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# Implications of Longer Term Rest from Grazing in the Sagebrush Steppe: an Alternative Perspective

*Allison Jones[1] and John G. Carter[2]*

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## Abstract

In the inaugural volume of this journal, Davies et al. (2014) attempt to make a general case that livestock grazing is benign in sagebrush steppe, and long-term rest is not beneficial because modern "properly managed" grazing produces few significant differences compared to ungrazed areas. In this brief review, we point out the problems with this broad theory, not the least of which is a lack of supporting evidence that this "modern" grazing is afforded in the studies cited. Additionally, areas with invasive species such as cheatgrass are conflated with areas lacking these species, while threat of fire is used to drive management decisions to include livestock grazing as a tool for fire control regardless of the state of the land or the presence/absence of invasives. Davies et al. shed light on an important problem we face in the range science literature. They correctly note that the effect of light to moderate grazing, and other grazing management scenarios, have received relatively little study compared to long-term rest on sagebrush community recovery. One reason for this may be the scarcity of established large, grazing-free reserves or control areas in the western U.S. that include sagebrush steppe habitat. Establishing large, ungrazed areas throughout the sagebrush steppe may be one of the key steps we need to take to better understand the impacts of livestock grazing on our western rangelands as our climate changes.

[1] Allison Jones (allison@wildutahproject.org; corresponding author) – Conservation Biologist, Wild Utah Project, Salt Lake City, UT

[2] John G. Carter (johncarter@hughes.net) – Ecologist, Kiesha's Preserve, Paris, ID

## Table of Contents



## Editor's note

This is a response to "Implications of longer term rest from grazing in the sagebrush steppe," by Davies et al., published in this journal in 2014:

Davies, K.W., Vavra, M., Schultz, B. & Rimbey, N. (2014). Implications of longer term rest from grazing in the sagebrush steppe. Journal of Rangeland Applications 1, 14-34. [link]

Authors of the original article, Davies et al., submitted a reply to this response by Jones and Carter:

Davies, K.W., Gearhart, A., Vavra, M., Schultz, B. & Rimbey, N. (2016). Longer term rest from grazing: a response to Jones & Carter. Journal of Rangeland Applications 3, 8-15. [link]

## Introduction

In the inaugural volume of this journal, Davies et al. (2014) venture out onto a few thin scientifically-supported limbs, as they attempt to make the case that: (1) livestock grazing is benign in sagebrush steppe, and (2) long-term rest is not beneficial because modern "properly managed" grazing produces few significant differences compared to ungrazed areas. This broad theory as presented lacks sufficient attention to the details, not the least of which is a lack of supporting evidence that this "modern" grazing, is applied in the studies cited.

While intending to address sagebrush steppe, articles from grasslands lacking shrub structure as well as semi-desert sagebrush communities were used to support the authors' arguments that properly managed grazing will convey the same benefits as long-term grazing rest in sagebrush steppe habitats. Areas with invasive species such as cheatgrass are conflated with areas lacking these species, while threat of fire is used to drive management decisions to include livestock grazing as a tool for fire control regardless of the state of the land or the presence/absence of invasives.

Davies et al.'s characterizes Beschta et al. (2013) as "more of an opinion article and that its authors selected studies or parts of studies to support their statements instead of presenting a thorough synthesis" (p. 20). Below we follow the topics presented in Davies et al. as we point out that these authors may be at risk of treating their topic in a similar fashion.

## Rest Effects Vary by Plant Community Composition

Davies et al. make many broad statements that are not necessarily specific to sagebrush systems. For example, "Perennial grasses have many structural and physiological adaptations that permit them to be grazed on an annual or nearly annual basis…" (p. 16). The term "adaptation" conveys that these grasses evolved with frequent grazing by large herds of hooved ungulates. The problem that arises with making this blanket statement for all sagebrush systems is that many if not most sagebrush systems outside of the Wyoming Basins were not historically grazed by large, consistent herds of the most prolific grazer, bison, at least, not since the Pleistocene (Mack & Thompson 1982). This is one reason why, in sagebrush steppe, native bunchgrasses such as bluebunch wheatgrass are sensitive to grazing during the growing season (Anderson 1991, Carter et al. 2014).

