Rocky Mountain
Research Station

Rocky Mountain Research Station
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Riparian Ecological Systems
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West Fork Allotment Riparian Monitoring Study 1993 - 1999

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Cover Photos: Photo 1 was taken by Gary Davis (Alpine Range Staff) in May 1990 to depict the riparian-aquatic condition of a site on Boggy Creek. The concern was elk trampling and over utilization of the streambanks. The photo date (5/90) was before cattle entry into the pasture in June. Photo 2 (8/27/98) shows the identical site in Photo 1. The vegetative differences are attributed to the exclusion of ungulates (see elk fence in background). Photo 3 was taken on May 15, 2000 (A. Medina) of a site about 50m downstream of the exclosure. All site attributes are nearly identical to those in Photo 1 with respect to soils, vegetation, channel characteristics, etc., except for time. The last cattle treatment was applied in summer of 1998. Photo 3 illustrates relative differences in vegetation cover, trampling, and overall in-channel elk use. A positive difference is that the banks have been reposed to facilitate the establishment of plants. The vegetation in Photo 2 obscures the presence of vertical banks similar to those apparent in Photo 1.

Table of Contents – Volume I

Chapter 1. Executive Summary………………………………..5

Summary of Findings…………………………………………………………….6

Summary of Management Implications and Recommendations……………….10

Chapter 2. Background…………………………………………17

Topography, Climate, Geology, and Soils……………………………………..17

Hydrology……………………………………………………………………….17

Vegetation……………………………………………………………………….17

Aquatic Fauna…………………………………………………………………..17

Watershed Influences…………………………………………………………18

Elk………………………………………………………………………………..18

Livestock………………………………………………………………………..18

Treatment Design………………………………………………………………19

Chapter 3. Biomass Production and Utilization………………26

General Procedures……………………………………………………………26

Standing Biomass and Total Production……………………………………..29

Production by Plant Groups…………………………………………………….32

Forage Utilization……………………………………………………………….37

Chapter Summary and Conclusions…………………………………………….46

Chapter 4. Streambanks………………………………………47

Channel Geomorphology……………………………………………………….47

Streambank Radial Transects…………………………………………………….51

Ungulate Trampling……………………………………………………………….53

Chapter Summary and Conclusions……………………………………………. 57

Chapter 5. GAWS HCI Indices and Apache Trout……………59

General Aquatic Wildlife Survey – Habitat Condition Indices……………………59

Apache Trout Dynamics……………………………………………………………...77

Chapter Summary and Conclusions……………………………………………...81

Chapter 6. Riparian Vegetation………………………………….82

Herbaceous Vegetation………………………………………………………….82

Woody Vegetation………………………………………………………………111

Chapter Summary and Conclusions…………………………………………...123

Chapter 7. Precipitation, Streamflow, and Water Quality…. 126

Precipitation……………………………………………………………………..126

Streamflow………………………………………………………………………128

Water Quality……………………………………………………………………130

Chapter Summary and Conclusions……………………………………………155

Chapter 8. Supporting Studies…………………………………156

Channel Characterization Study………………………………………………156

Riffle Formations Study………………………………………………………..156

Sedge Clipping Study…………………………………………………………..157

Historical Aerial Photo Comparisons………………………………………….162

Chapter 9. Management Implications (Recommendations). 167

References…………………………………………………….... 177

Table of Contents – Volume II

Chapter 10. Appendices

Appendix A. Repeat Photography: Vegetation Stations, Production/Utilization Cages, and Miscellaneous

Appendix B. References

Appendix C. Examples of Production/Utilization Calculations

Appendix D. Geomorphology Profiles.

Appendix E. Species Lists.

Appendix F. West Fork Channel and Soils Data

Appendix G. Radial Transect Profiles

Chapter 1 Executive Summary

In 1992, the Apache-Sitgreaves National Forest (A-S), the Arizona Game and Fish Department (AGFD), and the US Fish and Wildlife Service (USFWS) requested the Rocky Mountain Research Station (RMRS) (Research Work Unit 4302 in Flagstaff) design a sampling protocol for implementation monitoring of several parameters of interest on the West Fork Allotment (WFA). A protocol was proposed, accepted, and employed by the A-S in May 1993. In August 1993, the parties requested RMRS provide further assistance by performing the monitoring on their behalf. The monitoring study was started in 1993 and terminated in fall of 1999. The study was not a comprehensive research study owing to the nature of the objectives. Many parameters of interest were specified by the parties (e.g. General Aquatic Wildlife Survey – Habitat Condition Index) and not RMRS. The purpose of the monitoring study was to determine if proposed changes by the Alpine Ranger District in livestock grazing management on riparian habitats of the WFA affected positive changes in the overall condition of such habitats. Considerable debate existed over cattle and elk use of streamside areas, especially since the streams were classified as Apache trout (*Oncorhynchus apache*) habitats. The specific objectives of the proposed grazing action outlined in the Biological Evaluation were:

1. To improve habitat conditions for Apache trout in the three streams of the WFA.

2. To improve riparian habitat conditions on said streams to a satisfactory condition.

3. To improve riparian areas outside of established exclosures to at least 70 percent of their habitat potential as measured against established riparian exclosures within the WFA.

