Fish and Grazing Relationships:

The Facts and Some Pleas

By John N. Rinne

ABSTRACT

Information on the relationships or linkages between livestock grazing and fishes in the western and southwestern United States is sparse. Although much information in the literature demonstrates the direct impact of livestock grazing (herbivory) on vegetation and less on streambanks (trampling, compaction), limited information on the indirect effects of grazing on fishes and their habitats (e.g., channel morphology, streambanks, cover, instream substrates, water column characteristics) exists. Further, most available information is not scientifically derived and/or addresses salmonids and domestic livestock only. In the southwestern United States, cypriniform species of fishes and large, wild ungulates, especially elk, must be considered critical components of the "fish-grazing" management and research paradigm. Future management and research must address these two components within the context of linkages to watersheds, riparian areas, riparian habitats, fish habitat, and fish communities (native versus introduced species). Efforts must embrace adaptive management, intra- and interagency management-research partnerships, and data collection rather than opinions, summarizations, and promotion of the litany of information on fish-grazing relationships that often has been adopted as fact.

Grazing of domestic livestock is one of the multiple uses of National Forest System (NFS) lands. Livestock grazing has been a component of the southwestern landscapes for centuries (Scurlock 1998; Young 1998; Figure 1). Certainly by the time the U.S. Forest Service (FS) was established in 1905 (Steen 1976), cattle and sheep were widespread across the landscapes of Arizona and New Mexico (Hendrickson and Minckley 1986; Young 1998). Early attempts to control their numbers and use of forests and rangelands were first set forth by the 1897 Organic Act. The 1934 Taylor Grazing Act (Steen 1976: 206) was the next major legislative effort directed at controlling livestock grazing on pubic lands. As discussed by Rinne and Medina (1996), the Multiple Use and Sustained Yield Act of 1960, National Forest Management Act of 1974, and National Forest Renewable Resources Research Act of 1978 further addressed the roles of management and research on public lands, including livestock grazing and fisheries.

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Management of forested landscapes for timber, recreation, mining, and livestock all potentially affect riparian-stream areas (Debano and Schmidt 1989; Meehan 1991). In addition, in the arid American Southwest, disjunct and isolated riparian and aquatic areas serve as critical fish habitat (Rinne 1993, 1994; Rinne and Medina 1996). Water and its quantity and quality dictate where fishes can survive and sustain themselves. Because they are intimately related, riparian-stream areas can serve as indicators of the conditions of their watersheds (Debano and Schmidt 1989; Rinne 1990). Accordingly, FS managers must know the relationships of fish, their habitats, and land use practices to properly manage both fishery and range resources. Understanding and managing these relationships becomes more critical because of the threatened and endangered status of many fish species on NFS lands in the Southwest (Rinne and Medina 1996).

When compared to streams and rivers of the eastern United States (Rinne and Minckley 1991; Rinne and Stefferud 1999), native fish species diversity is low. Fewer than 60 fish species are native to the southwestern United States (Minckley 1973; Rinne and Minckley 1991). At the turn of the century, introductions of nonnative fish species began, principally in association with the sportfishing industry (Rinne 1994). Currently, more than 100 nonnative fish species have been introduced into the waters of Arizona alone (Rinne 1994, 1996); almost 50 of these have become permanently established in the state.

Because of nonnative fish introductions and associated changes in aquatic ecosystems in the Southwest caused by damming, irrigation, and groundwater mining (Rinne 1991, 1996), all native species have declined greatly in range and numbers (Minckley 1973; Rinne and Minckley 1991). Today, the native fish fauna of the Southwest comprises mostly federal- or state-listed species (Williams et al. 1989;

Minckley and Deacon 1991; Rinne and Minckley 1991). Current and future fisheries management of communities of often co-existing native and nonnative fishes (Rinne and Stefferud 1996; Rinne et al. 1998) have to be considered of equal or perhaps even greater importance than grazing-fisheries management. Research into the relative effects of nonnative fish species and livestock grazing on native fishes in the Southwest is in process.

The primary objectives of this paper are to address the relationships of fish, fish habitat and grazing in the FS's Southwestern Region (R-3), which includes Arizona and New Mexico. I will initially describe what is known about these relationships in general, then discuss them more specifically for the Southwest and suggest the interrelationship of FS research and management. Finally, I will cover the need for cooperative interagency and private partnerships and collection of data through interrelated monitoring and research.

State of knowledge

Most information on the relationship of domestic livestock grazing and fishes in the United States has been gathered in the northern Rocky Mountain states, Intermountain and Pacific Northwest regions (Table 1). Although extensive information exists about grazing in these regions (Larsen et al. 1998, Belsky et al. 1999) very little of the literature addresses fish-grazing relationships. The principal researcher and information-generator on fish and grazing relationships in the 1980s was William S. Platts. Recently, Platts (1991) summarized much of what is known about the effects of grazing on fishes in a comprehensive document on forest and rangeland management for salmonids. Initially, I will use Platts' state-of-the-knowledge review to generalize about grazing effects on fishes and their habitats. However, the reader is referred to Platts' (1991) comprehensive and invaluable document for further information about grazing

Table 1. I analyzed grazing-fisheries studies in the literature relative to (1) content of article (r=review, d=data, b=both); (2) research components incorporated; (3) statistics; (4) fish species, type of study; (5) additional extrinsic, un-analyzed, influencing factors; and (6) geographic location. Abbreviations under research are pretreatment data (pre), control (con), replication in time and space [rep(T/S)], and quantitative (Q1) or qualitative (Q2) data or both (B). Whether statistical analyses were performed is noted by Y and N. Fish species are salmonid (sal), or salmonid and nonsalmonid (B). Primary emphasis of study is designated by letters (riparian=R and fish=F) and their order.

