CALIFORNIA FIRE SCIENCE CONSORTIUM

JOINT FIRE SCIENCE PROGRAM

Research Synthesis for Resource Managers

Release:	Contact:	Phone:	Email:
October 2022	Kristina Wolf	[(916) 215-4947]	[kristina.wolf@bof.ca.gov]

California Fire Science Consortium | 137 Mulford Hall MC #3114, Berkeley CA 94720

Grazing for Fuel Reduction and Resilience in Forested Ecosystems

This synthesis summarizes the relevance of targeted grazing for fuel reduction and ecosystem resilience and discusses some of its primary applications and limitations.

Management Implications

- Targeted grazing is an effective tool for manipulating vegetation and fuel structure and composition with four main control points: species, season, duration, and stocking rate.
- As a fuel treatment, grazing is most effective at removing 1- and 10- hour fuels and controlling understory vegetation composition.
- Grazing is especially useful following or between treatments of larger fuels.
- Grazing in the context of fuel treatment and resilience frameworks is underutilized and frequently underexamined in research and publications.
- Grazing practitioners support quantitative research on targeted grazing to test anecdotal knowledge.

Targeted Grazing

Principles of targeted grazing are based upon controlled application of livestock to achieve specific ecological and vegetation management goals or outcomes. An important distinction in targeted grazing, compared to production-focused grazing, is that desired outcomes include both livestock and landscape-scale ecological objectives (Bailey at el. 2019). In addition to fuel reduction for wildfire mitigation, targeted grazing has shown effectiveness in reducing noxious weeds and wildlife habitat improvement (Green et al. 1982, Marchetto et al. 2021), although outcomes vary with location and factors involved in the grazing strategy (James et al. 2022).

Management factors in the practice of targeted grazing include species and livestock type, seasonality, frequency and duration, and stocking rate and density. Different species and livestock types (e.g., stocker vs. bull vs. cow) result in different impacts from herbivory and plant selection due to varying mouth size and design, past grazing experience, nutritional needs, and dietary preferences (Nader et al. 2007). Seasonality determines when target plant species are most susceptible to sustained damage from grazing (Launchbaugh et al. 2007). Duration and frequency of grazing can impact forage productivity and weed populations differently along natural climatic and productivity gradients, with increased duration and frequency of grazing often contributing to decreased productivity and desirable plant abundance, cover, and species richness (Bailey and Brown 2011). Stocking rate and density influence plant utilization, and if misapplied, can result in overgrazing,[1] particularly if duration and frequency are applied

[1] Defined as when plants are defoliated (grazed) prior to sufficient recovery of root systems and foliage from an initial grazing.

at inappropriate rates (Ralphs et al. 1990, Cipriotti et al. 2019). Moreover, these management factors may interact with abiotic environmental factors to produce variable or unpredictable outcomes. Thus, addressing critical management factors and achievement of targeted grazing goals is reliant on grazing practitioners with extensive ecological and management experience relevant within local socio-biological contexts.

Increasing Resistance and Resilience

Western North American forests and woodlands are increasingly prone to disturbance due to climate change, drought, wildfire, insects, and disease. Improved resistance and resilience to disturbance are frequently cited as restoration and management goals in California. Resistance refers to the capacity of an ecosystem to retain its fundamental structure, processes and functioning despite stresses, disturbances, or invasive species, while resilience is the ability to recover from stresses and disturbances (Walker and Salt 2006). The primarily arid and semi-arid ecosystems in California are especially susceptible to drought and wildfire. "Fuel treatments" are the most prevalent mechanisms discussed for increasing resistance and resilience (Stephens et al. 2009, Stevens et al. 2014, Moghaddas et al. 2018). North et al. (2022) theorize that in the case of Sierra Nevada mixed-conifer forests, reduction of stand density to historic levels (pre-European colonization) for the purposes of reducing competition and improving tree vigor may also improve ecosystem resilience.

The most common forest fuel treatments discussed in the context of resistance and resilience are mastication, mechanical thinning, hand thinning, and prescribed fire. These treatments manipulate living and dead vegetation to target surface fuel, ladder fuels, and canopy continuity for the purposes of managing fire severity and spread (Agee and Skinner 2005, Winford et al. 2015). In grazed ecosystems, grazing has the potential to address some of the same fuel treatment goals and contribute additional benefits to woodland and forest ecosystems if managed correctly (Figure 1) (Launchbaugh and Walker 2006).

