread
- Seedlings take advantage of disturbance
- Canada thistle response variable following fire (Doyle et al. 1998; Turner et al. 1997)
- How has Canada thistle abundance and persistence changed over time (between 1999 and 2006) or among sites (30 sites sampled)?

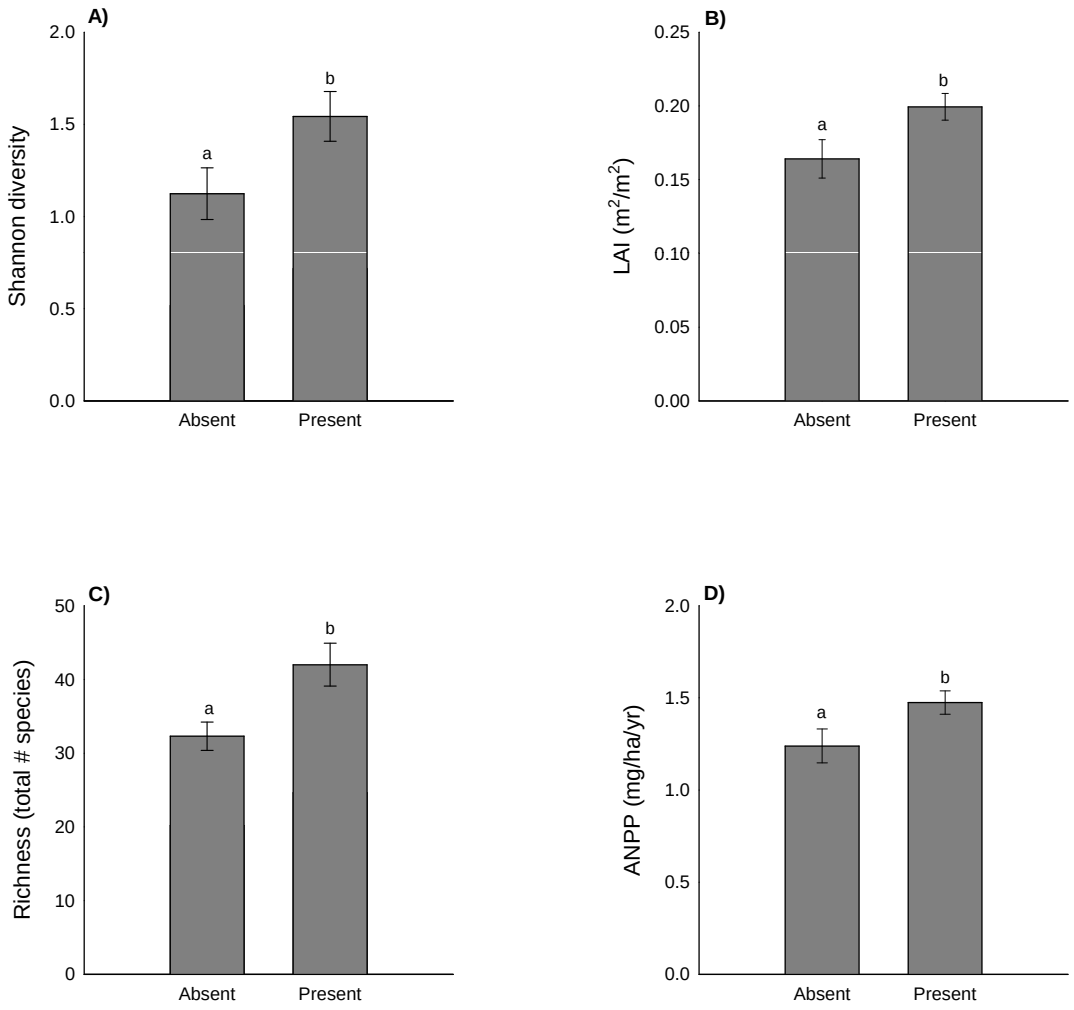
Change in *C. arvense* between sample years