Reference	Content	Research				Stats	Species	Fish/Ripar	Add factors	Location
		Pre	Con	Rep(T/S)	Q1/Q2					
Armour 1977	r	N	N	N/N	–	N	–	F	–	general
Behnke 1977	r	N	N	N/N	–	N	B	RF	Struct/plant	Utah
Berry, Goebel 1978[2]	d	N	N	–	Q1	N	–	F	–	–
Chapman/Knudsen 1980[2]	d	N	Y[1]	N/Y	B	N	Sal	RF	channeliz	Oregon
Claire and Storch 1983[2]	b	N	Y[1]	N/N	Q2	N	Sal	RF	exclosures	Oregon
Clarkson/Wilson 1995	d	N	N	N/Y	B	Y	Sal	RF	multi-use	Arizona
Duff 1983[2]	d	N	Y[1]	N/Y	B	N	Sal	RF	struct/beaver	Utah
Gunderson 1968[2]	d	N	N	N/Y	B	N	B	RF	channeliz/fire	Wyoming
Keller/Burham 1982	d	N	Y[1]	N/Y	Q1	Y	Sal	F	water table	Northern Rockie
Keller et al. 1979[2]	d	N	Y[1]	N/Y	B	N	Sal	RF	fish stocking	Idaho
Kimball/Savage 1977	d	N	Y	Y/Y	B	N	B	F	struct/plant	Utah
Knapp/Matthews 1996	d	N	Y[1]	Y/N	Q1	Y	Sal	RF	–	California
Lorz 1974[2]	d	N	Y	Y/Y[1]	B	Y	B	FR	–	Oregon
Marcuson 1977[2]	d	N	N	Y/Y	B	N	B	RF	–	Montana
Maynard 1982	b	N	N	Y/Y	B	N	Sal	RF	multiple/ungl	Montana
Platts 1981a[2]	d	N	N	N/Y	B	N	Sal	R	–	Idaho
Platts 1981b[2]	d	N	Y[1]	N/Y	B	Y	Sal	RF	–	Nevada, Utah, Idaho
Platts 1981[2]	d	N	Y[1]	Y/Y	B	Y	Sal	RF	–	Idaho
Platts/Nelson 1980	d	Y	Y	Y/Y	B	N	Sal	RF	fish stocking	Idaho
Platts/Nelson 1981[a]	d	Y	Y	Y/Y	Q1	N	Sal	RF	fish stocking	Nevada
Platts/Nelson 1981[b]	d	N	Y[1]	Y/Y	Q1	Y	Sal	RF	fish stocking	Utah
Platts et al. 1983	d	N	Y[1]	Y/Y	B	N	Sal	RF	fish stocking	Nevada
Rinne 1985	d	N	Y[1]	Y/Y	B	Y	B	FR	fish stocking	New Mexico
Rinne 1988a	d	N	Y[1]	Y/Y	Q1	y	B	RF	structure/hab	New Mexico
Rinne/Neary 1997	d	N	N	N/N	Q1	N/N	Sal	RF	grazing	Arizona
Staroska 1979[2]	d	N	Y[1]	Y/Y	B	N	Sal	RF	–	Utah
Stuber 1985	d	N	Y[1]	Y/Y	B	N	B	RF	–	Colorado
Storch 1979[2]	b	N	Y[1]	N/Y	Q2	N	Sal	RF	–	Oregon
Van Velson 1979[2]	d	Y	Y[1]	Y/Y	B	N	B	RF	–	Nebraska
Winget/Reichert 1976	d	N	Y[1]	N/Y	B	Y	Sal	R	multi-factors	Utah

[1] Controls positioned linearly on streams (see Figure 1).

[2] References cited in Platts 1982, 1991; remaining references cited in section below.

strategies and fish habitat, and their influence on fish populations in the Intermountain West and northern Rocky Mountain regions.

Conclusions from Platts (1991)

Scientific consensus, as summarized by Platts, has been that grazing has irrefutably harmed fishes and their habitats in the West and Southwest. More than two decades ago, Behnke and Zarn (1976:5) identified livestock over grazing as "the greatest threat to the integrity of headwater stream habitat quality in the West." Galliziolli (1977) suggested overgrazing by livestock was "the single most important range management problem limiting fish and wildlife benefits in Arizona." Davis (1977) stated that "management of the riparian habitat for wildlife could best be accomplished by the total exclusion of domestic livestock...." Saltzman (1977) also suggested that overgrazing and irrigation are the most serious and least understood ecological problems in the western states." Meehan and Platts (1978) were unable to identify any widely used grazing strategy that is compatible with the environmental needs of aquatic ecosystems.

