J. Range Manage.
51:661–664

Viewpoint: Livestock influences on riparian zones and fish habitat: Literature classification

ROYCE E. LARSEN, WILLIAM C. KRUEGER, MELVIN R. GEORGE, MACK R. BARRINGTON, JOHN C. BUCKHOUSE, AND DOUGLAS E. JOHNSON

Authors are natural resources advisor, University of California Cooperative Extension, San Luis Obispo, Calif. 93401; professor, Department of Rangeland Resources, Oregon State University, Corvallis, Ore. 97331; Extension range and pasture specialist, Agronomy and Range Science Department, University of California, Davis, Calif. 95616; research associate, professor, and professor, Department of Rangeland Resources, Oregon State University, Corvallis, Ore 97331.

Abstract

A key was used to classify articles about livestock influences on riparian zones and fish habitat into 3 classes: papers that contained original data, those that were commentary, and reports about methodology such as classification systems, policies, and monitoring criteria. Four hundred and twenty-eight of the total articles were directly related to grazing impacts on riparian zones and fish habitat. Only 89 of these grazing impact articles were classified as experimental, where treatments were replicated and results were statistically valid. This analysis revealed several limitations of riparian grazing studies that included: (1) inadequate description of grazing management practices or treatments, (2) weak study designs, and (3) lack of pre-treatment data. More long-term, replicated treatment studies are needed in the future.

Key Words: riparian areas, grazing impacts, streams, bibliography, experimental design

Livestock impact on riparian areas, stream systems, and fish habitat is a contentious issue throughout the western United States. While there is a wealth of literature that focuses on this issue, citations from a small group of reports are common (e.g., Gunderson 1968; Keller and Burnham 1979; Keller et al. 1979; Duff 1979, 1983; Platts 1979, Platts et al. 1983; Platts and Nelson 1985a, 1985b; Kauffman and Krueger 1984). This is given as general evidence of the widespread and acute impact of livestock on riparian areas and stream systems. Our initial impression of this literature was that there was a great deal of personal opinion and commentary interspersed with a little scientifically valid experimentation. In 1993, we began to review and evaluate the quality of the literature related to the influences of livestock on fish habitat, riparian zones, and streams. More than 1,500 articles were collected and analyzed from 1993 through 1996. These were synthesized and are reported in this paper

Manuscript accepted 14 Oct. 1997.

Resumen

Utilizando un sistema de clasificación, fueron identificados artículos sobre los efectos de la ganadería en zonas ribereñas y el habitat acuático. Las clasificaciones son tres: 1) obras de investigación original (datos originales); 2) obras que son comentarios; 3) informes sobre metodología, tal como los sistemas de clasificación, de reglamento o aspectos legales, y los criterios para controlar el experimento. Cuatro cientos veintiocho del total de los artículos revisados tratan directamente con los impactos a las zonas ribereñas y acuáticas ocasionados por el pastar de ganada. De estas obras, solo ochenta y nueve se podían considerar "experimental," donde se llevaron a cabo en duplicado los tratamientos, dando resultados estadísticamente válidos. Este análisis reveló varias limitaciones de las investigaciones sobre el pastar de ganado en zonas ribereñas: 1) descripciones inadecuades de modas de manejo del pasto o tratamientos, 2) modelos estadísticos inadecuados, y 3) falta de datos "pre-tratamiento." Hacen falta más investigaciones a larga plazo, con reduplicación de los tratamientos.

Methods

Literature was identified using bibliographies, computer literature searches, and routine library research. We attempted to find all literature that related grazing impacts with fish habitat, riparian zones, or stream systems. Sufficient fish habitat literature was acquired only to define key habitat requirements. During the search, literature that related to other riparian parameters, not exclusively related to grazing, was also cataloged. This included literature that described field methods, classification systems, models, monitoring criteria, management policies, and other literature that related riparian zones with their associated stream systems.

Literature citations were entered into the Pro-Cite® bibliographic database. These citations were classified following the key in Figure 1. Levels 1 and 2 were categories that were used to classify the literature. Levels 3, 4, and 5 in the key are keywords for the articles. Level 1 segregated literature into 3 categories:

1 Data—literature containing original data,
2. Commentary—literature classified as commentary,
3. Methods—literature that describes methods, classification systems, policies, etc.

