3) *Aspen abundance*: The density and extent of aspen also matters, with large, dense stands generally regenerating better. Whereas the fires in Yellowstone in 1988 were large and severe, there was still significant aspen and willow decline due to herbivory because there was limited browse material in this landscape to begin with. We have observed similar problems in southern Utah where patchy aspen stands regenerating after fire are browsed heavily even when ungulate populations are moderate.

Elk scat and browsed aspen sucker following a wildfire in Arizona.

4) *Aspen functional type*: As discussed in WAA Brief #1, there are different ecological considerations depending on whether the target aspen community is seral to conifer succession or stable (remaining in aspen cover over long periods). While seral aspen undergoes periodic rejuvenation via suckering/seeding following stand-replacing disturbance, stable aspen does not generally experience large disturbance (Rogers et al. 2014). In terms of recruitment opportunities, there is marked difference between continuous regeneration resulting in complex structure in stable stands, and generally even-aged aspen in seral communities. Thus, reliance on human or natural disturbance as a regeneration "engine" may be inappropriate for stable stands. For these forests, careful regulation of browsers is very important where lack of successful recruitment has been demonstrated through prior monitoring.

Management Recommendations

In areas with high ungulate browse potential: 1) avoid small, low severity burns; 2) protect small patches of isolated aspen, where practical, with fencing or other methods; 3) work with livestock and wildlife managers to reduce or move ungulates during high risk periods (i.e., late summer or post-fire); and 4) conduct follow-up monitoring and adjust tactics if necessary.

Key Findings:

1. Herbivory commonly inhibits successful aspen re-establishment, though browsing intensity varies geographically. Ungulate browsing of aspen tends to be greatest in late summer-early fall.
2. Susceptibility among clones varies due to levels of defense chemicals in aspen.
3. Key monitoring variables include browse intensity and stand-level recruitment.
4. Number and movement of herbivores, total aspen available stems, disturbance size and intensity, and aspen functional type play key roles in facilitating aspen recovery.

Sources

Bork, E.W., C.N. Carlyle, J.F. Cahill, R.E. Haddow, and R.J. Hudson. 2013. Disentangling herbivore impacts on *Populus tremuloides*: A comparison of native ungulates and cattle in Canada's Aspen Parkland. *Oecologia* 173:895-904.

Lindroth, R, and S.B. St. Clair. 2013. Adaptation of quaking aspen (*Populus tremuloides*) for defense against herbivores. *For. Ecol. Manag*. 299:14–21.

Rogers, P.C., S.M. Landhäusser, B.D. Pinno, and R.J. Ryel. 2014. A functional framework for improved management of western North American aspen (*Populus tremuloides* Michx.). *Forest Science* 60(2):345-359.

Seager, S.T., C. Eisenberg, and S.B. St. Clair. 2013. Patterns and consequences of ungulate herbivory on aspen in western North America. *For. Ecol. Manage*. 299: 81–90.

Villalba, J.B., S.B. Burrit, and S.B. St. Clair. 2014. Aspen (*Populus tremuloides* Michx.) intake and preference by mammalian herbivores: The role of plant secondary compounds and nutritional context. *J. of Chemical Ecol.* 40:1135-1145.

Wan, H.Y., A.C. Olson, K.D. Muncey, and S.B. St. Clair. 2014a. Legacy effects of fire size and severity on forest regeneration, recruitment, and wildlife activity in aspen forests. *For. Ecol. Manage*. 329:59-68.

Wan, H.Y., A. Rhoades, and S.B. St. Clair. 2014b. Fire severity alters plant regeneration patterns and defense against herbivores in mixed aspen forests. *Oikos* 123: 1479-1488.