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MANAGEMENT OF NEW MEXICO'S RIPARIAN AREAS

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HISTORY OF RIPARIAN AREAS IN NEW MEXICO

Current discussions regarding riparian area management usually fail to consider adequately the historical factors that combined to create the riparian ecosystems we see today in New Mexico. It is important to understand those historical factors if we are to manage appropriately riparian areas to maintain the numerous important ecological functions they serve. Simply identifying current management as the problem may be shortsighted and merely removing a present management activity may not result in substantial improvement.

Probably the first significant event that caused stream and riparian systems in New Mexico to become altered from their historic conditions occurred in the higher elevations beginning in the early 1800s with the arrival of trappers in search of beaver (*Castor canadensis*) pelts. These trappers were among the earliest European explorers of the region and had a tremendous impact on beaver populations (Clements 1991). In fact, by the late 1800s, beavers were in danger of extinction throughout the United States and evidence suggests they were virtually eliminated from every stream in New Mexico except for small populations located on the Upper Rio Grande and San Juan drainages (Berghofer 1967). Beavers are excellent engineers and their dams played a significant role in reducing the velocity and energy of streamflow (Gurnell 1998, Naiman et al. 1988, Naiman et al. 1986, Parker et al. 1985). The sequence of pools created by series of dams along low-order headwater streams not only served to mitigate disturbance to channel shape but also affected water tables, promoted conditions conducive to establishment and maintenance of riparian vegetation, controlled nutrient cycling processes along the stream continuum, and affected terrestrial and aquatic wildlife habitat. As the beaver and their dams disappeared, streamflow and high runoff events contributed to channel downcutting and alteration of stream shape (Naiman et al. 1988, Parker et al. 1985, Munther 1981). The effects of these disturbances became magnified and accrued downstream. More recently, beavers have been hailed as tools to improve stream and riparian systems (Skinner 1986, Bergstrom 1985, Brayton 1984).

Another major disturbance to stream and riparian systems, mining, came following the discovery of gold and silver in California (Todd and Elmore 1997). Throughout New Mexico, miners flocked to areas that today may be little more than ghost towns. Kingston, NM, for example, is currently home to approximately 32 permanent residents. At its peak in the late 1800s, Kingston was reportedly home to more than 7,000 people–mostly miners and the people that ran the businesses supporting the miners. Such a concentration of people and their livestock undoubtedly had a significant impact on stream and riparian areas, particularly as these are the areas in which people tend to congregate. More significant still was the mining itself. Probably no reach of stream escaped the attention of miners who sifted through the gravel, cobble, and sand in search of valuable minerals. One form of mining that became popular in many parts of the West was placer mining. Miners would build large flumes into which the materials comprising streambeds were placed and sifted through. This virtually turned streams and the substrate on which they were formed inside out. Hydraulic nozzling was also a popular form of mining during the period, although it is unclear how much actually took place in New Mexico (Scurlock 1998, Todd and Elmore 1997). This involved pumping large amounts of water from a stream to inject water under high pressure onto hillsides and other areas to remove materials in search of gold and silver. The combined impacts to stream and riparian systems created by the mining industry (i.e., displacing streambeds, removing vegetation, road networks, settlement, etc.) were probably the most significant experienced by these systems to date, and a suite of disturbances from which they are still recovering.

Along with, but predominantly after, the miners came settlers. Agricultural settlements began to appear along streams, rivers, and close to springs; almost anywhere there was a reliable source of water (Scurlock 1998). Adjacent to perennial water sources, stream and river bottoms were often farmed. Riparian vegetation was undoubtedly removed to accommodate crops and livestock in the fertile river bottoms. Most of the settlers came from more eastern areas of the United States and did not understand that lower rainfall in the West did not permit the heavy stocking rates they were accustomed to in areas of higher rainfall. Therefore, in many areas, livestock numbers were out of balance with forage sustainability and overgrazing was common (Carrier and Czech 1996, Elmore and Kauffman 1994, Krueper 1995, Todd and Elmore 1997). At that time, livestock were not controlled nor managed nearly as intensively as they are today. Another disturbance to stream and riparian systems began to take shape at this time that persists today. Wagon roads and trails were often located next to streams where the terrain was already made gentler by the erosive forces of floodwaters (Jones et al. 2000). Many of our current roads are located on these historic roads and trails. We know today that a majority of the sediment, as well as other contaminants, which enters streams and rivers, comes from road networks in our watersheds (Waters 1995, Swank and Crossley 1988, Van Lear et al. 1985, Hewlett 1979, Dissmeyer 1976).