4. To manage grazing by all ungulates to coincide with the physiological needs of herbaceous and shrubby riparian plants.

5. To manage for stubble height of residual vegetation of 3-6 inches at the end of the grazing season in riparian areas for the purposes of reducing erosion, trapping sediment, enabling the restoration of the streambanks and channels, enhancing the vigor of herbaceous riparian species, and ameliorating soil temperatures.

6. To raise water tables of the three streams to within 18” of the existing valley bottoms.

7. To improve meadows to good or excellent condition.

Grazing treatments consisting of (1) un-grazed controls, (2) areas available only to elk (elk treatments), and (3) areas available to both elk and cattle (elk/cattle treatments) were established across the streams. Herbaceous biomass production and utilization, streambanks and stream channel morphology, fish habitat and numbers, herbaceous and woody riparian vegetation, and water quality were intensively monitored using a variety of sampling methods. Sampling of riparian vegetation, streambanks and stream channel morphology, and fish habitat and numbers occurred primarily within permanent 40-meter stream reaches (sampling stations) dispersed among the streams and treatments. Sampling stations were established within Boggy and Centerfire Creeks on alder and non-alder sites (hence referred to as stands), whereas in Wildcat Creek transects were established based on flow conditions, since there were no alder or woody stands in Wildcat. Herbaceous biomass production and utilization was monitored on the treatment level, while water quality was monitored at several locations in each stream.

SUMMARY OF FINDINGS

Production and Utilization of Forage

1) In general, greater amounts of herbaceous biomass were produced across time in all streams and grazing treatments, greater amounts of biomass were consumed by elk across time, and greater amounts of residual biomass were left.

2) Elk use alone (measured prior to cattle turnout) exceeded the 45% utilization guideline (for all ungulates) established by the A-S on 7 of 10 instances in the elk/cattle treatments, and on 3 of 15 instances in the elk treatments. Spring elk use averaged at least 42% (across all treatments) in each year (1995-1998) in which spring use was measured.

3) Combined elk and cattle use exceeded 60% in the elk/cattle treatments during each year (1995, 1996, and 1997) that cattle grazing occurred.

4) The relative proportion of the total standing biomass made up of native obligate graminoids increased across all streams and treatments during the study, with the exception of the Boggy elk and Wildcat control treatments, indicating improved vegetative conditions.

5) Each plant group (i.e. native obligate graminoids, forbs, other graminoids) responded differently to biomass production across grazing treatments. Native obligate graminoid production increased in the elk/cattle treatments, and decreased in the elk only treatments. Forb production was greater in the elk/cattle treatments compared to the controls.

Streambanks

1) Analysis of cross-sectional stream channel profiles indicated that changes in channel geomorphology during the study were generally minute and that active channel downcutting is not occurring on any of the three streams.

2) No grazing-related effects on channel geomorphology were detected. Losses of channel and streambank material were similar or slightly lesser in grazed versus un-grazed areas in Boggy Creek, similar or slightly greater in grazed versus un-grazed areas in Centerfire Creek, and mixed in Wildcat Creek (greatest in the elk treatment, intermediate in the un-grazed control, and least in the elk/cattle treatment).

3) Data from streambank radial transects used to monitor gains or losses in streambank material at ungulate crossing and areas of intense rodent activity (burrowing) suggest that streambank material was lost on nearly all ungulate crossings and areas of intense rodent activity that were surveyed across the three streams. However, the sizes of these decreases were relatively similar between grazed areas and un-grazed controls, and on Boggy Creek were actually slightly greater in the control. The net effects of the relatively small changes in channel geomorphology were expected to have been minute. Some sites exhibited relatively greater changes than others did. We attribute these to localized responses of the channel to changing hydrologic conditions.

4) Streambank trampling by elk increased during the study across all streams, treatments, and stands. Elk trampling was higher than cattle trampling in 1995 and 1998, but was lower in 1996.

5) Contrasts of photographs taken in May 1990 with those of May 2000 (see cover photos) of sites within the same proximity (100m) illustrate that trampling has not changed much between these periods, despite management changes in livestock grazing.

GAWS HCI Indices and Apache Trout

1) GAWS – HCI values declined between 1993 and 1998 across all streams and treatments, except for the Wildcat elk treatment where values increased slightly. In Boggy and Centerfire Creeks, values were generally lowest in the un-grazed controls, while in Wildcat Creek values were lowest in the elk treatment.

2) The criterion that GAWS – HCI values in grazed treatments (elk and elk/cattle) attain values at least 70% of those in the un-grazed controls was meet on every occasion.

3) GAWS – HCI values were unchanged by cattle grazing treatments. Results were mixed with high HCI values observed in areas grazed by elk and cattle, and low values in the control. These are partially attributed to the inherent limitations of the HCI method.

4) Limited data obtained during fish sampling suggest Apache trout population dynamics were independent of grazing treatments. Impoverished flow was the principal factor affecting fish.