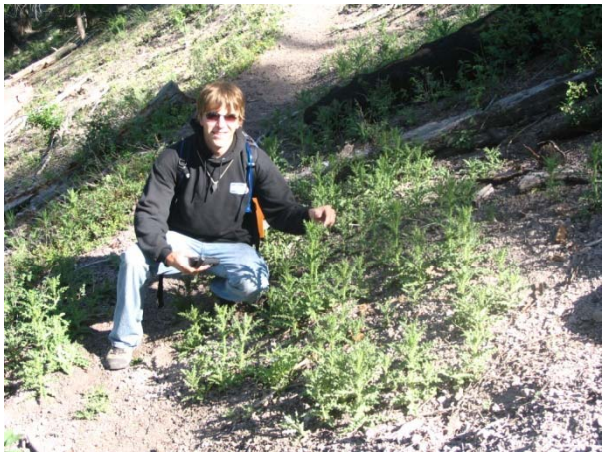
C. arvense	1999	2006
Present	**9**	**7**
Absent	**21**	**23**
Persisted	**n/a**	**3**
Disappeared	**n/a**	**6**
Invaded	**n/a**	**4**
Never Present	**n/a**	**17**



Wright and Tinker, submitted

- How does *C. arvense* relate to community function, such as Shannon diversity, Richness, ANPP, or LAI?





Wright and Tinker, submitted

•Summary of *C. arvense* study, cont.

- Variability between years and among sites in 2006
- Canada thistle found where:
  - Higher biotic measures
  - Lower sapling density
  - Higher fire severity
- Community composition where Canada thistle present:
  - Non-natives abundant
  - Species in Asteraceae abundant
  - Early successional species abundant