Another major disturbance was initiated around the turn of the century with the advent of fire control. Fire control occurred both as a result of overgrazing, which reduced the fine fuels necessary to carry fire, but also more importantly, as a result of an increasing population. At first, private citizens and communities largely conducted fire suppression efforts, but with the creation of the Forest Reserves and their management charged to a federal agency, increasing emphasis was put on fire prevention and suppression. Over the last century, fire suppression became more widespread and effective. According to the wisdom of the time, fire suppression was a good idea. We know today, however, that the absence of fire represented a disturbance to some ecosystems that depend on relatively frequently recurring fires. This is true for the ponderosa pine ecosystem, which as a result, is heavily overstocked with timber (Covington et al. 1997, Covington and Moore 1994, Cooper 1961, Cooper 1960). Exclusion of fire, coupled with removal of portions of the overstory through timber harvesting, created conditions favorable to the establishment of small-diameter trees (Schubert 1974, Weaver 1967, Weaver 1943). Largely due to the density of small-diameter trees, the fire regime within the ponderosa pine ecosystem has changed significantly (Swetnam and Baisan 1994, Baisan and Swetnam 1990, Dieterich 1980, Weaver 1951) and is conducive to creating catastrophic fire events (GAO 1999), similar to those observed with the Cerro Grande fire near Los Alamos in 2000. It has been postulated that less water is now produced from these watersheds (Brown et al. 1974, Rich 1972, Clary and Pfolliott 1969) as the dense forests consume more water and precipitation evaporates from litter on the forest floor. The effect of these phenomena on stream and riparian systems has been to reduce the amount of water delivered to and through stream systems, thereby reducing the extent of riparian areas.

A similar phenomenon has occurred in the lower-elevation piñon-juniper ecosystem where the trees have been able to invade into grass-covered lowlands and mesa tops previously excluded due to frequent fire occurrence (Ernst and Pieper 1996, Leopold 1924). Unable to compete for water and nutrients under dense canopies of trees and the broad, spreading fibrous root systems of piñon and juniper, infiltration-promoting grasses have been excluded while surface runoff, and therefore erosion, has become prevalent. Unlike the ponderosa pine systems where less water ultimately filters through the watershed and feeds stream systems, the piñon/juniper systems probably transport the same amount of water, but it has a much shorter residency time in the watershed because a large portion does not infiltrate, become stored, and transported as subsurface flow; rather it is transported as surface flow. As a result, greater quantities of sediment are delivered through riparian systems to stream systems, contributing to the number one water quality problem in the state of New Mexico–sediment loading. It is important to remember the landscape pattern within a watershed. The vast majority of a watershed is upland areas, yet as Norman McLean stated "eventually all things merge into one, and a river runs through it." That is a convenient way of saying that the impacts of activities in the much larger upland landscape eventually manifest themselves in the concentrated, much smaller landscape of riparian and stream areas. Although problems with fire suppression and watershed management were initiated over a century ago, those problems, although identified, are still prevalent and remain inadequately addressed.

The cumulative effects of the historical disturbances discussed above inevitably impact the larger river systems into which smaller streams and tributaries flow. However, these larger river systems were subjected to their own disturbances. Major river systems would look and function much differently today than they currently do in the absence of dams. In serving valuable functions to society such as flood control, hydroelectric power generation, and storing water for agricultural irrigation, dams nonetheless change the way a river functions by altering the natural hydrograph. Around the same time dams were being constructed, aggressive soil conservation efforts ironically contributed to one of the major ecological challenges that face many of the streams and rivers in New Mexico. Salt cedar (*Tamarix* spp.) was introduced into New Mexico and other western states to help reduce erosion and maintain streambanks. A notoriously thirsty tree, salt cedar consumes greater quantities of water than native vegetation types and also contributes to increasing soil salinity through leachate from its foliage. Salt cedar has proven itself a worthy competitor against native riparian vegetation resulting in extensive monocultures throughout the state that many ecologists regard as biological deserts. Although salt cedar has been found to provide nesting habitat for wildlife species such as the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), natural resource managers and ecologists should carefully weigh the entire suite of benefits that will accrue to riparian habitats and their associated wildlife species through the conversion of salt cedar mono-cultures to native riparian vegetation communities.