Literature that was classified as data in Level 1 was further classified as experimental, documented case history, observational, abstract or poster at Level 2. Literature was classified experimental if there were 2 or more replications subjected to statistical analysis (i.e., p values, r^2 values, confidence intervals, or variation given). Documented case histories are studies that were not replicated but contained temporal or spatial comparisons or were replicated but were not subjected to statistical analysis. Some photo studies were included as documented case histories if the photos were paired temporal or spatial comparisons. Studies classified as observational reported original data from unreplicated studies and did not present temporal or spatial comparisons, and were not associated with a statistical analysis. Photo studies that were not paired comparisons were included as observational. Abstracts and posters containing original data but lacking enough information to classify as experimental, documented case history or observation were included. Literature that was classified as commentary at Level 1, was further segregated into review, opinion, position or textbook in level 2. The data and commentary classes were further separated using descriptive keywords listed in Level 3: fish, grazing, bird, wildlife, ecology, geomorphology, economics, logging, fire, riparian, recreation, or mining. Literature classified as fish or grazing in level 3, whether it was data or commentary in level 1, was further segregated using the keywords in levels 4 and 5 of the key (Fig. 1).

Results and Discussion

This bibliography consisted of 1,521 articles, with 428 articles that related directly to grazing impacts on riparian zones and fish habitat. These 428 articles included 248 articles that contained original data and 168 classified as commentary. Of those classified as containing data, 89 were experimental, 76 were documented case histories, 66 were based on observations, and 29 were abstracts or posters. Papers were classified as experimental if they were replicated and statistically valid, avoiding pseudoreplication. Pseudo replication has been reviewed by Hurlbert (1984) and Brown and Waller (1986). The use of subsamples from unreplicated treatments as replications in the analysis of variance is a form of pseudo-replication found in the studies reviewed here. The experimentally-based papers, though well replicated and statistically valid, usually lacked pre-treatment data and covered short time frames, often less than 4 years. Of the papers classified as experimental with the keyword grazing, 31 were grazing studies, 21 were water quality studies, 19 were hydrology studies, and 18 were studies of riparian or stream characteristics.

A review of the 428 papers that were related to grazing and riparian zones or fish habitat exposed several problems: (1) inadequate description of grazing management practices or treatments, (2) weak study designs, and (3) lack of pre-treatment data.

Grazing treatments were often described as grazed versus ungrazed, or described so vaguely it was impossible to reconstruct the grazing practices used in the study. To assess and interpret the impacts of grazing treatments or other treatments applied

Fig 1. Key used to classify literature in the bibliography of livestock influences on riparian zones and fish habitat.

Level 1. DATA
Level 2. Experimental, Documented Case History, Observation or Abstract
Level 3. Keywords: fish, grazing, bird, wildlife, ecology, geomorphology, economics, logging, fire, riparian, recreation, mining.

Level 1. COMMENTARY
Level 2. Review, Opinion, Position, Textbook
Level 3. Keywords: fish, grazing, bird, wildlife, ecology, geomorphology, economics, logging, fire, riparian, recreation, mining.

If Level 3 Keyword is *fish* then the following keywords were added in Level 4: temperature, sediment, cover, flow, nutrient, do, spawning, food, benthos, habitat, population, competition, growth, migration.

If Level 3 Keyword is *grazing* then Level 4 is grazing strategies, water quality, hydrologic, or riparian stream communities.

If Level 4 is *grazing strategies* then the following keywords are added at Level 5: grazing management system, distribution, behavior, utilization, exclusion.

If Level 4 is *water quality* then the following keywords are added at level 5: sediment, temp, bacterial, nutrient, protozoa, pathogens.

If Level 4 is *hydrologic* then the following keywords are added at level 5: infiltration, runoff, erosion, protection, compaction, ice.

If Level 4 is *riparian stream communities* then the following keywords are added at level 5: range plant community, morphology, fish habitat, streambank, restoration, fish population, bufferstrip, impact, cover, willows.