	Mechanical Thinning	Mastication	Hand Thinning	Prescribed Fire	Targeted Grazing
Surface fuels	+	+	±	—	—
Height to live crown	+	+	+	+	+
Canopy continuity	—	-/	-/	—	0

Figure 1: Responses to Management: Fitting targeted grazing into fuel treatment and fire resistance frameworks. Adapted from Agee and Skinner 2005 and Winford et al. 2015.

Key to responses: + increase; – decrease; ± variable; -/ = slight reduction to no change; 0 no change

Grazing for Fuel Reduction

Targeted grazing is becoming increasingly common as a management tool in recreation areas and the wildland-urban interface (WUI) to reduce fuel load and shrub density (Taylor 2006). In practice, grazing reduces surface fuels (1- and 10- hour fuels) and may break up dense stands of brush. Fine fuels can be trampled and mixed into soil in the grazing process, reducing ignition risk (Nader et al. 2007). Grazing with browsing species can trim ladder fuels, mimicking the fire pruning effect of low-severity fires and increasing the height to live crown. These outcomes make targeted grazing an effective strategy for managing fuel breaks, the WUI, and escape zones after initial treatment of larger fuels and disrupting the continuity of fuel loads by preventing excessive grass and brush regrowth and disrupting the continuity of fuel loads (Taylor 2006). However, much of the current information on grazing for fuel reduction is qualitative or anecdotal (Nader et al. 2007).

Grazing to Alter Structure and Composition

Grazing is the most widespread tool utilized in California for vegetation management across a variety of ecosystems (Huntsinger and Barry 2021). In plantation settings, grazing can be used to manage understory vegetation to the benefit of conifer species, primarily through more rapid nutrient cycling, increased soil moisture, and reduced competition for water and nutrients with brush and herbaceous vegetation (Grelman 1988, Kosco and Bartolome 1983). Sharrow (2006) compiled a series of case studies in which—when compared to ungrazed sites—Douglas fir (*Pseudotsuga menziesii*) plantings increased from 8–22% in diameter and 10–27% in height with targeted grazing by sheep, and 26–31% in diameter and 7–18% in height with targeted grazing by cattle. Similar results were observed in ponderosa pine (*Pinus ponderosa*), with increases of 13–15 % in diameter and 9–27% in height when grazed by cattle (Doescher et al. 1989).

Younger trees can be susceptible to damage or mortality due to browsing or trampling; however, this is dependent on the species of tree, seasonality of grazing, grazing pressure, and grazing species. In mixed conifer clear-cut regeneration, cattle did not significantly damage regenerating trees more than deer alone (Kosco and Bartolome 1983), and grazing brush to release post-burn plantings of conifer seedlings in the Tahoe National Forest resulted in damage of only 1–2% of tree seedlings and produced successful reduction of palatable brush species (Grelman 1988).

Several case studies in Monterey Pine (*Pinus radiata*) forests and California chaparral investigated goat herbivory on fuel reduction and plant composition. Tsiouvaras et al. (1989) assessed grazing of fuel breaks in mixed pine (*Pinus* spp.) and *Eucalyptus* spp. forest and found brush understory reduced by 46% and 82% at 20 and 59 inches in height, respectively. Species such as coyote brush (*Baccharis pilularis*) and toyon (*Heteromeles arbutifolia*) experienced large decreases in cover, while others, such as poison oak (*Toxicodendron diversilobum*) and *Eucalyptus* exhibited little change. In chaparral, Green et al. (1982) found high rates (80–95%) of herbivory by goats for all mountain mahogany (*Cercocarpus betuloides*) and scrub oak (*Quercus dumosa*) plants, but low selection rates for desert ceanothus (*Ceanothus greggii*).

Grazing in Combination with Other Treatments

Integrating grazing as one tool in combination with other treatment types may provide the best overall outcome for fuels reduction, particularly in landscapes with variable topography and sensitive resources (e.g., riparian areas, steep slopes, rocky soils). Grazing after mechanical treatment, such as mastication or hand-cutting, can reduce fuels of varying diameters and densities (Nader et al. 2007). Targeted grazing offers a key opportunity in the annual maintenance of fuel break treatments, a strategy employed in both oak woodland and chaparral ecosystems. Grazing can be applied to maintain fuel breaks after initial prescribed fire or fuel break clearing (Green et al. 1982, Tsiouvaras et al. 1989, Rouet-Leduc et al. 2021). In Southern California chaparral, grazing following a combination of cutting, pile burning, and herbicide application resulted in an 87% and 92% reduction in herbaceous cover and height, respectively (Grupenhoff and Molinari 2021). Combinations of targeted grazing and prescribed burning are complementary tools that can effectively reduce fuels (Huntsinger and Barry 2021).