As livestock grazing is one of the more prominent uses of rangelands in New Mexico, grazing managers have increasingly responded to calls for implementing innovative strategies for managing livestock in and around stream and riparian systems. Some of these are discussed below

The following discussion is excerpted from New Mexico State University's Range Improvement Task Force Publication 50.

GRAZING SYSTEMS

Grazing systems developed to incorporate the objective of maintaining or improving the ecological functions served by stream and riparian systems must be site specific. However, some general systems and guidelines are currently being used and can be implemented according to need. Most research on developing grazing systems compatible with streams and riparian areas has been conducted in the Pacific and Interior Northwest. Although not discussed in this paper, virtually every grazing system should include *distribution aids* that move livestock away from recovering riparian areas and reduce the amount of time the animals spend in healthy riparian areas. Whereas historically, riparian areas were considered sacrifice areas due to their proximity to limited sources of water for livestock, grazing managers are demon-strating that grazing and healthy ecosystems are not mutually exclusive.

Corridor Fencing

Fencing selected portions of the riparian corridor and nonuse may be the best alternative for rapid improvement of severely degraded riparian areas (Kovalchik and Elmore 1992). A severely degraded riparian area with few trees or shrubs may require total rest, at least for a few years (Davis 1982, Leonard et al. 1997). However, fences are expensive to build and maintenance can be particularly challenging in south-western riparian areas, which are subject to seasonal, high-velocity floods. Fences also interfere with wildlife movement and access to water, they affect the aesthet-ic properties of riparian systems, and they may not be practical depending on such factors as topography.

If it is determined that fencing is the best approach for recovering a severely degraded riparian area, creative designs that keep in mind future grazing systems and pasture rotations may allow the fenced area to be used separately (see discussion of riparian pastures, below). Elmore and Kauffman (1994) and Kovalchik and Elmore (1992) maintain that other strategies such as riparian pastures or other willow-compatible grazing systems (see below) may be more practical while serving the same purpose.

Riparian Pasture

Riparian pastures are pastures of rangeland containing both upland and riparian vegetation that are managed together to obtain specific management objectives. Because they are separate from the rest of the ranch, riparian pastures can be grazed or rested depending on current conditions and riparian needs (Kauffman et al. 1983, Swanson 1987, Platts and Nelson 1985, Elmore and Kauffman 1994). Therefore, the objective of riparian pastures is not to exclude livestock from the riparian areas, but to provide for closer management and control of their use.

Seasonal grazing strategies that permit growing-season regrowth of forage and browse species can strengthen plant vigor (McNaughton 1979, 1983, 1985; Anderson et al. 1990; but see McNaughton 1986); increase nutritional quality of autumn/winter forage (Anderson and Scherzinger 1975, Rhodes and Sharrow 1983, Evans 1986, Pitt 1986); shift species composition to more desirable plant species (Sims and Singh 1978, Anderson et al. 1990, Webster 1990); increase vegetal cover (Anderson et al.1990); and improve the ecological status of the plant community (Anderson et al. 1990) above that which would occur without livestock grazing.

Riparian pastures can be used seasonally, in conjunction with rotation strategies, or as special use pastures (Leonard et al. 1997). However, a variety of factors such as the size of the riparian area, construction and maintenance costs, and terrain may limit the practicality of a riparian pasture system.

Early Growing Season Grazing

Because of the lack of precipitation, spring does not necessarily mean arrival of the growing season in New Mexico. Therefore, we must consider early season grazing as that time after sufficient rainfall or snowmelt spurs plant growth – sometimes mid- to late summer. However, riparian vegetation often benefits from a greater availability of moisture than upland vegetation. In some areas, riparian vegetation can begin growing much earlier than upland vegetation. The beginning of the growing season is site-specific and grazing strategies should be tailored to those conditions – keeping in mind that suitable alternative forage such as grasses and forbs will minimize livestock use of woody species.