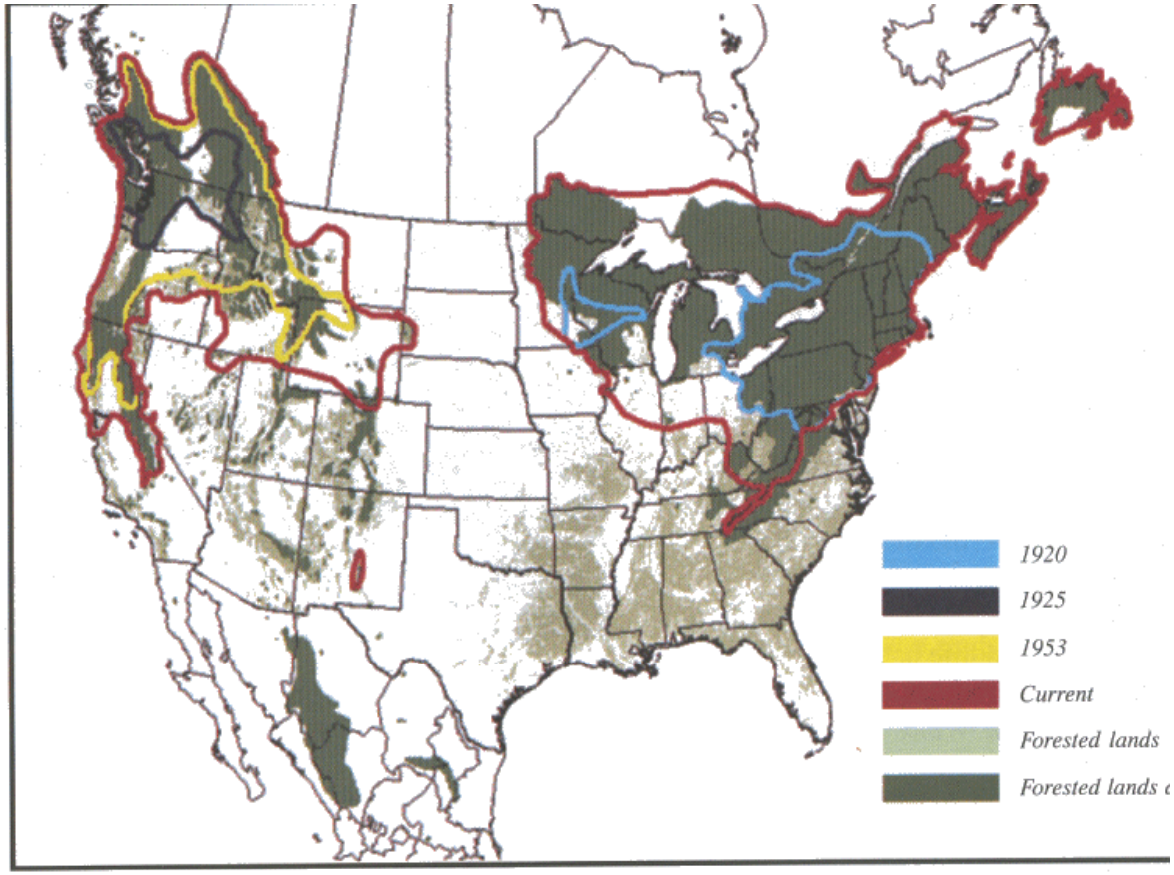
Wright and Tinker, submitted

3. Interactions of mountain pine beetle and white pine blister rust in YNP

- White Pine Blister Rust (*Cronartium ribicola*)
- Non-native fungus that causes branch and stem cankers
  - Leads to top kill or death of most trees
- Infests all five-needle pines (whitebark, limber, western white, sugar, bristlecone)

Spread of WP Blister Rust Across the US

- WP Blister Rust
  - Native to Asia
  - Introduced into US around turn of 20th century
  - Now present in 38 states
  - Continues to spread into high elevation areas



Life History - White Pine Blister Rust

Blister rust cankers and whitebark pine;
photos by Anna Shoettle

- Able to infect trees of all sizes and ages
- Spores are wind-dispersed from 300m – 3km
- Fungus usually moves from foliage to branch to stem
- Complex 5-stage life cycle requires two hosts
- Alternate host is commonly a currant or gooseberry (*Ribes* sp.), but other genera now identified as alternate hosts (*Castilleja* sp. Or *Pedicularis* sp.)

Relevance for GYTE

Photos by Nancy Bockino

Whitebark Pine (*Pinus albicaulis*) and White Pine Blister Rust Research:
Primary Objectives

Quantify

1. *Whitebark characteristics associated with beetle selection*
2. *Beetle host-selection patterns*
3. ***Influence of blister rust***

Provide

1. *Conditions of whitebark in the Greater Yellowstone*
2. *Predictions of beetle selection*
3. *Management strategies*

Whitebark Condition in Greater Yellowstone - 2007

Sample Size	*1,947 trees*
Dead	*52 %*
Blister Rust Symptomatic	*83 %*
Infested by Mountain Pine Beetle	*69 %*
Infested with Rust & Beetle	*61%*

Bockino and Tinker, submitted

Selection Ratio Analysis

$$= \frac{(\text{\# preferred host attacked} \div \text{total attacked})}{(\text{\# preferred host available} \div \text{total available})}$$

- Accounts for:
  1. stand density
  2. species composition
  3. sequence of attack
- Selection Ratio 1.0 = No Preference
- Host characteristics:
  - blister rust severity
  - tree species