Level 1. METHODS (measures, methods, criteria, management, modeling, bibliography, definitions, classification, policy, research).

where livestock are grazing, researchers and managers must be provided with quantitative information about: (1) grazing intensity (stocking rate, utilization, or residual dry matter); (2) frequency of grazing (length of graze periods and rest periods); and (3) season of grazing (related to plant growth stage). Light, moderate, or heavy grazing terminology is inadequate unless accompanied by quantitative measures of grazing intensity. Where impacts on streams or riparian corridors were measured, the number of livestock per linear measure of accessible stream or corridor would be more useful than stocking rate for interpreting grazing impacts (Kauffman et al. 1983).

Inadequate or improper replication of treatments on non-random and non-uniform experimental units weakened the statistical designs in many studies. Platts (1991) reported that most available information on effects of livestock grazing on stream/riparian systems was the product of unreplicated exclosure comparisons. These studies frequently suffer from lack of replication, pseudo-replication, and nonrandom placement of experimental units (Knapp and Matthews 1996). Hurlbert (1984) and Rinne (1985) previously discussed the short comings inherent in exclosure studies.

While unreplicated exclosure comparisons have shown that rest from grazing often improves riparian and fishery values (e.g., Gunderson 1968; Van Velson 1979; Keller and Burnham 1982; Keller et al. 1979; Duff 1979, 1983; Platts et al. 1983; Platts and Nelson 1985a; Stuber 1985; Hubert et al. 1985; Knapp and Matthews 1996), they have not provided management solutions to grazing impacts other than exclusion and lease termination. The only conclusion that can be made from these studies is that whatever the prevailing grazing practice in the study, it adversely affected the riparian/stream system. Without testing alternative grazing regimes natural resource managers never acquire the information that would facilitate riparian improvement while continuing to graze. Instead these comparisons are often the end of investigation, leaving hypotheses unstated and untested and questions unanswered. What has been lacking is the development of hypotheses from observation of these grazed and ungrazed comparisons. Experimentation to test hypotheses developed from exclosure comparisons has been the exception rather than the rule (Buckhouse et. al. 1981, Kauffman et al. 1983, Platts and Nelson 1985a). Platts (1984) recognized the need to conduct research to determine those grazing strategies compatible with each of the riparian/stream habitat types. He stated 8 research questions that needed answers. Our review of this literature suggests that after 14 years we have made little progress toward answering these questions.

Ecosystems rarely provide researchers with uniform experimental units. For example, the "stream segment" is a common experimental unit to which grazing treatments are applied. Because riparian ecosystems are complex and produce stream segments that differ greatly in physical and biological characteristics and response potential, large experimental errors are common. In addition, results from 1 segment of a stream or riparian system may differ from another segment when treated similarly, resulting in no statistically significant differences. Only a carefully designed experiment can minimize these problems.

Small sample size is a common problem in many riparian studies. There is a relationship between sample size and reliability of the estimate for a parameter. In general, an increase in sample size helps reduce the standard error of an estimated parameter and increases the statistical power of comparisons among treatments. A small sample size increases the chances of a Type II error; the finding of no significant difference when a true difference exists. However, an increase in sample size is seldom possible because of time and funding constraints. Consequently, real differences may not be revealed because sampling was inadequate to segregate natural variation from treatment differences. Replicated or multiple location pre-treatment and post-treatment comparisons can help to increase sample size, reduce the chances of a Type II error and improve the scientific credibility of riparian and stream system studies.

Pre-treatment data that describes the size and nature of a watershed, current and historic grazing, and other land use practices in the watershed is crucial to interpret experimental results but are seldom explained. Several studies (e.g., Gunderson 1968; Van Velson 1979; Keller and Burnham 1982; Keller et al. 1979; Duff 1979, 1983; Platts et al. 1983; Platts and Nelson 1985a, 1985b; Stuber 1985; Hubert et al. 1985; Knapp and Matthews 1996) have reported improved fish habitat or fish population parameters in grazing exclosures when compared with adjacent grazed areas. However historic grazing intensity, season of use, and frequency of use prior to construction of the exclosure or exclosures are not adequately quantified for the reader. Consequently, the reader cannot know the nature of the cumulative grazing treatment effects that caused the fishery impairment. If the management objective is to reduce or remove grazing from riparian areas, as Knapp and Matthews (1996) suggested, then we know all that is needed. However, if the objective is to properly manage these lands for a variety of goods, services, and values, then we should understand what caused the impacts before we consider steps to reduce them. Furthermore, if the objective is to contribute to the scientific knowledge base, grazing treatments must be described in specific terms so that other scientists might attempt to duplicate the study and verify results.