Early growing season grazing encourages cattle to graze uplands where forage palatability and climate are more favorable than in the riparian zone (Platts 1984). The availability of succulent upland vegetation and cold-air ponding in the riparian zone may induce livestock to spend time out of the riparian area and thus reduce their use of riparian plants as well as reduce the amount of soil compaction and bank trampling (Ehrhart and Hansen 1998). In addition, spring grazing allows for regrowth and plant recovery more than summer or fall grazing (Leonard et al. 1997). Generally, willow browsing is light and seedling survival high with spring grazing (Kovalchik and Elmore 1992). According to Kovalchik and Elmore (1992), response of riparian vegetation can be positive, even on sites in poor condition. In fact, spring grazing can be beneficial to establishing woody plants (Kovalchik and Elmore 1992), although the effect of grazing on willows during flowering and early seedling establishment has not been quantified.

Dormant Season Grazing

Winter grazing can be compatible with riparian habitat needs and has been successfully implemented on lower elevation ranges (Kovalchik and Elmore 1992). In fact, Masters et al. (1996) indicated winter use may be one of the least detrimental grazing systems to riparian areas and may benefit both range and riparian conditions by improving livestock distribution and plant response (Masters et al. 1996).

Because riparian herbaceous vegetation is not very palatable during winter, it may not receive extensive use. In some higher elevations, livestock avoid riparian areas because they contain depressions that tend to be colder than surrounding uplands.

However, dormant season grazing may also be the period of greatest use of browse species by livestock depending on temperatures, snow depth and duration, availability of upland forage, animal concentration and distribution, forage/browse preference, and the extent of the woody plant community (Leonard et al. 1997). A number of successes have been observed when dormant- and early-season grazing systems were combined (*Wayne Elmore and Steve Leonard* pers. comm.). It should be noted that under certain conditions, continued dormant season grazing may exert selective pressure on the same species of vegetation, thereby favoring those species less palatable during the dormant season.

Early Growing Season and Late Growing Season Strategies

This type of grazing system allows pastures to be used for a short period in the early growing season before summer pastures are ready and again in the late growing season or fall before cattle are moved to winter pasture (Kovalchik and Elmore 1992). According to Leonard et al. (1997), willows can be overused with this grazing system. If this grazing system is to be effective, close monitoring of forage use during the late-season period is required (Kovalchik and Elmore 1992).

Spring-fall grazing can be acceptable in good-condition riparian zones if much of the woody vegetation has matured beyond the reach of livestock and if early use is ended before the critical growing period. Late growing season use may have to be delayed or deferred until there is adequate forage in the uplands and on adjacent hillsides (Kovalchik and Elmore 1992). Special care should be taken to leave adequate residual vegetation after fall grazing to help protect against high flows if spring runoff can be expected.

Late Growing Season Grazing

Late growing season grazing is similar to season-long or deferred grazing in its effects on willows (Kauffman and Krueger 1984, Platts 1984). Livestock are more likely to browse woody species during this period and less likely to move away from riparian areas because of the lack of palatable forage in the uplands (Ehrhart and Hansen 1998). Late-season use can be most effective for willow management by removing cattle at 45% herbaceous forage use or by delaying grazing until there is adequate upland forage (Kovalchik and Elmore 1992).

Growing Season Grazing

Repeated or extended grazing during the hot summer season is generally considered to have negative impacts on riparian areas (Ehrhart and Hansen 1998). When temperatures are high and water distribution is limited, livestock tend to concentrate in riparian areas during the summer when the desire for shade and water is more intense (Leonard et al. 1997). If growing season grazing strategies are used, distribution aids must be used to help discourage livestock from loafing in the riparian area. Strategies that can be used to affect livestock distribution include off-stream water, stable access points, salt and mineral block placement, improved upland forage, riding, drift fences, and shading structures in the uplands (Ehrhart and Hansen 1998). Also, if growing season grazing strategies must be used, periodic rest, (i.e., grazing the pasture every other year) is recommended.

Season-Long Grazing

In season-long grazing systems, livestock are released into an allotment in the early spring and removed in the fall of the same year (Platts 1984). Early use of the range is often acceptable for the reasons outlined under early season grazing. Late-season grazing systems may also be appropriate if livestock utilization is closely monitored. However, cattle may begin to congregate in riparian areas during the hot summer months, so overuse of riparian forage can occur by mid-summer, causing livestock to switch to willows (Kovalchik and Elmore 1992). Once again, distribution aids are important tools in this grazing system and periodic rest is recommended.