Bockino and Tinker, submitted

Selection Ratio Analysis

Selection Ratio 1.0 = No Preference

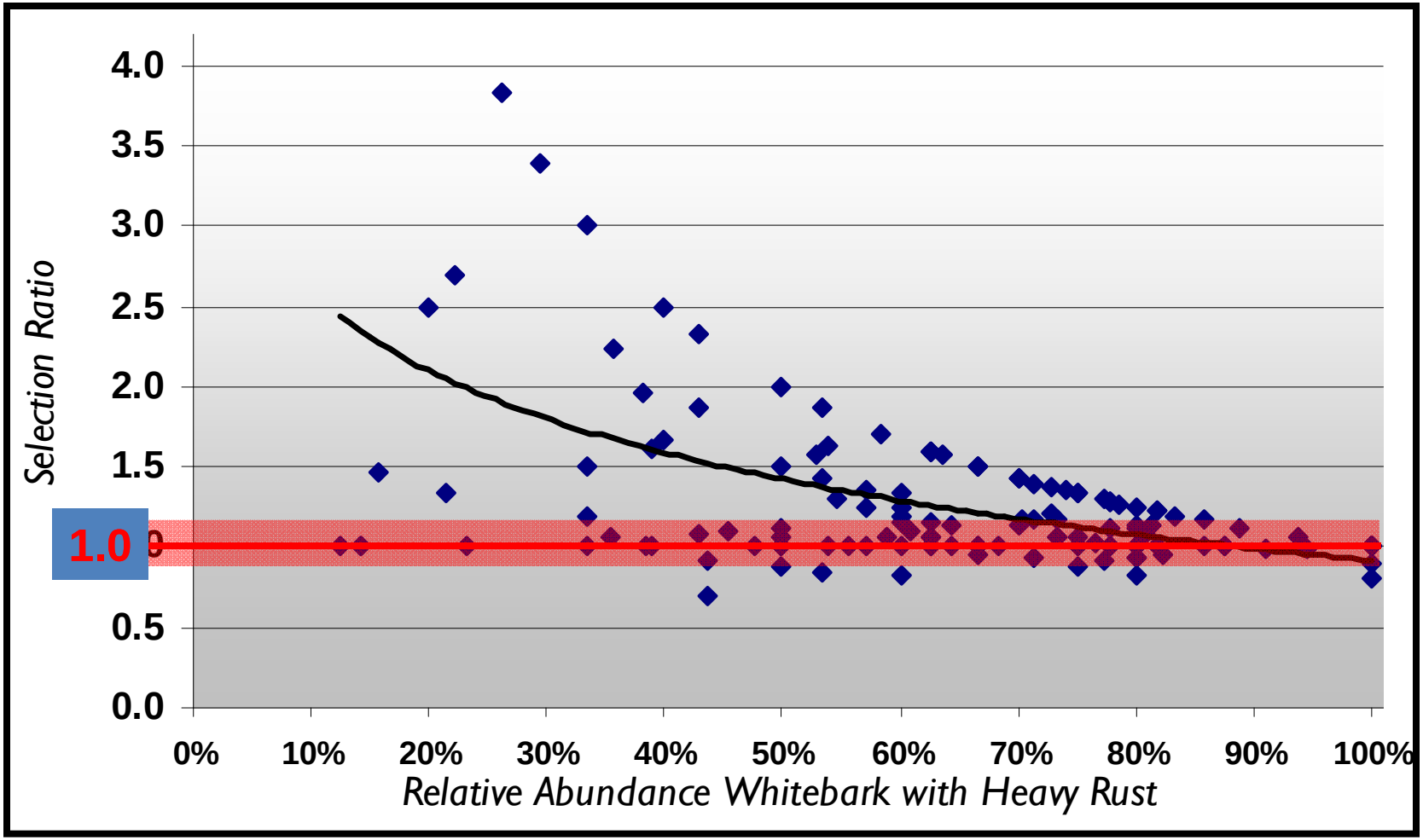
Host Characteristic	Mean Selection Ratio	Deviates from 1.0?
Species = whitebark	1.3	yes
Rust severity = heavy	1.28	yes

Beetles prefer:

1. whitebark over lodgepole
2. whitebark with heavy blister rust

Bockino and Tinker, submitted

Selection Ratio Analysis for Trees with WPBR



1. Beetles prefer high severity rust
2. Selection stronger when fewer trees with high severity rust available

Bockino and Tinker, submitted

Hope lies in the reproductive strategies of the “stone” pine.

- 2009 considered a “mast” year for cones and seeds in whitebark pine in the GYTE
- Some Whitebark pine appear to be **rust resistant!**
- Regeneration appears robust!

4. Influence of beetle-killed trees on post-outbreak fire behavior

- The debate as to whether bark beetles increase the likelihood of severe fires has existed for many years.
- Early studies:
  - Amman and Schmitz 1988, McCullough et al. 1998 suggest that risk increases due to increased dead and ladder fuels
  - Despain 1990, Schmid and Amman 1992 suggest that risk decreases from a “natural” thinning of canopy fuels

More Recent Studies

- Kulakowski et al. 2003; Kulakowski and Veblen 2007 - did not support the hypothesis of increased fire hazard following bark beetle outbreak in spruce-fir or lodgepole pine forests in Colorado
- Bigler et al. (2005) found a slightly elevated probability of high-severity burns 60 years after beetle outbreak.

