 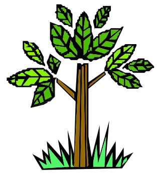   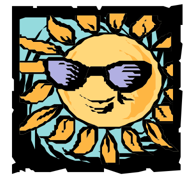

# Water, Grass & Livestock:

## An Annotated Bibliography of Riparian Grazing Publications


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***A Land Stewardship Project publication***

# *Water, Grass & Livestock:*
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# Table of Contents

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**This is a publication of the Land Stewardship Project, a private, nonprofit organization devoted to fostering an ethic of stewardship for farmland, promoting sustainable agriculture and developing sustainable communities.**

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***Water, Grass & Livestock* was edited by Caroline van Schaik. Please call 651-653-0618 or e-mail caroline@landstewardshipproject.org with comments or questions about this publication.**

# I. Preface

Information about the ecology of streams is seldom seen in farm-oriented publications. Similarly, farming concerns are rarely addressed in ecology-oriented journals. Yet many farmers who manage livestock in riparian areas think deeply about the interactions between water, grass, and animals. They *have* to – the unique characteristics of a riparian setting require particular attention. And while creek side pastures are traditionally maligned as grazing acreage, their careful management can offer significant benefits in the way of farm cash flow, herd health, and environmental mitigation.

This is a reference for action by farmers and their colleagues who are determined to farm as though their decisions mattered – financially, yes, as well as ecologically. There are sections on the stream bank, the riparian-influenced landscape beyond, and the influential uplands. Such aspects as sedimentation, insects, forest buffers, pasture systems, and issues unique to the Western United States are addressed. Note that each reference has been listed just once, even though it may well qualify for several sections. Also, while this publication was inspired by the apparent dearth of readily available materials on behalf of riparian grazing, not all notations are unequivocally supportive.

Funding was provided by a USDA/SARE grant, "Training on Grazing and Monitoring Riparian Corridors in Minnesota and Wisconsin," to The Land Stewardship Project. The authors thank Caroline van Schaik (The Land Stewardship Project), and the grant's publications committee of Mary Hanks (Minnesota Department of Agriculture), Helene Murray (Minnesota Institute for Sustainable Agriculture), Laura Paine (University of Wisconsin – Extension), and Joshua Ramisch (formerly, Agricultural Ecosystems Research Group, University of Wisconsin) for their support and guidance. The assistance of Barbara Bellows of Appropriate Technology Transfer for Rural Areas (ATTRA) is especially noted with thanks.

# II. How to use this bibliography

- Use the table of contents to find the section of interest.
- Note that each section is alphabetized by author.
- Scan the **title in bold letters** to get a sense of the content of each piece.
- Glance at the source and note who the article, chapter, or bulletin is geared toward, i.e.: a general audience or a specific science such as hydrology, fisheries, geology, or geomorphology.
- Remember that research is usually highly site- or region-specific and reported results may or may not be applicable to your region or situation.
- Read the annotation. This might be all you want to know, or you might decide you would like to read the entire paper.
- The public library can use the inter-library loan system to help you get a copy of a publication referenced here. Another route is to contact the Minnesota Department of Agriculture/Energy and Sustainable Agriculture Program, 651-296-7673, and ask about having a copy sent to you. This service applies primarily to articles and short bulletins.
- References that can be found in the "Grazing Reference Materials Manual" identify the manual in parenthesis after the original citation.
- A second paragraph in some citations is denoted by ➔ and lists appendices and other aspects of particular note.

# III. Practical, on-the-ground information

Alberta Riparian Habitat Management Program. 2002. Cows and Fish. Accessed at: <http://www.cowsandfish.org/index.html>.

This very detailed web page developed by a multi-agency program in Alberta, Canada includes highly illustrated, easy-to-use checklists for monitoring stream bank health, water quality in riparian areas, biodiversity, and grazing practices. It also provides agency personnel with guidelines for implementing community-based riparian protection programs. Case studies of communities and producers are available through this web site.

Anderson, L. 2000. **Stream banks and cattle crossings**. Acres U.S.A. Feb. pg. 14-15.

A southern Minnesota farmer has found that cattle-grazed stream banks exhibit less erosion than ungrazed stream banks. After a gravel-bedded cattle crossing was installed, the cattle preferred crossing there.

Barnhart, S., D. Morrical, J. Russell, K. Moore, P. Miller, C. Brummer. 1998. **Pasture management guide for livestock producers.** Iowa State University Extension Bulletin PM-1713. Ames, Iowa.

"Water is often the single greatest factor restricting the development of more efficient grazing systems" (pg. 52). On a very basic level there are two options: take the cows to the water or take the water to the cows. To promote healthy streams it is often best to bring the water to the cows. When assessing the capacity of a delivery system, the authors suggest planning for future herd growth, hot summer days when more water is consumed, and lactation periods. If it is impractical to bring the water to the cattle, stream side grazing can work for the farmer *and* the stream if access points are fortified rock or cement blocks (pg. 53).

Bartlett, B. 2000. **Watering systems for grazing livestock.** The Great Lakes Grazing Network and Michigan State University Extension. 24 pp.

"Improving water access along with a managed rotational grazing plan optimizes animal performance, pasture use, and wildlife in riparian areas" (pg. 6).

➔ Many examples of water delivery systems with cost comparisons are included. Some interesting sections are: animal behavior and grazing efficiencies, pasture productivity as it relates to nutrient distribution and management, and alternative pumping system.

Caneff, D. 1993. **Sustaining Land, People, Animals, and Communities.** Midwest Sustainable Agriculture Working Group. Washington, D.C. 26pp.

This treatise on behalf of livestock on the landscape does not directly address riparian grazing except in the context of grazing as a beneficial option in land management decisions. Grazing in general is strongly advocated for financial and environmental reasons. A case for social justice and the role of family-sized farms in a vital rural community is made, and policy recommendations finish up this well-written document.

Clary, W.P. and W.C. Leininger. 2000. **Stubble height as a tool for management of riparian areas.** Journal of Range Management 53(6): 562–573.

Stubble height is discussed as an indicator for monitoring grazing duration in riparian pastures. Authors generally recommend that animals are removed from pastures before forages are grazed to a height of 10 cm or 4 inches. However, they note that at high elevations or when stream banks are dry and stabilized, forages can be grazed as short as 7 cm or 3 inches. Areas that have woody riparian vegetation should not be grazed shorter than 15–20 cm in order to reduce browsing impacts on willows.

Daigle, P. 1996. **Lanes that keep dairy animals high and dry.** Marathon County Land Conservation Dept. Feb. 27. (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997) 7pp.

Properly constructed access lanes will improve cattle access to pasture and water, and keep animals healthier and cleaner. Includes eight options for lanes to the barn or water, one streambed crossing, and an idea for the transition from the lane to the pasture, with figures.

Doll, J. 1996. **Brush management options in western pastures**. Modified version of a paper published in the 1993

Proceedings of the Fertilizer, AgLime & Pest Management Conference, Vol. 32: 269-280. University of Wisconsin-Extension (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997) 10pp.

Cultural, mechanical, and chemical options for control of woody plants are explored with an emphasis on herbicides. A multi-flora rose control program is outlined as an example including the economic cost of each herbicide used.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE (Conservation of Agricultural Resources and Environment).** North American Waterfowl Management Plan, Manitoba, Canada. 2pp.

Manitoba Prairie CARE offers financial incentives and technical assistance to farmers so that they can adapt their farming practices to conserve soil and water resources, and in so doing improve the environment for wildlife. The program is a major component of the North American Waterfowl Management Plan and focuses primarily on rivers and streams.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE fact sheet: forage establishment assistance.** Agdex 123. North American Waterfowl Management Plan, Manitoba, Canada. 2pp.

Manitoba Prairie CARE assists farmers in converting cultivated land from annual crops to forage.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE fact sheet: habitat land lease.** Agdex 127. North American Waterfowl Management Plan, Manitoba, Canada. 2pp.

Guidelines for leases by Manitoba Prairie CARE of wetland areas include the maintenance of perennial cover during the lease term.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE fact sheet: delayed hay cutting.** Agdex 129. North American Waterfowl Management Plan, Manitoba, Canada. 2pp.

Manitoba Prairie CARE makes agreements with farmers to delay hay cutting in wetland areas to after July 15 to enhance and protect cover for nesting. They pay $7.00 (Canadian)/acre for land enrolled in the program.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE fact sheet: planned grazing systems.** Agdex 131. North American Waterfowl Management Plan, Manitoba, Canada. 2pp.

Manitoba Prairie CARE assists farmers in planning grazing systems to allow at least some of the land to remain ungrazed during the waterfowl nesting season.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE fact sheet: habitat land purchase.** Agdex 812. North American Waterfowl Management Plan, Manitoba, Canada. 2pp.

Preferred properties will be purchased from willing landowners and then managed to maintain a healthy vigorous stand of perennial vegetation to serve as nesting cover and wildlife habitat.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE Practical soil and water management choices.** Winnipeg and Brandon, Canada. 17pp.

Six examples of Prairie CARE projects highlight how taking care of the soil and water on a farm greatly assists the bottom line. A glossary gives brief explanations of Prairie Care programs.

Ducks Unlimited Canada. 1991. **Manitoba Prairie CARE Rotation grazing principles.** Winnipeg and Brandon, Canada. 1pp.

Rotational grazing does not need to be complicated to garner results. Farmers can increase their productivity by combining tame forage pasture with native pasture, fertilizing the tame pasture, dividing land into 2 paddocks for each forage type, moving the herd every 2 to three weeks in summer, and consulting their local agronomist with questions.

Gerrish, J. R. 1997. **Grazing system layout and design**. In: Missouri Grazing Manual. University of Missouri, Forage Systems Research Center. (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997) 6pp.

This article describes how to subdivide land into rotational grazing paddocks including options for water access, types of fences and their costs, paddock size and shape, and number of paddocks needed.

Gerrish, J. R., J. R. Brown, P. R. Peterson. 1995. **Impact of grazing cattle on distribution of soil minerals.** In: Missouri Grazing Manual. University of Missouri, Forage Systems Research Center. (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997) 2pp.

Grazing cattle redistribute soil minerals unevenly throughout a pasture, since livestock tend to concentrate (and defecate) in shady areas or around the water source. Placement of water troughs and shade can minimize the development of single-direction nutrient gradients in pastures (pg. 1).

Huel, D. 1998. **Stream bank stewardship: a Saskatchewan riparian project.** Saskatchewan Wetland Conservation Corporation, Agriculture and Agri-Food Canada. Accessed at: <http://www.agr.gc.ca/pfra/land/stream/streamtc.htm>.

This nicely-illustrated guide to riparian area ecology, restoration, and agricultural use clearly describes principles of riparian ecology, with a dedicated eye to viable management options and stewardship goals. Sections offer useful insights but wisely avoid specifics for what rightly are site-specific decisions. They also include case studies of farmers and ranchers who have implemented riparian grazing practices.

➔ The guide includes riparian health checklists.

Huel, D. 2000. **Managing Saskatchewan wetlands: a landowner's guide.** Saskatchewan Wetland Conservation Corporation, Regina, Saskatchewan. 68pp.

Southern Saskatchewan is part of the prairie pothole region where cattle ranching and grain farming are the main agricultural activities. A wetland management plan can protect farms from excessive erosion and provide habitat for wildlife. Rotational grazing, alternative watering sites, converting cropland to forage, rest, and monitoring vegetative changes are all important.

➔ Case studies illustrate specific examples.

Macon, D. 2002. **Grazing for change: range and watershed management success stories in California.** California Cattlemen's Association, Sacramento, CA. Accessed at: http://www.calcattlemen.org/rangewq.htm.

Each of nine California rancher profiles compares the historic management of the land with current management practices, with emphasis placed on tools and innovations used to meet production and stewardship objectives. Ranchers also discuss how they modify practices based on on-going monitoring of their animals and land.

➔ This publication was nearly sold out as of press time, but is likely to be reprinted in early 2003. To order a hard copy, call the California Cattlemen's Association, 916-444-0845.

McCormack, K. 1998. **Water management guide: for livestock production, water quality and wildlife habitat.** Ontario Federation of Anglers and Hunters, Peterborough, Ontario, Canada. 64pp.

Livestock always need water and each farm requires its own unique solution to providing water to its animals. Water can be accessed as a stream, pond, or lake, or through a large selection of pump and tank arrangements. If a natural waterway is utilized, care must be taken to preserve the integrity of stream banks through the use of alternate fencing systems and managed or delayed grazing.

➔ Many new and innovative water systems are covered, along with five case histories of specific farms and appendices of manufacturers and suppliers of pumping equipment.

Natural Resources Conservation Service. 1995. **Vegetated filter area.** Conservation Practice Standard Code 393. 4pp.

A vegetated filter area will remove sediment and suspended solids from concentrated livestock areas, agricultural wastewater, cropland runoff, and forest runoff. Grazing of the filter strips is prohibited.

➔ Some brief notes on plans, specifications, operation, and maintenance are included.

Natural Resources Conservation Service. 1997. **Profitable pastures: a guide to grass, grazing, and good management.** Des Moines, Iowa 20pp.

"Pasture management involves choosing and managing forages, soil fertility, fencing, water development and

distribution, harvesting, resting pastures, and much more" (pg. 2). It is important to consider all of these aspects when planning and implementing a system while also adapting them to your particular farm. Some state or federal money may be available to assist farmers in setting up their system.