5) The determination of livestock-fishery relationships were not possible owing to impoverished flows, which precluded rigorous sampling. Not enough data precludes drawing conclusions about ungulate-fish grazing effects. Climatic and other environmental factors were most influential to aquatic habitats. The natural thresholds of geology, soils, and water limit the streams from being habitat for Apache trout as discussed in Chapter 9, GAWS – HCI section (e.g. non-habitat, marginal habitat, and habitat).

Riparian Vegetation

1) No evidence was found to suggest total mean herbaceous cover responded to ungulate grazing treatments. Herbaceous cover decreased across all streams, treatments, and stands between 1993 and 1998 with the exception of non-alder stations in the Centerfire control and elk treatment where cover increased slightly. Herbaceous cover increased in a subset of treatments measured in 1999 and this increase was attributed to much-above normal precipitation during the summer of 1999.

2) Reponses by plant groups (native obligate graminoids, other graminoids, native obligate forbs, other forbs, shrubs) appeared to be tied to changes in alder canopy cover, ground cover-vegetation dynamics (i.e. litter accumulation), climate, and grazing treatments.

3) Decreases in herbaceous cover were generally offset by increases in litter and cryptogam cover. Litter cover increased during the study in each stream, treatment, and stand, although increases tended to be substantially greater in the un-grazed controls. Cryptogam cover increased or remained the same in each stream, treatment, and stand except the Boggy elk/cattle treatment, where it decreased. Soil cover increased within the elk treatments and decreased within the elk/cattle treatments and controls.

4) Stem density of mature alders in Boggy and Centerfire Creeks increased at least 44 % between 1994 and 1998 in each treatment and stand combination except the Centerfire control, where stem density decreased. Stem density of immature alders was relatively constant among years for most treatments and stands. Stem density data, corroborated by repeat photographs and historical aerial photographs, suggests that upstream to downstream encroachment of alders is occurring in Boggy Creek, while in Centerfire Creek, alder stands are older and showing signs of decline.

5) Canopy cover increased slightly (elk treatment) or remained nearly the same (elk/cattle treatment) on alder stations in Boggy Creek, but decreased substantially (82 % in control, 41 % in elk treatment) in Centerfire Creek. Canopy cover on non-alder stations within both streams increased from near 0 % in 1993 to above 10 % in 1998 except in the Centerfire elk treatment where values remained below 2 %.

6) The Wildcat control reflected many desired vegetative and ground cover qualities. Vegetation, litter, and cryptogams accounted for over 90% of ground cover in 1999. Vegetation cover in general and native obligate graminoid cover in particular, changed little from 1993 to 1999. The primary observed response to protection from ungulate grazing was in the litter component, which increased from 2.1% in 1993 to 23.2% in 1999.

7) Ground cover responses suggest that assessments of ecosystem response cannot be made based on vegetative cover alone. Interactions between vegetation, litter, and cryptogams appear to be especially important, as decreases in plant cover and corresponding increases in litter and cryptogam cover were common.

Precipitation, Streamflow, and Water Quality

1) Precipitation was much above average during 1993 (135 %), much below average during 1994 (80.7 %) and 1996 (72.7 %), and near normal during the other years.

2) Absence of streamflow was noted along portions of Boggy Creek during 1994, 1996, 1997, and 1999, along portions of Centerfire Creek during 1994, 1996, and 1997, and along portions of Wildcat Creek during all years except 1994 and 1999. Drought conditions were most severe during 1994 and 1996.

3) In general, summer stream temperatures in alder sites were lower than in non-alder sites in Boggy and Centerfire Creeks. However, maximum daily stream temperatures at the upper "gaining" reach site in Wildcat Creek, a non-alder site, were nearly always lower than values at any of the other monitoring sites. Furthermore, daily fluctuations between maximum and minimum temperatures were also generally less severe at the upper Wildcat Creek site than at other sites due to groundwater input.

4) Critical thermal maximum threshold values for Apache trout appear to have been frequently exceeded at two of six water-temperature sampling sites and occasionally exceeded at two other sites. Occasions when these thresholds values were exceeded nearly always coincided with periods of low flow prior to the loss of surface flow.

5) Stream pH and conductivity values fell within the range expected for streams in the White Mountain region flowing through basalt-derived soils and were well within the tolerance limits of Apache trout. Dissolved oxygen values fluctuated widely in response to stream temperatures and flow conditions: very low values were recorded during periods of low streamflow and prior to the drying up of pools. Turbidity values were generally greater than the turbidity standard for cold-water streams in Arizona of 10 NTU. Possible explanations include the influence of basin geology on stream channel substrates, the current condition of channels and streambanks, and the impacts of elk, livestock, and rodents.

6) Suspended sediment values tended to peak following summer monsoon thunderstorms. Mean and median values generally decreased during the period sampled (1994 – 1996) and were often highest in un-grazed controls.

This report presents the results of a very intensive effort to best provide answers to the seven objectives described above and more importantly to quantify the effects of ungulate grazing on riparian habitats important to native fish. Some objectives were not achieved, some were partially achieved, and some were fully met. In hindsight, answers to these objectives, although seemingly obtainable in 1992, were difficult to achieve due to complex interactions between physical, biological, and chemical factors governed by climate and geology, at the very least.