More Recent Studies

- Page and Jenkins (2007), Jenkins et al. (2008), Derose and Long (2009) suggest a reduced probability of crowning in post-outbreak stands and increased probability of torching in older post-outbreak stands;
- However, Page and Jenkins (2007) and Jenkins et al. (2008) showed an increase in surface fine fuels during red and gray phases of beetle infestation, which could increase surface fire intensity and rate of spread

More Recent Studies

- Lynch et al. (2006) found that the 1988 fires in Yellowstone National Park were ~11% more likely to have occurred where MPB were active in the 1970s (~15 yrs post-outbreak) but not in the 1980s (~ yrs post-outbreak)

Simard et al. 2011

Our recent JFSP-funded work

- In the *short term,* (1-5 years) following bark beetle mortality, dead surface fuels (1-hour to 1000-hour) and canopy base height in beetle-killed stands (red and gray stages) **did not differ** from undisturbed stands.
- However, in beetle-killed stands, canopy fuel loads, bulk density, and foliar moisture were much **lower** than in undisturbed stands.
- Simulation results suggested that under intermediate fire weather conditions, probability of active crown fire was **lower** in the red and gray-stage stands, compared to the undisturbed stands.

Our recent JFSP-funded work

- In the *longer term* (2-35 years), only 1000-hour fuels increased approximately twofold
- 10-hour and 100-hour fuels did not change, and 1-hour fuels decreased.
- Modeling results indicated that because understory sapling growth greatly reduced canopy base height, torching could potentially occur, however crowning was unlikely, and thus **only passive crown fires were predicted**.

Simard et al. 2011

5. Advance Regeneration in post-outbreak lodgepole pine forests in SE Wyoming

- Focus was on stands that were predominantly lodgepole pine before bark beetle outbreak
- Twenty stands sampled
  - Varied by density and landscape position
- All mature (live and dead) trees, saplings, and seedlings of all species were recorded

Kayes and Tinker, in prep.

