Livestock Grazing Effects on Southwestern Streams: A Complex Research Problem[1]

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Abstract.--Conducting viable research on the effects of domestic livestock grazing on stream environments and biota in southwestern National Forests is problematic. The multiple-use concept, spatial temporal factors, inadequate control and replication, and changes in land management objectives and direction render it difficult to effectively study grazing impacts.

INTRODUCTION

National Forest lands cover about 21 million acres in Arizona and New Mexico. These lands are typically upper elevation (>1,500 m) and are the coolest and best-watered areas in the predominantly arid Southwest. Because of the greater annual precipitation, extensive, harvestable stands of conifer forests flourish. Livestock graze on herbaceous forage over more than 75% of all forest lands in the western states. In these upland, more mesic areas, streams support both wild and put-and-take populations of trout and other native fishes.

Until recently, most studies relating the interactions of grazing and fisheries have been descriptive, popularized, and have lacked scientific approach and proper study design (Platts 1982). Accordingly, the effects of domestic livestock grazing on stream habitat, water quality, and fish populations are little known and often misinterpreted. Grazing and stream habitat/fisheries interactions have become the topic of increased research in the last decade, but most effort has been in the northern Rocky Mountains and Great Basin states (Kauffman and Krueger 1984).

In 1982, research was initiated on a montane stream in northern New Mexico that was previously fenced to exclose domestic livestock. The objective of the study was to determine if removal of grazing was beneficial to stream habitat and fisheries. Preliminary data have been acquired on fishes and their habitat on this stream and several nearby streams draining watersheds that have been either subjected to or restricted from multiple use management.

Results so far have not been what we anticipated. The purpose of this paper is neither to present startling results, nor to admit defeat. The purpose is to point out the complexity of the relationships that must be studied in riparian habitats. Managers cannot expect quick, broad-scale solutions to resource use conflicts, and researchers must be exceedingly perceptive in how they design their studies if they are to provide meaningful results.

STUDY AREA DESCRIPTION

Two disjunct study areas were examined. The first, the Rio de las Vacas, is a third order montane stream draining the San Pedro Parks Wilderness Area, Santa Fe National Forest, New Mexico. Descriptions of this study area and livestock grazing history are given in Szaro et al. (1985). The other, the Santa Fe River, is a second-order stream in the Sangre De Cristo Mountains of northern New Mexico. It serves as the primary water supply for the city of Santa Fe. Its lower reaches are bounded by Public Services (a water utility) property and its upper reaches are on the Santa Fe National Forest. To insure high water quality, the watershed has been closed to normal multiple uses since the 1930's. The stream is impounded by a series of water storage reservoirs on the lower public utilities land. The Rios Nambe and Capulin head on the same mountain as the Santa Fe River, but drain north-northwest on its opposite side. Both watersheds are subject to normal National Forest multiple uses. Steep mixed conifer slopes border all three streams.

The Rio de las Vacas supports three native and at least two introduced species of fishes. The Rio Grande sucker (Pantosteus plebius) and Rio Grande chub (Gila pandora) along with the Rio Grande cutthroat trout (Salmo clarki virginalis)

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occur naturally in the stream. Brown trout (Salmo trutta) and rainbow trout (S. gairdneri) have been and are continually being introduced into the stream. The rainbow hybridizes with the native cutthroat. The Santa Fe River and Rios Nambe and Capulin contain both native cutthroat and introduced rainbow trout and their hybrids. All streams but the Santa Fe River are subject to sport fishing.

METHODS

Fish numbers and biomasses were estimated by blocking 50-m sections of stream and electrofishing each section three times (Rinne 1978). Initially, six 50-m sections were established in the upstream exclosed (ungrazed) reaches of the Vacas and four in the downstream non-exclosed (grazed) area (fig. 1). Water quality was analyzed by means of a portable Hach field water quality kit, streambank stability was estimated following methods of Binns (1982), and streambank vegetation and overhanging vegetation were measured with a meter tape and expressed as percentage of streambank. Fine content of the substrate was estimated by a modified Mark IV Standpipe corer.