> The habitat conditions for Apache trout were partially achieved. Vegetation conditions improved across all streams in general, but the interactions of vegetation, hydrology, and geomorphology appear to have precluded the expansion of sedges and rushes on some sites. These plant types are key to establishing stable streambanks. The in-channel conditions, e.g. substrates, pools, riffles, did not exhibit much change because the streams have other inherent

natural factors (i.e. geology, substrates, soils, hydrology, climate) that limit the streams potential to achieve the 'desired' context of optimal trout habitat.

Riparian habitat conditions generally improved with respect to vegetation. More vegetation and residual biomass were evident in later years, despite a continued increase in forage utilization by elk and intensive cattle treatments. Sites where alder invaded sedge stands may be considered in a lesser condition then previously, owing to plant dynamics. Some alder stands were less vigorous owing to senescence of individual plants. The question of what constitutes a satisfactory condition is key to contrasting existing conditions with previous conditions. Continuous grazing by elk did not promote improved riparian conditions, since some sites exhibited a similar over-use appearance in May 2000 as in May 1990 (see cover photos).

Most riparian areas improved with respect to the established exclosures to the specified 70 percent criterion as determined from the Habitat Condition Indices. However, several factors need to be considered in using the index as a measure of fishery habitat and as an ungulate effects assessment protocol.

We failed to manage grazing by all ungulates to coincide with the physiological needs of riparian vegetation. Livestock grazing was imposed as a treatment to determine the approximate grazing capacity appropriate for WFA, and this segment was achieved. The A-S has provided for livestock grazing management through use of deferred-rotation grazing systems. However, this is a mute point considering that elk grazing occurs on a continuous basis. Herein, we illustrate examples of key plants that are disfavored by early season grazing. This objective can't be met until a balance is obtained between total ungulate numbers and the forage resource.

Virtually all sites met the stubble height criterion of 3-6 inches at the end of the grazing season. In general, very little sediment was trapped because very little was produced. As stated above, there are important natural factors (i.e. geology, substrates, soils, hydrology, climate) that limited the restoration of channels as originally perceived.

We failed to raise the water tables of the streams to within 18" of the existing valley bottoms. Quite simply this task was impossible because climate dictated the hydrology of the streams. Streams were dry in 4 years out of seven, which affected other parameters as well (e.g. fish, vegetation, geomorphology). To achieve this objective would require considerably more sedimentation (erosion) and sustained flows to interact with herbaceous vegetation to cause aggradation of the channel. At the current erosion rates, it would take approximately 500-700 years of sediment processing to attain this criterion, assuming all sediment inputs are retained and not lost from the system.

The criterion to improve meadows to good or excellent condition requires consideration of several factors beyond those typically examined for vegetation. Some meadow reaches were at their potential (e.g. Wildcat control), exhibiting E-type channels with sedge predominance, or C or B channel types that are also appropriate for the streams. Other reaches that were incised had mesic species as their principal herbaceous component, which collectively with the hydrology, geomorphology, and continuous grazing interacted to produce a condition less than good or excellent. To this extent animal trampling can be viewed as a positive factor acting to change the geomorphic state by reposing vertical streambanks to a state that vegetation can establish.

SUMMARY OF MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Caution should be exercised not to extrapolate beyond the limits of the data presented. The authors should be consulted in doubtful instances to best provide interpretations that are within the scope of the study. This caution is not intended to restrict the application of knowledge beyond the West Fork study area, but rather to alert users that the dynamics presented here are very complex, and should not be oversimplified into statements of ungulate effects. Some reviewers may contend that these works are case studies limited to the West Fork area. As such, we undertook great effort across the 8-10 years of study to validate our observations across various other study areas throughout the White Mountains and the Mogollon Rim. We are confident that much of what was learned is applicable across similar habitats of Region 3 (e.g. Gila NF, Carson NF, Santa Fe NF, Coconino NF), and possibly other areas of the greater Southwest. Central to all recommendations is understanding that the streams and meadows incurred major changes over the past 50 years that set in motion a sequence of disturbance dynamics that influenced the type and condition of the riparian habitats present today.

Production and Utilization of Forage

The data clearly demonstrates that biomass production, biomass utilization, and residual biomass were markedly greater in the later years (1996-1998) in contrast to the initial years. This response suggests that habitat conditions improved most likely in response to management changes. Key management changes included: a) deferral of livestock use between 1993 and 1995, a period during which RMRS evaluated the grazing capacity of the study sites and established treatment controls; b) limiting livestock grazing to a season of use during August-September, since only this period had enough forage available for cattle grazing treatments. Total biomass utilization by elk was incrementally greater with each passing year and accounted for a major proportion of the total forage budget. Quite simply – more forage, less cattle use days, more elk use of available forage. Cattle numbers on the riparian habitats were initially at least proportionate to permitted stocking densities across the allotment and permitted season of use, and increased considerably in 1998. The effect on forage utilization from increased cattle numbers (treatments) was masked by the season of use (i.e. monsoon, late growing season), in that plants may have produced more biomass than was utilized. The effects of elk grazing were also masked during the late growing season (late July monsoons), which is coincident with elk dispersal unto upland habitats. This change in elk behavior is coincident with a time when calves are older and more mobile, the arrival of monsoon weather, and production of forages across all habitats. Key questions about these responses are: what are the thresholds? What are the upper limits of biomass production of these sites? What are the thresholds of production, utilization, season of use, animal numbers, etc.?