Limitations

Labor and Legislation

California Assembly Bill 1066 (Phase-In Overtime for Agricultural Workers Act of 2016) requires goat and sheep herders to receive compensation for on-call hours. Herders live with the herd and are considered “on call” 24 hours a day, resulting in a calculated 168-hour work week, and employee costs that are prohibitive for most grazing operations (Ingram et al. 2022). Grazing practitioners are primarily limited due to obstacles associated with a small domestic labor pool. Opportunities to hire knowledgeable and experienced herders are rare. Additional logistical obstacles include procurement of driver’s licenses and visas, and associated recruitment of international, primarily Peruvian, herders on 2-HA Temporary Agricultural visas (Soares 2022).

Ecological Concerns

The primary ecological concerns raised around grazing treatments are water pollution (Belsky et al. 1999, Agourdis et al. 2007), disease transfer (Schieltz and Rubenstein 2016), spread of invasive species (HilleRisLambers et al. 2010), habitat degradation (see Seligman and Perevolotsky 1994), erosion (George et al. 2004), and impacts to wildlife (Schieltz and Rubenstein 2016). However, reported negative outcomes of livestock grazing may be highly dependent on abiotic factors and local conditions, and grazing management may counter potentially detrimental effects, even producing positive results for a variety of these elements (see also Seligman and Perevolotsky 1994, Frost and Launchbaugh 2003, Jackson et al. 2006, Krausman et al. 2009, Lai and Kumar 2020, Voeller et al. 2021). These elements should be considered in the development of a targeted grazing plan.

Research and Literature

Literature on grazing for fuel reduction in California's forest systems is limited. Poor grazing management is regularly cited along with fire suppression and climate conditions as a contributor to forest fuels accumulations responsible for catastrophic wildfires in the West (Borman 2005). Many published works discuss grazing impacts on structure and fuels in terms of "grazed" or "ungrazed" without citing stocking rates or livestock species and may overgeneralize findings (Donovan et al. 2022). These studies lack adequate information to draw such conclusions in the context of modern grazing science and contribute negatively to perceptions of grazing in forests (Belsky and Blumenthal 1997). Research at the intersection of modern grazing science and forestry management is required to clarify and update knowledge in this field (Borman 2005, Huntsinger and Barry 2021).

Looking Forward

Recent publications have indicated that decreased forest stocking may be key to improving forest resilience in the face of changing climate conditions and fire regimes (Bernal et al. 2022, North et al. 2022). While reductions in forest stocking will initially require treatments that can remove large fuels, such as mechanical thinning, prescribed burning, and managed wildfire, grazing may become an important cost-effective tool for co-managing areas where understory conditions are dominated by herbaceous vegetation and shrubs. However, the benefits to tree growth and health conferred by grazing in the understory of plantations have not been adequately investigated in wildland settings. With tree health identified as a factor in Sierra Nevada mixed-conifer forest resilience (North et al. 2022), this may be a beneficial research direction for some of our most fire vulnerable systems.

Authors

This synthesis was adapted from a synthesis written in fulfillment of a graduate level college course at UC Berkeley by Harrison Raine and Genoa Starrs in Spring 2022.

Literature cited

Agee, James K., and Carl N. Skinner. 2005. "Basic Principles of Forest Fuel Reduction Treatments." Forest Ecology and Management, Relative Risk Assessments for Decision–Making Related to Uncharacteristic Wildfire. 211 (1): 83–96. https://doi.org/10.1016/j.foreco.2005.01.034.

Agourdis, Carmen T., Stephen R. Workman, Richard C. Warner, and Gregory D. Jennings. 2007. "Livestock Grazing Management Impacts on Stream Water Quality: A Review." Journal of the American Water Resources Association 41 (3): 591–606. https://doi.org/10.1111/j.1752-1688.2005.tb03757.x.