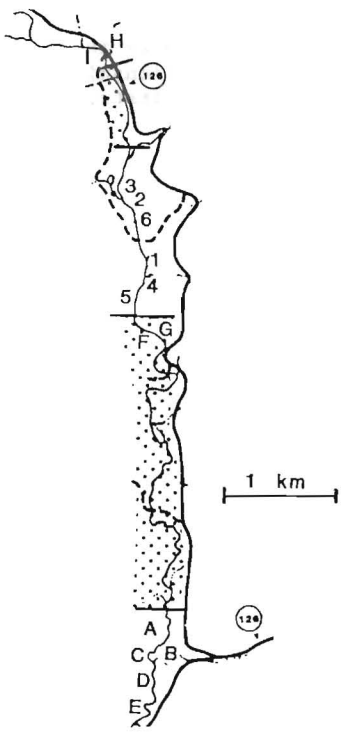

Figure 1.--Detailed map of the Rio de las Vacas indicating study sections within grazing exclosures (1-6) and those in grazed areas (A-I). Stippled area indicates where the stream passes through private lands.

Table 1.--Comparative physical habitat of study sections in ungrazed (1-6) and grazed (A-F) reaches of the Rio de las Vacas

Study section	Streambank vegetation (%)	Overhanging vegetation (%)	Bank instability (%)
1	24.00	17.4	0
2	11.03	56.0	0
3	2.00	33.5	0
4	13.00	5.3	0
5	0.00	2.0	0
6	0.00	0.0	0
Mean	8.38	17.2	0
A	6.00	0.0	100
B	0.00	0.0	74
C	0.00	0.0	80
D	0.00	0.0	80
E	0.00	0.0	30
F	0.00	0.0	20
Mean	1.00	0.0	64

RESULTS AND DISCUSSION

Physical habitat structure in the Rio de las Vacas was dramatically different between grazed and ungrazed reaches of stream (table 1). Streambank vegetation and overhanging vegetation were much greater in the exclosed compared to the non-exclosed reaches. Bank instability varied from 20 to 100% in the grazed areas and averaged 64% overall. Banks were totally stable in the exclosed areas.

In 1982, fish abundance in the Vacas was highly variable (table 2). In the ungrazed area, 86 to 95% of total numbers of fish and 51 to 75% of total biomass were comprised of suckers and chubs. By comparison, these two taxa contributed 95% or more of total number and biomass in the grazed area. Chubs and brown trout were inversely abundant within and outside exclosures. Overall, numbers of fish were greater in the grazed area, but biomass was greater in the ungrazed area, reflecting larger mean size of fish in the exclosed study sections.

Subsequent examination of fish populations in summers of 1983 and 1984 (data not presented here) revealed a dramatic decrease in total numbers and biomass of fish per 50-m section in both the grazed and ungrazed areas. In contrast, overall numbers and biomasses of salmonids generally increased between 1982 and 1984 in all study sections in the grazed area and in half the sections in the ungrazed areas. These data basically contradict reasonable fish habitat relationships (tables 1, 2), and immediately suggest other factors may be altering or concealing suspected functioning of the stream ecosystem under protection from grazing. Several factors are immediately suspect.

First, although structurally a stream is a discretely defined, narrow band of habitat situated in the overall landscape, functionally, it is not so simplistic or easily defined. Streams are dynamically interrelated with their watersheds (Hynes 1975, Platts 1979, Triska et al. 1982). A given reach is not independent, but affected by reaches both up- and downstream (Vannote et al. 1980). The marked bank instability that logically should negatively impact fish populations in grazed reaches of the Vacas may be mitigated to some degree by the two upstream exclosures containing stable streambanks. In like manner, the improved streambank and riparian condition in the exclosed reaches are affected by riparian and watershed conditions upstream that have been impacted not only by domestic livestock grazing, but by other multiple uses. In context of the river continuum concept, 2 km of apparently enhanced streambank and riparian condition are most likely either not sufficient to positively influence fish populations, or positive influences are being mitigated or masked by contiguous negative influences.