Natural Resources Conservation Service. 1998. **Prescribed grazing.** Conservation Practice Standard Code 528A 7pp.

Prescribed grazing as a management technique includes: improving and maintaining the health and vigor of a desired plant community, providing food cover and shelter for domestic animals and wildlife, maintaining grazing animal health and productivity, maintaining and improving water quality and reducing soil erosion, and improving soil condition.

→ Criteria for prescribed grazing are outlined including specific grazing animal (cattle) management practices for specific conditions. Two tables give guidelines for assessing when specific pasture plants have been adequately grazed.

Natural Resources Conservation Service. 1998. **Riparian forest buffer.** Conservation Practice Standard Code 391A. 3pp.

A riparian forest buffer is installed to moderate water temperature, provide a source of detritus to the stream, reduce non-point source pollutants, and improve or restore aquatic/terrestrial habitats. Zone 1 is closest to the stream and provides shade and detritus. Zone 2 extends from zone 1 a minimum distance of 20 ft. Zone 3 is a vegetated filter area as outlined in Standard Code 393.

→ Comments on operation and maintenance are included.

Natural Resources Conservation Service. 1999. **Fish stream improvement.** Conservation Practice Standard Code 395. 4pp.

To improve or restore aquatic ecosystem function within a stream corridor, criteria for stabilizing banks and improving in-stream cover, improving water quality, improving spawning and incubation areas, and eliminating fish migration barriers are covered. These criteria should increase survival and production of fish species, and increase the diversity of fish in streams.

Natural Resources Conservation Service. 1999. **Riparian forest buffer.** Conservation Practice Standard Code 391. 9pp.

Stable areas adjacent to or immediately up-gradient of streams and rivers running through forest should be managed as buffers to protect the stream. These buffers should reduce excess sediment and organic matter entering the stream, create shade, provide a source of detritus, provide room for the watercourse to establish geomorphic stability, and create corridor habitat for wildlife. Updated and expanded from 1998.

→ Criteria for these goals are outlined and sections on operation and maintenance are included.

Reid, E., P. Doris. 1997. **W3 Cold Creek wetlands/woodlands/wildlife.** Ontario Federation of Anglers and Hunters. 24pp.

The goal of The Cold Creek Wetland/Woodland/Wildlife Project is for farmers, anglers and hunters to work together to improve habitat for wildlife and improve farm management operations. Specific practices and technologies available to farmers and landowners include: alternative livestock watering systems, restricted cattle access, mid-level stream crossing, wild turkey habitat enhancement, fish habitat enhancement/erosion control, and sustainable woodlands/hardwood regeneration. Ten farms in the program are highlighted with a farm description, project description, and both the agricultural and environmental benefits expected from the project.

Reid, E., P. Doris. 1997. **W3 Snake River wetlands/woodlands/wildlife.** Ontario Federation of Anglers and Hunters. 27pp.

The goal of The Snake River Wetland/Woodland/Wildlife Project is for farmers, anglers, and hunters to work together to improve habitat for wildlife and improve farm management operations. Up to 100% financial assistance was offered to eligible farmers to demonstrate some of the following techniques: fencing or managing access to the Snake River and its associated wetlands, alternative livestock watering systems, protecting woodlands with fencing, and planting trees and shrubs. Twelve farms are highlighted with a farm description, the W3 project that was installed, and both the agricultural and environmental benefits expected from the project.

Saskatchewan Wetland Conservation Corporation. 1998. **Streambank stewardship: a Saskatchewan riparian project.** SWCC Regina, Saskatchewan, Canada. 43pp.

This publication combines the following four citations and includes a section on how to develop a riparian area management plan (including monitoring) for a ranch or farm.

Saskatchewan Wetland Conservation Corporation. 1998. **Streambank stewardship: farming along the stream.** (Fact Sheet) SWCC Regina, Saskatchewan, Canada. 2pp.

Until recently in much of Saskatchewan, fields were tile drained and cultivation was carried right up to the stream. Today farmers are seeing the value of preserving a healthy riparian area for its sediment trapping and filtration qualities. Buffer strips help to regain healthy streams.

Saskatchewan Wetland Conservation Corporation. 1998. **Streambank stewardship, living on the edge: wildlife along the stream.** (Fact Sheet) SWCC Regina, Saskatchewan, Canada. 2pp.

Many species of birds, fish, mammals, amphibians, and invertebrates use or live in a healthy stream. Protecting riparian habitat involves controlling livestock access, keeping buffer strips intact, and using a rotational grazing system.

Saskatchewan Wetland Conservation Corporation. 1998. **Streambank stewardship: ranching along the stream.** (Fact Sheet) SWCC Regina, Saskatchewan, Canada. 2pp.

Unrestricted grazing can greatly harm stream banks through trampling, excessive vegetation removal, and manure contamination. Carefully controlled streamside grazing can help promote native vegetation and healthy streamside cover to benefit cattle *and* stream health.

Saskatchewan Wetland Conservation Corporation. 1998. **Streambank stewardship: what makes a healthy riparian area?** (Fact Sheet) SWCC Regina, Saskatchewan, Canada. 2pp.

A healthy riparian zone performs many valuable ecological functions. A degraded ecosystem has reduced or seasonal flow, shallow rooted vegetation with low productivity, a lack of shade, excessive down-cutting, a wide shallow channel, exposed soil on stream banks, and undesirable plant species. Protecting and conserving healthy riparian areas will only be the result of careful management.

Shaeffer, C. C., R. D. Mathison, N. P. Martin, D. L. Rabas, H. J. Ford, D. R. Swanson. 1993. **Forage legumes: clovers, birdsfoot trefoil, cicer milkvetch, crownvetch, sainfoin and alfalfa.** Station Bulletin 597-1993, Minnesota Agricultural Experiment Station, University of Minnesota, St. Paul MN (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997). 40pp.

This booklet covers how to identify perennial legumes and then devotes one page per legume to give a brief history of the plant, its adaptation, and current use. Color photos are included. Finally, the how-to's of planting and growing legumes are covered, along with hay and silage management and grazing management.

Undersander, D., B. Albert, P. Porter, A. Crossley, N. Martin. 1993. **Pastures for profit: a guide to rotational grazing.** University of Wisconsin Extension and Minnesota Extension Service, Cooperative Extension, Publication A3529, Madison, Wisconsin.

Many pastures produce poorly because they are continuously grazed. In contrast, rotational grazing allows significant rest of 30 days or more for most pastures which in turn causes more stable production, greater yield, higher quality forage, decreased weed and erosion problems, and more uniform soil fertility levels. Economic savings are realized because start-up costs are less and rotational grazing reduces spending on equipment, fertilizer, pesticides, labor, and veterinary services.

➔ Sections on improving pasture productivity, animal needs and grazing, how to set up a rotational grazing system, fencing, troubleshooting problems, and three example farms are included.

Undersander, D., D. Smith, K. Kelling, J. Doll, G. Worf, J. Wedberg, J. Peters, P. Hoffman, R. Shaver. 1992. **Red clover**

**establishment, management, and utilization.** University of Wisconsin-Extension, Publication A3492. (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997)[out of print but available on the web at http://www.uwex.edu/ces/pubs/agcat.html]. 13pp

Red clover thrives in wet soils and "the yield is higher than other forage legumes except alfalfa" (pg.1).

→ Variety selection, seed establishment, management for production, soil needs, and weed management, are covered, along with a section each on diseases and insects that affect red clover (color pictures included).

Undersander, D., L. Greub, R. Leep, P. Beuselinck, J.Wedberg, D. Smith, K. Kellog, J. Doll, D. Cosgrove, C. Grau, S. Peterson, M. Wipfli, J. English. 1993. **Birdsfoot trefoil for grazing and harvesting forage**. North Central Regional Extension Publication 474. (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997). 15pp

Birdsfoot trefoil grows well in poorly drained, acidic soils where alfalfa production is difficult (pg. 1). Animal performance on trefoil is excellent when compared to unimproved grass and improved grass plus NPK (pg. 7). Trefoil is better used for rotationally grazed pastures than for hay since its yields will decline under continuous harvesting, and baling is very time sensitive.

→ Variety selection, seed mixtures, establishment, herbicide options, fertilizer needs, weed management techniques, diseases, and common insect pests are also covered.

Undersander, D. and B. Pillsbury 1999. **Grazing streamside pastures.** Cooperative Extension of the University of Wisconsin Publication #A3699 16pp.

Healthy streams support the health of Wisconsin farms. This booklet covers paddock layout, stream crossings, watering systems, management during freezing and thawing, and when to allow cattle into streamside pastures.

→ There is also a two-page section on stream attributes.

USDA Soil Conservation Service. 1993. **Grazing lands conservation initiative.** 2pp.

Healthy grazing lands provide habitat to animals, good water, recreational opportunities, and economic and social stability. The Grazing Lands Conservation Initiative is a voluntary program for landowners. It is run by a consortium of farming and ranching groups to help enhance and preserve rangeland.

University of Wisconsin Agronomy Department. 1991. **Forage mixtures for Wisconsin**. Agronomy Advice, F.C. 12.9.1 (Dec.1991) (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997). 2pp.

Specific legumes and grasses are recommended for well drained, less well drained, and poorly drained soils. Options for, "seeding into existing sod and seeding forage mixtures into tilled or sod-killed fields," are outlined (pg. 2).

University of Wisconsin-Extension. 1995. **Weed and brush control in grass pastures**. pg. 20-24 from: UWEX Bulletin a1981, 1995 edition, Forage and small grain pest management in Wisconsin. (Grazing Reference Materials Manual. Cooperative Extension Division of Wisconsin-Extension, College of Agriculture and Life Sciences, University of Wisconsin, Madison. Revised January 1997)

No-till pasture renovation with herbicides is considered on highly erodible slopes in Wisconsin (pg. 24).

→ Some herbicides are recommended.

University of Wisconsin-Madison College of Agriculture and Life Sciences. 1998. **Over-wintering dairy cattle: manure management issues.** Research Brief #27. The Center for Integrated Agricultural Systems (CIAS), Madison, Wisconsin (also available at http://www.wisc.edu/cias/pubs/resbrief/027.html). 2pp.

Thirty-three management intensive rotational grazing dairy farms in Wisconsin were studied to determine the destination of nutrients, organic matter, and biological components in dairy cattle over-wintering areas. There were three basic management approaches used by farmers in the study: rotation through paddocks, sacrifice paddocks, and bedded packs. In all three situations, wastes produced could be controlled and managed to

enhance pasture fertility, and waste could be kept out of the water cycle.

University of Wisconsin-Madison College of Agriculture and Life Sciences. 1998. **Over-wintering dairy cattle: animal health issues.** Research Brief #28. The Center For Integrated Agricultural Systems (CIAS), Madison, Wisconsin. (also available at http://www.wisc.edu/cias/pubs/resbrief/028.html). 2pp.

With careful management, dairy cattle can stay outside through the Wisconsin winter. Care must be taken to prevent frostbitten teats, provide adequate nutrition, keep animals clean, and provide a windbreak.

White, R. J. and O. M. Brynildson. 1967. **Guidelines for management of trout stream habitat in Wisconsin.** Wisconsin Department of Natural Resources, Technical Bulletin 39. Madison Wisconsin. 65pp.

Reed canary grass is an excellent choice to reduce streamside erosion in streams wider than four feet. In smaller streams, sedges should be used, while bluegrass, shrubs, and trees should always be avoided. Most streams will heal themselves with minimal intervention from land use managers.

➔ This extensive publication covers vegetation, in-stream alterations, spawning grounds, and flood control, with an emphasis on the natural and managed physical stream attributes that influence trout. Pages 11 and 12 cover measures to improve and protect stream vegetation, including many pictures of streams before and after treatments. Some construction projects are explained in detail and with excellent graphics, should it be deemed necessary to undertake them. Appendix A provides an index of commonly used physical and hydrologic terms.

# IV. The Stream Bank

## a. Bank erosion and vegetation

Beeson, C.E., P. F. Doyle. 1995**. Comparison of bank erosion at vegetated and non-vegetated channel bends.** Water Resources Bulletin 31:983-990.

Effects of riparian vegetation on bank erosion were studied on 748 bends of typical streams in British Columbia. "Major bank erosion was 30 times more prevalent on non-vegetated bends as on vegetated bends" (pg. 983). All landowners, public and private, should consider vegetating stream banks as a high priority in their conservation plans.

Buckhouse, J. C., J. M.. Slovlin, R. W. Knight. 1981. **Streambank erosion and ungulate grazing relationships**. Journal of Range Management 34:339-340.

Replications of season-long, deferred rotation, rest rotation, and no grazing treatments were tested on 19 different streamside areas at a stocking rate of 3.2 ha per animal unit month. "Most erosion occurred during wintering periods [and] it appears that high runoff and occasional ice flows are the most significant factors in bank cutting on this stream" (pg. 339). Grazing was not found to be a significant cause of bank erosion.

Cohen, P. J., P. R. Saunders, W. W. Budd, F. R. Steiner. 1987. **Stream corridor management in the Pacific Northwest: II. Management strategies.** Environmental Management 11:599-605.

Eight strategies are recommended. The second dictates that livestock should be fenced off stream banks to prevent fecal contamination and high water temperatures as a result of less streamside cover. If animals are allowed access, a concrete ramp should be built and care should be taken to keep them on the ramp while watering.