Davies et al. recommend grazing residual grass growth to reduce fire risk. But this recommendation fails to consider the important role of residual vegetation in providing cover and food for wildlife (Carter et al. 2014), promoting productivity and vigor of the plant (Sauer 1978), providing soil litter cover (Carter et al. 2014), collecting snow and harvesting rain water (Gee et al. 1988), and the moderating effect of the plant crown on temperature which reduces thermal damage to the plant (Hinds & Rickard 1968, Sauer 1978). In the absence of livestock grazing, these attributes increase infiltration and reduce overland flow and erosion (Gee et al. 1988, Holechek et al. 2000, Carter et al. 2014). These benefits of residual plant matter are not acknowledged under Davies et al.'s view that dormant season use provides the same benefits as long-term rest while ignoring soil compaction, and damage to other ecosystem attributes described above. Davies et al. do admit that "If maintaining high amounts of the previous years' herbaceous growth is a management goal, then long-term rest would be more effective than dormant season use" (p. 26).

Davies et al. state that "sagebrush/bunchgrass co-dominant plant communities already have the desired vegetation composition from a resilience perspective; thus, long-term rest is unlikely to achieve any notable benefits in plant community composition" (p.19). This appears to imply that these systems always have the species composition and productivity of their pre-settlement natural state. However, Carter et al. (2014) and Beschta et al. (2013) illustrated the loss of biodiversity resulting from livestock grazing and the increase of diversity in the absence of livestock grazing. Current surveys of ecological sites in sagebrush steppe in northern Utah (e.g. Catlin et al. 2011) show that under rotation grazing systems lacking long-term rest, native grass and forb species are greatly reduced in abundance and productivity compared to potential.

The citations that Davies et al. choose to support their arguments are often not supportive of their case. For example, citing Svecjar & Tausch (1991), Davies et al. describe the invasion of exotic species on ungrazed Anaho Island in Nevada. However, that paper cites descriptions by early explorers of grazing by goats and sheep on the island. Davies et al. also cite Manier & Hobbs (2006) as evidence that 42 years of grazing exclusion decreased above-ground net primary production and biodiversity in mountain big sagebrush plant communities in Colorado. However, Manier & Hobbs did not measure production. Grazing-sensitive species such as bluebunch wheatgrass and Idaho fescue had greater cover in exclosures while increasers such as rabbitbrush, snakeweed and pussytoes had greater cover in grazed areas. If increased biodiversity is based on all species present, both native and non-native, then it is not always a desirable outcome of management.

Davies et al. cite Fox & Edelman (2003) as finding that juniper continued to increase over 30 years on the Island Research Natural Area (IRNA) near Madras, Oregon, in the absence of livestock grazing and fire, while perennial grass cover declined by 1.5%. A possible explanation for the small decrease in perennial grass cover in the ungrazed IRNA when comparing the early 1960s to the 1993 study could be precipitation, which was higher than average in the early 1960s and lower than average in the early 1990s (DRI 2015). Interestingly, and not reported in Davies et al., Fox and Edelman's cover data showed that in the IRNA, cheatgrass declined from 1.7% to 0.1%, litter/moss/lichen increased from 30.7% to 55.9%, and juniper remained unchanged during the 30 year ungrazed period.

## Rest Influence on Soil Biological Crusts and Other Soil Characteristics

In this section of their article it appears that Davies et al. downplay livestock grazing as a destructive force to cryptobiotic soils, which should be prevalent in big sagebrush communities (Belnap 2001). Although they cite a few studies that suggest that grazing is benign for crusts, the overwhelming consensus in the scientific literature is that any type of livestock grazing compared to ungrazed or very lightly grazed areas will have detrimental impacts to cryptobiotic soils (e.g., Jeffries & Klopatek 1987, Marble 1990, Kaltenecker et al. 1999).