CONCLUSIONS

It is clear that numerous disturbances to stream and riparian habitats throughout New Mexico have resulted in a landscape that is different than what may have been observed prior to European settlement. In fact, it could be argued that few if any truly "pristine" environments still exist throughout New Mexico. However, in relatively recent years, society has become sufficiently prosperous to invest its concerns, efforts and finances toward ecological conscience and restoration. During earlier times, pioneers and settlers were faced with the serious prospect of merely surviving and making a living. They probably could not afford to think about the ecological consequences of their pursuits. However, as we learn more about the importance and value of managing stream and riparian habitats for ecological functions, resource managers are increasingly develop-ing management systems to meet simultaneously ecological objectives while maintaining economic viability. It should be understood that the severity and extent of disturbances to stream and riparian systems have decreased steadily over the last century. As science and resource management strategies continue to improve, it is likely that these disturbances will continue to decrease in severity and extent, and that stream and riparian systems throughout the West will benefit. However, this scenario is contingent upon improving our ability to not only define the appropriate source of disturbance and the appropriate remedy, but also the courage to address that disturbance and implement that remedy.

REFERENCES

Allred, M. 1980. A re-emphasis on the value of beaver in natural resources conservation. *Journal of the Idaho Academy of Science*. 16:1:3-10.

Anderson, E.W. and R.J. Scherzinger. 1975. Improving quality of winter forage for elk by cattle grazing. *Journal of Range Management*. 28:120-125.

Anderson, E.W., D.L. Franzen, and J.E. Melland. 1990. Rx grazing to benefit watershed-wildlife-livestock. *Rangelands*. 12:105-111.

Baisan, C.H. and T.W. Swetnam. 1990. Fire history on a desert mountain range: Rincon Mountain Wilderness, Arizona, U.S.A. *Canadian Journal of Forest Research*. 20:1559–1569.

Berghofer, C.B. 1967. Protected furbearers. In *New Mexico Wildlife Management, New Mexico Department of Game and Fish*. Santa Fe, NM. pp. 187-189.

Bergstrom, D. 1985. Beavers: biologists "rediscover" a natural resource. In *Forestry Research West*. USDA Forest Service. pp. 1-6.

Brayton, S.C. 1984. The beaver and the stream. *Journal of Soil and Water Conservation*. 39:108-109.

Brown, H.E., M.B. Baker, Jr., J.J. Rogers, W.P. Clary, J.L. Kovner, F.R. Larson, C.C. Avery, and R.E. Campbell. 1974. *Opportunities for increasing water yields and other multiple use values on ponderosa pine forest lands*. Research Paper RM-129. Fort Collins: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Carrier, W.D. and B. Czech. 1996. Threatened and endangered wildlife and livestock interactions. In *Rangeland Wildlife*. P.R. Krausman, (ed.) Denver, Colorado. Society for Range Management. pp 39-47.

Clary, W.P. and P.F. Ffolliott. 1969. Water holding capacity of ponderosa pine forest floor layers. *Journal of Soil and Water Conservation*. 24:22–23.

Clements, C. 1991. Beavers and Riparian Ecosystems. *Rangelands*. 13:6:277-279.

Cooper, C.F. 1960. Changes in vegetation, structure, and growth in southwestern pine forests since white settlement. *Ecological Monographs*. 30:129–164.

Cooper, C.F. 1961. Patterns in ponderosa pine forests. *Ecology*. 42:493–499.

Covington, W.W. and M.M. Moore. 1994. Southwestern ponderosa forest structure: Changes since EuroAmerican settlement. *Journal of Forestry*. 92:39–47.

Covington, W.W., P.Z. Fule, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and M.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the Southwest. *Journal of Forestry*. 95:23–29.

Davis, J. 1982. Livestock and riparian habitat management: Why not? In *Proceedings of the 62nd Western Association of Game and Fish*

Commissioners Meeting. Las Vegas, NV. Department of Agriculture, Forests Service, Intermountain Forest and Range Experiment Station. pp. 225-232.

Dieterich J.H. 1980. Chimney Spring forest fire history. *Research Paper* RM-220. U.S.

Dissmeyer, G.E. 1976. Erosion and sediment from forest land uses, management practices, and disturbances in the southeastern US. In Proc. Third Inter-Agency Sedimentation Conf. (Denver, CO) Symp. 1, Sediment yield and sources. *Water Resour. Counc*. 140-148.