Dunaway, D., S. R. Swanson, J. Wendel, W. Clary. 1994**. The effects of herbaceous plant communities and soil textures on particle erosion of alluvial stream banks.** Geomorphology 9:47-56.

Seventy-one samples from five stream banks were tested to measure the influence of herbaceous plant communities and sandy loam, loam, and clay loam soils, on particle erosion rates (pg. 47). Increased percent clay was positively correlated with increased erosion of soils, while increased root volume was negatively correlated with erosion. Many studies look at soils or plants to determine erodability when they should be looking at both factors in combination.

Heede, B. H. 1980. **Stream dynamics: an overview for land managers.** General Technical Report Rm-72. Fort Collins, Colorado. 26pp.

To manage streambank areas, owners and managers must understand how a stream behaves and what causes that behavior. Water flow and sediment transport leading to alignment, shape or profile changes are outlined. Factors influencing bank stability are covered on page 18. Generally banks with higher clay content and healthy vegetation are more stable. Implementing a long-term, broad-based monitoring regime is the best way to gain additional knowledge about stream behavior.

Hunt, R. L. 1979. **Removal of woody streambank vegetation to improve trout habitat.** Wisconsin Department of Natural Resources, Technical Bulletin No. 115. 37pp.

"Portions of three small Class I trout streams were selected to evaluate the impact of streamside brush removal on trout habitat, trout populations, and the sport fishery" (pg. 4). Because of unusually low stream flow, the results of this experiment varied greatly. Only Spring Creek saw an increase in trout populations because of more stable discharge, greatly increased amounts of aquatic plants, greater scouring and deepening of the stream, and continued good recruitment of age-0 stock (pg. 28). More research should be conducted on the effects of woody plant removal along trout streams, with particular attention to flow regime, in-stream plants, water temperatures, and percent of woody plants removed.

Hunt, R. L. 1985. **A follow-up assessment of removing woody streambank vegetation along two Wisconsin streams.** Wisconsin Department of Natural Resources, Research Report 137, Madison, Wisconsin. 16pp.

It was hypothesized that removing woody vegetation along a stream would allow more grasses to grow, thereby stabilizing the stream bank and supporting an improved fish habitat. In two of three study streams, increased populations of trout were observed as a direct result of the treatment. The third stream exhibited improved trout habitat but no increase in trout populations. Future trout management objectives should include woody vegetation removal, provided that summer water temperatures are found to be suitable.

Karr, J. R. and I. J. Schlosser. 1977. **Impact of near stream vegetation and stream morphology on water quality and stream biota.** USEPA Ecological Research Series EPA-600/3-77/079, Athens, Georgia.

Many attempts to control non-point source pollutants use the Universal Soil Loss Equation (USLE) to measure erosion. But the USLE considered inadequate. This report reviews pertinent literature to come up with a better "understanding of the link between terrestrial and aquatic systems and the effect of stream morphology on the dynamics of sediment transport and quality of the stream biota" (pg. V). Significant improvements in water and biological quality of streams can result from better management of stream bank vegetation.

Kauffman, J. B., W. C. Krueger, M. Vavra. 1983. **Impacts of cattle on stream banks in Northeastern Oregon**. Journal of Range Management 36:683-685.

"Stream bank loss, disturbance, and undercutting were compared between grazing treatments, vegetation type and stream meander position" (pg. 683 abstract). Greater stream bank erosion occurred in grazed areas. Measuring the intensity of use with the number of animals per length of stream bank rather than per unit area may be a better method to estimate the grazing capacity of riparian areas.

Minnesota Planning. 1999. **To what extent are surface waters affected by or at risk from allowing pastured animals access to surface waters?** General Environmental Impact Statement in Agriculture. G87-G99.

Overgrazing can reduce vegetative cover and infiltration, compact the soil, and increase runoff, erosion and nutrient sediment yield. Although some studies indicate that low or moderate grazing has less significant negative effects, and may have some positive effects, little information is available about effects to riparian ecosystems of the upper Midwest. Studies of sediment delivery rates, nutrient loading, and pathogen transport in relation to grazing are most needed.

Murgatroyd, A. L., J. L. Ternan. 1983. **The impact of afforestation on stream bank erosion and channel form.** Earth Surface Processes and Landforms 8:357-369

Fifty years after a streambank was planted with Sitka spruce, it shows more active bank erosion than nearby unforested (meadow) reaches. The channel width increased and sinuosity decreased as a result of active bank erosion in the forest. This occurs because the forest suppresses the protective thick grass turf that grows in nearby meadows. Log jams also contribute to enhanced erosion.

Paine, L. 1997. **How does management intensive grazing affect stream ecology, water quality?** Sustainable Agriculture Magazine 1pp.

A 2-3 year study is being conducted on trout streams on 19 southwest Wisconsin farms, comparing streambank characteristics between ungrazed vegetative filter strips, rotationally grazed pasture, and continuously grazed riparian areas. After the first season, results indicate that whole watershed health has a greater affect on a streambank than the local streambank conditions.

Platts, W. S., K. A. Gebhardt, W. L. Jackson. 1985. **The effects of large storm events on basin-range riparian stream habitats.** Pp 30-34. In Riparian Ecosystems and their management: reconciling conflicting uses. R. R. Johnson, C. D. Ziebel, D. R. Patton, P. F. Folliott, and R. H. Hamre (eds.) Proceedings of the First North American Riparian Conference, U.S. Forest Service General Technical Report Rm-120.

Grazed stream banks exhibited greater erosion effects after large storm events compared to ungrazed stream banks. Grazed stream banks tend to become more broad and shallow when they erode, causing trout populations to decline.

Smith, M. A., J. L. Dodd, Q. D. Skinner, J. D. Rodgers. 1993. **Dynamics of vegetation along and adjacent to an ephemeral channel.** Journal of Range Management 46:56-64.

Above- and below-ground biomass was measured on an ephemeral stream "to evaluate the potential for controlled livestock grazing to improve channel condition for base flow augmentation" (pg. 56). With a stocking rate of 0.33 animal unit months/ha by 30 cow/calf pairs, perennial forage was utilized 25-50% (pg. 57). Above-ground biomass was less abundant on middle and low stream banks while below-ground biomass was not affected by grazing. This study concludes that moderate grazing does not detrimentally affect vegetation.

Swanson, W. and M. Myers. 1994. **Streams, geomorphology, riparian vegetation, livestock feedback loops; thoughts for riparian grazing management by objectives.** Pp 254-264. In Effects of human induced change on hydrologic systems. R. A. Marston and V. R. Hasfurther (eds.). American Water Resources Association.

To improve streambank vegetation through proper grazing management, the riparian zone must be monitored. To set site specific objectives, one must ask, "how will the vegetation change the stream and how will the stream change the vegetation?" (pg. 255). Then ask how cattle will influence that change. By combining interdisciplinary knowledge, skills, and abilities, farmers and resource managers can answer riparian ecosystem questions.

Trimble, S. W. 1994**. Erosional effects of cattle on stream banks in Tennessee, USA.** Earth Surface Processes and Landforms 19:451-464.

A 5- to- 8- year controlled experiment on Jenkins Creek in Tennessee investigated the morphological differences between a grazed and ungrazed streambank. The increased erosion rate for grazed compared to ungrazed stream banks is about 0.04$m^3$of soil/meter of streambank/year during the period of the study. Scour rates were not affected by the presence of cattle, showing in this case that woody vegetation did not increase resistance to scour. Any long-term extrapolations of this work should be carried out with caution.

Trimble, S. W. and A. C. Mendel. 1995. **The cow as a geomorphic agent - a critical review.** Geomorphology 13:233-253.

Cows influence soil characteristics of uplands as well as riparian areas and have a greater impact than other hoofed animals in riparian areas. Grazing hoof action and a tendency to visit water often cause increased erosion. Additional long-term, carefully framed studies of cow effects on geomorphology should be conducted to learn more about the impact of this ubiquitous animal on different ecosystems.

Zimmerman, R. C., J. C. Goodlett, G. H. Comer. 1967. **The influence of vegetation on channel form of small streams.** International Association of Scientific Hydrology Publication. 75:255-275.

In the small streams in the Sleepers River Basin of Vermont, channels are generally wide in the forest and narrow in sod. Upstream of the 0.2 to 0.8 square mile drainage, width of the stream does not increase and flow is generally underground. Downstream of the drainage area, widths of streams will increase but channel form is highly variable and dependent upon streamside vegetation (pg. 255). Vegetation alters the roughness and sheer strength of bed and banks, whereas events such as wind throw or frost heaving greatly affect channel width (pg. 255).

## b. Sediment in the stream

Ellis, M. M. 1936. **Erosion silt as a factor in aquatic environments**. Ecology 17:29-42.

Seven hundred stations on streams of the Mississippi-Ohio-Missouri watershed(s) were studied (i.e. Zumbro and Root rivers of Minnesota and St. Croix and Chippewa rivers of Wisconsin). Silt load was determined by passing colored light through each water sample. Excess erosion silt altered these aquatic environments by screening out light, changing heat radiation, blanketing stream bottoms, and by retaining organic material (pg. 41).

Fairchild, J. F., T. Boyle, W. R. English, and C. Rabeni. 1987. **Effects of sediment and contaminated sediment on structural and functional components of experimental stream ecosystems.** Water, Air, and Soil Pollution 36:271-293.

Low concentrations of clean and contaminated sediments were released into experimental streams at the National Fisheries Containment Research Center. Both treatments were detrimental to stream organisms; the contaminated sediments caused the greatest destruction.

Owens, L. B., W. M. Edwards, R. W. Van Keuren. 1983. **Surface runoff water quality comparisons between unimproved pasture and woodland**. Journal of Environmental Quality 12:518-522.

Many sources are advising farmers to fence cattle away from streams flowing through pastures. In this study, a spring calving herd of 22 Charolais beef cows grazed from May to October on a 25- ha pasture with a stream (shade was available away from the stream and the pasture was unimproved). "A 17.7 ha wooded watershed that contained no pastured areas and received no agricultural chemical inputs, had concentrations of chemical parameters in surface discharge that were greater than or equal to those from the unimproved pasture during the grazing period" (pg. 518). Although sediment loss was greater from the grazed streambank, it was within acceptable limits and there was no measurable change in water quality over a three-year summer grazing regimen.

Waters, T. F. 1995. **Sediment in streams: sources, biological effects, and control.** American Fisheries Society Monograph 7. American Fisheries Society, Bethesda, Maryland. 251pp.

Agriculture is by far the most important source of pollution, in the form of sediment, afflicting streams. Grazing animals (like cattle) cause the channel to become wider and shallower, the streambank to slump and eventually fall off into the water, and increased deposition. This affects invertebrates, fish, and fish habitat in a myriad of ways that need more and extensive study. The primary prevention of excess sedimentation is to fence cattle out of riparian areas, although other methods that allow limited grazing are becoming popular.

Wood, P. J. and Patrick D. Armitage. 1997. **Biological effects of fine sediment in the lotic environment**. Environmental Management 21:203-217.

Many land uses, including agriculture, result in increased sediment deposits in waterways. Impacts to biota, primary producers, benthic macro-invertebrates, and fish are outlined. The authors emphasize using a holistic approach to prevent stream siltation.

## c. Fish and insects in the stream

Kownacki, A. 1983. **Stream ecosystems in mountain grassland (West Carpathians) 8. Benthic invertebrates**. Acta Hydrobiologia 24:375-390.

To determine the dependences between the intensification of sheep grazing and the communities of benthic invertebrates in streams, samples were taken in three places on a stream in Poland. The results were difficult to interpret, but it appears that some invertebrates thrive in sheep-polluted water before their overall numbers decrease significantly. Increases in deforestation in the region have also caused changes in stream invertebrate populations.

Larsen, R.E., W.C. Krueger, M.R. George, M.R. Barrington, J.C. Buckhouse, and D.A. Johnson. 1998. **Viewpoint: livestock influences on riparian zones and fish habitat: Literature classification.** Journal of Range Management 51(6): 661–664.

A detailed review of 428 articles on grazing impacts on riparian zones and fish habitat was conducted. This

review revealed that many studies lacked good descriptions of grazing management practices, had weak research designs, or lacked baseline information for valid analyses of impacts. The authors recommend that more long-term, replicated treatment studies be conducted.

Lemly, D. A. 1982. **Modification of benthic insect communities in polluted streams: combined effects of sedimentation and nutrient enrichment.** Hydrobiologia 87:229-245.

The benthic insect community of a southern Appalachian trout stream was monitored for eight months. The section of the stream receiving nutrient runoff from pastured livestock showed only slightly elevated levels of nitrate, phosphate, and sediments, but the biggest effect to insects was the result of increased sedimentation. Particles appear to become stuck to body surfaces and respiratory structures as a function of wax and mucus secretions or surface electrical properties. Data indicate that the combined effects of nutrient enrichment and sedimentation have a greater detrimental effect on these insects than one pollutant acting alone.

Lyons, J., B. M. Weigel, L. K. Paine, D. J. Undersander. 2000. **Influence of intensive rotational grazing on bank erosion, fish habitat quality, and fish communities in Southwestern Wisconsin trout streams.** Journal of Soil and Water Conservation. 55(3):271-276. 12pp.