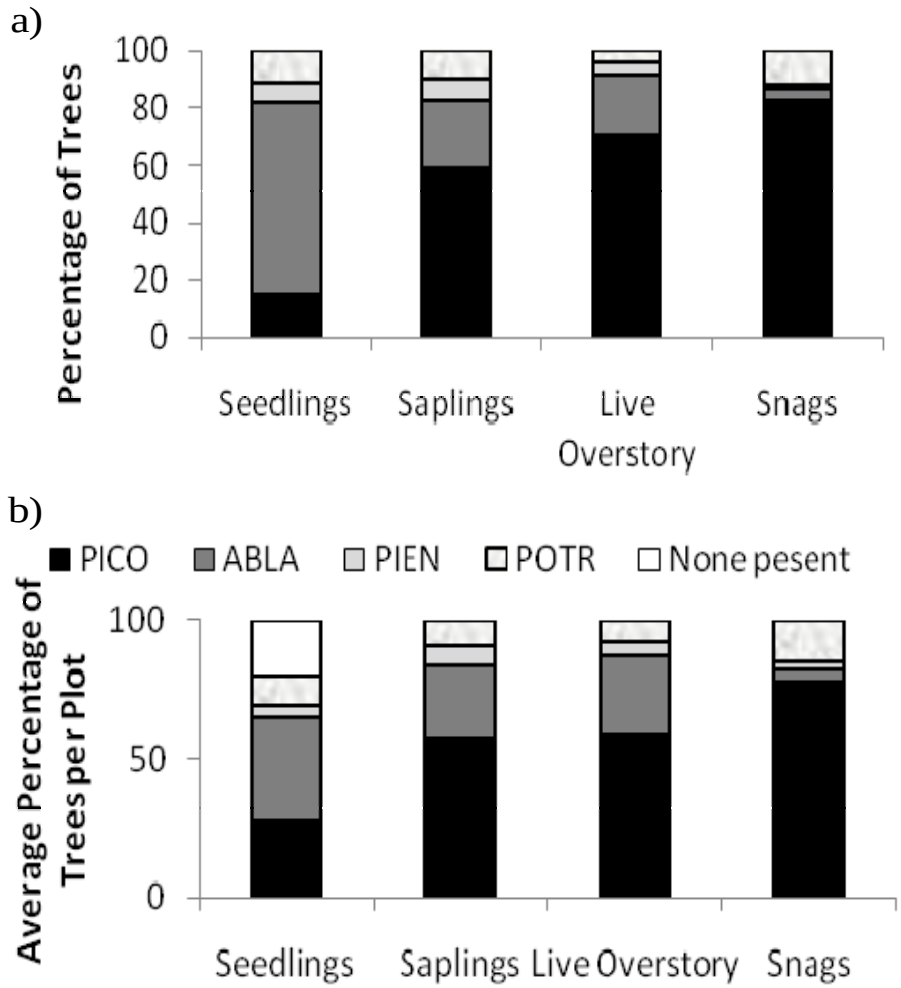
RESULTS OF STUDY – all 20 plots

- Average bark beetle caused mortality of lodgepole pine ranged from 0 - 70% of lodgepole pine trees in the overstory (average = 37%, SD = 19.6%).
- The density of advance regeneration varied widely, from 100 to 12,933 stems per hectare for all species combined.
- The density of advance regeneration exceeded 1,000 stems per hectare in all but three stands.

Kayes and Tinker, in prep.

RESULTS OF STUDY – all 20 plots

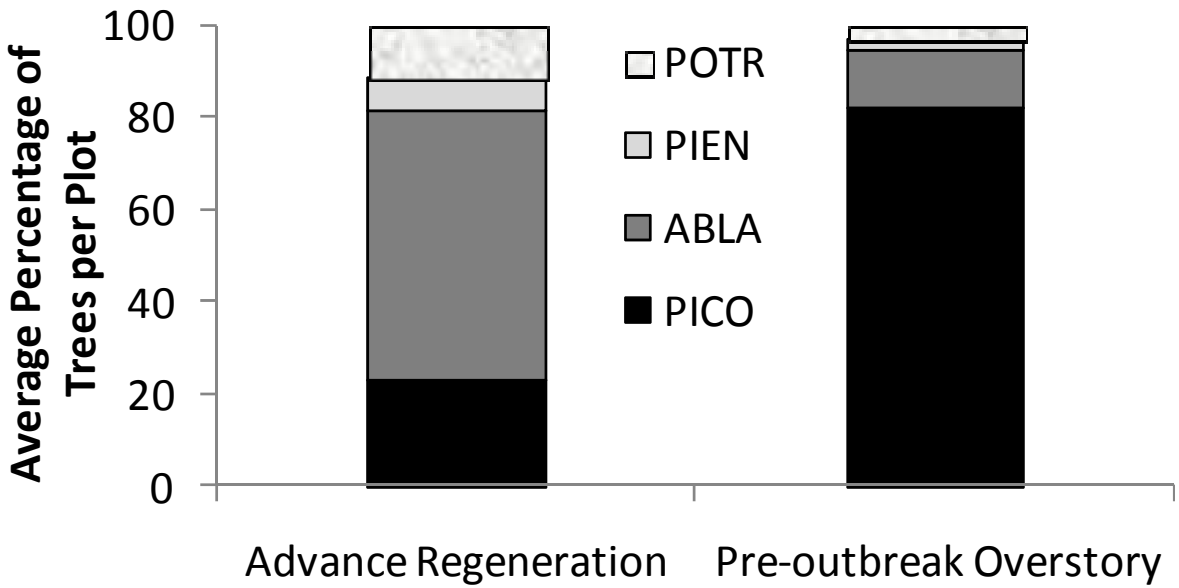
- Subalpine fir was the most abundant seedling overall, accounting for almost 70% of all seedlings (a).
- However, at the stand level, subalpine fir seedlings comprise only 37% of seedlings (b).



Kayes and Tinker, in prep.

Advance Regeneration (seedlings and saplings combined)