Complexities of the interacting physical and biological components in the ecosystem make it very difficult to link effects of management or natural phenomena to changes in fisheries (MacDonald et al. 1991). Cause and effect are often separated in time and space, concealing linkages in a complex series of physical and biological interactions. Consequently, it is often difficult to: 1) clearly link land use or management effects to environmental impacts and 2) separate man caused impacts from those that result from natural phenomena. Discreet uniform experimental units are difficult to identify on the landscape because of naturally occurring biological and physical complexity. Additionally, episodic natural phenomena on instantaneous to geologic time scales cause experimental units to change in ways that cannot be attributed to applied treatments. Monitoring of soil, water table, vegetation and channel morphology over periods exceeding 2 or 3 years may provide the opportunity to objectively evaluate the effects of grazing on riparian ecosystems.

Long-term studies are rare, but they offer the best solution for clarifying linkages between land use and environmental impacts. Long-term studies will allow comparison of treatments and controls over a long period, and under a variety of weather and hydrologic conditions. Well replicated studies on a variety of stream and riparian systems will allow determination of the tolerance of various ecosystems to natural and man caused perturbations. This will allow managers and an informed public to make objective decisions about grazing in riparian areas. It is time for researchers who have a stake in these issues to develop common

strategies and to apply replicated experimental designs in numerous riparian systems throughout the West. It is time for interstate, interagency, and interdisciplinary coordination of research activities. Funding agencies, including USDA and EPA, should embrace and fund long-term studies.

Conclusion

The base of the commonly accepted body of knowledge on livestock influences on riparian zones and fish habitat is made up of many unrefereed, nonexperimental reports. Only a few papers have been the product of the scientific method and can be relied on for an objective evaluation of the management strategy under review. A high percentage of the work we surveyed did not meet our standard of being experimentally or statistically adequate. Often data were reported with no measure of variability or statistical analysis. Review and commentary papers repetitively referred to the same few experiments and case histories to support their points. Unfortunately, regulatory agencies, as well as the general public and sometimes scientists, frequently do not recognize the difference between science and non-science based literature. Many of the opinion papers and nonexperimental reports were cited by others as science.

A few broad generalizations can be gleaned from this review: 1) It is clear that livestock or big game can and do co-exist within sustainable riparian systems. Likewise, ungulates can and sometimes do change riparian vegetation structure in undesirable ways. 2) Vegetation responses are highly site specific. Consequently, every grazing strategy won't work somewhere. There is no formula or template that can be used to guarantee success in all situations. 3) Ecosystems are highly variable in space and time. Most driving forces that change ecosystems seem to result from interactions of factors, and seemingly obvious and simple relationships can be relatively unimportant in directing long-term changes. Therefore, careful evaluation of riparian zone potentials, forces (interacting factors) driving change, desired future vegetation structure, and how ungulates interact with the system should be the foundation of any practical grazing management strategy or restoration effort.

In late 1996, this database was also transferred to ASCII text, WordPerfect® 5.1, Microsoft®Word , and Papyrus® formats. All of these formats are available from Oregon State University Extension Service (Publication EM 8660).

Literature Cited

Brown, M.A. and S.S. Waller. 1986. The impact of experimental design on the application of grazing research results—an exposition. J. Range Manage. 39:197–199.

Buckhouse, J.C., J.M. Skovlin, and R.W. Knight. 1981. Streambank erosion and ungulate grazing relationships. J. Range. Manage. 34:339–340.

Duff, D.A. 1979. Riparian habitat recovery on Big Creek, Rich County, Utah a summary of 8 years of study. p. 91–92. *In:* O.B. Cope (ed.), Proceedings Of the Forum Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, Colo.