Although Ponzetti & McCune (2001) stated that soil biological crusts were much more influenced by soil chemistry and climate than by grazing, they also found lower cover of biotic crusts and lichens, less crust-dominated soil surface roughness, and lower species richness in grazed versus ungrazed transects. Davies et al. also point to Muscha & Hild (2006) who reported that biological crust cover did not differ inside and outside 32-45 year-old grazing exclosures in Wyoming big sagebrush, and to Manier & Hobbs (2006) who found no difference in biotic crust cover and frequency with 40-50 years of grazing exclusion compared to grazed areas. While Muscha & Hild (2006) found that total biological crust cover did not significantly differ inside and outside nine livestock exclosures in Wyoming big sagebrush sites, inspection of their tabulated and graphical data show they found less bare ground inside eight of nine of the exclosures and more crust cover inside seven of nine exclosures and more native grass cover inside five of nine exclosures. And while Manier & Hobbs (2006) did not find significant differences in cover of grasses, forbs, crusts or bare soil inside and outside exclosures, they did not describe the grazing management for their study sites. This paper provides no evidence to support Davies et al.'s (2014) claim about modern grazing techniques being equivalent to long-term rest.

An example of a study that accounts for stocking rate when determining effects of rest versus grazing on cryptobiotic soils is Kaltenecker et al. (1999). This study addressed differences in crust cover inside and outside sagebrush exclosures in east-central Idaho. The age of the exclosures ranged from 8 to 11 years at the time of the study. Stocking rates ranged from 17.9 acres/AUM to 23.3 acres/AUM outside the exclosures. Exclosures had significantly greater crust cover inside and significantly less bare soil than outside the exclosures. The authors noted that biological crust and litter outside exclosures occurred only in protected areas beneath the shrub canopy. They concluded that in the 8–11 year timeframe of this study, the current management (light grazing) in sagebrush sites has not allowed for recovery of crusts.

Davies et al. fail to describe the actual grazing practices used in Ponzetti & McCune (2001), Manier & Hobbs (2006), or Muscha & Hild (2006), because those details were not provided in these studies. So, the claim that "modern grazing techniques" are somehow supportive of healthy biological crusts lacks support. In addition, even studies using exclosures may not represent true recovery comparisons because there is often no data for conditions at the time of exclosure construction. In many of these cases it is likely that biological crusts are often absent or are only left residually under shrubs at the time the exclosure is built. Belnap et al. (2001) concluded that Wyoming big sagebrush communities have potential for high cover of crusts and estimated that recovery from severe disturbance (e.g. transition from bare soil to late successional crust) in the Northern Great Basin takes about 125 years. Thus, exclosures built after crusts were already diminished by grazing will tend to not show significant effects when compared to grazed areas outside of enclosures for long periods of time.

## Rest – Fire Interactions

Few range scientists will disagree that in sagebrush systems which are nearly converted to exotic annuals, if livestock can effectively consume the problematic species then this is a desirable course of action. However, we should be careful when setting management options for control of cheatgrass. Davies et al. cite Diamond et al. (2009) who note that cattle grazing may be used to break the annual grass-fire cycle. Their study was conducted in an area lacking shrubs and dominated by cheatgrass and annual weeds. They demonstrated that grazing in areas such as this can reduce biomass and cover to the point that fires did not spread in the grazed plots. However, in sagebrush steppe with native perennial grasses and shrub cover, grazing at the levels required here (up to 80 – 90% utilization rates) will also negatively impact the native grasses, leading to their decline or loss (Catlin et al. 2011) even while presumably also reducing exotic annuals. Furthermore, West (1983) notes that sagebrush can contribute up to 70% of the phytomass at a site, so removing herbaceous biomass may not decrease the severity of fire.

Davies et al. cite Davies et al. (2009, 2010), reporting that long-term rest increases the likelihood of fire-induced mortality of perennial bunchgrasses because more fuel resides on the root crown of perennial bunchgrasses. We note that, in the absence of exotic annual grasses, fire that may naturally spread among perennial grass root crowns should not necessarily be seen as a problem. Historically, based on the location and type of sagebrush, and depending on grass species and fire behavior, these systems burned anywhere from every 75 to 300 years (Welch & Criddle 2003, Welch 2005, Baker 2011), and in the absence of exotic annuals in pre-settlement times, perennial grasses would have carried the fires, and still persisted.

## Implications for Wildlife

Davies et al. states that "long-term rest from grazing may also negatively impact the diversity of wildlife because the composition and structure of the vegetation of the ungrazed landscape can be rather homogeneous, particularly on landscapes that lack physiographic diversity" (p.25). However, these statements beg the question of what historic disturbance regime today's livestock are simulating, and which Davies et al. seemingly claim the native biota of the sagebrush steppe relied on in the past. It also suggests that sagebrush steppe in its natural state lacks diversity of habitats or, without livestock grazing, would be a uniform medium.