Farmers are not inclined to spend money or time to put land into riparian buffer strips if they will not be able to use these areas in the future. This study of 23 trout stream reaches in southwestern Wisconsin found that careful, intensive rotational grazing (IRG) including buffer strips had a positive impact on bank erosion and fine substrate in the channel. "Data collected included percent bank erosion, fish habitat quality, trout abundance, and index of biotic integrity of the fish community" (pg. 3).

Miller, T. 1997. **Can trout and cows coexist?** Natural Resources Report. 8 (3): 4-5.

This is a brief article after the first of two years' research by Wisconsin scientists interested in the interactions between biotic and farming systems, especially rotational grazing. See Weigel et al. 2000 in this section for results from the full project.

Modde, T., H. G. Drews, M. A. Rumble. 1986. **Effects of watershed alteration on the brook trout population of a small Black Hills stream.** Great Basin Naturalist 46:39-45.

The effects of clear cutting, pond dredging, and intermittent livestock grazing were studied. Water quality variables thought to affect trout were measured at three-week intervals during the spring and summer of 1981and 1982. Variables measured included total hardness, alkalinity, dissolved oxygen, pH, conductivity, turbidity, total P, N, and fecal coliform bacteria. Brook trout were found to be tolerant to changes in the water medium and are therefore poor indicators of moderate alterations in water quality (pg. 44), although they are sensitive to *physical* disruptions within streams.

Niesiolowski, S. 1983. **Stream ecosystems in mountain grassland (West Carpathians) 10. *Simuliidae* and *Empididae* (Diptera)**. Acta Hydrobiologia 24:399-404.

The number of larvae and pupae of *Simuliidae* and *Hemerodromiinae* decreased in a stream near grazing sheep in Poland.

Peterson, A. M. 1993. **Effects of electric transmission rights-of-way on trout in forested headwater streams in New York.** North American Journal of Fisheries Management 13:581-585.

To make electric transmission rights-of-way, the area must be cleared of large trees. If this is done carefully, and stream temperatures do not rise significantly, increased sunshine encourages dense streambank vegetation, which shades the stream and provides better trout habitat.

Platts, W. S. 1991. **Livestock grazing. Influences of forest and rangeland management on salmonid fishes and their habitats**. American Fisheries Society Special Publication 19:389-423.

Public rangelands have been managed without much care to the health of fish habitat. As a result, the majority of grazed streams show less fish cover, more silt, higher temperatures, and greater stream bank erosion than ungrazed streams. Current evidence supports eliminating grazing along stream banks by fencing cattle and sheep out of riparian areas. As this solution is costly and politically difficult, more interdisciplinary research is needed to come up with viable solutions that will benefit ranchers as well as stream ecosystems.

➔ A list of research needs (in question form) is included.

Quinn, J. M., R. J. Davies-Colley, C. W. Hickey, M. L. Vikers, P. A. Ryan. 1992. **1. Effects of clay discharges on streams 2. Benthic invertebrates.** Hydrobiologia 248(3):235-247.

Six streams on the West Coast of New Zealand were measured for water quality, sediment characteristics, and benthos, upstream and 0.3 to 2km downstream, of placer gold mines. As these mines add only sediment, and not nutrients or toxic agri-chemicals, they are ideal for studying the effects of sediment alone. Impacts to invertebrates were found at seven to 23 NTU (a measure of turbidity). Density of invertebrates provided a more sensitive indicator than did taxonomic richness of the impact of suspended solids (pg. 242). Also, “changes in total invertebrate density provide a better indicator of sediment pollution than changes in density of a particular species” (pg. 242). Governments should allow up to five NTU to prevent substantial impacts to stream invertebrate communities in New Zealand.

Quinn, J. M., B. Williamson, K. Smith, M. Vickers. 1992. **1. Effects of riparian grazing and channelization on streams in Southland, New Zealand 2. Benthic invertebrates**. New Zealand Journal of Marine and Freshwater Resources 26:259-273.

The effects of riparian grazing and channelization were studied on four catchments draining Mt. Hamilton and two others draining land in Southland. As stream size increases, effects of grazing to stream biota increase. It is increased light, not nutrients, that are responsible for higher periphyton mass in open reaches (pg 269). Shading by riparian vegetation is the number one factor that decides how healthy the stream ecosystem is. Cattle and sheep should be fenced out of stream reaches to protect shady streamside vegetation.

Rabeni, C. F., M. A. Smale. 1995. **Effects of siltation on stream fishes and the potential mitigating role of the buffering riparian zone.** Hydrobiologia 303:211-219.

Two studies found that, “community responses to siltation were at best poorly described by common structural indices such as diversity and species richness” (pg. 216). Siltation predictably affects fish, and it is important that any buffer strip to be built effectively addresses siltation issues. Finally, even if other areas of the watershed are managed to help reduce erosion, these practices will be ineffectual without good riparian conditions (pg. 218).

Reed, J. L., I. C. Campbell, P. C. E. Bailey. 1994. **The relationship between invertebrate assemblages and available food at forest and pasture sites in three southeastern Australian streams.** Freshwater Biology 32:641-650.

Biomass of shredder and grazer invertebrate assemblages was compared in streams bordered by pasture and forest. Biomass of shredders was significantly higher, and that of grazers significantly lower, at forest than pasture sites. Inconsistent results indicated that species numbers are poor indicators of environmental change. Instead, levels of primary and secondary production could be more helpful.

Strand, M. and R. W. Merritt. 1999. **Impacts of livestock grazing activities on stream insect communities and the riverine environment**. American Entomologist 45:13-29.

Beginning with a brief analysis of the differences between cattle and bison behavior around streams, this article explains that filterer to gatherer (insect) ratios reflect the higher amounts of particulates affecting cattle-grazed streams. Michigan’s Carlson Creek provides an example of stream bank restoration that has been successful by excluding cattle (pg. 20).

Thorn W. C., C. S. Anderson, W. E. Lorenzen, D. L. Hendrickson,, and J. W. Wagner. 1997. **A review of trout management in southern Minnesota streams**. North American Journal of Fisheries Management 17:860-872.

It is estimated that by 1900, native brook trout populations were very low or non-existent in southeastern Minnesota. Through acquisition of public access, a brook trout decision key formulated by the DNR, and habitat improvement, brook trout and brown trout populations have increased since then. The DNR recommends monitoring of habitat variables and trout abundance to assess stream health.

➔ Three appendices outline case histories of specific creeks, watershed management practices, and evaluations by a range of authors.

Weigel, B.M., J. Lyons, L.K. Paine, S.I. Dodson, D.J. Undersander. 2000. **Using stream macro-invertebrates to**

**compare riparian land use practices on cattle farms in southwestern Wisconsin.** Journal of Freshwater Ecology. 15(1): 93-106.

Two years of research along four differently managed stream stretches found less macro-invertebrate response to local riparian conditions than to watershed influences. Macro-invertebrate and sedimentation date were collected from four streams in each of the following land use categories: continuously grazed pastures, intensive rotationally grazed pastures, undisturbed grassy vegetative buffer strips, and undisturbed woody buffer strips. Researchers note "the importance of accounting for inherent stream variability in comparative analyses of multiple streams" (pg. 103).

## d. Channel morphology

Beschta, R. L. and W. S. Platts. 1986**. Morphological features of small streams: significance and function.** Water Resources Bulletin 22:369-379.

Now that more interest is being paid to small streams and how to manage them, a few stream factors should be considered before a conservation plan is put together. These factors are stream energy and channel morphology (including an assessment of pools, riffles, bed material, and channel banks). Management practices should aim to restore and retain native features, although often more study is needed to assess what these features are.

Karr, J. R. and I. J. Schlosser. 1978. **Water resources and the land-water interface.** Science 201:229-234.

Some responses to stream degradation, such as channelization and dredging, serve to degrade the stream further. These stream systems involve a complex interplay of many factors. Streams in agricultural watersheds must be managed with an interdisciplinary approach that looks at impacts to stream vegetation, temperature, channel morphology, and stream biota.

Lyons, J., L. Wang, T. Simonson. 1996. **Development and validation of an index of biotic integrity for coldwater streams in Wisconsin**. North American Journal of Fisheries Management 16:241-256.

The index of biotic integrity (IBI) for coldwater streams measures five metrics and is appropriate for streams whose maximum daily mean water temperature is usually less than 22 C$^{E}$. Since warm water streams support more kinds of fish than coldwater streams, it is important to measure health of a stream through biotic integrity rather than biotic diversity (pg. 253). The IBI can probably be put to good use in nearby states but may have to be altered to suit different bioregions.

Menzel, B. W., J. B. Barnum, L. M. Antosch. 1984. **Ecological alterations of Iowa prairie-agricultural streams.** Iowa State Journal of Research 59:5-30.

In 1979 and 1980, ten headwater streams of the Cedar River basin were surveyed for water quality, habitat structure, and macro-invertebrate and fish communities (pg. 6). These streams were found to carry increased sediment load, perhaps carry added phosphorus and nitrogen, exhibit more incidences of flooding, contain a large amount of algae, have small in-stream animal populations which are dominated by collectors and scrapers, and support less sport fish and more rough fish species, than indicated by historical record. Best management practices suggested by other authors are recommended.

Myers, T. and S. Swanson. 1994. **Grazing effects on pool forming features in central Nevada.** Pp 235-244. In Effects of human induced changes in hydrologic systems. R. A. Marston and V. R. Hasfurther (eds.). American Water Resources Association.

The effects of deferred rotation grazing and recreational roads on pool formation and quality was studied on three streams. The ungrazed stream improved by narrowing the undercuts in comparison to the grazed streams. All streams exhibited equal pool formation, possibly due to similar underlying geology. Some evidence suggests that vegetation management improves pool quality, although managers must be cautious as, "substantial improvement in stream morphology may lag significantly behind vegetative expression" (pg. 242).

Resh, V. H., A. V. Brown, A. P. Covich, M. E. Gurtz, H. W. Li, G. W. Minshall, S. R. Reice, A. L. Sheldon, J. B. Wallace, R. C. Wissmar. 1988. **The role of disturbance in stream ecology.** Journal of the North American Benthological Society 7:433-455.

Disturbance is the dominant organizing factor in stream ecology (pg. 450). Disturbance is defined as, "any relatively discrete event in time that is characterized by a frequency, intensity, and severity outside a predictable range, and that disrupts ecosystem, community, or population structure and changes resources or the physical environment" (pg. 433).

➔ Examples from different areas of the United States point out the relative importance of agricultural and other sources of disturbance. A method is proposed to foresee how a specific disturbance will affect stream dynamics, and the authors include a list of 10 suggestions for further research on this topic.

## e. Other stream characteristics

Greb, S. R. and D. J. Graczyk. 1993. **Dissolved oxygen characteristics of Wisconsin streams.** Water Science and Technology 28:3/5-6: 575-581.

Nine rural streams throughout Wisconsin were continuously monitored for dissolved oxygen content. Warm water sites violated the state of Wisconsin standard for dissolved oxygen more often than cold water sites. Severe storms caused the greatest reduction of dissolved oxygen.

Gurtz, M. E., G. R. Marzolf, K. T. Killingbeck, D. L. Smith, and J. V. McArthur. 1982. **Organic matter loading and processing in a pristine stream draining a tall grass prairie/riparian forest watershed.** Contribution 230, Kansas Water Resources Research Institute, Manhattan Kansas. 78pp.

To provide an observational basis for future research related to water quality, samples of organic matter contributions were collected for a year. In this way patterns of import, storage, decomposition and export of organic matter were assessed. The grassland portion of the watershed contributed a steadier, slower flow of organic materials than the forested section. It is thought that fire reduces the storage of organic matter in the floodplain. To improve water quality, decomposition of organic matter by native stream biota in the headwaters should be maximized, and to accomplish this, natural retention structures should not be altered by clearing and snagging (pg. 2 of summary).

# V. The Riparian Area

## a. General riparian buffer information

Belt, G. H. and J. O'Laughlin. 1994**. Buffer strip design for protecting water quality and fish habitat.** Western Journal of Applied Forestry 9:41-45.

Buffer strips improve water quality by filtering sediment and nutrients, moderating stream temperature, and producing organic debris. The width of a buffer strip, and what is planted on it, should be determined by individual circumstances such as topography, soil type, and stream width. Existing high quality streams and buffer strips should be monitored with hopes of informing future public policy.

Binford, M. W. and M. J. Buchenau. 1993. **Riparian greenways and water resources.** Pp 69-104. In Ecology of Greenways. D. S. Smith and P. Cawood (eds.). University of Minnesota Press, Minneapolis, MN.

This chapter describes the role of riparian greenways in stream health and suggests ways to improve the management of waterways.

➔ Pages 83-86 describe effects of human activities in riparian corridors including sections on livestock and agriculture. Guidelines for riparian greenway design are outlined and ecologists are encouraged to apply their knowledge by helping citizens find answers to their riparian greenway questions.

Clark, E. A. 1998. **Landscape variables affecting livestock impacts on water quality in the humid temperate zone.** Canadian Journal of Plant Science 78:181-190.

Much ado has been made about the damage to riparian areas by livestock in the arid west. Policy based on this information does not take into account the ecology of more temperate, humid regions. Climate, landform characteristics, biophysical characteristics of watercourses, and pasture and livestock management, are unique

to a specific area of the country and even to a specific field. Damage to riparian areas due to livestock appears localized, manageable, and smaller in scale than damage due to orchards and row cropping. Further, controlled rotational grazing is associated with improved riparian zone condition (pg. 187). More research is needed on the landscape level with a focus on humid, temperate regions.