Despite these statements that livestock grazing has harmed fishes and aquatic habitats, Platts (1991) wrote (and I agree), that controversy exists because published, valid evaluations of grazing strategies as related to fishery productivity are lacking in the literature (Tables 1, 2, 3), and we do not completely understand cause and effect in livestock grazing and fishes.

Livestock grazing and fishes

Platts (1991) reported that of 21 studies of domestic livestock grazing and riparian areas, all concluded that grazing harmed riparian ecosystems. My own review of almost 200 references gathered under the key words *riparian*, *grazing*, and *fish*, revealed that approximately two-thirds considered effects of grazing on riparian ecosystem components (i.e., stream channel, instream structure, vegetation, and stream banks; Table 2); whereas only one-third (66) included fish as a study component within a primarily riparian emphasis of study. My review of the literature on grazing, riparian relationships, and fish studies throughout the West (see also Belsky et al. 1999) revealed that a low proportion of the studies document the impact of livestock grazing on fishes. Of the 66 papers discussing fishes and riparian condition, 47 (72%) considered salmonid species, and 19 (28%) addressed nonsalmonids. Of these 66 papers, I categorized 10 (15%) as "fish general" or papers reviewing and reporting on general, often hypothetical, effects of grazing on fishes. Another, 11 (17%) were opinion, summary, or review papers that discussed previous study results, presented no new data, and primarily promoted the litany on the effects of grazing on fishes. Eight papers were from the Southwest, and only half of these were data-based.

Table 2. I compared and analyzed 200 literature references with the key words *riparian*, *fishes*, and *grazing*.

Total references	200
Fish-related	66
Salmonid only	47 (of 66)
Nonsalmonid	19 (of 66)
Fish general	10 (of 66)
Fish—opinion, review	11
Studies in Southwest	8
Data-based studies in Southwest	4

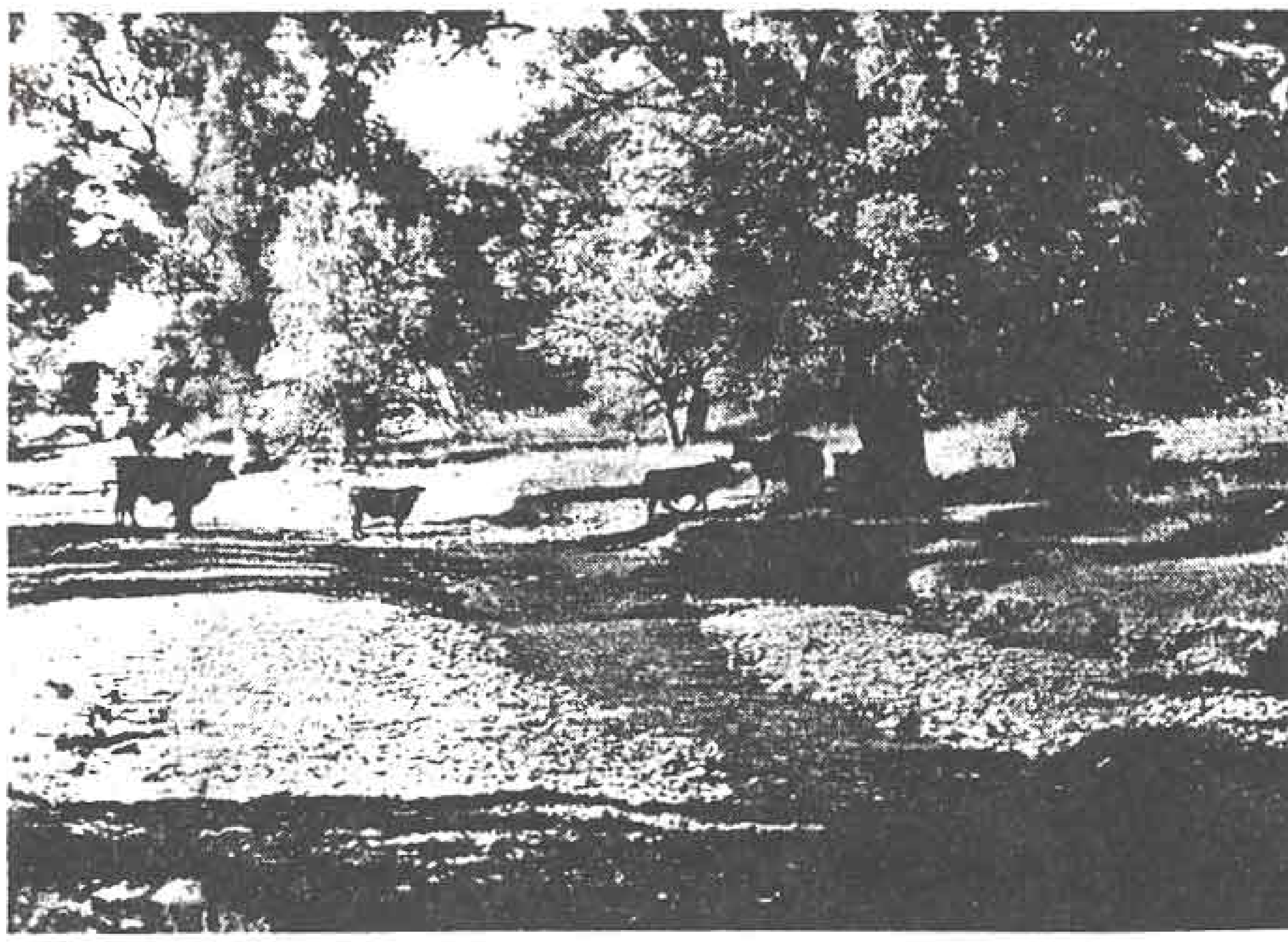
Platts (1991) reported that 15 of the 21 studies he examined indicated that grazing harms fish populations. However, more-careful examination of these same 15 documents—as well as an additional 15 I found in my review—indicated that in most cases, the effects of grazing on riparian-stream attributes that may serve as fish habitat were actually the focus of study rather than fishes. I performed a rigorous examination and evaluation of these combined 30 papers (Tables 1, 3). My intent was to dissect the studies relative to scientific criteria that would better discern the nature, validity, and reliability of data available on livestock grazing and fishes. A further objective was to provide information to assist researchers and land managers with future research and monitoring efforts on the effects of grazing on fishes and their habitats.