Recent studies of Hart Mountain and Sheldon National Wildlife Refuges in Oregon illustrate the recovery and diversity of vegetation and their associated wildlife communities following removal of livestock from large areas of sagebrush steppe in the northern Great Basin. Livestock were removed from Hart Mountain and Sheldon NWRs in 1990. After 1990, biologists recorded a steady increase of pronghorn populations on the Hart Mountain National Antelope Refuge (Collins 2012). And five to seven years after livestock removal from the Hart Mountain refuge, sage-grouse nesting initiation, nest success and brood-rearing success all increased, compared to these vital rates before livestock removal (Coggins 1998).

## Discussion/Conclusions

Davies et al. shed light on an important problem we face in the range science literature. They correctly note that the comparison of light to moderate grazing to long-term rest has received relatively little study in sagebrush steppe. One reason for this may be the scarcity of large, established grazing-free reserves or control areas in the western U.S. including sagebrush steppe habitat. In fact, calling for the establishment of these large, ungrazed areas in many different ecosystems was a specific point made by Beschta et al. (2013) as one of the key steps we may need to take to better understand the impacts of livestock grazing on our western rangelands as our climate changes.

Davies et al. identified studies that indicate that long-term rest may not be beneficial for sagebrush steppe systems. Yet, while claiming that today's grazing practices are not detrimental to these communities, Davies et al. fail to clearly define these practices or point out exactly which practices were applied in the articles they cite. We also caution Davies et al. to not confuse the problem of fire spreading in an unnatural way (with exotics), with fire spread in a natural way (as a pristine system would). While Davies et al. certainly do not mean to imply that "grass needs to be grazed", as range ecologists we must be careful not to inappropriately extrapolate this old adage, especially in ecosystems that did not evolve with large herds of grazing ungulates. This includes most of the West's sagebrush systems.

Grazing in sagebrush steppe means that other communities present within the larger steppe habitat are also grazed. These include springs, riparian areas, and adjacent aspen and Western juniper stands, with concomitant impacts to their ecosystem services and contributions to diversity (as reviewed in Fleischner 1994, and Belsky & Uselman 1999). In these cases, functions such as soil infiltration rates, water storage, and water quality are also affected (as reviewed in Trimble & Mendel 1995, and Jones 2000). Any grazing strategy designed for sagebrush steppe, in addition to those to address invasives, must also consider these different communities and functions and their susceptibility to grazing impacts.

Davies et al. use the terms “well-managed grazing,” “current managed grazing,” “properly managed grazing,” “managed grazing,” and “modern grazing” interchangeably, but definitions are not offered for any of them and the articles cited offered little illumination on the subject. We look forward to working with the range science community, livestock operators, and land managers to help better define “well-managed” grazing, perhaps with more care towards truly sustainable utilization rates in the sagebrush steppe, and hope that one day this can be the predominant form of management in the sagebrush steppe, rather than the exception to the rule.

**Common and Scientific Names** of Plants Listed in Text According to the USDA PLANTS Database (http://www.plants.usda.gov/).

| Common Name | Scientific Name |
|---|---|
| Bluebunch wheatgrass | *Pseudoroegneria spicata* (Pursh) Á. Löve |
| Cheatgrass | *Bromus tectorum* L. |
| Idaho fescue | *Festuca idahoensis* Elmer |
| Mountain big sagebrush | *Artemisia tridentata* Nutt*. spp. vaseyana* (Rydb.) Beetle |
| Pussytoes | *Antennaria* species Gaertn. |
| Rabbitbrush | *Chrysothamnus viscidiflorus* (Hook.) Nutt. or *Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird |
| Snakeweed | *Gutierrezia sarothrae* (Pursh) Britton & Rusby |
| Wyoming big sagebrush | *Artemisia tridentada* Nutt. ssp. *wyomingensis* Beetle & Young |

## Literature Cited

Anderson, J. E., & Inouye, R. S. (2001). Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. *Ecological Monographs*, 71(4), 531-556. Doi:10.1890/0012-9615(2001)071[0531:LSCIPS]2.0.CO;2

Anderson, L. (1991). *Bluebunch wheatgrass defoliation: effects and recovery. A review*. (Technical Bulletin 91-2). BLM Idaho State Office, 1991. Accessed from publiclandgrazing.org.