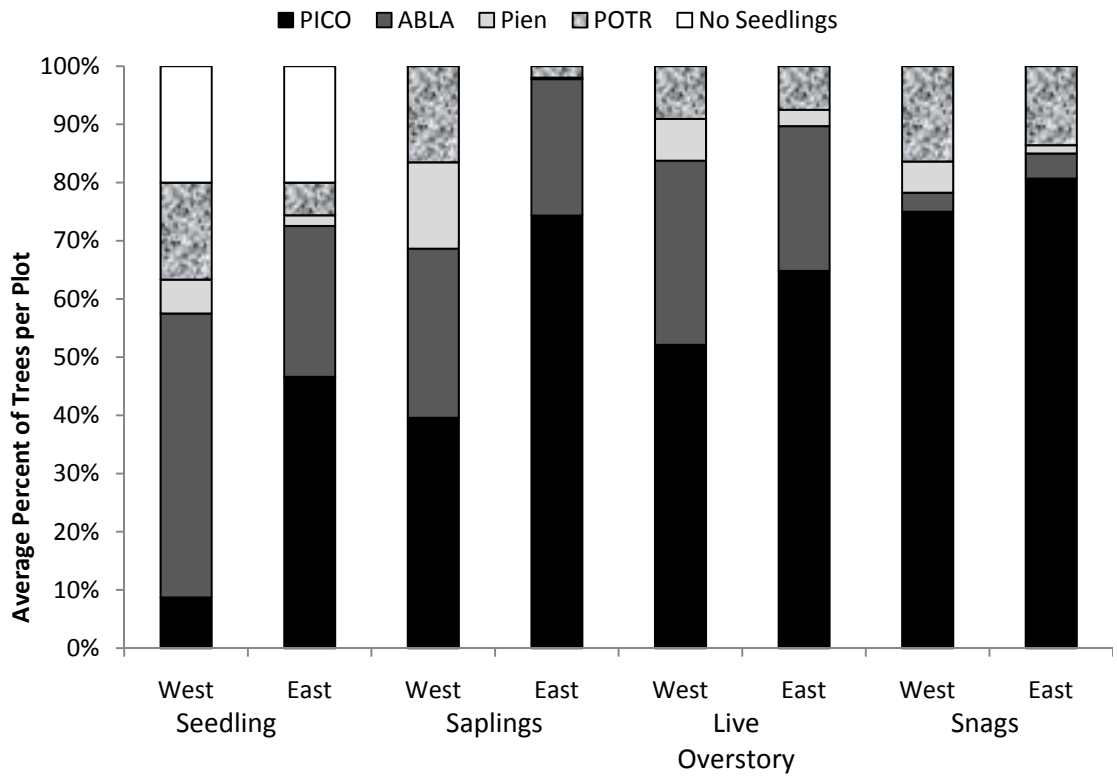
- Pre-outbreak overstory was comprised of 82% lodgepole pine, while the advance regeneration was only 23% lodgepole pine, and was dominated by subalpine fir, suggesting a potential shift in dominant species in many stands.



Kayes and Tinker, in prep.

Influence of landscape position (*Western side of range (wetter) versus Eastern side of range (drier))*on advance regeneration

- West (wet) side of range dominated by subalpine fir **seedlings**, but by lodgepole pine **saplings**.
- Surviving live overstory trees dominated by lodgepole pine on both sides of range, but subalpine fir a substantial component



Kayes and Tinker, in prep.

SOME FINAL THOUGHTS

- Results from these and many other studies in lodgepole pine forest systems emphasize the resilience of these forests to the primary disturbance regimes typically associated with them
- Developing a better understanding of how these forests respond will be critical in helping to inform future forest management

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References

Amman, G.D., and R.F. Schmitz. 1988. Mountain pine beetle-lodgepole pine interactions and strategies for reducing tree losses. Ambio 17: 62-68.

Bigler, C., D. Kulakowski, and T.T. Veblen. 2005. Multiple disturbance interactions and drought influence fire severity in Rocky Mountain subalpine forests. Ecology 86: 3018-3029.

Bockino, N.K., and D.B. Tinker. Interactions of white pine blister rust and mountain pine beetle in whitebark pine ecosystems in the Greater Yellowstone Area. Submitted to Natural Areas Journal.

Derose, R. J., and J. N. Long. 2009. Wildfire and spruce beetle outbreak: Simulation of 20 interacting disturbances in the central Rocky Mountains. Ecoscience 16:28-38.

Despain. D.G. 1990. Yellowstone Vegetation: Consequences of environment and history in a natural setting. Roberts Rinehart Publishers, Boulder, CO.

Jenkins, M. J., E. Hebertson, W. G. Page, and C. A. Jorgensen. 2008. Bark beetles, fuels, fires and implications for forest management in the Intermountain West. Forest Ecology and Management 254:16-34.