Clark, E. A., I. Duncan, P. Kevan, D. P. Stonehouse, H. Whiteley. 1999. **Grazing cattle and riparian ecosystems: final report 1999.** Submitted to the Ontario Cattleman's. 158pp.

One solution to the negative effects cattle have on streams and stream banks is to exclude cattle from these areas completely. Since this is not practical for many farmers, this report (which consists of many individual research papers and a summary) recommends reinforcement of preferred access points, alternate water sources, and controlled rotational grazing as the most cost effective solutions. Any solution must be site specific, as each stream reach has different strengths and weaknesses. Unlike many researchers, this group found that cattle did not spend a lot of time wallowing in the stream and that coliform counts were not elevated in monitored streams.

Cooper, J. R., J. W. Gilliam, R. B. Daniels, W. P. Robarge. 1987. **Riparian areas as filters for agricultural sediment.** Soil Science Society of America Journal 51:416-420.

Analysis of cesium-137 from nuclear weapons fallout was used to determine the amount of sediment deposited in riparian areas of two watersheds during the last 20 years. Eighty-four to 90 percent of the sediment that left cultivated fields remained in the same watershed (pg. 416). The best way to protect important waterways from increased sediment load is to identify critical areas (such as cultivated fields in close contact with higher order streams) and install riparian area buffer strips.

Elmore, W. 1992. **Riparian responses to grazing practices.** Pp 442-457. In Watershed Management: Balancing Sustainability and Environmental Change. R. J. Naiman (ed.). Springer Verlag, N.Y.

Ten grazing strategies that are being used to restore riparian areas are addressed. To ensure that the strategy fits a particular stream and pasture, resource managers and farmers should evaluate the physical filtering of sediment, bank stability, water storage, and recharge of subsurface aquifers. By looking at whole watersheds, farmers and ranchers can significantly improve riparian habitat and increase quality forage for their livestock.

Elmore, W. and R. L. Beschta. 1987. **Riparian areas: perceptions in management.** Rangelands 9:260-265.

Because the destruction of streams through overgrazing began so long ago, many people have never seen a healthy riparian ecosystem. Judicious use of grazing is also the key to recovery. Enlightened grazing management is inexpensive and flexible enough to adapt to changing moisture, forage, and landscape-scale conditions.

Federal Interagency Stream Restoration Working Group. 2001. **Stream corridor restoration: principles, processes, and practices.** Part 653 of the National Engineering Handbook. USDA-Natural Resources Conservation Service. Accessed at: <http://www.usda.gov/stream_restoration/newtofc.htm>.

"This section provides an overview of stream corridors, steps in restoration plan development, and guidelines for implementing riparian area restoration. Part I describes stream corridor structure, processes, functions, and impacts of disturbances. Part II examines restoration plan development. Part III describes how information in the first two parts can be used to create a riparian restoration initiative."

Fitch L., B. W. Adams. 1998. **Can cows and fish co-exist?** Canadian Journal of Plant Science 78: 191-198.

Through their review of topical literature the authors contend that past management of cattle rangeland has, for the most part, been detrimental to water quality and stream health. By understanding riparian ecosystems, one can learn to monitor stream health. With this in mind, ranchers can control where animals graze, and thereby improve the health of riparian areas.

→ Special management practices are outlined, including their benefits to forage quality. Ranchers are encouraged to manage stream banks for productivity *and* ecological health.

Gregory, S. V., F. J. Swanson, W. A. McKee, K. W. Cummins. 1991. **An ecosystem perspective of riparian zones.** BioScience 41:540-551.

Past research on riparian zones defined them on the basis of vegetation, hydrology, or topography without a complete analysis of riparian zones as *ecosystems*. A new perspective based upon the interaction between riparian areas and all other ecological areas is needed. Only when we understand this interactive model can we identify riparian management objectives that will be successful.

Johnson, B. and T. Ward. 1997. **Evaluating the impacts of intensive rotational grazing on wildlife and water quality on the riparian zone of an intermittent stream in east-central Wisconsin.** Fox-Wolf Basin 2000, Appleton, Wisconsin. 50pp.

As rotational grazing increases in popularity, farmers and resource managers need to know, "what are the impacts of IRG on wildlife and water quality in nearby streams and waterways?" and "what role does vegetative cover play in mitigating potentially detrimental impacts?" (pg. 2). This literature review outlined animal nutrition and water quality, and two surveys were completed to assess the success of IRG in the Lake Michigan drainage area of Wisconsin. Recommendations include: more education about IRG, increased flexibility in public policy, rewards and incentives for good agricultural streambank stewardship, and a call for additional research.

Kauffman, J. B. and W. C. Krueger. 1984. **Livestock impacts on riparian ecosystems and streamside management implications...a review**. Journal of Range Management 37:430-437.

Riparian areas offer a wealth of productive wildlife habitat (pg. 432) and tend to sustain considerable damage by cattle. Fencing and managing riparian zones separately from terrestrial upland sites as special use pastures has been shown to adequately protect the riparian zone. Choosing species of animals that prefer upland sites, such as sheep, or even breeding cattle to prefer upland sites can be advantageous.

Minnesota Planning. 1999. **Impacts on fish and wildlife.** General Environmental Impact Statement in Agriculture Literature Review. G46-G62.

Many reports indicate that, "well managed livestock grazing is compatible with a healthy riparian ecosystem but that practices and their impacts should be viewed as site specific testable hypothesis rather than generic practices to be widely applied" (pg. G46). Micro-invertebrates are useful for detecting grazing impacts, since they are diverse and easily sampled and analyzed. Fish, birds, and mammals are also affected by riparian grazing although more research is needed that focuses on terrestrial vertebrate effects in the humid upper Midwest. Using an ecosystem approach, more baseline data should be collected and compiled to develop a causation.

Naiman, R. J. and H. Decamps. 1997. **The ecology of interfaces: riparian zones.** Annual Review of Ecology and Systematics 28:621-658.

Riparian zones encompass a huge diversity of plants, animals, geologic processes, soils, life-history strategies, biogeochemical cycles and rates, flood regimes, altitudinal climate shifts, and other ecological agents/factors. In many cases these dynamic environments have been greatly changed by human actions. As humans come to understand how all of these factors interact with each other, we are better able to plan effective land use strategies to preserve riparian areas.

National Research Council. 2002. **Riparian areas: functions and strategies for management.** National Academy Press. Washington, D.C. Accessed at: <http://books.nap.edu/books/0309082951/html/index.html>.

This very current document describes structures, functions, and environmental services of riparian areas and the impacts of local environmental conditions and human activities on these characteristics. Detrimental impacts of human activities on riparian areas are subdivided into hydrological (stream) alteration, agriculture, industrial, urban, and recreational impacts. After reviewing the current status of riparian lands in the U.S., authors provide recommendations for land management practices, legal ordinances, and monitoring tools for riparian area protection.

Platts, W. S. 1990. **Fish, wildlife, and livestock: protection of riparian areas**. Western Wildlands, Summer pg 16-19.

Many western riparian areas are severely damaged from a century of overgrazing. The Henry's Fork watershed is an example of a success story where anglers, ranchers, and local citizens worked together to improve fish habitat and increase cattle productivity by 25%! There is no single recipe to recover overgrazed stream banks; six strategies are recommended here.

Scheuler, T. 1995. **The architecture of urban stream buffers.** Watershed Protection Techniques 1:155-163.

Stream buffers in urban areas often appear as no more than a line on either side of the stream in development maps, and subsequently are largely ignored. This paper presents a detailed scheme for how to design buffers based upon 10 performance criteria. Although grazing is not mentioned, many of the criteria concerning buffers apply in rural as well as urban areas.

Schlosser, I. J., J. R. Karr. 1981. **Water quality in agricultural watersheds: impact of riparian vegetation during base flow.** Water Resources Bulletin 17:233-240.

"Six agricultural watersheds [in Illinois], differing in type of riparian vegetation and magnitude of point source inputs, were studied" (pg. 233). During base flow conditions the theory that, "concentrations of suspended solids are positively correlated with the potential energy of the stream" does not apply when riparian vegetation is removed and in-stream organic production is high (pg. 238). Areas with intense agriculture should encourage riparian vegetation and in this way protect local and regional watersheds from excess pollution.

## b. Riparian forest buffers

Behmer, D. J., C. P. Hawkins. 1986. **Effects of overhead canopy on macro-invertebrate production in a Utah stream.** Freshwater Biology 16:287-300.

Cobbles were used as sampling units to measure macro-invertebrate abundance in a shaded versus open section of an ungrazed stream. Twice as many macro-invertebrates were found at the open (sunny) site than at the covered (forested) site, with the exception of black flies.

Hubbard, R. K., R. R. Lowrance. 1994. **Riparian forest buffer system research at the Coastal Plain Experimental Station, Tifton, Georgia.** Water, Air and Soil Pollution 77:409-432.

The projects reviewed in this paper include: 1) filtering of nutrients, sediments, and pesticides from row crop agriculture; 2) restoration of a wetland to filter nutrients entering from an animal waste site; and 3) comparison of different management techniques for filtering animal waste applied to riparian forest buffer systems by overland flow. Results will be evaluated by the Riparian Ecosystem Management Model (REMM), which includes a three-zone concept (zone 3- grass buffer, zone 2- upland pine forest, zone 1- streamside hardwood forest) with subcomponents for hydrology, sedimentation, and nutrients (pg. 427).

Jordan, T. E., D. L. Correll, D. E. Weller. 1993. **Nutrient interception by a riparian forest receiving inputs from adjacent cropland.** Journal of Environmental Quality 22:467-473.

Groundwater was examined from a transect of wells beginning at a cornfield, running through a wooded river bottom and ending at the river. Nitrates decreased significantly, whereas sulfates and pH level increased as the water moved from the field to the river. More research is needed to determine the environmental conditions that cause this to occur.

Lowrance, R. R. 1992. **Groundwater nitrate and denitrification in a coastal plain riparian forest.** Journal of Environmental Quality 21:401-405.

Understanding nitrogen dynamics in riparian forest buffer systems is essential to their proper management. This study found that $NO_3$ and the $NO_3$/Cl ratio decreased significantly in the first 10m of forest (pg. 403). This and other factors indicate that a fully functioning riparian ecosystem is necessary to trigger denitrification of agricultural runoff.

Lowrance, R. R. 1998. **Riparian forest ecosystems as filters for non-point-source pollution.** Pp 113-141. In Successes, limitations, and frontiers in ecosystem science. M. L. Pace and P. M. Groffman (eds.). Springer Verlag, N.Y.

Riparian areas are effective controllers of sediment and nutrient movement to water bodies, and increasingly are being used to perform that task. Management of filter strips is based on ecosystem research and is a success story for the application of ecosystem science to real world problems (pg. 113). The U.S. government extensively uses this research to inform public policy (i.e.: the 1996 Farm Bill).

➔ A list of six primary questions is included to guide further research.

Lowrance, R. R., S. McIntyre, C. Lance. 1988. **Erosion and deposition in a field/forest system estimated using cesium-137 activity.** Journal of Soil and Water Conservation 43:195-199.

Soil eroding from an agricultural field is deposited in lower parts of the field and in the riparian zone. Erosion and deposition are about 63 and 256 mg/ha/yr. The riparian zone is an excellent sediment trap.

Lowrance, R. R., R. Todd, J. Fail, Jr., O. Hendrickson, R. Leonard, L. Asmussen. 1984. **Riparian forests as nutrient filters in agricultural watersheds.** BioScience 34:374-377.

Nutrient cycling was studied to determine whether riparian ecosystems filter nutrients and help maintain water quality on agricultural watersheds. Many bottomland forests in the southern U.S. are being cleared and planted in crops as economic pressures on farmers mount. This practice results in unhealthy streams with high nutrient and sediment loads. In the future, streamside forests should be managed through periodic harvesting to maintain nutrient uptake with minimal soil disturbance.

Lowrance, R. R., G. Vellidis, R.D. Wauchope, P. Gay, D. D. Bosch. 1997. **Herbicide transport in a managed riparian forest buffer system.** Transactions of the American Society of Agricultural Engineers 40:1047-1057.

The riparian buffer system consisted of 1) a grass buffer strip adjacent to the field; 2) a managed pine forest down-slope from the grass buffer; and 3) a narrow hardwood forest containing the stream (pg. 1047). Of the three regions, the grass buffer reduced concentrations of atrazine and alachlor the most per meter of flow. Surface runoff infiltration and concentrations of shallow groundwater appear to be directly connected (pg. 1056).

Mander, Ü., V. Kuusemets, K. Lõhmus, T. Mauring. 1997. **Efficiency and dimensioning of riparian buffer zones in agricultural catchments.** Ecological Engineering 8:299-324.

Along with the authors' work on buffer strips in Estonia, 50 literature sources were compared to analyze the influence of pollution load on nutrient retention in riparian ecosystems. Estonian vegetated buffers analyzed include riparian forests, shelterbelts, hedges, riparian grasslands, grassy slopes, and grassland strips in strip cropping (pg. 304). Young forest stands, bushes, and wet grasslands removed the most nutrients. In order to maintain peak efficiency, these buffer strips must be harvested to keep them in the young succession stage (pg. 320).

Phillips, J. D. 1989. **Non-point source pollution controls effectiveness of riparian forests along a coastal plain river.** Journal of Hydrology 110:221-237.