Baker, W. L. (2011). Pre-Euro-American and recent fire in sagebrush ecosystems. In S. T. Knick & J. W. Connelly (eds.), *Greater sage-grouse: ecology and management of a landscape species and its habitats* (pp. 185–201) Berkeley, CA, USA: University of California Press.

Belnap, J., Eldridge D., Kaltenecker J. H., Rosentreter R., Leonard S., & Williams, J. (2001). *Biological Soil Crusts: Ecology and Management*. U.S. Department of the Interior, Bureau of Land Management Technical Reference 1730-2. 118 p.

Belsky, A. J., Matzke, A., & Uselman, S. (1999). Survey of livestock influences on stream and riparian ecosystems in the western United States. *Journal of Soil and Water Conservation,* 54(1), 419-431. http://www.jswconline.org/content/54/1/419.short.

Beschta, R. L., Donahue, D. L., DellaSala, D. A., Rhodes, J. J., Karr, J. R., O’Brien, M. H., Fleischner, T. L., & Williams, C. D. (2013). Adapting to climate change on western public lands: Addressing the ecological effects of domestic, wild, and feral ungulates. *Environmental Management*, 51(2), 474-491. doi:10.1007/s00267-012-9964-9

Catlin, J. C., Carter, J. G., & Jones, A. L. (2011). Range management in the face of climate change. In T. A. Monaco, (ed.). *Proceedings: Threats to Shrubland Ecosystem Integrity* (pp 207 – 249). Logan, Utah, USA: S. J. Quinney Natural Resources Research Library.

Carter, J., Jones, A., O'Brien, M., Ratner, J. & Wuerthner, G. (2014). Holistic Management: Misinformation on the Science of Grazed Ecosystems. *International Journal of Biodiversity*. doi:10.1155/2014/163431

Coggins, K.A. (1998). *Relationship Between Habitat Changes and Productivity of Sage Grouse at Hart Mountain National Antelope Refuge, Oregon*. (Master's Thesis). Oregon State University, OR, USA.

Collins, G. (2012). *Result of the July 2012 aerial survey of Hart Mountain National Antelope Refuge*. Internal report, Sheldon – Hart Mountain National Wildlife Refuge. Lakeview, Oregon.

Davies, K. W., Svejcar, T. J., & Bates, J. D. (2009). Interaction of historical and nonhistorical disturbances maintains native plant communities. *Ecological Applications*, 19(6), 1536-1545. doi:10.1890/09-0111.1

Davies, K. W., Bates, J. D., Svejcar, T. J., & Boyd, C. S. (2010). Effects of long-term livestock grazing on fuel characteristics in rangelands: An example from the sagebrush steppe. *Rangeland Ecology & Management*, 63(6), 662-669. doi:10.2111/REM-D-10-00006.1

Davies, K.W., Vavra, M., Schultz, B. & Rimbey, N. (2014). Implications of longer term rest from grazing in the sagebrush steppe. *Journal of Rangeland Applications* 1, 14-34. http://journals.lib.uidaho.edu/index.php/jra/article/view/15

Diamond, J. M., Call, C. A., & Devoe, N. (2009). Effects of targeted cattle grazing on fire behavior of cheatgrass-dominated rangeland in the northern Great Basin, USA. *International Journal of Wildland Fire*, 18(8), 944-950. doi:10.1071/WF08075

DRI (Desert Research Institute), (2015). *Western Regional Climate Summaries*. Madras and Metolius Oregon climate stations. http://www.wrcc.dri.edu/climate-summaries/. Accessed May 27, 2015.

Fleischner, T. L. (1994). Ecological costs of livestock grazing in western North America. *Conservation Biology*, 8, 629-644.

Fox, M. A., & Eddleman, L. E. (2003). A time comparison study of vegetation on the Island Research Natural Area in central Oregon. *Northwest Science*, 77(3), 246-254.