Duff, D.A. 1983. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. p. 129–142. *In:* J.W. Menke (ed.). Proc. of the Workshop on Livestock and Wildlife-Fisheries Relationships in the Great Basin. Univ. of Calif. Div. of Agr. Sci, Berkeley, Calif.

Gunderson, D.R. 1968. Floodplain use related to stream morphology and fish populations. J. Wildl. Manage. 32:507–514.

Hubert, W.A., R.P. Lanka, T.A. Wesche, and F. Stabler. 1985. Grazing management influences on two brook trout streams in Wyoming. p. 290–294. *In:* R.R. Johnson et al. (Technical. Coordinator), Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North Amer. Riparian Conf. USDA Forest Serv. Gen. Tech Rep. RM-120.

Hurlbert, S.H. 1984. Pseudo replication and the design of ecological field experiments. Ecol. Monogr. 54:187–211.

Kauffman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications a review. J. Range Manage. 37:430–438.

Kauffman, J.B., W.C. Krueger, and M. Vavra. 1983. Impacts of cattle on streambanks in northeastern Oregon. J. Range Manage. 36:683–685.

Keller, C.R. and K.P. Burnham. 1982. Riparian fencing, grazing, and trout habitat preference on Summit Creek, Idaho. North Amer. J. Fish. Manage. 2:53–59.

Keller, C., L. Anderson, and P. Tappel. 1979. Fish habitat changes in Summit Creek, Idaho after fencing the riparian area. p. 46-52. *In:* O.B. Cope, (ed.), Proceedings Of the Forum— Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, Colo.

Knapp, R.A. and K.R. Matthews. 1996. Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: Impacts and management implications. North Amer. J. Fish. Manage. 16:805–820.

MacDonald, L.E., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. EPA 910/9-91- 001. Univ. of Washington Center for Streamside Studies. Seattle, Wash. 166 p.

Platts, W.S. 1979. Livestock grazing and riparian/stream ecosystems an overview. p. 39–45. *In:* O.B. Cope (ed.), Proceedings of the Forum Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, Colo.

Platts, W.S. 1984. Riparian system/livestock grazing interaction research in the Intermountain West. p. 424–429. *In:* R.E. Warner and K.M. Hendrix (eds.). California Riparian Systems: Ecology, Conservation, and Productive Management. Univ. Calif. Press.

Platts, W.S. 1991. Livestock grazing. p. 389–423. *In:* W.R. Meehan, (ed.), Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. Amer. Fish. Soc. Spec. Publ. 19, Bethesda, Md.

Platts, W.S. and R.L. Nelson. 1985a. Impacts of rest-rotation grazing on stream banks in forested watersheds in Idaho. North Amer. J. Fisheries Manage. 5:547–556.

Platts, W.S. and R.L. Nelson. 1985b. Stream habitat and fisheries response to livestock grazing and instream improvement structures, Big Creek, Utah. J. Soil and Water Cons. 40:374–379.

Platts, W.S., R.L. Nelson, O. Casey, and V. Crispin. 1983. Riparian-stream habitat conditions on Tabor Creek, Nevada, under grazed and ungrazed conditions. p. 162–174. *In:* Western Proceedings: 63rd Annual Conference of the Western Association of Fish and Wildlife Agencies.

Rinne, J.N. 1985. Livestock grazing effects on southwestern streams: A complex research problem. p. 240–247. *In:* R.R. Johnson et al. (Technical Coordinator), Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North Amer. Riparian Conf. USDA Forest Serv. Gen. Tech Rep. RM-120.

Stuber, R.J. 1985. Trout habitat, abundance, and fishing opportunities in fenced vs unfenced riparian habitat along Sheep Creek, Colorado. p. 310–314. *In:* R.R. Johnson et al. (Technical Coordinator), Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North Amer. Riparian Conf. USDA Forest Serv. Gen. Tech Rep. RM-120.

Van Velson, R. 1979. Fish habitat changes in Summit Creek, Idaho after fencing the riparian area. p. 53-55. *In:*O.B. Cope (ed.), Proceedings Of the Forum on Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, Colo.