RECOMMENDATION (S): Riparian areas that can be identified as having reduced herbaceous production from native obligate graminoids benefit from deferred grazing, both seasonally and annually. The period of grazing can be changed to improve production consistent with other resource needs identified below. Overall, grazing appears to favor or have a neutral effect on biomass production of native obligate graminoids, when grazed during the latter portion of warm growing seasons.

RECOMMENDATION (S): Montane meadows should be grazed during the latter part of the growing season (August-September). This recommendation is consistent with other studies (Steele et al. 1984). The season of use should not impair the production of biomass or seed, especially on sites with reduced productivity. By early August, sedges and other key obligate graminoid species have completed their most critical period of growth and have begun to translocate carbohydrates to their roots.

RECOMMENDATION (S): Continuous grazing by elk on intensively used sites (e.g. Wildcat Creek) should be reduced to provide for the physiological needs of individual plants and plant communities. The relative utilization rates were consistently high from late winter to summer (i.e. March-July). The long-term consequences of continuous grazing on plant diversity, invasive and exotic species dynamics, and overall riparian health have been well documented in the livestock grazing literature and applies equally to wild ungulates.

RECOMMENDATION (S): Opportunities to promote grazing of sites with vertical streambanks should be sought and closely monitored. Obligate graminoids are more apt to expand onto the streambank if they are reposed to less than about 35 degrees. Some sites may require repeated applications to attain desired effects. These geomorphologic treatments are needed to improve the vegetative composition and productivity, especially on sites where the hydrology can also be improved.

RECOMMENDATION (S): Riparian areas that can be identified as dysfunctional owing to poor native obligate plant composition and unstable streambanks should be managed to maximize benefits from the production of seed, rhizomes, and residual biomass. This plant material is defined herein as the **restoration value**. The restoration value concept acknowledges the important role that residual biomass plays in many ecosystem functions such carbohydrate growth reserves for sedges, erosion protection, sediment trapping, sustaining moist microclimates to promote organic decomposition and subsequent incorporation into the soil. The restoration value should be a major consideration in grazing all riparian and aquatic habitats. Management for restoration value entails managing the plant litter component to achieve higher productivity of native obligate graminoids.

RECOMMENDATION (S): Riparian areas that have been identified as dysfunctional/degraded and targeted for restoration should be re-examined for causal factors. The hydrogeomorphic condition of the stream, or sections thereof, is critical to understanding the capability of the site to respond to any grazing or restoration treatment. Attempts to increase biomass production of key obligate species may not be practical owing to limited site potential factors (e.g. hydrology, substrates, landform, etc.). The surface and subsurface hydrology of riparian sites directly influences the biological aspects of plant productivity, plant composition, and all associated biological and chemical functions within the soil.

RECOMMENDATION (S): The proposed A-S NF forage utilization guideline of 45 percent (based on total, end of growing season production), for sites in fair-good condition seems reasonable and prudent, considering the various factors that preclude better measures of utilization. The guideline is fitting for situations where the aim is to improve plant vigor, density, composition, and seed and biomass production under the influence of continuous and seasonal grazing. A utilization factor of 45 percent should also provide for the restoration value of the sites, as well as for the physiological needs of key species. This level of utilization would also reduce and mitigate the physical effects of ungulate grazing on streambanks, by reducing ungulate foraging time, and increase residual biomass to protect soil surfaces from subsequent visits by ungulates, and provide for general watershed protection. The guideline is conservative and can be changed to reflect increases under special circumstances where site conditions warrant (e.g. favorable soil conditions, hydrology, or geomorphology; litter inhibition of plant productivity). Some sites may require a utilization guideline that is much less than 45 percent, owing to inherent site conditions, management goals, or other resource needs.

RECOMMENDATION (S): We recommended that livestock grazing not be permitted on WFA riparian areas as long as elk utilization levels remain near or above the A-S forage utilization guidelines for the reasons noted above. There would no forage allotment available for livestock when elk use is near the guideline.

RECOMMENDATION (S): It is recommended that the utilization guidelines be adopted that permit litter accumulation. Litter accumulation provides for two important functions. Sites with residual litter are less apt to be intensively grazed the following year. Hence, this is one mechanism for altering ungulate foraging behavior through avoidance of plants with standing litter. This type of response can manifest into reduced streambank trampling as well. Second, litter enhances the microclimate of sedge stands and soil nutrient cycling processes.

RECOMMENDATION (S): Forage utilization and production determinations should be realized within the context of the actual grazing dynamics. Some graminoids are capable of **over-compensation**, a plant response to herbivory in which plants respond to herbivory by producing a greater quantity of biomass than would be produced in the absence of herbivory. Plants also exhibit **compensation**, or the ability to equally replace biomass lost due to herbivory. Utilization is generally underestimated under continuous grazing, and such may have lasting effects across time. Estimates of this error approximate 10-15 percent.