Of the 30 studies, only 3 (10%) contained pre-treatment information (Tables 1, 3) (e.g., prior to grazing treatment, at least a year of baseline data was collected on fish populations, fish habitat, or riparian-stream ecosystem components that comprise fish habitat). Ideally, several years of such data are desirable to define the range of variation (Platts 1978), especially of biological components such as fish populations and vegetation components (e.g. diversity, density, biomass). Admittedly, it is easy to suggest that managers obtain this type of information; in practice, it is difficult to acquire. The lack of pretreatment data, in part, has largely resulted from not knowing in advance that grazing allotment management plans will change or that fencing and exclosure of areas will be (or has been) undertaken. Both Platts (1991) and I (Rinne 1988) have suggested the importance of having pretreatment data with which to evaluate change that may result from livestock grazing relative to that resulting from natural variation alone. Knapp and Matthews (1996) also acknowledged the necessity and desire to obtain such data in their study; however, they were unable to achieve them because of a remote study area and unavailability of comparable riparian-stream areas.

A second desirable component of grazing studies is availability of reference or control areas. Of the 30 studies examined, 9 had no control stream reaches with which to compare

Table 3. I analyzed 30 references in Table 1 relative to basic criteria for valid research conducted in the context of the scientific method.

Pretreatment data available	3
Controls	21
Controls positioned linearly on stream	17
Replication in space	24
Replication in time	16
Quantitative data only	6
Qualitative data only	2
Both quantitative and qualitative	19
Statistical analyses of data	10
Salmonid species only	19
Salmonids and nonsalmonids	9
Non-peered-reviewed outlets	24



Domestic livestock grazing has been ubiquitous on southwestern landscapes for more than a century, ranging from upper-elevation, montane meadows such as Colter Creek in the Apache Sitgreaves National Forest (a) to low-desert riparian areas such as Redfield Canyon in the Coronado National Forest (b). Cattle congregate in low-desert riparian areas because of availability of forage, shade, and water. Recent removal of livestock grazing from many riparian areas in Region 3 of the U.S. Forest Service presents an excellent opportunity to collect information on responses of fish habitat and populations.