Ehrhart, R.C. and R.L. Hansen. 1998. *Successful strategies for grazing cattle in riparian zones.* Montana BLM Riparian Technical Bulletin No. 4, Montana Forest and Conservation Experiment Station, Billings, MT.

Elmore, W. and J.B. Kauffman. 1994. Riparian and watershed systems: Degradation and restoration. In *Ecological implications of livestock herbivory in the West*, M. Vavra, W.A. Laycock, and R.D. Piper (eds.). Society for Range Management, Denver, CO. pp. 212-231.

Ernst, R. and R.D. Pieper. 1996. Changes in piñon-juniper vegetation: a brief history. *Rangelands*. 18:1:14–16.

Evans, C. 1986. *The relationship of cattle grazing to sage grouse use of meadow habitat on the Sheldon National Wildlife Refuge*. M.S. Thesis, University of Nevada, Reno, Nevada. 108 pp.

Gurnell, A.M. 1998. The hydrogeomorphical effects of beaver dam-building activity. *Progress in Physical Geography*. 22:2:167-189.

Hewlett, J.D. 1979. An experiment in harvesting and regenerating Piedmont forests. *Ga. For. Res. Pap*., University of Georgia, Athens. 22 pp.

Huey, W.S. 1956. *New Mexico beaver management*. New Mexico Department of Game and Fish. Bulletin No. 4. Santa Fe, NM.

Kauffman, J.B., W.C. Krueger, and M. Vavra. 1983. Effects of late season cattle grazing on riparian plant communities. *Journal of Range Management*. 36:685-691.

Kauffman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian ecosystem and streamside management implications: A review. *Journal of Range Management*. 37:430-438.

Jones, J.A., F.J. Swanson, B.C Wemple, and K. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. *Conservation Biology*. 14:76-85.

Kovalchik, B.L. and W. Elmore. 1992. Effects of cattle grazing systems on willow-dominated plant associations in central Oregon. In *Proceedings: Symposium on ecology and management of riparian shrub communities,* W.P. Clary, E.D. McArthur, D. Bedunah, and C.L. Wambolt (eds.). USDA Forest Service General Technical Report INT-289. Intermountain Research Station, Ogden, UT.

Krueper, D.J. 1995. *Effects of livestock management on southwestern riparian ecosystems*. Gen. Tech. Rep. RM-272: U.S. Department of Agriculture, Forest Service, Rocky Mountain Experiment Station. pp. 281-303.

Leonard, S., G. Kinch, V. Elsbernd, M. Borman, and S. Swanson. 1997. *Riparian area management: Grazing management for riparian-wetland areas*. USDI Bureau of Land Management Technical Reference 1737-14. National Applied Resource Sciences Center, Denver, CO.

Leopold, A. 1924. Grass, brush, timber, and fire in southern Arizona. *Journal of Forestry*. 22:6:1–10.

Masters, L., S. Swanson, and W. Burkhardt. 1996. Riparian grazing management that worked: I. Introduction and winter grazing. *Rangelands*. 18:192-195.

McNaughton, S.J. 1979. Grazing as an optimization process: Grass-ungulate relationships in the Serengeti. *American Naturalist*. 113:691-703.

McNaughton, S.J. 1983. Compensatory plant growth as a response to herbivory. *Oikos*. 40:329-336.

McNaughton, S.J. 1985. Ecology of a grazing ecosystem: The Serengeti. *Ecological Monographs*. 55:259-294.

McNaughton, S.J. 1986. On plants and herbivores. *American Naturalist*. 128:765-770.

Munther, G.L. 1981. Beaver management in grazed riparian ecosystems. In *Proceedings of the wildlife-livestock relationships symposium*. Coeur d'Alene, Idaho April 20-22. Forest, Wildlife, and Range Experiment Station, University of Idaho, Moscow, Idaho. pp. 234-241.

Naiman, R.J., C.A. Johnson, and J.C. Kelley. 1988. Alteration of North American streams by beaver: The structure and dynamics of streams are changing as beaver recolonize their old habitat. *Bioscience*. 38:11:753-762.