Several other important factors that fall under the umbrella of "biological influence" are likely contributors to the atypical fish population structure in the grazed and ungrazed areas. First, although the Vacas contains both salmonid and non-salmonid fishes, the majority of the numbers and biomass is in suckers and chubs (table 2). Any estimation of the impact on the fishery resource is therefore largely an estimation of the effect that grazing potentially has on non-salmonid fishes. Then consider that a critical life history stage in any biological entity is its reproductive stage. Increased fines in substrates affect not only fish spawning success (Saunders and Smith 1965) but also their food base, aquatic macroinvertebrates (Chutter 1969). Increased silt load in the streambed interstices reduces not only living space for aquatic insects, but also water flow and resultant dissolved oxygen levels of water within the streambed. Based on permeability estimates, fines in the channel substrate were only slightly higher on an average in the grazed areas. The Rio Grande sucker and Rio Grande chub most likely spawn on the substrate surface (Reigard 1920), while trout deposit spawning products below the surface in redds. In addition, the tolerance of the native sucker and chub to increased silt load and lower O_2 levels is most likely greater than that of the salmonids (Hoar and Randall 1970:273). Perhaps, therefore, we should not expect any differences in fish populations between the grazed and ungrazed reaches of stream.

Table 2.--Summary of fish numbers and biomass (parentheses) in 10 50-m sections of the Rio de las Vacas, summer 1982. Biomasses are in grams. Sections 1-6 denote ungrazed reaches and A-D grazed sections

Section	Rio Grande sucker	Rio Grande chub	Brown trout	Hybrid	Total
1	51(1,630)	33(354)	8(646)	2(118)	94(2,748)
2	93(1,116)	27(267)	7(328)	3(123)	130(1,834)
3	135(1,124)	53(714)	17(710)	5(191)	210(2,739)
4	63(750)	66(756)	7(1,317)	0(0)	136(2,823)
5	123(1,279)	26(322)	9(1,540)	1(10)	159(3,151)
6	114(1,695)	51(739)	13(1,305)	3(118)	181(3,857)
A	86(502)	55(394)	0(0)	0(0)	141(896)
B	261(1,871)	281(2,905)	2(62)	1(208)	545(5,046)
C	174(828)	128(735)	0(0)	0(0)	302(1,470)
D	217(1,287)	207(1,088)	2(23)	5(8)	431(2,046)

Second, normal fluctuations in fish populations also affect interpretations of grazing effects on fishes, especially in this brief (3 years) frame of reference. Between the 1982 and 1984 sampling periods, non-salmonids decreased in 75% of study sections. In contrast, brown trout decreased in all study sections in the exclosed areas, but increased in all but one study section in the grazed areas. The rainbow-cutthroat hybrid group increased in 90% of all study sections during this same time period. These fluctuations lack any logical pattern, and certainly make it difficult or impossible to interpret the effect of grazing on fish populations.

The differential management of salmonids versus non-salmonids is a factor that certainly must contribute to the lack of pattern in fish populations. Casual analysis of the impact of stocking and sport fishing in the Vacas demonstrates this potential effect. Between 1 July 1982 and 30 June 1983, 9,000 catchable rainbows were stocked in the Vacas from the nearby Seven Springs Hatchery. In addition, 800 brown trout were stocked in September 1982. Detailed creel census records were unavailable, but in 1981, estimated fisherman days on the Vacas were 9,051 and catch was 21,855 trout. Even these spotty data, in context of the estimated low numbers of salmonids in the Vacas (table 2), suggest attempting to relate trout numbers and biomasses to grazing effects in the Vacas is problematic at best.

Third, interspecific interactions likewise must affect fish populations in the Vacas. Observations while electrofishing suggest that undercut banks and pools with large numbers of brown trout had fewer chubs, which also select for this type of habitat. Brown trout are highly piscivorous, and the 800 stocked in September 1982 certainly may, in part, be responsible for the general reduction in native chubs and conceivably even suckers between 1982 and 1984.

Finally, mobility of fish populations also has to be considered in any exclosure study. Tag-recovery data indicate that sucker and chub populations are moderately to very mobile, and fish reared in ungrazed reaches of stream certainly may become part of the biomass estimates in ungrazed reaches, and vice versa.