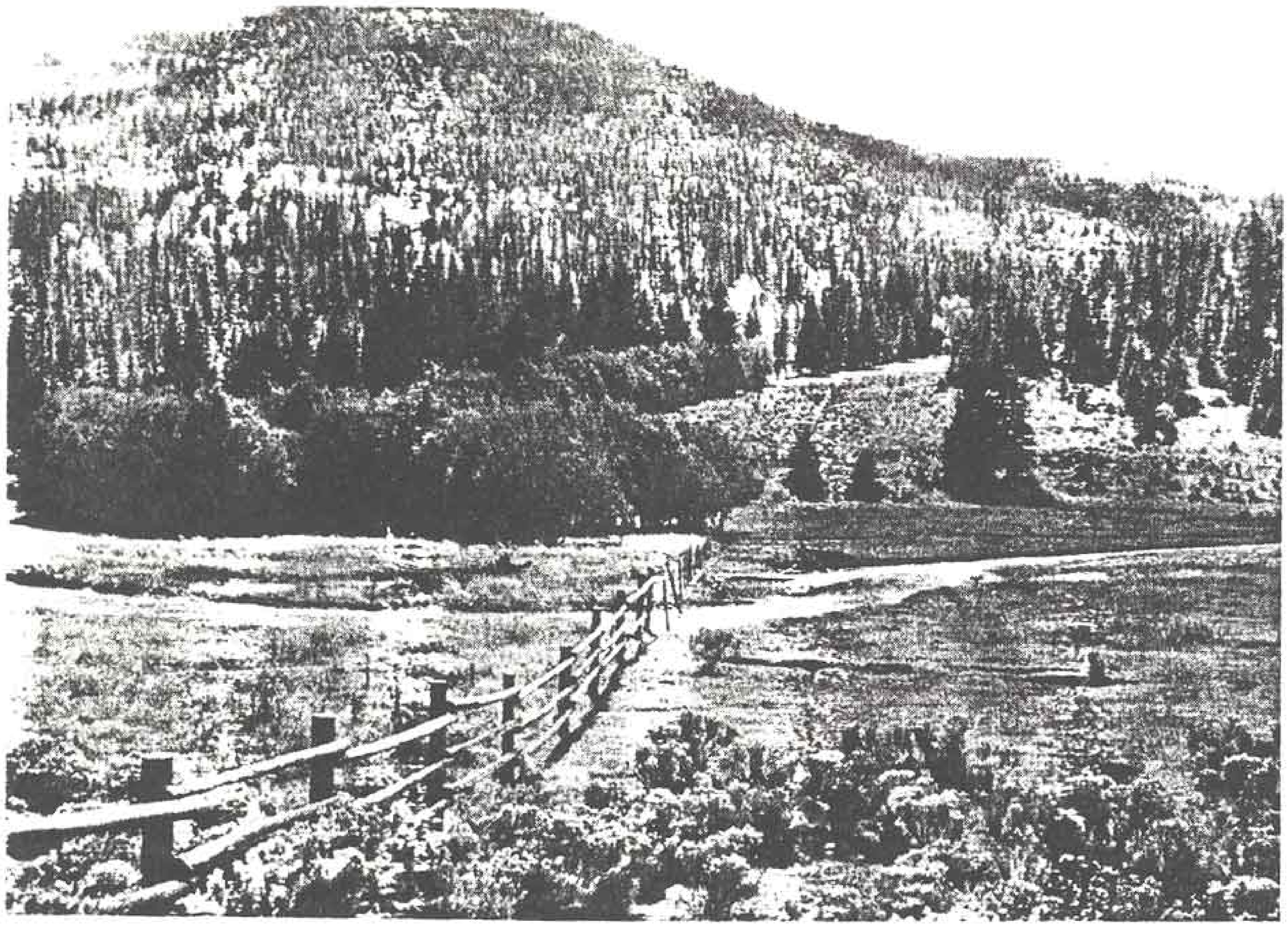
treatment or grazing effects. Of the 21 studies that had controls as a component, 17 (81%) were in the form of upstream or downstream (or both) reaches. Most studies of grazing effects on riparian-stream areas that I have reviewed have been conducted with a linear positioning of treatment and control areas on a riparian-stream system. Indeed, all grazing-fish studies with which I have been involved in Arizona and New Mexico (Table 1; Rinne, in press) suffered from a lack of pre-treatment information.

It could be debated that it is more valid to have treatment and control reaches on the same stream rather than paired stream units to control inter-stream variation. However, such linear, contiguous, interdigitated reaches are not independent of each other. That is, positive (control reaches) and negative (treated reaches), or both, are inherently interactive with reaches both upstream and downstream that may be subject to differing grazing strategies (Figure 2). Platts and Nelson (1980, 1981a) designed stream study reaches to address those potential interactive influences by extending the length of study reaches. Nevertheless, one can never unequivocally state that there is no influence on fish habitat or populations from upstream or downstream reaches. Fish population mobility within limits can be estimated by tagging; however, water quality (e.g., suspended and substrate sediment, water temperature, acidity, nutrients, and pollutants) is a continuum from one stream reach to another, unaffected by barb wire strands or flood gates traversing a stream at boundaries of control and treated reaches.

Ideally, studying paired watersheds with pre-treatment data (two to five years) on fishes and habitat components prior to imposing grazing (treatment effect) is perhaps a better study approach. Unfortunately, to my knowledge, such a study design has never been achieved. Attainment of the entire upstream reaches of a stream course within a watershed was attempted in one of three streams in the West Fork ungulate grazing and Apache trout study in the White Mountains of Arizona (Rinne, in press). Although a sizeable length of stream (6 km) was fenced upstream of study reaches, excluding domestic livestock grazing, elk could still access the most-upstream, headwater riparian-stream area. In conclusion, the ideal design for combined grazing-riparian-fish studies has not been achieved to date.

Replication is another necessary component of a valid study design and can be achieved in both time and space. Most (24 of 30, 80%) studies examined (Tables 1, 3) were replicated in space. Because of the spatial design characteristic of most studies (i.e., linear positioning of study reaches along stream courses) replication in space, albeit on the same stream, is readily achieved, but replication spatially on paired watersheds has not been accomplished. However, design of the West Fork allotment study with three streams on contiguous watersheds is an attempt to satisfy that requirement. Temporal replication or re-sampling the same reaches of stream for the same data for two or more years was evident in only a little more than half (52%) of the studies examined. Platts (1978) recommended a minimum of three or more years of replication to define variability and provide valid, defensible results. Of the 10 studies in which data were collected for more than one year, only a second year of sampling was normally accomplished.