How well a buffer controls non-point source pollution depends in part upon the characteristics of the soil a stream runs through. When the Tar River watershed in South Carolina was studied, udic upland soils and sandy entisols were better at reducing nitrate runoff than poorly drained ultisols and entisols. Therefore, as buffer strip width should depend on a particular soil's ability, recommendations for this watershed varied from 5 - 93m. "Since the larger widths [were] associated with soils poorly suited for agriculture, riparian filters at the high end of the range would not necessarily pose undue hardship on landowners" (pg. 236).

Trimble, S. W. 1997. **Stream channel erosion and change resulting from riparian forests.** Geology 25:467- 469.

Riparian forests have a significant effect on stream channels by promoting channel and bank erosion. Converting a forested stream bank to grass makes a stream more able to catch sediments before they pollute downstream. Public policies promoting forested stream banks over grassy stream banks should be questioned.

Wallace, J. B., S. L. Eggert, J. L. Meyer, J. R. Webster. 1997. **Multiple trophic levels of a forest stream linked to terrestrial litter inputs.** Science 277:102-104.

Many human activities, including grazing of cattle, reduce vegetative litter in streams. The impact of litter inputs to a forest stream on abundance of biomass and production of animals is measured in eastern North America (pg. 102). Between moss-covered bedrock systems and mixed substrate systems, the latter clearly shows lower levels of macro-invertebrates when leaf litter is eliminated. Reestablishing detritus into riparian areas should be considered an integral part of any stream conservation plan.

## c. Comparisons of grassy and riparian forest buffers

Burcham, J. 1988. **Fish communities and environmental characteristics of two lowland streams in Costa Rica.** Review of the Biology of the Tropics 36:273-286.

A forested stream and a stream running through a pasture were studied to determine whether the trophic structure of the fish community differed, and to relate the apparent food resources to the distribution and abundance of fishes (pg. 247). The pasture stream supplied food directly to fish, while the forested stream depended upon surrounding trees to supply food to its fish. Thus seven more species of fish were found in the pasture stream (pg. 283). An extensive study including many more streams, would eliminate some of the effects that cannot be directly attributed to the specific land-use practices being analyzed on just two streams.

Daniels, R. B and J. W. Gilliam. 1996. **Sediment and chemical load reduction by grass and riparian filters.** Soil Science Society of America Journal 60:246-251.

This study was undertaken to quantify the removal of sediment and nutrients by natural and planted buffer strips under field conditions. Although high volume flows were shown to overwhelm filter strips, under moderate or light rainfall between 20 and 80% of agricultural runoff nutrients, and 60-90% of sediment, were retained by the grassy strips. The forested strips reached peak effectiveness only in dry periods. A field lane in the buffer strip will serve as a sediment source and will reduce buffer strip effectiveness.

Davies-Colley, R. J. 1997. **Stream channels are narrower in pasture than in forest.** New Zealand Journal of Marine and Freshwater Research 31:599-608.

Stream channel morphology determines the nature and amount of stream and riparian habitat. Twenty streams of different sizes were measured up- and down-stream from “transition” areas from pasture to forest, in West Hamilton, New Zealand. Second-order streams were wider in native, compared to pasture catchments, and streams in 18-year-old pine plantations were suffering from active stream bank erosion (pg. 599). Although the pasture streams have reduced channel width, and therefore less habitat is available for aquatic organisms, the results of this study show that promotion of shady vegetation in the riparian zone may increase sediment yields and degrade the riparian ecosystem. Resource managers should be cautious when deciding how best to manage pastoral streams.

Groffman, P. M., E. A. Axelrod, J. L. Lemonyon, W. M. Sullivan. 1991. **Denitrification in grass and forest vegetated filter strips.** Journal of Environmental Quality 20:671-674.

Denitrification was measured in two grass and two forested filter strips in Rhode Island. Nitrates were higher in the grass plots than in the forested plots. Vegetation, soil type, and pH all affect the ability of a plot to trigger denitrification. Runoff containing high levels of carbon (such as a feedlot) may be treated effectively by a forest vegetated filter strip.

Hawkins, C. P., M. L. Murphy, N. H. Anderson, M. A. Wilzbach. 1983. **Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States.** Canadian Journal of Fisheries and Aquatic Sciences 40:1173-1185.

This study confirms that unshaded streams support more fish and salamanders than shaded streams. However, opening a previously shaded stream to more light should not be undertaken without considering other consequences. These might include temperature change, and changes in the kinds of invertebrates and vertebrates living in the stream.

Haycock, N. E. and G. Piney. 1993. **Groundwater nitrate dynamics in grass and poplar vegetated riparian buffer strips during winter.** Journal of Environmental Quality 22:273-278.

The poplar riparian zone reduced nitrate leaching into the adjacent creek by 100%, with almost all activity occurring in the first five meters of the zone. Apparently the amount of carbon available on the riparian zone will dictate how well that zone buffers nitrates, even in winter. Future work should concentrate on the winter months and the role of carbon in the denitrification cycle.

Lyons, J., S. W. Trimble, L. K. Paine. 2000. **Grass versus trees: managing riparian areas to benefit streams of central North America.** Journal of the American Water Resources Association 36(4): 919-930.

In agricultural areas, where streamside forests were logged long ago, grassy riparian areas may be the best way to prevent erosion. Ideally, stream banks should be a mix of forested reaches and meadow/prairie reaches for diversity, but many farmers are reluctant to lose agricultural land to forest. In these instances, grassy stream banks can serve to reduce erosion and agricultural runoff while also cycling the collected nutrients back to cattle through careful streambank grazing. More research should be conducted comparing the benefits (economical, ecological) of grazing wooded and riparian buffer strips.

Osborne, L. L. and D. A. Kovacic. 1993. **Riparian vegetation buffer strips in water quality restoration and stream management.** Freshwater Biology 29:243-258.

A 39m-wide grass buffer, a 16m-wide mature forested buffer, and a buffer planted in row crops up to the streambank were analyzed for nitrate, total P, and dissolved P (pg. 246). The riparian forest was more efficient at removing nitrate-N in shallow subsurface water than the grass or cropped buffer strips. Drain tiles reduced the effectiveness of all buffer strips. Because of the relative popularity of grassed buffer strips over riparian forest, more information should be compiled on the subject before any policy is put in place.

Paine, L.K. and C.A. Ribic. 2001. **Comparison of riparian plant communities under four land management systems in southwestern Wisconsin.** Agriculture, Ecosystems and Environment 92(1): 93–105.

Four types of riparian buffer management were compared in Wisconsin: woody buffer strips, grassy buffer strips, rotational grazing, and continuous grazing. Woody buffer strips had greater native species diversity than grassy buffers, but provided poor aquatic habitat and were associated with degraded stream banks. Rotationally grazed stream banks had moderate species richness and allowed for good erosion control and aquatic habitat protection. Grazing stream banks helped control the growth of reed canarygrass and invasive species that displace native plants in riparian areas in the eastern U.S.

Parsons, J. E., J. W. Gilliam, R. Munoz-Carpena, R. B. Daniels, T. A. Dillaha. 1994. **Nutrient and sediment removal by grass and riparian buffers.** Transactions of the American Society of Agricultural Engineers 37:147-154.

Although the USDA Soil Conservation Service (now Natural Resources Conservation Service) has guidelines for installation of vegetated filter strips, not much research has been conducted on how effective the filter strips are. This study analyzes the effectiveness of field edge grass buffers and forested riparian zones for trapping sediment and surface water-transported nutrients, in North Carolina (pg. 45). The strips seeded to fescue were more effective against severe runoff than the natural vegetation in the riparian buffers. Forested areas still may be more effective in subsurface nutrient movement.

Peterjohn, W.T., D. L. Correll. 1984. **Nutrient dynamics in an agricultural watershed: observations on the role of the riparian forest.** Ecology 65:1466-1475.

Concentrations of carbon, nitrogen, and phosphorus were measured in groundwater and surface runoff in a small cropland watershed in Maryland (pg. 1466). The riparian forest retained 89% of nitrogen whereas the cropland retained only 8%, and phosphorus was lost primarily through crop harvest (pg. 1473). Research to learn why nitrates leave groundwater in the riparian forest would be helpful.

Renfrew, R.B. and C.A. Ribic. 2001.**Grassland birds associated with agricultural riparian practices in Southwestern Wisconsin.** Journal of Range Management 54(5): 546–552.

"Grassland bird communities were analyzed on buffers that were continuously grazed, rotationally grazed, and on 10-meter-wide ungrazed strips separating row cropping from streams. While total bird species richness did not vary across buffer types, the number and diversity of grassland birds was greater on the grazed compared to the ungrazed buffers. Contrary to previous research, the rotationally grazed buffers did not have more grassland bird species than the continuously grazed buffers."

Sovell, L. A., B. Vondracek, J. A. Frost, K. G. Mumford. **Impacts of rotational grazing and riparian buffers in physicochemical and biological characteristics of southeastern Minnesota streams.** Environmental Management 26:629-641.

The relationship between riparian management and stream quality was assessed on five southeastern Minnesota streams, by examining rotationally and continuously grazed pastures, and different types of riparian buffer strips. Water quality, physical habitat, benthic macro-invertebrates, and fish were examined as indicators of stream quality (pg. 2). Continuously grazed sites had higher fecal coliform levels and wooded sites had a higher percent fines than pasture sites. Fish did not appear to respond to grazing practices but rather to buffer type. Further in-depth research should focus on combination pasture/wooded riparian buffers.

## d. Denitrification and pollution removal by buffers

Coyne, M. S., R. A. Gilfillen, R. W. Rhodes, R. L. Bevins. 1995. **Soil and fecal coliform trapping by grass filter strips during simulated rain**. Journal of Soil and Water Conservation 50:405-408.

> Although some studies have found that grass filter strips successfully control sediment runoff, less is known about how the strips handle coliform runoff. In Kentucky, poultry waste application of 7 tons/acre incorporated with a chisel plow, was followed by (simulated) high intensity rain (pg. 405). The 9m long strips trapped between 43 and 74% of coliforms in the two plots studied, leaving the runoff to exceed primary contact water standards of 200 fecal coliforms per 100 ml (pg. 405). Even with best management practices in place, if rain occurs shortly after manure is applied, groundwater will be contaminated.

Dillaha, T. A., R. B. Reneau, S. Mostaghimi, D. Lee. 1989. **Vegetative filter strips for agricultural non-point source pollution control.** Transactions of the American Society of Agricultural Engineers 32:513-519.

> The ability of a vegetated filter strip to remove sediment, nitrogen (N), and phosphorus (P) from cropland runoff was studied using a series of 5.5m by 18.5m bare soil plots. Although significant amounts of nutrients were trapped by the filter strip (up to 70% suspended solids, 61% P, 73% N), there were still enough nutrients to cause eutrophic plant growth in the neighboring aquatic ecosystems. Actual on-farm use of vegetated filter strips to remove pollution could be less effective than the results of this research indicate.

Dillaha, T. A., J. H. Sherrard, D. Lee., S. Mostaghimi, V. O. Shanholtz. 1988. **Evaluation of vegetated filter strips as a best management practice for feedlots.** Journal of the Water Pollution Control Federation 60:1231-1238.

> A series of nine experimental field plots containing a simulated feedlot source area and vegetative filter strips (VFS) of known lengths, were located on an eroded Greseclose silt loam soil in Virginia. If the runoff was shallow and uniform, the VFS effectively reduced sediment loads. *Total* nitrogen and phosphorus were not removed as effectively as sediment. *Soluble* nitrogen and phosphorus were not removed at all (pg. 1231).

Gilliam, J. W. 1994. **Riparian wetlands and water quality.** Journal of Environmental Quality 23:896-90.

> Many streams have wet soils in the riparian area that are difficult to farm, and by default serve as buffer strips. These strips remove sediments, nutrients, pesticides, and fecal bacteria and as such, should be kept in place or instituted where none exist. Wet streamside buffers are critical to preserve water quality.

Hanson, G. C., P. M. Groffman, A. J. Gold. 1994. **Denitrification in riparian wetlands receiving high and low groundwater nitrate inputs.** Journal of Environmental Quality 23:917-922.

> “Denitrification was measured using an acetylene-based intact core (0 to 15cm) technique under unamended, water amended, and water plus nitrate-amended conditions” (pg. 917). The wetland was able to trigger denitrification on 50% of the groundwater $NO_3^-$-N that entered it.

Lowrance, R. R., R. Leonard, J. Sheridan. 1985. **Managing riparian ecosystems to control non-point pollution.** Journal of Soil and Water Conservation 40:87-91.

> Riparian areas should be managed by assessing the needs of the whole watershed. In the Midwest, non-point source pollution may be effectively controlled by restoring riparian ecosystems. A case study during 1979 and 1980 found that the amount of sediment influx affected the nutrient cycling ability of the Little River watershed in Georgia.

Magette, W. L., R. B. Brinsfield, R. E. Palmer, J. D. Wood. 1989. **Nutrient and sediment removal by vegetated filter strips.** Transactions of the American Society of Agricultural Engineers 32:663-667.

> By determining the best length of filter strip to remove nutrients and sediments, researchers can assist farmers in finding that rare balance between monetary sustainability and resource protection. The study used simulated rain on bare plots next to vegetated filter strips 4.6 and 9.2m long. Generally the larger filter strip removed more nutrients, but its effectiveness decreased as the number of runoff events increased (pg. 663). Sediment was effectively removed by 9.2m long strips but filter strips alone are not a reliable means by which to reduce nutrient losses from farm fields (pg. 663).