RECOMMENDATION (S): It is important to ascertain reasonable estimates of the production potential of the varied community types that comprise riparian habitats, and how changes in site conditions affect the site capability to achieve potential. Estimates of biomass production potentials can be derived from the data presented for the controls. It is also important to classify riparian habitats as per their inherent range of site factors, so that riparian areas are not managed based on a one size fits all standard. This information is lacking, with only generalizations available about site (range) types.

RECOMMENDATION (S): The determination of production and utilization should include other forage species besides key graminoids when habitat conditions are less than optimal. Some species are important pioneer plants that mitigate site conditions for the establishment of native obligate graminoids, provide food and cover for aquatic fauna, and interact with hydrologic and geomorphic factors to affect a more stable habitat condition.

Streambanks and Ungulate Influences

A major reason for these studies was concern for ungulate damage of streambanks, with subsequent adverse effects on aquatic habitat. The preponderance of channel (cross-sectional profile) geomorphology data reveals that channel conditions across treatments remained relatively unchanged between 1993 and 1998. The geomorphological conditions observed today are a consequence of historic disturbance activities that upset the hydrologic equilibrium of the streams, thereby setting in motion several other biophysical factors. Historic photo evidence (pre- 1950) reveals stream channels devoid of woody vegetation and unincised. In contrast, 1990's photos show heavily wooded streambanks, incised channels, but relatively little lateral channel migration since the 1950's. Our explanation of the consequences is process driven. Logging activities in the three study watersheds began around 1950. The mid-century logging practices were not considerate of potential damage to other resources. Large logs were placed longitudinally across streams as road crossings. These crossings impeded normal flows, accumulated logging induced sediments, and eventually were washed out leaving the site and sections upstream and downstream in disequilibrium. Flood flows incised downstream channels, increasing stream gradients, and exposing parent materials. Subsequently, alder invaded and established on exposed streambanks. The period of channel incision is thought to have been relatively quick, probably 1-5 years. The channels retained the incised character for many years into present-day. The depth of channel incision was limited by boulder-bedrock substrates. The role of ungulates as process contributors is taken from evidence of supporting studies. Ungulates probably reposed vertical streambanks, much as they continue to do, to produce "C" type channels (Rosgen 1996). The cumulative effects of logging-induced channel disturbance and ungulate trampling of channels most likely disrupted fragile riffle bars, which in turn caused additional channel erosion. These riffle bars are yet evident in the soil profiles.

The net effect of direct and indirect ungulate induced loss of streambanks did not constitute impairment to stream functions, as evidenced from the vegetation data. First, the mean net losses were quite small. Second, despite net losses, long-term benefits can be derived from the new geomorphic state. Vertical banks are unstable and may remain in that state for very long periods, until enough erosion has occurred to reduce the instability, with the final streambank exhibiting a reposed angle. In this case, ungulates may act as geomorphic agents to increase the rate of streambank recovery. Various plants, including sedges, then colonize reposed streambanks. Therefore, what is viewed as a negative effect (soil loss) may result in a greater benefit (bank recovery). Furthermore, the natural processes of degradation and aggradation serve to establish a balance across the stream such that the net result is a continuous process of building streambanks by taking soil material from one location and depositing in another location to form point bars, etc.

The rate and type of change are important factors in understanding how new equilibriums are attained and in assessment of impacts upon aquatic resources. Depending on the type of riparian or aquatic habitat, the rate and type of change resulting from a disturbance (nature or man) may be very slow (across decades) or fast (days). The consequences of changes may or may not be adverse to aquatic resources (e.g. fish), since fauna and flora have withstood various other changes of smaller and considerably larger magnitudes. Herein, greater channel geomorphological differences were generally detected in the control treatments, owing to other governing processes and factors other than ungulates.

Various methods continue to be devised by many resource managers to account for ungulate trampling effects, including counting hoof marks and relating such to degradation of streambanks, and extrapolating such to harmful effects on aquatic fauna. Such relationships are difficult to understand much less relate cause and effect. The amount of trampling a streambank can withstand is best understood within the context of its hydrology, soils, vegetation composition, rodent activity, and geomorphic state. For example, the Wildcat Creek elk/cattle treatment withstands intense daily trampling from foraging elk, but many other streambank sites exhibit high bare soil cover from one crossing event. The processes involved are dynamic and relative to ungulate behavior and site conditions.

Wooded streambanks are apt to incur moderate to severe sloughing from frequent ungulate crossings. Ungulate crossings on herbaceous streambanks may incur slight to severe incision, depending on the dominant vegetation type. However, ungulates tend to use the same crossings, generally over riffle bars, such that extensive streambank damage is not the norm under moderate use. Additionally, wooded streambanks inhibit the growth and establishment of the sun-loving sedges and rushes. Hence, such sites may be inherently at risk from ungulate induced erosion.