Type of data collected is important in valid study design. Quantified, measured data are more desirable than qualitative, classified data. In 28 data-based studies, only 7 (25%) contained quantified, measured data; 2 had qualitative data; and 19 (60%) had a combination of the two. Repeatability and consistency of data (Platts 1981) are much greater with quantitative versus qualitative data. Categorizing substrate, bank damage



The ubiquitous "fence-line contrast" of the Southwest, as illustrated here on Comanche Creek in the Carson National Forest, demonstrates the resilience of southwestern riparian stream areas if properly managed for grazing. However, despite marked and significant responses by vegetation, fish population response has not been adequately studied.

nd/or stability, and other measurable components of riparian-stream areas leads to subjectivity and reduces repeatability of measurements and strength of data. Monitoring and research must continually be designed to achieve objectivity and unbiased data collection. Such objectivity is necessary for both effective and efficient management of riparian-stream areas and in the event of legal proceedings.

Statistical analyses are necessary to estimate validity of apparent differences of data in control versus treatment reaches of riparian areas. Of the 30 studies surveyed, only 10 contained some level of statistical analysis. Statistical advice should be obtained during study design stages prior to collection of data. Statistics are tools that when combined with "biological" or "practical" significance enhance the reliability of data interpretations. Many of the studies without statistical foundation made statements such as "x percent greater fish numbers or biomass inside (control) than outside (treatment or grazing) the exclosure," without temporal definition of the variability of fish populations in the study areas. Expression of the difference in the fish resource also can vary with species, numbers versus biomass (Rinne 1998, in press), and units of expression (e.g., surface area versus length of stream; Knapp and Matthews 1996).

As stated for all studies reviewed on fishes and riparian areas (Table 1), most (19 of 28, 68%) of the grazing-fish studies evaluated addressed only salmonid (i.e., trout) species. Only a single study (Rinne and Neary 1997) exclusively addressed nonsalmonid fishes; nine considered both. Indeed, most of the grazing-fish literature comes from upper-elevation, montane areas inhabited by coldwater, salmonid species. There is a complete lack of research or monitoring of nonsalmonid species in lower elevation riparian-stream systems. Although most NFS lands are on upper-elevation watersheds, the U.S. Bureau of Land Management (BLM) is responsible for enormous acreages of lower-elevation landscapes in the Southwest that are grazed and that contain valuable riparian-stream areas and native, often threatened and endangered species of fishes (Rinne and Minckley 1991). As suggested by a recent study of a low-elevation river in the Southwest, we likely cannot apply our current state of knowledge of grazing effects on salmonids to cypriniform (minnow and sucker) species occupying lower-elevation streams and rivers because their habitat requirements and innate behavioral traits differ from salmonids (Rinne and Neary 1997).

Finally, and significantly, most (80%) of the literature addressing fish and grazing relationships appears in publications that are not peer-reviewed (Table 3). This does not invalidate these studies, but I believe the results of research and monitoring of fishes and grazing relationships should be subject to sound, scientific peer review. Although, it is important to get information to the land manager in a timely fashion, if studies contain one or more of the above shortcomings of good scientific design (i.e., lack of pretreatment data, replication, control, etc.) and are not subjected to peer review and statistical scrutiny, both the grazing industry and fish species may suffer.

Linkages of grazing effects and fishes

My review of the literature on studies of grazing effects and their component parts and design clearly demonstrates that extensive information is available on components of fish habitat, principally vegetation. Because of the direct effect of vegetation removal by livestock grazing, they are least difficult to study and define. The literature reflects this fact: 21 of 21 studies of livestock grazing effects on riparian habitat examined by Platts (1982) contained impacts that the authors characterized as negative. By comparison, less information is available, and what is available is less conclusive, with respect to effects of grazing on fishes. Because of the indirect effect of livestock on fishes, cause-and-effect relationships are less easily demonstrated. Accordingly, Platts' (1982) evaluation indicated that only 15 of the same 21 papers reported a negative impact of grazing on fishes. Finally, few of the studies demonstrated the relationship or linkage of fish habitat components of riparian areas such as stream width, depth, bank integrity, vegetation density, or biomass to fish diversity or density or biomass to grazing effects. Indeed, in most cases these relationships or linkages are probably complex and nonlinear in nature.

Confounding factors: case studies from the Southwest

Based on my personal research at 3 sites during the past 15 years in 2 upper-elevation streams and a low-desert stream, I conclude that certain factors were obvious from data that confound fish-grazing studies and lead to inconclusive results (Rinne 1998). I only abstract these findings here.

Between 1983 and 1997, I researched the effects of livestock grazing on fishes and their habitats on several streams at three study sites in Arizona and New Mexico. The Rio de las Vacas is located in northern New Mexico on the Santa Fe National Forest. This montane riparian-stream system contained grazing exclosures in existence for 10 years prior to study. The second study area was located on the West Fork grazing allotment on the Apache-Sitgreaves National Forest and encompasses three montane riparian-stream areas. This research-adaptive-management study was initiated because of a Biological Opinion by the U.S. Fish and Wildlife Service on the threatened Apache trout (*Oncorhynchus apache*). Finally, studies on the Verde River, Prescott National Forest, have been ongoing for five years. One component of overall research on the Verde River was to examine the linkages of stream channel, streambank, fish habitat, and fish populations relative to livestock grazing. Six native fishes, including the threatened spikedace (*Meda fulgida*), inhabit the upper reach of river, and an equal number of nonnative fish species are common (Stefferud and Rinne 1995).