Muscutt, A. D., G. L. Harris, S. W. Bailey, D. B. Davies. 1993. **Buffer zones to improve water quality: a review of their potential use in UK agriculture.** Agriculture, Ecosystems and Environment 45:59-77.

As agriculture in Great Britain intensifies, greater pollutant stresses are placed on rivers and streams. Studies of buffer zones indicate they can retain nitrogen, phosphorus, pesticides, and sediment before these pollutants endanger a stream. Buffers are limited in their capacity to filter when drain tiles and other subsurface channels reroute nutrient/pesticide laden water directly to streams without passing the buffer. However, before buffer strips can be recommended, more study should be undertaken on their long term viability, economic aspects to farmers, effects on crop yield, effect on pest populations, and benefits to natural communities.

Schnabel, R. R., J. A. Shaffer, W. L. Stout, L. F. Cornish. 1997. **Denitrification distributions in four valley and ridge riparian ecosystems**. Environmental Management 21:283-290.

Denitrification rates in the valley and ridge province of Pennsylvania were greatest near the stream and near the soil surface. Grassy riparian buffer strips reduced nitrogen load more effectively than wooded buffer strips. Thus the results for steeper riparian areas match the data collected by other researchers for flatter riparian areas with similar vegetative cover.

Vought, L. B.-M., J. Dahl, C. L. Pederson, J. O. Lacoursiere. 1994. **Nutrient retention in riparian ecotones.** Ambio 23:342-348.

Agriculture is now the major source of nutrients to aquatic systems in much of the world. Buffer strips can filter out much of the sediment and nutrients, although factors such as optimal width and vegetation, saturation states and seasonal variations are largely unstudied. This Swedish review of the literature found that a 10-20m-wide buffer strip retained most nitrogen and phosphorus carried on the surface. If drain tiles have been installed, the effectiveness of filter strips is reduced and a different method should be used to reduce pollution input.

Young, R. A., T. Huntrods, W. Anderson. 1980. **Effectiveness of vegetated buffer strips in controlling pollution from feedlot runoff.** Journal of Environmental Quality 9:483-487.

The feedlot contained 310 head of cattle and was located in Stevens County, MN. Six plots located 1/3 in the feedlot and 2/3 outside of the feedlot were examined for two years. Of the portions outside of the feedlot, two plots were planted in corn, two in orchard grass, and two in a mixture of sorghum and sudan grass. Feedlot runoff was reduced by 67% and total solids transported were reduced by 69%. A 36m-wide buffer appears to reduce concentrations of nutrients and microorganisms to acceptable levels in this feedlot.

## e. Size of buffers

Barling, R. D., I. D. Moore. 1994. **Role of buffer strips in management of waterway pollution: a review.** Environmental Management 18:543-558.

A breadth of research on riparian buffer strips was reviewed including different models to determine effectiveness for different purposes (i.e. stream protection based on protection of runoff generating area, sediment bound pollution transport etc.). The authors found that: 1) the best buffer width for streams is 30m; 2) buffer strips are more effective at removing sediment than nutrients; 3) filter strips are more effective when the flow is shallow, slow, and enters the filter strip in a uniform way; and 4) woodlands used as buffer strips are an important source of nitrogen removal (pg. 555). Since the long-term effects of accumulation of phosphorus, pesticides, and nitrogen have not been studied, there is a call for more research on the effectiveness of buffer strips over time.

Barton, D. R., W. D. Taylor, R. M. Biette. 1985. **Dimensions of riparian buffer strips required to maintain trout habitats in southern Ontario streams.** North American Journal of Fisheries Management 5:364-378.

Forty sites in 38 streams were examined, and weekly maximum water temperature was the only variable that clearly defined which streams supported trout. The only cold water stream that did not support trout was heavily grazed upstream of the study site (pg. 377). Cooler streams can be achieved by maintaining buffer strips whose dimensions can be determined empirically (pg. 377).

Castelle, A. J., A. W. Johnson, C. Conolly. 1994. **Wetland and stream buffer size - a review.** Journal of Environmental Quality 23:878-882.

Buffer size should be determined by scientific merit instead of political acceptability. A literature search found that a buffer 15m wide was large enough to protect most streams but that site specific conditions should be considered, and buffers should be adjusted accordingly.

Wenger, S. 1999. **A review of the scientific literature on riparian buffer width, extent and vegetation.** Publication of the Office of Public Service and Outreach, Institute of Ecology, University of Georgia. 58pp.

To develop a legally defensible basis for determining riparian buffer width, extent, and vegetation, 140 articles and books were reviewed. The best option proposed stipulates: 1) a base width of 100 ft plus 2 ft per 1% slope; 2) extend to the edge of the floodplain; 3) include adjacent wetlands; 4) impervious surfaces and slopes over 25% do not count toward the base width; and 5) buffer applies to all perennial, intermittent, and ephemeral streams (pg. 3). These practices will only work if pollution is also managed on-site. Farmers and others must work to reduce erosion from fields, nutrient leaks from sewage/manure lagoons and sewer pipes, and limit the amount and extent of stream crossings (including roads that cross streams).

# VI. The Upland Area

## a. Soil animals and plant species

Abbot, I., C. A. Parker, I. D. Sills. 1979. **Changes in the abundance of large soil animals and physical properties of soils following cultivation.** Australian Journal of Soil Research 12:343-353.

The size and frequency of animals in soils under native vegetation was compared to soils under farmed land. Large soil animals were more abundant in virgin (unploughed) soil than in cultivated soil. The animals, including termites, ants, and beetles, aerate the soil and make it more permeable to water. By reintroducing these animals, using minimal tillage and direct drilling of seed, farmers could prevent further cropland deterioration.

Axelrod, D. I. 1985. **Rise of the grassland biome, central North America.** Botanical Review 51:163-201.

Fossil records indicate that the American Great Plains have few endemic species of plants and thus are a relatively new phenomenon. Periods of increased aridity, natural and human-induced fires, and the actions of large mammals of the late Quaternary period, all played a role in the formation of this unique ecosystem.

Curtis, J. T. 1959. **The vegetation of Wisconsin: an ordination of plant communities.** University of Wisconsin Press, Madison, Wisconsin 300+pp.

Wetter prairies are more sensitive to grazing pressure than dryer prairies, experiencing replacement of original fauna by exotics (such as Bluegrass, redtop grass, European canary grass) within 2-3 years of being disrupted (pg. 307). Therefore it is more likely that a good quality prairie (full complement of native plants) will be found in grazed upland pasture than in a grazed riparian zone. Fires are a major influence in prairie maintenance.

Smith, W. R. 1975 (Reprint of an 1838 edition). **Observations on the Wisconsin territory.** Arno Press, A New York Times Company, New York. 134 pp.

The “Wisconsin Land District” of 1838 was bordered by the Mississippi River on the West, by the Four Lakes and the Sugar River in the East, by the Wisconsin River in the North, and by the Illinois state line in the south. Now referred to as the Driftless Area, it was comprised primarily of prairies with springs and small creeks throughout. These streams are “three or four yards broad and two feet deep” until they enter a wooded region where they become “nearly full with the banks and have a firm sandy and gravelly bottom” (pg. 23). It appears that the prairies were maintained by repeated fire and that there were never forests here as the author could find no charred remains of forests (pg. 27).

U. S. Survey General. 1848-1907. **Field notes: township and exterior subdivision lines.** Minnesota State Archives, 57.J.5.9B-57.J.8.8F, Minnesota Historical Society, St. Paul, Minnesota. 30 boxes.

When Minnesota was first surveyed to be split into townships, sections, etc., the surveyors often commented in their surveyors’ journal about the topography and vegetation of the country they were walking through.

➔ This resource consists of thirty boxes of handwritten surveyors’ journals concentrating on southeastern Minnesota. The best way to use it is to ascertain the section and/or meridian of the piece of land you are interested in and bring a legal description of the land to the library of the Minnesota Historical Society to

compare to these journals.

Wallwork, J. A. 1970. **Ecology of soil animals.** McGraw-Hill, London.
Two small sections in this book are of interest: grassland soils (pg. 4), and fauna of grassland soils (pg. 215). The first section outlines how grassland soils are different from forest soils and the second describes the type and amount of soil animals (mostly insects) particular to prairies.

Wells, P. V. 1970. **Postglacial vegetational history of the Great Plains.** Science 167:1574-1582.
Fossil records show that the Great Plains once had great numbers of coniferous trees, supported by a climate much like today's. Therefore the assumption that climactic conditions, and in particular a reduction in rainfall, was a primary cause for the rise of the plains ecosystem, must be reexamined. Careful research shows that fire combined with the flat topography is a more likely explanation for the existence of the Great Plains we know today.

## b. Infiltration and pollutants

Bari, F., M. K. Wood, L. Murry. 1993. **Livestock grazing impacts on infiltration rates in a temperate range of Pakistan.** Journal of Range Management 46:367-372 .
This study was undertaken to determine how much phytomass should be left in a grazed field, with a slope of 30% or greater, to minimize runoff. Results showed that areas left ungrazed had the most biomass and least runoff but since it is not practical in this area to cease grazing, the authors recommend reducing grazing pressure. Regression analysis and cumulative infiltration equations were used to manipulate the collected data.

Cooper, C. M. 1993. **Biological effects of agriculturally derived surface water pollutants on aquatic systems - a review.** Journal of Environmental Quality 22:402-408.
Agriculture is a major polluter of waterways throughout the country, contributing to high levels of suspended sediment, pesticides, metals (specifically arsenic and mercury, used as early pesticides), and nutrients. A primary effect of these contaminants is a loss of biodiversity. Solutions must be implemented on a watershed level as well as at the local stream and lake level.

Copeland, O. L. 1965. **Land use and ecological factors in relation to sediment yield.** Pp 72-84. In Proceedings of the Federal Inter-agency Sedimentation Conference. USDA Miscellaneous Publication 970.
Land use, including grazing, has resulted in "Impairment of hydrologic processes, aggravation of flood peaks, and the increasing menace of sedimentation" (pg. 73). Since vegetation binds the soil, promotes infiltration, dissipates raindrop energy, develops greater porosity, and enriches the soil surface, overgrazing it so that rangeland cannot regenerate properly is very destructive to the local and regional hydrologic system (pg. 77). It is the responsibility of the U. S. government to properly care for rangelands it holds in trust for all citizens by regulating grazing intensities to prevent excessive sedimentation.

Gifford, G. F., R. H. Hawkins. 1978. **Hydrologic impact of grazing on infiltration: a critical review.** Water Resources Research 14:305-313.
A review of the literature regarding the hydrologic importance of grazing finds only fragmented information. Further research should include, "a detailed definition of the long-term effects of grazing on infiltration rates as a function of site, range condition, and grazing intensity" (pg. 305).

Harris, W. G., H. D. Wang, K. R. Reddy. 1994. **Dairy manure influence on soil and sediment composition: implications for phosphorus retention.** Journal of Environmental Quality 23:1071-1081.
Soil material was examined using optical microscopy, x-ray diffraction, scanning electron microscopy, energy dispersive x-ray analysis, electron microprobe analysis, thermograimetry, density separation and selective dissolution techniques. A lack of calcium phosphate (Ca-P) was found, suggesting that manure inhibits crystallization of Ca-P, leaving phosphorus more soluble in water. Damage from phosphorus attributed to cattle manure could be reduced if the barrier to crystallization of Ca-P could be eliminated (pg. 1071).

Heathwaite, A. L., T. P. Bert, S. T. Trudgill. 1990. **The effects of land use on nitrogen, phosphorus, and suspended sediment delivery to streams in a small catchment in southwest England.** Pg 161-177 In Vegetation and Erosion. J. B.

Thornes (ed.) Wiley, Chichester.

Since the 1970s the U.K. has seen two major changes in agricultural land use: a conversion from grassland to arable land, and increased livestock (dairy) numbers (pg. 162). This study found that where animals trample and compact the soil surface there can be an 80% reduction in the infiltration capacity of the area. Where an area is heavily grazed, the runoff volume is 12 times greater, and this runoff has high nitrogen, phosphorus, and sediment delivery during storms (pg. 175). Limiting grazing around watercourses is critical to protecting aquatic resources.

Hofmann, L. and R. E. Ries. 1991. **Relationship of soil and plant characteristics to erosion and runoff on pasture and range.** Journal of Soil and Water Conservation 46:143-147.

Reclaimed pastures and rangelands were used to determine soil loss and water runoff. The treatments compared were: reclaimed heavily, moderately, and lightly grazed pastures; reclaimed burn; reclaimed ungrazed; native grazed; native burn; and native ungrazed. As soil cover increased, runoff decreased. Other soil characteristics were not related to runoff. This study could be used to develop a method to predict runoff likeliness on particular sections of rangeland or pasture.

Jacobs, T. C. and J. W. Gillian. 1985. **Riparian losses of nitrate from agricultural drainage waters.** Journal of Environmental Quality 14:472-478.

A three-year study of two North Carolina coastal plains watersheds was undertaken to find out whether riparian areas reduced nitrogen content of runoff from nearby agricultural fields. Although the natural floodplain has the capacity to remove excess nitrogen from groundwater, in this instance the low nitrogen content detected in the floodplain was a result of low input from nearby fields. Excess nitrogen carried off of fields was absorbed by a subsurface layer of dense clay before it had a chance to reach the riparian zone.