RECOMMENDATION (S): The determination and understanding of cause and consequence is essential in formulating management options to restore the productivity of riparian and aquatic habitats. Multi-disciplinary teams should examine historical evidence carefully to seek process-driven explanations for present day conditions. An understanding of the site potential is central to prescribing grazing prescriptions. Riparian habitats are extremely patchy (e.g. soil types, vegetation types, hydrology, geomorphology) and may not respond uniformly to changes in management actions (e.g. grazing, protection). Marginal habitats should not be expected to respond to management actions in a fashion similar to that of good habitat. Unfortunately, sound habitat delineation criteria are lacking.

RECOMMENDATION (S): The use of ungulate trampling indices are discouraged based on their inability to account for the wide range of variability in responses from natural and induced factors. Preferred methods include channel profiles in conjunction with radial profiles (described in Chapter 4). These methods are replicable and results can be expressed in terms of rates of change/unit area.

RECOMMENDATION (S): The use of channel classification attributes as described in Rosgen (1996) is encouraged as the baseline monitoring data that can be used to evaluate channel changes and possibly link them to land uses. The characterization of substrate types and abundance are very useful for evaluating aquatic habitats. In addition, substrate composition may be used to differentiate fish habitats as non-habitat, marginal habitat, and habitat.

RECOMMENDATION (S): We recommend that managers carefully evaluate the hydrogeomorphological condition of riparian meadows and associated stream reaches when making grazing management decisions. Groundwater levels can have profound effects on biomass production and species composition within meadows. Responses to management actions are often dictated by site hydrology, geomorphology, and soils. Correct hydrogeomorphological assessments can identify if poor vegetative conditions are primarily the result of improper use (i.e. biological thresholds exceeded) or if dysfunctional site hydrology and geomorphology (i.e. physical thresholds exceeded) factors are also significant. If the later is the case, changes in grazing management alone are unlikely to result in significant improvements to site condition. Rather, improvements in vegetative and site conditions may require restoration of meadow hydrology and channel geomorphology, within the limits of the watershed's potential. Biological recovery will typically follow once hydrologic equilibrium is attained.

Extreme caution should be observed in the design of monitoring protocols intended to detect ungulate effects. There are many other major operative factors (e.g. geomorphology, vegetation, hydrology, rodents) and interactions that need to be considered, before drawing conclusions of negative impacts. Natural erosional processes must be well understood. Ungulates can act as geomorphic agents to induce changes in streambanks with a net positive result of increased stability and vegetation density.

Riparian Vegetation

The dynamics of ground cover (i.e. plant, litter, substrates, cryptogams) relative to climate, site conditions (e.g. hydrology, geomorphology, woody plants), aquatic habitats, and ungulate use are very complex. Single discipline assessments are subject to misinterpretation of actual cause and effect relationships. Extrapolation from literature surveys can result in the misapplication of management models derived from other bioregions to the Southwest (e.g. trout model applied to Southwest native fisheries). In the absence of good information, efforts should be made to collect such using the technical expertise of researchers.

We conclude that alder dynamics were responsible for a significant proportion of the limited streambank and channel erosion that occurred during the study, and were responsible for creating disturbance niches that were conducive for further alder establishment. We propose that interactions between obligate riparian vegetation and hydrologic and geomorphic factors are a major factor influencing long term ecosystem responses to treatments (i.e. ungulate grazing) and climate (e.g. rainfall, temperature). Fundamentally, we hypothesize that changes in obligate (and in some cases non-obligate) vegetation on streambanks in response to grazing treatments will occur to the extent that hydrology and geomorphology (e.g. flow, channel aggradation or degradation, lateral erosion, bank shape) permit.

RECOMMENDATION (S): The use of plant litter cover as a variable in monitoring ground cover composition should be well defined relative to the vegetation type (e.g. sedge, Kentucky bluegrass, woody). Each vegetation type exhibits different production, retention, and degradation potentials for litter. Our studies revealed that ground cover (i.e. plant cover, litter, soil, rock, gravel, cryptogams) components changed in their relative coverage over time on sites that improved in vegetative condition (as measured in production, composition, and cover). Litter and cryptogam cover increased over time on sites that were improving. However, there is an upper threshold at which litter may negatively affect plant production.

Ground cover is a common parameter that is used to monitor habitat conditions and relate them to ungulate use. It is suggested that a careful interpretation be performed of the relative change or composition of components before relating such to a management action or other factors. Changes in plant and litter cover may result from several influences (e.g. climate, ungulate grazing, flooding, fire) or remain relatively static until a disturbance effects a change. Decreases in plant cover may be brought about by increases in litter, woody plant density (e.g. alder, willow), or canopy cover in general. Thus, changes in the structure and composition of riparian sites effect changes in ground cover that may or may not be a function of ungulate use. For example, sedge dominated streambanks can exhibit a reduction in sedge cover over time as a function of reduced availability of sunlight resulting from increases in woody (or herbaceous) canopy cover.