Most publications citing the results of studies at these three sites address fish population dynamics, community structure, and fish-habitat relationships and are referenced in Rinne (in press). However, a number of studies (Rinne 1985, 1988, 1998) have examined fish habitat, populations, and communities relative to livestock grazing. Results of these studies demonstrate that certain factors potentially and dramatically affect conclusions with respect to the effect of ungulate grazing on fish populations. These are (in no order of importance): (1) species of fish (salmonid versus nonsalmonid), (2) temporal and spatial variation, (3) habitat influences, (4) fishery management influences, and (5) influences of natural factors.

As outlined above, most studies of fish-grazing relationships address salmonid species. In the Southwest, cypriniform (minnow and sucker) species have to be separated from trouts in delineating grazing effects. This was especially demonstrated in the Rio de las Vacas with two cypriniform species and several species of trout (Rinne 1988). The temporal, year-to-year variation in fish populations has an important influence on the interpretation of study results and is a critical factor that has not been addressed properly (Platts and Nelson 1988). Tables 1 and 3 suggest a basic problem with grazing and fish interactions studies—there is a tendency not to replicate collection of data in time. Pseudoreplication (Hurlburt 1984) also may become a design problem affecting validity of results and conclusions of study because of the lack of independence of temporal measurements. The lack of replication results only in a snapshot of the status of fish populations that year. Spatial variation is an equal or greater problem in fish-grazing studies. Replication in space of most fish-grazing studies occurred in most of the 30 studies examined (Table 1). However, as discussed above, when present, replication is often arrayed in contiguous, upstream-downstream design (Rinne 1988). Benefits accrued in terms of fish habitat and populations in ungrazed reaches may influence not only reaches immediately downstream, but also noncontiguous downstream reaches.

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Extensive study, principally of salmonids and their habitats, has been conducted (Fausch et al. 1988), but the influence of habitat on fish community structure, density, and biomass has not been properly addressed in fish-grazing studies. Habitat (e.g., gradient, substrate, velocity, channel type) can potentially affect interpretations of study results, and its influences were evident in research efforts at all three southwestern study sites. For example, the influence of stream channel type on fish community structure was evident in the Rio de las Vacas study. Grazed reaches were more than 4 km downstream from ungrazed, excluded reaches of stream and were separated by private lands. Experimental design was, therefore, not only spatially disjunct but included different stream channel types (Rinne 1985; Rosgen 1994). Recent studies of Rio Grande sucker (Calamusso 1996) habitat indicate it occupies lower-gradient (< 3%) reaches of streams—reaches characterized by pool and glide habitat—as present in the downstream, disjunct stream reaches of the Rio de las Vacas (Rinne 1998).

Management of fisheries resources in Region 3 of the FS is currently a critical issue with respect to evaluating the effect of a land management activity such as grazing on fish populations. Fisheries management in Arizona has to address, both temporally and spatially, sport fish and native, nongame species. The Arizona Game and Fish Department's current protocol is to look for opportunities to manage selected watersheds or stream systems for one or the other species groups (Rinne and Janisch 1995). Nevertheless, most stream systems in Arizona contain both native and nonnative species (Stefferud and Rinne 1995). In these cases, interactions of the two groups of species have to be considered when studying azing effects on native fish species inne 1998).

Last, and certainly not least, the influence of natural factors such as geology and historic and current flow regimes of streams must be factored into any grazing-fish study (Platts et al. 1985; Rinne, in press). We need to understand grazing effects in the context of natural factors and their variations and trends. Platts (1991:422)

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stated, "The combined influences of geology, climate, soil, vegetation, and water runoff often create unstable stream conditions even without livestock grazing," and most aquatic systems have been variously modified by nd uses for a long time. According- it is difficult for managers and researchers to separate natural from anthropogenic effects. Because natural stream systems and their fish populations are inherently dynamic, perhaps chaotically so in the arid American Southwest (Minckley and Meffe 1987; Rinne and Stefferud 1996), land use impacts on aquatic habitats and their respective fish populations are often difficult to separate from those that occur naturally.

Research needs and future study design

Because of the lack of peer-reviewed literature containing sound data on grazing-fish relationships, recommendations are needed for future study design, research and land management relationships, and data collection. Several key components are required for a valid, viable, defensible definition of grazing-fish relationships: (1) definition of linkages, (2) cooperative management and rearch, and (3) collection of scientific ita rather than regeneration of reviews and opinions.