Bailey, Derek W., Jeffrey C. Mosely, Richard E. Estell, Andres F. Cibils, Marc Horney, John. R. Hendrickson, John W. Walker, Karen L. Launchbaugh, and Elizabeth A. Burritt. 2019. "Synthesis Paper: Targeted Livestock Grazing: Prescription for Healthy Rangelands." Rangeland Ecology and Management 72 (6): 865–77. https://doi.org/10.1016/j.rama.2019.06.003.

Bailey, Derek W., and Joel R. Brown. 2011. "Rotational Grazing Systems and Livestock Grazing Behavior in Shrub-Dominated Semi-Arid and Arid Rangelands." Rangeland Ecology and Management 64 (1): 1–9. https://doi.org/10.2111/REM-D-09-00184.1.

Belsky, A. Joy, A. Matzke, and S. Uselman. 1999. "Survey of livestock influences on stream and riparian ecosystems in the western United States." Journal of Soil and Water Conservation 54 (1): 419–31. https://arc.lib.montana.edu/range-science/item/125.

Belsky, A. Joy, and Dana M. Blumenthal. 1997. "Effects of Livestock Grazing on Stand Dynamics and Soils in Upland Forests of the Interior West." Conservation Biology 11 (2): 315–27. https://doi.org/10.1046/j.1523-1739.1997.95405.x.

Bernal, Alexis A., Scott L. Stephens, Brandon M. Collins, and John J. Battles. 2022. "Biomass Stocks in California's Fire-Prone Forests: Mismatch in Ecology and Policy." Environmental Research Letters 17 (4): 044047. https://doi.org/10.1088/1748-9326/ac576a.

Borman, Michael M. 2005. "Forest Stand Dynamics and Livestock Grazing in Historical Context." Conservation Biology 19 (5): 1658–62. https://doi.org/10.1111/j.1523-1739.2005.00115.x.

Cipriotti, Pablo A., Martín R. Aguiar, Thorsten Wiegand, and José M. Paruelo. 2019. "Combined Effects of Grazing Management and Climate on Semi-Arid Steppes: Hysteresis Dynamics Prevent Recovery of Degraded Rangelands." Journal of Applied Ecology 56 (9): 2155–65. https://doi.org/10.1111/1365-2664.13471.

Doescher, Paul S., Steven D. Tesch, and William E. Drewien. 1989. Water relations and growth of conifer seedlings during three years of cattle grazing on a southwestern Oregon plantation. Northwest Science63:232-240.

Donovan, Victoria M., Caleb P. Roberts, Dillon T. Fogarty, David A. Wedin, and Dirac Twidwell. 2022. "Targeted Grazing and Mechanical Thinning Enhance Forest Stand Resilience Under a Narrow Range of Wildfire Scenarios." Ecosphere 13 (5): e4061. https://doi.org/10.1002/ecs2.4061.

Frost, Rachel A., and Karen L. Launchbaugh. 2003. "Prescription Grazing for Rangeland Weed Management." Rangelands 25 (6): 43–47.

George, M., R. Larsen, N. McDougald, K. Tate, J. Gerlach, and K. Fulgham. 2004. "Cattle Grazing Has Varying Impacts on Stream-Channel Erosion in Oak Woodlands." California Agriculture 58 (3): 138–143. https://doi.org/10.3733/ca.v058n03p138.

Green L.R., C.L. Hughes, and W.L. Graves. 1982. "Goats control of brush regrowth on Southern California fuel-breaks." First International Rangeland Congress. 14–18 August, Denver CO: 451–5.

Grelman, Harley L. 1988. "Sheep grazing in conifer plantations." Rangelands 10 (3): 99–101.

Grupenhoff, Ashley, and Nicole Molinari. Preprint 2021. "Plant Community Response to Fuel Break and Goat Grazing in Southern California." Fire Ecology. https://doi.org/10.21203/rs.3.rs-185028/v1.

HilleRisLambers, Janneke, Stephanie G. Yelenik, Benjamin P. Coulman, and Jonathan M. Levine. 2010. "California Annual Grass Invaders: The Drivers or Passengers of Change?" Journal of Ecology 98 (5): 1147–56. https://doi.org/10.1111/j.1365-2745.2010.01706.x.

Huntsinger, Lynn, and Sheila Barry. 2021. "Grazing in California's Mediterranean Multi-Firescapes." Frontiers in Sustainable Food Systems 5 (715366): 1–22. https://doi.org/10.3389/fsufs.2021.715366.