RECOMMENDATION (S): We need to learn more about vegetation-litter thresholds as they relate to understanding site qualities, condition classifications, and ungulate grazing and to translate this knowledge into management guidelines. Our studies revealed that vegetation changes over 6-7 years were minimal under some circumstances. Herbaceous vegetation cover did not increase unless the streambank geomorphology changed from a vertical bank profile to a reposed profile. Additionally, vegetation was less apt to change on sites where streamflow ceased. On alder sites, alder-derived litter accumulated across the stream channel, causing major changes in ground cover, inducing streambank erosion and changing channel geomorphology, and influencing ungulate use of the areas (e.g. crossings). On other sites, soil cover increased because sediments were trapped by vegetation. However, these same sites exhibit increased vegetation response (e.g. rhizomes, shoots) to the sedimentation the following year. Sedimentation was an important function needed for recovery of hydrological components and rejuvenation (or re-establishment) of obligate graminoids. Hence, monitoring of riparian vegetation should embrace extended annual visits to ascertain cause and effect relationships. Furthermore, it is important to understand the natural thresholds under which riparian habitats function.

RECOMMENDATION (S): Reference riparian areas should be established and monitored to provide a uniform basis for comparison of habitat data across landscapes. A need exists to define ranges of variability and relate such into acceptable use guidelines.

RECOMMENDATION (S): The determination of channel-streambank conditions of woody sites should account for the natural causes of woody plants affecting vegetation cover, streambank erosion, and changes in aquatic habitat. Woody sites produce large litter (e.g. limbs, stems, leaves) that is commonly trapped to form debris dams. These dams result in streambank erosion and channel widening, and deposition of fines downstream. These two processes directly affect streambank ground cover components, and the long-term geomorphological state and hydrology of the sites, essentially affecting a chain reaction of physical and biological imbalances that require re-adjustments.

General Aquatic Wildlife Survey – Habitat Condition Index

The Habitat Condition Index (HCI) component of the General Aquatic Wildlife Survey (GAWS) methodology was intended as a measure "to identify conditions or activities that are limiting fishery productivity" (USDA Forest Service 1988). Six parameters (pool measure, pool structure, stream bottom, bank cover, bank soil stability, and bank vegetation stability) are averaged to derive an index of habitat condition. The results of this study indicate the methodology is a poor assessment technique to relate the condition of the stream and its potential for improvement for the reasons discussed below. Fundamentally, the HCI index is insensitive to cause and effect relationships, lacks connectivity to process driven functions, and assumes that all stream systems are equal with respect to elements of 'potential'. HCI was not intended as a livestock impact assessment protocol, nonetheless it has been used to implicate cause and effect relationships between fishery habitat conditions and livestock.

The three streams within the study area were identified as perennial, Apache x rainbow trout hybrid streams, restocked with pure Apache trout in Wildcat Creek, and had been surveyed using GAWS (AG&FD 1991a, 1991b, 1991c). However, over the 7 years of study, the streams dried up 4 years during the summer months, limiting trout and speckled dace to headwater pools (refugia), or pools within gaining reaches. Determinations of fish habitat qualities and relationships to ungulate impacts are meaningless under these conditions.

RECOMMENDATION (S): The validity of HCI as assessment index of fishery habitat conditions is questionable. The continued use of HCI should be suspended pending further validations of its utility across other landscape types, and at least supported by extensive measurements of streambank, channel attributes, watershed conditions, and other supporting resource data, as well as a well-founded fishery habitat classification based on geological and physiographic attributes.

RECOMMENDATION (S): The classification and definition of fishery habitats should be a prerequisite for developing fishery management plans. It is evident that the present definition of "fishery habitat" is all encompassing without regard for inherent limitations of the landscape to provide elements (e.g. substrates, aquatic vegetation, pools, perennial streamflow, spawning gravels) that have been deemed as essential for quality habitat. This classification should provide a fundamental basis for describing the capabilities or site potentials of non-habitat (incidental), marginal habitat, and habitat. These criteria are essential in restoration projects, evaluation of management impacts, and management of stream ecosystems based on their inherent potential.

Water Quality and Streamflow

We recommend that water quality monitoring be very specific in purpose. As in this study, extreme environmental conditions resulting from climatic or geological influences may overwhelm the objectives of the monitoring. For example, water temperature was not an issue when we sampled within a gaining reach with sustained flows. We also recommend that the streams within the study area be classified as marginal habitat for Apache trout based on the natural thresholds that preclude them from attaining optimal trout habitat potential. The water quality and flow data supports this conclusion.

Fish

The three streams of the study area should be classified as marginal fisheries and management goals should be adopted that are appropriate to the landscape conditions. There are at least three major natural factors limiting the fishery potential – basalt derived soils dominated by fine sediments, interrupted flows (flow regime), and frequent droughts (climate). The management options available to overcome these factors would be impractical and would have a high risk of failure. The fishery is composed of Apache-Rainbow hybrids that survive under restricted habitats constrained by the natural character of the channel and substrates. The fishery habitat is best suited for speckled dace. Since 1937, thousands of nonnative-trout have been transplanted with little success (Rinne and Janisch 1995). These introductions were often facilitated by stream renovations using fish toxicants, which have a generic mortal effect on all native aquatic fauna, the consequences of which may have long-term adverse effects on benthic species – the food base (Mangum and Madrigal 1999).