Of these, the first is a prerequisite. Currently, abundant knowledge exists in the literature about fish-habitat relationships, especially those of salmonid species (Fausch et al. 1988) and, to a lesser extent, of nonsalmonids. Platts (1991) suggested fish-habitat data are "on solid ground" and presented some possible effects of grazing on riparian attributes that may affect fish habitat (e.g., riparian streambanks, water column, channel) and fish populations. Accordingly, researchers need to evaluate, define, and link what is known about fish habitat requirements and limiting factors to how grazing affects these parameters and, in turn, fish populations. One cautionary note: These linkages or relationships should not be assumed to be simple and linear but rather complex and nonlinear.

Cooperative endeavor

A vital component of grazing-fish studies should include an approach that involves interagency, collaborative research and management (Rinne 1989). The six-year West Fork ungulate study on the Apache Sitgreaves National Forest, now in its sixth year, is one example of such cooperation and collaboration. Forest personnel and the grazing permittee provided the grazing strategies in time and space on this allotment. The Arizona Game and Fish Department has expended significant funds to construct elk-proof and standard livestock fences to facilitate the design. The Rocky Mountain Research Station, which designed the study, collects and analyzes the data. Although the total study is six years, analyses, evaluation, and interpretation of data were conducted at years two and four. Adjustments to management were made at these points to achieve management goals and obtain the most reliable information for future management of riparian and fishery resources.

In 1998 a similar, but greatly enhanced, cooperative effort was organized to address ecosystem management, including fish and grazing relationships, on the upper Verde River. This effort, the Upper Verde River Adaptive Management Program, includes FS management and research, the public (including grazing permittees and private citizen-environmental interests), the Arizona Game and Fish Department, and the U.S. Fish and Wildlife Service. The main objective is to exchange ideas and provide a forum to begin addressing concerns, needs, and constraints of all parties relative to fisheries and grazing management. Basic to the approach is coordination of research and management activities, monitoring and evaluation, and making changes and alterations (if needed) in either, or both, again throughout short (two-year) periods. The more comprehensive and inclusive the cooperation, the more difficult the task becomes because of differing agency policies and mandates. However, if cooperation is effected, the payoff can be large.

Finally, the time has come to remove ourselves from promoting and sustaining the litany about effects of grazing on fishes and to embrace collection of scientifically sound, defensible information that can be used by land managers. Too often, qualitative, nonscientific data are collected (Table 1). In retrospect, the reliability of these data is low; however, their use and incorporation into management and public opinion have

> **...monitoring of land use activities is woefully lacking.**

been too common. At this point, I must emphasize that the above analysis of fish-grazing relationships substantiates only the lack of data and the question of reliability of those data available. It does not, in any way, suggest that grazing has no potential or real effect on fishes.

Monitoring and research

I make a final plea in this effort to delineate and discuss the relationships of grazing and fishes. We must begin to monitor, evaluate, and conduct well-designed research studies of these relationships. Throughout my FS career, I have heard expressed that we need to "monitor our (FS) land management activities;" however, the dollars are not budgeted to do so. Because there is no budget line item for monitoring (as exists for research activity), monitoring of land use activities is woefully lacking. The 1974 National Forest and Rangelands Resources Planning Act states, "Land management planning should insure research on and evaluation of the effects of each management system to the end that they will not produce substantial and permanent impairment of the productivity of the land." Further, the 1978 National Forest and Rangelands Renewable Resources Research Act states that the NFS shall "conduct, support, and cooperate in investigations, experiments, tests, and other activities to obtain, analyze, develop, demonstrate, and disseminate scientific information to protect, manage, and utilize forest and rangeland renewable resources." In other words, the mandate is there, but funding is not. Furthermore, by law, NFS management funds cannot be used for FS research or vice versa.

Paradoxically, monitoring and research both collect data on resources. Indeed, one could readily argue that their objectives are very similar, and their synchronization should be the rule rather than the exception. I suggest that collection of any resource data may feasibly involve both research and monitoring activities. For example, during the past 5 years almost 17,000 individual fish have been collected at 7 sites over the upper 60 km of the Verde River (Stefferud and Rinne 1995; Rinne et al. 1998) with the research objective of testing whether stream hydrograph or nonnative fishes are more important in controlling native fish distribution and abundance (Rinne and Stefferud 1996). After five years, it would be hard to dispute that a database that monitors the fish community in the upper Verde River during that timeframe has not been achieved. That is, both data collection activities, research and monitoring, have been accomplished simultaneously. Similarly, on the Rio de las Vacas, researc on the effects of grazing on fish popt lations began in the mid-1980s. After a half-dozen years, a database was available on fish populations in this upper-elevation montane stream. The same rationale follows for the West Fork monitoring and research study. The key to effecting such collaborative activities lies in intimate, coordinated interaction and synergistic funding by FS management and research.

I finish with two thoughts pertinent to the subject of monitoring and research on fishes and grazing relationships in the Southwest or Region 3 of the FS. The first is that little new data are being collected, and there is continuing reiteration of what is in the literature about fish and grazing relationships. Selective rather than objective comprehension by individuals has dictated management alternatives for the past several decades. We as environmental groups, managers, and researchers need to stop expressing opinions, disputing, and constant- litigating or threatening to and art collecting data from well-designed, defensible research and monitoring activities. Second, as the saying goes, "Without data, one is just another person with an opinion."

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