Gee, G. W., Beedlow, P. A. & Skaggs, R. L. (1988). Water balance. In W. H. Rickard, L. E. Rogers, B. E. Vaughan, and S. F. Liebetrau (eds.), *Shrub-Steppe Balance and Change in a Semi-Arid Terrestrial Ecosystem*, pp. 61–81, Elsevier, New York, NY, USA, 1988.

Hinds, W. T. & Rickard, W. H. (1968). Soil temperatures near a desert steppe shrub. *Northwest Science*, 42, 5–8.

Holechek, J. L., Gomes, H., Molinar, F., Galt, D., & Valdez, R. (2000). Short-duration grazing: the facts in 1999. *Rangelands*, 22(1), 18–22.

Jeffries, D. L. & Klopatek, J. M. (1987). Effects of grazing on the vegetation of the blackbrush association. *Journal of Range Management*, 40, 390-392.

Jones, A. (2000). Effects of cattle grazing on North American arid ecosystems: A quantitative review. *Western North American Naturalist*, 60(2), 155-164.

Kaltenecker, J. H., Wicklow-Howard, M. C., & Rosentreter, R. (1999). Biological Soil Crusts in Three Sagebrush Communities Recovering from a Century of Livestock Trampling. In: McArthur, E. D. Ostler, W. K.; Wambolt, C. L., (eds.) *Proceedings: Shrubland Ecotones*; 1998 August 12–14; Ephraim, UT. Proc. RMRS-P-11. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Mack, R. N. & Thompson, J. N. (1982). Evolution in steppe with few large hooved mammals. *American Naturalist*, 119(6), 757–773.

Manier, D. J., & Hobbs, N. T. (2006). Large herbivores influence the composition and diversity of shrub-steppe communities in the Rocky Mountains, USA. *Oecologia*, 146(4), 641-651. doi:10.1007/s00442-005-0065-9.

Marble, J. R. 1990. *Rangeland microphytic crust management: Distribution, grazing impacts, and mineral nutrition relations*. (Doctoral dissertation). University of Utah, Salt Lake City, Utah, Salt Lake County.

Muscha, J. M., & Hild, A. L. (2006). Biological soil crusts in grazed and ungrazed Wyoming sagebrush steppe. *Journal of Arid Environments*, 67(2), 195-207. doi:10.1016/j.jaridenv.2006.02.010

Ponzetti, J. M., & McCune, B. P. (2001). Biotic soil crusts of Oregon's shrub steppe: Community composition in relation to soil chemistry, climate, and livestock activity. *The Bryologist*, 104(2), 212-225. doi:10.1639/0007-2745(2001)104[0212:BSCOOS]2.0.CO;2

Sauer, R. H. (1978) Effect of removal of standing dead material on growth of Agropyron spicatum. *Journal of Range Management*, 31(2), 121–122.

Svejcar, T., & Tausch, R. (1991). Anaho Island, Nevada: A relict area dominated by annual invader species. *Rangelands*, 13(5), 233-236.

Trimble, S. W. & Mendel, A. C. (1995). The cow as a geomorphic agent - a critical review. *Geomorphology*, 13, 233-253.

Welch, B. L. (2005). *Big sagebrush: A sea fragmented into lakes, ponds and puddles*. (General Technical Report 144). Ogden, Utah: USDA, Forest Service, Rocky Mountain Research Station.

Welch, B. L. & Criddle, C. (2003). *Countering misinformation concerning big sagebrush*. (Research Paper No. 40). Ogden, Utah: USDA, Forest Service, Rocky Mountain Research Station.

West, N. E. (1983). Western Intermountain Sagebrush Steppe. In: N.E. West (ed.), *Temperate Deserts and Semi-Deserts* (pp. 351 -373), Amsterdam, NL: Elsevier Publishing Company.

Whisenant, S.G. (1989). Changing fire frequencies on Idaho's Snake River plains: Ecological and management implications. In E.D. McArthur, E.M. Romney, S.D. Smith, & P.T. Tueller (eds.). *Proceedings - Symposium on Cheatgrass Invasion, Shrub die-off, and Other Aspects of Shrub Biology and Management* (pp. 4-10). (General Technical Report No. 276). Ogden, UT: USDA, Forest Service, Intermountain Research Station.

Wright, H.A. & Bailey, A.W. (1982). *Fire Ecology: United States and Southern Canada*. New York, NY: John Wiley & Sons.