Platts (1982) suggests that study design is a major factor in reducing reliability of data in grazing-fisheries studies. Land ownership in this study area demonstrates the effect of differential land ownership and management as a barrier to proper study design (fig. 1). Because private land was positioned immediately up- and downstream from the two exclosures, sample sections in the exclosed areas (1-6) initially were distant from those established in downstream non-exclosed areas (A-E) on National Forest lands. In 1983, permission was obtained to sample reaches of stream on private land immediately below the exclosures. Two additional study sections (F, G) were placed here in 1983, and two more (H, I) were placed upstream from the exclosures (fig. 1) in 1984. Estimated fish numbers in 1984 in the contiguous grazed sections (F-I) versus the non-contiguous sections (A-E) demonstrate the possible influence of space on appraisal of grazing-fisheries interactions. The upper ungrazed (exclosed) sections ranged from 73 to 126 fish (mean 91) per 50-m section, and the upper, more contiguous grazed sections (F-I) ranged from 62 to 104 fish (mean 86). By comparison, the lower grazed sections (A-E) ranged from 133 to 356 (mean 225) fish per 50-m section. Numbers of fish in the distant downstream grazed area were markedly higher than those in not only the upper ungrazed reaches but the grazed reaches as well. These data suggest that the change in stream habitat in 4 km (fig. 1) in itself may have as much influence on fish populations as does domestic livestock grazing.

Another multiple use factor is recreational activity. Initially, water in an upper ungrazed reach (study section 3) was significantly higher in nutrients (phosphates, nitrates, and sulfates) than water in a downstream reach (section D) sampled the next day. Because of these differences additional samples were analyzed two days later from the upstream locality. Nutrients were no longer detectable, but hardness had increased significantly. The temporarily high level of phosphates, nitrates, and sulfates were very likely associated with observed heavy weekend recreational activity (23-24 June). Increased nutrient levels were not detected downstream the next day in the lower grazed area, perhaps because of rapid uptake by aquatic plants along the way and cessation of camping. Although stream nutrient levels may increase or decrease relative to grazing, periodic (weekly) recreational inputs of nutrients of this magnitude certainly must have an impact on the flora and fauna of the stream. Certainly, such inputs may mask detection of either the more subtle increases of nutrients from grazing (direct waste elimination) and naturally occurring breakdown of litter and debris, or from decreases resulting from plant and tree uptake.

In keeping with the idea that watershed management impacts a stream, data on fish populations were collected from three watersheds that have been managed differently for a considerable period of time (table 3). Estimated fish populations in study section 1 in the Santa Fe River were comparable between 1982-1983, but

Table 3.--Comparative fish numbers and biomasses in the Santa Fe River, and Rios Nambe and Capulin, 1982-1984

Stream	Year	Section	Number	Biomass (gr)
Santa Fe River	1982	1	40	1,052
		2	40	1,423
	1983	1	36	1,110
		2	57	2,786
Mean			43	1,593
Rio Capulin	1983	1	50	1,092
	1984	1	38	1,340
		2	35	1,165
		3	19	801
Mean			36	1,100
Rio Nambe	1983	1	37	1,117
	1984	1	23	1,626
		2	8	394
Mean			23	1,046

increased 43% in numbers and 96% in biomass between years in section 2. Study section 1 in the Rio Capulin decreased about 25% in number of fish between 1983 and 1984, but, biomass increased 23% in the same time period. Number of fish in study section 1 decreased almost 40% from 1983 to 1984 in the Rio Nambe, but, biomass increased 46% during the same time period.

Point-in-time fish population estimates in the "quasi pristine" Santa Fe watershed were not significantly greater than in the Rios Nambe and Capulin, which are under normal multiple use management. The question of comparability of watersheds immediately arises. The three streams are relatively close--they head on the same mountain. However, geologic strata, watershed exposure, and vegetation may be different. The most obvious difference among the streams is that sport fishing is prohibited on the Santa Fe River, but occurs on the Rios Nambe and Capulin. One might therefore expect greater fish populations in the Santa Fe. Indeed, although average fish numbers and biomass in this stream were higher than in the other two streams (table 3), natural variation and sport fishing effects cannot be adequately defined in two years (Platts 1981).