Ingram, Roger, Cole Bush, Rosie Busch, Marie Hoff, Ryan Indart, Beth Reynolds, Rob Rutherford, Andree Soares, and Bianca Soares. 2022. "Targeted Grazing Survey Report to California Wool Growers Association". March 2022. Produced for the California Wool Growers Association. http://californiawoolgrowers.org/wp-content/uploads/2022/03/2022-Targeted-Grazing-Survey-Report-CWGA-Final.pdf.

Jackson, R.D., B. Allen-Diaz, B., L.G. Oates, K.W. Tate. 2006. "Spring-water Nitrate Increased with Removal of Livestock Grazing in a California Oak Savanna." Ecosystems 9: 254–267. https://doi.org/10.1007/s10021-005-0166-7.

Krausman, Paul R., David E. Naugle, Michael R. Frisina, Rick Northrup, Vernon C. Bleich, William M. Block, Mark C. Wallace, and Jeffrey D. Wright. 2009. "Livestock Grazing, Wildlife Habitat, and Rangeland Values." Rangelands 31 (5): 15–19.

Lai, Liming, and Sandeep Kumar. 2020. "A Global Meta-Analysis of Livestock Grazing Impacts on Soil Properties." PLoS ONE 15 (8): e0236638. https://doi.org/10.1371/journal.pone.0236638.

Launchbaugh, Karen, and John Walker. 2006. "Targeted Grazing—A New Paradigm for Livestock Management." Pp. 2–9 in: K. Launchbaugh, J. Walker, and R. Daines (eds) Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement. Centennial, CO: American Sheep Industry Association.

Leininger, Wayne C., and Steven H. Sharrow. 1989. "Seasonal Browsing of Douglas-Fir Seedlings by Sheep." Western Journal of Applied Forestry 4 (3): 73–6. https://doi.org/10.1093/wjaf/4.3.73.

Marchetto, Katherine M., Tiffany M. Wolf, and Daniel J. Larkin. 2021. "The effectiveness of using targeted grazing for vegetation management: a meta-analysis."

Restoration Ecology 29, no 5: e13422. https://doi.org/10.1111/rec.13422.

Jason J. Moghaddas[1], Gary B. Roller[1], Jonathan W. Long[4], David S. Saah1, Max A. Moritz[3], Dan T. Stark[3], David A. Schmidt[1], Thomas Buchholz[1], Travis J. Freed[1], Erin C. Alvey[1], John S. Gunn[2]. 2018. "Fuel Treatment for Forest Resilience and Climate Mitigation: A Critical Review for Coniferous Forests of California." California Natural Resources Agency. Publication number: CCCA4-CNRA-2018-017.

Nader, Glenn, Zalmen Henkin, Ed Smith, Roger Ingram, and Nelmy Narvaez. 2007. "Planned Herbivory in the Management of Wildfire Fuels: Grazing Is Most Effective at Treating Smaller Diameter Live Fuels That Can Greatly Impact the Rate of Spread of a Fire along with the Flame Height." Rangelands 29 (5): 18–24. https://doi.org/10.2111/1551-501X(2007)29[18:PHITMO]2.0.CO;2.

North, Malcolm P., Ryan E. Tompkins, Alexis A. Bernal, Brandon M. Collins, Scott L. Stephens, and Robert A. York. 2022. "Operational Resilience in Western US Frequent-Fire Forests." Forest Ecology and Management 507 (March): 120004. https://doi.org/10.1016/j.foreco.2021.120004.

Ralphs, Michael H., M. Mort Kothmann, and Charles A. Taylor. 1990. "Vegetation Response to Increased Stocking Rates in Short-Duration Grazing." Journal of Range Management 43 (2): 104–8.

Rouet-Leduc, Julia, Guy Pe'er, Francisco Moreira, Aletta Bonn, Wouter Helmer, Shahin A. A. Shahsavan Zadeh, Alexander Zizka, and Fons van der Plas. 2021. "Effects of Large Herbivores on Fire Regimes and Wildfire Mitigation." Journal of Applied Ecology 58 (12): 2690–2702. https://doi.org/10.1111/1365-2664.13972.