Kashian, D. M., D. B. Tinker, M. G. Turner and F. L. Scarpace. 2004. Spatial heterogeneity of lodgepole pine sapling densities following the 1988 fires in Yellowstone National Park, Wyoming, USA. Canadian Journal of Forest Research 34 2263-2276.

Kayes, L., and D.B. Tinker. Forest structure and regeneration following mountain pine beetle outbreak in Southeastern Wyoming. *In preparation* for submission to Forest Ecology and Management.

Kulakowski, D, T.T. Veblen, and P. Bebi. 2003. Effects of fire and spruce beetle outbreak legacies on the disturbance regime of a subalpine forest in Colorado. Journal of Biogeography 30: 1445-1456.

Kulakowski, D., and T.T. Veblen. 2007. Effects of prior disturbances on the extent and severity of wildfire in Colorado subalpine forests. Ecology 88: 759-769.

Lynch, H.J., R. A. Renkin, R. L. Crabtree, and P.R. Moorcroft. 2006. The influence of previous mountain pine beetle (*Dendroctonus ponderosae*) activity on the 1988 Yellowstone fires. Ecosystems 9: 1318-1327.

McCullough, D.G., R.A. Werner, and D. Neumann. 1998. Fire and insects in northern and boreal ecosystems of North America. Annual Review of Entomology 43: 107-127.

Page, W. G., and M. J. Jenkins. 2007b. Predicted fire behavior in selected mountain pine beetle infested lodgepole pine. Forest Science 53:662-674.

References, cont.

Romme, W. H., M. G. Turner, R. H. Gardner, W. W. Hargrove, G. A. Tuskan, D. G. Despain and R. A. Renkin. 1997. A rare episode of sexual reproduction in aspen (*Populus tremuloides*) following the 1988 Yellowstone fires. Natural Areas Journal 17:17-25.

Romme, W. H., M. G. Turner, G. A. Tuskan and R. A. Reed. 2005. Establishment, persistence and growth of aspen (*Populus tremuloides*) seedlings in Yellowstone National Park. Ecology 86:404-418.

Schmid, J. M., and G. D. Amman. 1992. *Dendroctonus* beetles and old-growth forests in the Rockies. In: M. R. Kaufmann, W. H. Moir, and R. L. Bassett, editors. Old-growth forests in the Southwest and Rocky Mountain regions. Proceedings of a workshop. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-213, Fort Collins, CO.

Schoennagel, T., M. G. Turner and W. H. Romme. 2003. The influence of fire interval and serotiny on postfire lodgepole pine density in Yellowstone National Park. Ecology 84:1967-1978.

Simard, M., W.H. Romme, J.M. Griffin, and M.G. Turner. 2011. Do mountain pine beetle outbreaks change the probability of active crown fire in lodgepole pine forests? *In press*, Ecological Monographs.

Tinker, D. B., W. H. Romme, W. W. Hargrove, R. H. Gardner and M. G. Turner. 1994. Landscape-scale heterogeneity in lodgepole pine serotiny. Canadian Journal of Forest Research 24:897-303.

Tinker, D.B. and D.H. Knight. 2000. Coarse woody debris following fire and logging in Wyoming lodgepole pine forests. Ecosystems 3:472-483.

Turner, M. G., W. H. Romme, R. H. Gardner and W. W. Hargrove. 1997. Effects of patch size and fire pattern on succession in Yellowstone National Park. Ecological Monographs 67:411-433.

Turner, M. G., W. H. Romme and D. B. Tinker. 2003. Surprises and lessons from the 1988 Yellowstone fires. Frontiers in Ecology and the Environment 1(7):351-358.

Turner, M. G., D. B. Tinker, W. H. Romme, D. M. Kashian and C. M. Litton. 2004. Landscape patterns of sapling density, leaf area, and aboveground net primary production in postfire lodgepole pine forests, Yellowstone National Park (USA). Ecosystems 7:751-775.

Wright, B.R., and D.B. Tinker. Canada thistle (*Cirsium arvense* (L.) Scop.) dynamics in young, postfire forests in Yellowstone National Park, Northwestern Wyoming, USA. Submitted to Natural Areas Journal.