Parker, M., F.J. Wood, Jr., B.H. Smith and R.G. Elder. 1985. Erosional downcutting in lower order riparian ecosystems: Have historical changes been caused by removal of beaver? In *Riparian ecosystems and their management: Reconciling conflicting uses*. Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliett and R.H. Hamre (tech cords.). First North American Riparian Conference, April 16-18, Tucson, AZ. USDA Gen. Tech. Rep. RM-120. pp. 35-38.

Pitt, M.D. 1986. Assessment of spring defoliation to improve fall forage quality of bluebunch wheatgrass (*Agropyron spicatum*). *Journal of Range Management*. 39:175-181.

Platts, W.S. 1984. Compatibility of livestock grazing strategies with riparian-stream systems. In *Range watershed riparian zones and economics: Interrelationships in management and use short course*. Oregon State University, Corvallis, OR.

Platts, W.S. and R.L. Nelson. 1985. Will the riparian pasture build good streams? *Rangelands*. 7:7-11.

Platts, W.S. and R.L. Nelson. 1989. Characteristics of riparian plant communities with respect to livestock grazing. In *Practical approaches to riparian resource management.* R.E. Gresswell (ed.). USDI Bureau of Land Management, Billings, MT.

Rhodes, B.C. and S.H. Sharrow. 1983. Effect of sheep grazing on big game habitat in Oregon's coast range. In *1983 Progress Report "Research in Rangeland Management."* Special Report 682. Oregon State University. Corvallis, OR. pp 28-31.

Rich, L.R. 1972. Managing a ponderosa pine forest to increase water yield. *Water Resource Research*. 8:2:422–428.

Schubert, G.H. 1974. *Silviculture of southwestern ponderosa pine–the status of our knowledge*. Research Paper RM-RP-123. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Scurlock, D. 1998. *From the Rio to the Sierra: An environmental history of the middle Rio Grande Basin.* Rocky Mountain Research Station Gen. Tech. Rep. RMRS-GTR-5. Fort Collins, CO: U.S. Department of Agriculture, Forest Service.

Sims, P.L. and J.S. Singh. 1978. The structure and function of ten western North American grasslands. III. Net primary production, turnover and efficiencies of energy capture and water use. *Journal of Ecology*. 66:573-597.

Skinner, D. 1986. BLM Beavers. An innovative employee is using native engineers to cipe with erosion. *Wyoming Wildlife*. Wyoming Game and Fish Commission. 50:3-15.

Swank, W.T. and D.A. Crossley, Jr. (Editors). 1988. *Forest hydrology and ecology at Coweeta*. Springer-Verlag, New York. pp. 469.

Swanson, S. 1987. *Riparian pastures*. Nevada Cooperative Extension Fact Sheet 87-53. University of Nevada, Reno, NV.

Swetnam T.W. and C.H. Baisan. 1994. Historical fire regime patterns in the Southwestern United States since AD 1700. In *Fire effects in southwestern forests: Proceedings of the second La Mesa fire symposium*. Allen, C. D. (ed.) General Technical Report RM-GTR-286. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. pp. 11–32.

Todd, M. and W. Elmore. 1997. Historical changes in western riparian ecosystems. *Transactions of the 62nd North American Wildlife and Natural Resources Conference*. pp. 454-468.

U.S. General Accounting Office. April 1999. Western National Forests–a cohesive strategy is needed to address catastrophic wildlife threats. *Catastrophic Wildfire Threats.* GAO/RCED-99-65

Van Lear, D.H., J.E. Douglass, S.K. Cox, and M.K. Augspurger. 1985. Sediment and nutrient export in runoff from burned and harvested pine watersheds in the South Carolina Piedmont. *Journal of Environmental Quality*. 14:169-174.

Waters, T.F. 1995. Sediment in Streams--Sources, Biological Effects, and Control. American Fisheries Society Monograph 7. American Fisheries Society, Bethesda, MD.

Weaver, H. 1943. Fire as an ecological and silvicultural factor in the ponderosa pine region of the Pacific Slope. *Journal of Forestry*. 41:7–15.

Weaver, H. 1951. Fire as an ecological factor in the Southwestern ponderosa pine forests. *Journal of Forestry*. 49:93–98.

Weaver, H. 1967. Fire and its relationship to ponderosa pine. *Proceedings–Tall Timbers Fire Ecology Conference*. Tall Timbers Research, Inc. 7:127–149.

Webster, W.P. 1990. Prescribed grazing. *Rangelands*. 12:103-104.