Seligman, N.G., and A. Perevolotsky. 1994. "Has intensive grazing by domestic livestock degraded Mediterranean Basin rangelands?" Pp. 93–103 in: Arianoutsou, M., Groves, R.H. (eds) Plant-animal interactions in Mediterranean-type ecosystems. Tasks for vegetation science, vol 31. Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-94-011-0908-6_9

Sharrow, Steven. 2006. "Applying targeted grazing to coniferous forest management in western North America." Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement. Centennial, CO: American Sheep Industry Association. p: 90–9.

Stephens, Scott L. Stephens, Jason J. Moghaddas, Carl Edminster, Carl E. Fiedler, Sally Haase, Michael Harrington, Jon E. Keeley, Eric E. Knapp, James D. McIver, Kerry Metlen, Carl N. Skinner, Andrew Youngblood. 2009. "Fire Treatment Effects on Vegetation Structure, Fuels, and Potential Fire Severity in Western U.S. Forests." Ecological Applications 19 (2): 305–20. https://doi.org/10.1890/07-1755.1.

Stevens, Jens T., Hugh D. Safford, and Andrew M. Latimer. 2014. "Wildfire-Contingent Effects of Fuel Treatments Can Promote Ecological Resilience in Seasonally Dry Conifer Forests." Canadian Journal of Forest Research 44 (8): 843–54. https://doi.org/10.1139/cjfr-2013-0460.

Taylor Jr., Charles A. 2006. "Targeted grazing to manage fire risk." Pp. 107–12 in: K. Launchbaugh and J. Walker, (eds) Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement. Centennial, CO: American Sheep Industry Association.

Tsiouvaras, C.N., N.A. Havlik, and J.W. Bartolome. 1989. "Effects of Goats on Understory Vegetation and Fire Hazard Reduction in a Coastal Forest in California." Forest Science 35 (4): 1125–31. https://doi.org/10.1093/forestscience/35.4.1125.

Voeller, D.J., Brannon J. Ketcham, and Benjamin H. Becker. 2021. "Improved Microbial Water Quality Associated with Best Management Practices on Coastal Dairies and Livestock Grazing Operations." Rangeland Ecology and Management 76: 139–149. https://doi.org/10.1016/j.rama.2021.02.011.

Walker, B., and D. Salt 2006. "Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Washington, DC: Island Press. 192 p.

Winford, Eric M., Jen T. Stevens, and Hugh Safford. 2015. "Effects of Fuel Treatments on California Mixed-Conifer Forests." California Agriculture 69 (3). https://doi.org/10.3733/ca.v069n03p150.

Suggestions for Further Reading

James, Jeremy J., Josh Davy, Morgan P. Doran, Theresa Becchetti, Philip Brownsey, and Emilio A. Laca. 2017. "Targeted Grazing Impacts on Invasive and Native Plant Abundance Change with Grazing Duration and Stocking Density." Rangeland Ecology and Management 70, no. 4: 465–8. https://doi.org/10.1016/j.rama.2017.01.006.

Hollings, C.S. 1973. Resilience and Stability of Ecological Systems. Annual Review of Ecology and Systematics 4: 1–23. https://doi.org/10.1146/annurev.es.04.110173.000245.

Kuzco, Barbara H., and James W. Bartolome. 1983. "Effects of Cattle and Deer on Regenerating Mixed Conifer Clearcuts." Journal of Range Management 36 (2): 265. https://doi.org/10.2307/3898178.

Leininger, Wayne C., and Steven H. Sharrow. 1989. "Seasonal Browsing of Douglas-Fir Seedlings by Sheep." Western Journal of Applied Forestry 4 (3): 73–6. https://doi.org/10.1093/wjaf/4.3.73.

Shieltz, Jennifer M., and Daniel Rubenstein. 2016. "Evidence Based Review: Positive Versus Negative Effects of Livestock Grazing on Wildlife. What Do We Really Know?" Environmental Research Letters 11(11): 113003. https://doi.org/10.1088/1748-9326/11/11/113003.

Zamora-Nasca, Lucía B., Romina D. Dimarco, Daniela Nassini, Pablo A. Alvear, Ariel Mayoral, Martin A. Nuñez, and M. Andrea Relva. 2020. "Sheep Feeding Preference as a Tool to Control Pine Invasion in Patagonia: Influence of Foliar Toughness, Terpenoids and Resin Content." Scientific Reports 10 (1): 12113. https://doi.org/10.1038/s41598-020-68748-y.