RECOMMENDATIONS

Basic requirements of scientific research are control of variables in time and space, replication of experiments, and a valid research area. The case study on the Rio de las Vacas typifys the difficulty in achieving such control and replication on National Forest lands. A researcher's lack of ability to control the varying degree of multiple uses precludes determining the differential impacts of these respective uses. Differential management of

habitat and the sport fishery on these lands further complicates the situation. Presently, land use planning is a very essential and functioning component of the Resources Planning Act. However, studies that initially may have been well designed and conducted by the scientific method under one management plan, can be invalidated by a change in management direction. For example, despite the past lengthy closure of the Santa Fe watershed, the current draft Forest Plan for this area gives potential for opening the stream to multiple use management.

Possible solutions to the above dilemma are 1) to utilize existing experimental forests or 2) to designate areas solely for research, and manage these with only research in mind. In the Southwest, there are two experimental forests, Sierra Ancha and Fort Valley. Within these confines one theoretically should be able to control and design studies wherein management variables such as grazing can be controlled. These Forests, however, have been subjected to previous study and manipulation. Two of the three watersheds on the Sierra Ancha Experimental Forest have been experimentally manipulated (Rich et al. 1961).

As an alternative, specially designated areas (allotments or watersheds) on National Forest lands conceivably could provide areas for viable scientific examination of the effects of grazing on fish habitat and fisheries. These areas could function similar to the "Research Natural Area" concept. The recently aquired Valle Vidal in northern New Mexico is an example of such a potential research area. Within such a management framework, both short-term manipulative and reliable long-term research could be conducted.

The importance of long-term data for defining natural variability cannot be overstated. Research on a watershed deteriorated by domestic livestock grazing may require 10-20 years or even longer to begin to detect significant changes once a change in management direction is instituted. The present alternative to the controlled, long-term approach is to examine areas that have been differentially managed in a "case history approach." Such an approach has some merit, but normally will result in only descriptive, subjective results that will ask more questions than are answered. Realistically, such an approach will never delineate the interrelated processes that are functioning between a watershed subjected to domestic livestock grazing and an affected stream ecosystem and thus will not provide the land manager with reliable conclusions on which to base management decisions.

LITERATURE CITED

Binns, N. A. 1982. Habitat quality index procedures manual. Wyoming Game and Fish Department, Cheyenne. 209 p.

Chutter, F. M. 1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. Hydrobiologica 34:57-76.

Hoar, W. S., and D. J. Randall (eds.). 1970. Fish physiology: Vol. 4. The Nervous System, Circulation, and Respiration. Acad. Press, New York, New York. 532 p.

Hynes, H. B. N. 1975. The stream and its valley. Verhand. Internat. Verein. Limnologie 19:1-15.

Kauffman, J. B., and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: A review. J. Range Manage. 37(5):430-437.

Platts, W. S. 1979. Relationships among stream order, fish population, and aquatic geomorphology in an Idaho river drainage. Fisheries 4(2):5-9.

Platts, W. S. 1982. Livestock and riparian-fishery interactions: What are the facts? Trans. 47th North Amer. Wildl. and Nat. Res. Council: 507-515.

Reigard, J. 1920. The breeding behavior of suckers and minnows. Biol. Bull., Wood's Hole Biol. Stn. 38 p.

Rich, L. R., H. G. Reynolds, and J. A. West. 1961. The Workman Creek watershed. USDA Forest Service, Research Paper RM-65. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Rinne, J. N. 1978. Development of methods of population estimation and habitat evaluation for management of the Arizona and Gila trouts. p. 113-125. In J. R. Moring (ed.). Proc. Wildl. Trout-Catchable Trout Symp. Oregon Department of Fish and Game, Corvallis.

Saunders, J. W., and M. W. Smith. 1965. Changes in a stream population of trout associated with increased silt. J. Fish. Res. Bd. Canada 27(2):395-404.

Szaro, R. C., S. C. Belfit, J. K. Aitkin, and J. N. Rinne. 1985. A preliminary study on the impact of grazing on a high elevation population of wandering garter snakes. Proc. Riparian Ecosystems Management Symposium. [Tucson, Ariz., April 16-18, 1985].

Triska, F. J., J. R. Sedell, and S. V. Gregory. 1982. Coniferous forest streams. p. 292-332. In Edmond, R. C. (ed.). Analysis of Coniferous Forest Ecosystems in the Western United States. US/IBP Synthesis Series 14, Stroudsburg, Pennsylvania.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Can. J. Fish. and Aqua. Sci. 37:370-377.