Mosley, J. C., T. A. Lance, J. W. Walker, D. E. Lucas, C. M. Falter. 1992. **How does grazing affect water quality?** pg. 5. In Focus On Renewable Resources. D. Ortiz (ed.) Idaho Forestry, Wildlife and Range Experiment Station. Annual Report.

To help farmers, scientists must formulate a scientific principle to guide effective grazing management. “Mowing or grazing may promote more rigid plant stems that better slow runoff and filter nutrients and may stimulate plant uptake of nutrients from the soil” (pg. 5). Vegetation in two plots was regulated by haying and grazing respectively, and preliminary results indicate that soil nutrient levels were not influenced by mass or height of standing vegetation.

Owens, L. B., W. M. Edwards, R. W. Van Keuren. 1984. **Peak nitrate-nitrogen values in surface runoff from fertilized pastures.** Journal of Environmental Quality 13:310-312.

To determine whether animal waste or fertilizer causes peak $NO_3$-N runoff concentrations, pastured watersheds on hill slopes in eastern Ohio were fertilized with ammonium nitrate at two different levels for five years (pg. 310). The study found that fertilizer, not manure from pastured cattle, was the reason for high nitrate runoff.

Owens, L. B., W. M. Edwards, R. W. Van Keuren. 1989. **Sediment and nutrient losses from an unimproved, all-year grazed watershed.** Journal of Environmental Quality 18:232-238.

“A 28.2-ha unimproved pasture in east-central Ohio was studied for surface runoff, nutrient loss, and sediment transport during a 2- yr ungrazed period, and a 6- yr all-year grazing period” (pg. 237). Concentrations of N, $NO_3$-N, P, Ca, Mg, Na, and Cl were all similar to a ungrazed wooded watershed nearby. Thus all-year grazing on a humid, unimproved eastern watershed should not degrade stream water quality from nutrient concentration or transport (pg. 232).

Owens, L. B., R. W. Van Keuren, W. M. Edwards. 1982. **Environmental effects of a medium-fertility 12-month pasture program: I. Hydrology and soil loss.** Journal of Environmental Quality 11:236-240.

Four small sloping pastures were rotationally grazed in summer and one pasture was used to winter cattle every winter of this five-year project. The summer-only pastures saw a slight increase in surface runoff and soil loss over ungrazed pasture, while the winter feeding pasture had large increases in runoff and soil loss. Most of the winter deterioration occurred during large runoff events.

Owens, L. B., R. W. Van Keuren, W. M. Edwards. 1982. **Environmental effects of a medium-fertility 12-month pasture program: II. Nitrogen.** Journal of Environmental Quality 11:241-246.

Effects on nitrogen levels in water were studied on four small summer-grazed and winter-feeding pastures in Ohio. Transported subsurface nitrogen levels were the same during summer and winter. The surface transport, however, was greater in the winter pasture. Winter-feeding pastures should be rotated to spread nitrogen loads more equally.

Owens, L. B., R. W. Van Keuren, W. M. Edwards. 1983. **Hydrology and soil loss from a high-fertility, rotational pasture program.** Journal of Environmental Quality 12:341-346.

Five small, sloping (average of 12% slope) watersheds were rotationally grazed in the summer and winter with additional forage brought in during the winter months (pg. 341). Higher than average precipitation was the primary cause for greater runoff during the growing season, while cattle management was responsible for greater runoff during the winter. Overall soil loss from these pastures was minimal but increased vegetative cover was correlated with a decrease in soil loss.

Owens, L. B., R. W. Van Keuren, W. M. Edwards. 1983. **Nitrogen loss from a high-fertility, rotational pasture program.** Journal of Environmental Quality 12:346-350.

Beef cattle were rotationally grazed on four sloped (12%) pastures in summer, and rotationally grazed/ fed on four other similarly sloped pastures in winter. All pastures received 224 kg N/ha as $NH_4NO_3$ fertilizer (pg. 346). The winter pastures had higher subsurface concentrations of $NO_3$-N (well below the 10 mg/L limit established by the U.S. Public Health Service), and both pastures increased their concentrations as the season progressed (pg. 350). Sediment-N concentrations were low because of low soil loss.

Rauzi, F. and F. M. Smith. 1973. **Infiltration rates: three soils with three grazing levels in northeastern Colorado.** Journal of Range Management 26:126-129.

Ascalon sandy loam, Shingle sandy loam, and Nunn loam were tested. All three types can handle moderate grazing without a large reduction in infiltration rates. Heavy grazing significantly reduces infiltration on all three soil types.

Sartz, R. S., D. N. Tolsted. 1974. **Effect of grazing on runoff from two small watersheds in Southwestern Wisconsin.** Water Resources Research 10:354-356.

For 11 years, storm runoff from two small open pasture watersheds was measured to determine the runoff effects of grazing. In the third year after cessation from grazing, runoff from the ungrazed watershed dropped sharply. Thus, even moderately grazed sloping pastures in the region contribute to flooding (pg. 356).

Timmons, D. R. and R. F. Holt. 1977. **Nutrient losses in surface runoff from a native prairie.** Journal of Environmental Quality 6:369-373.

Losses of N, P, chemical oxygen demand, Kjeldahl nitrogen, $NH_4$-N, ($NO_2$ + $NO_3$) –N, ortho P, Na, Ca, and Mg were measured for five years on a native prairie dominated by little bluestem. Nutrient losses on a native prairie provide a baseline to compare levels of nutrient due to agriculture and other uses.

Trimble, S. W. 1988. **The impact of organisms on overall erosion rates within catchments in temperate regions.** Pp. 83-142. In: Biogeomorphology. H. Viles (ed.). Blackwell, Oxford.

With a focus on hillslopes, many causes of erosion are covered including some agricultural practices. In figure 3.14 (pg. 111) where 10 different agricultural practices are compared, all forms of pasture show higher rates of infiltration than other farm practices (like tillage) with “old pasture or heavy mulch” the highest. As grazing intensity increases, infiltration is reduced by as much as 60% (pg. 125).

➔ Although the author finds little to recommend organic agriculture from an erosion point of view, he does mention a Missouri study where, “herbicide treatments increased runoff 2-4 times, increased soil loss 4-8 times and reduced maize yield up to 30%” (pg. 119).

Trimble, S. W. 1990. **Geomorphic effects of vegetation cover and management: some time and space considerations in prediction of erosion and sediment yield.** Pp55-65 In: Vegetation and Erosion. J. B. Thornes (ed.). Wiley, London .

Accurate predictions of erosion and sediment yield cannot be ascertained simply by noting changes in vegetative cover. “One must know, a) whether the soil is in a wetting or drying phase and b) the non-linear relationship of the two variables for each phase” (pg. 63). The geomorphic history and recent land use also affect geomorphic work from vegetation cover (pg 63). More research is needed to further clarify these relationships.

Trimble, S. W. 1993. **The distributed sediment budget model and watershed management in the Paleozoic Plateau of the upper Midwestern United States.** Physical Geography 14:285-303.

The distributed sediment budget model could be used to control sediment yield in the Upper Mississippi River hill country, a region that includes the Driftless Area (pg. 286). Coon Creek and Whitewater River watersheds are profiled, as they have both been greatly affected by erosion, often the results of cattle overgrazing. The best way to reduce sediment loads in this area is to reduce and treat high cut banks (pg. 301). Unfortunately, this could cause enhanced erosion downstream and continued flooding.

Trimble, S. W. and S. W. Lund. 1982**. Soil conservation and the reduction of erosion and sedimentation in the Coon Creek Basin, Wisconsin**. U. S. Geological Survey Professional Paper 1234: 35pp.

Soil conservation measures, begun in the 1930s, have greatly reduced erosion in the Coon Creek Basin. Although the amount of land planted in row crops did not change significantly, conservation management practices have reduced erosion to 1-2% of earlier rates. Currently, grazing is moderate and most forests are ungrazed. Water movement is confined primarily to subsurface flow.

## c. Compaction

Bryant, H. T., R. E. Blaser, J. R. Peterson. 1972. **Effect of trampling by cattle on bluegrass yield and soil compaction of a meadowville loam.** Agronomy Journal 64:331-334.

Trampling compacted the soil and adversely affected the growth of bluegrass, but "the height of forage at trampling had no significant effect on either the force required to penetrate the soil, or depth of soil at which maximum resistance to penetration was encountered" (pg. 331).

Naeth, M. A., D. J. Pluth, D. S. Chanasyk, A. W. Bailey, A. W. Fredkenheuer. 1990. **Soil compacting impacts of grazing in mixed prairie and fescue grassland ecosystems of Alberta.** Canadian Journal of Soil Science 70:157-167.

The grasslands studied were grazed early, late, and continuously during the growing season, with a range of light to very heavy intensities. "Grazing affected soil bulk density to depths of 7.5cm in aspen parkland fescue grassland on Chernozemic soils, and 65cm. in foothills fescue grassland on Chernozemic soils, but did not affect soil bulk density in mixed prairie on Solonetzic soils" (pg. 165). In general, heavier trampling caused greater compaction and earlier season trampling caused more compaction than late season trampling.

Tollner, E. W., G. V. Calvert, G. Langdale. 1990. **Animal trampling effects on soil physical properties of two Southeastern U.S. ultisols.** Agriculture, Ecosystems and the Environment 33:75-87.

Effects of animal trampling on vegetated soils were studied with alfalfa, Bermuda grass, and wheat or rye followed by soybeans. Stocking rates were from four to eight animals per ha. Where it was measured, trampling affected density and infiltration on all three treatments. Freeze-thaw and shrink-swell cycles could overcome the affects of trampling but more research should be conducted to determine the impact of these amelioration mechanisms (pg. 86).

Usman, H. 1994. **Cattle trampling and soil compaction effects on soil properties of a northeastern Nigerian sandy loam.** Arid Soil Research and Rehabilitation 8:69-75.

Trampling effects were measured around watering points in northeastern Nigeria. Soil bulk density and cone perimeter resistance increased, and dense zones were produced at 7.5cm in depth (pg. 69). Overgrazing of domestic cattle can degrade soil structure on rangelands.

Warren, S. D., T. L. Thurow, W. H. Blackburn, N. E. Garza. 1986. **The influence of livestock trampling under intensive rotation grazing on soil hydrologic characteristics.** Journal of Range Management 39:491-495.

Infiltration rate was tested on bare soil in Texas under four trampling rates: moderate (1 time - 8.1 ha/AU/yr), double (2 times - 4.1 ha/AU/yr), triple (3 times - 2.7 ha/AU/yr), and no trampling. On this silty clay surface soil, infiltration rate decreased and sediment production increased with increased trampling. Thus "hoof action" does not enhance infiltration in intense rotation grazing systems.

## d. Pasture systems

Blanchet, K., H. Moechnig, J. DeJong-Hughes. 2000. **Grazing Systems Planning Guide.** University of Minnesota Extension Service BU-07606-S. 44pp.

Written by Extension Service staff and Minnesota's grazing specialist, this accessible manual takes a reader through the decisions required for a grazing management plan as the first step to transitioning into rotational grazing. Sections cover a resource inventory (goals, land, livestock, forages, water, fence), grazing plan development (the design of paddocks, fencing, water, and heavy use areas), pasture management (forage and livestock, soil fertility, weed control, sacrificial paddocks), and monitoring/record-keeping.

➔ Ten appendices provide worksheets, grass identification keys, water system considerations, average forage yields for Minnesota and Wisconsin, and formulas to calculate reserve herd days.

Correll, D. L. 1996. **Environmental impact of pasture systems on surface water quality.** Pp. 231-243. In Nutrient cycling in forage systems. R.E. Joost and C. A. Roberts (ed.) PPI-FAR, Manhattan, Kansas.

Very few studies have focused on pastureland effects on receiving water quality. This study reviews past research and finds that low intensity grazing (including rotational grazing) seldom causes significant nutrient or sediment impacts. High-intensity grazing with high manure loads can cause nitrate in ground water if the pastures are drained with field tiles, and phosphorus in overland flows. These impacts can exceed the impacts from row crops.

D. G. Hayman Environmental Consultants. 1999. **Livestock access impact review.** Prepared for: Ontario Cattleman's Association, March 1999. 77 Doncaster Ave. London, Ontario N6G 2A4. 55pp.

Past research on grazing and stream management focuses on the arid western U.S. This report from Ontario, "analyzes and summarizes data to determine the extent and magnitude of phosphorus and bacterial loading to surface water quality by livestock with access to water courses and left to graze in pastures without supplemental feeding" (pg. 3). It also provides recommendations for how to research the impacts of pasture management on downstream attenuation, and develop appropriate management strategies that will balance surface water quality with cost effectiveness for farmers.

Kinucan, R. J. and F. E. Smeins. 1992. **Soil seed bank of a semi-arid Texas grassland under three long-term (36 years) grazing regimes.** American Midland Naturalist 128:11-21.

Long-term grazing by domestic livestock can significantly reduce a pasture's soil seed bank by harvesting grasses before they produce seed heads. Grazing treatments tested were: heavily continuous, moderate deferred rotation, and ungrazed enclosure. Total seed densities did not differ among grazing treatments. Vegetation and seed bank composition reflected an earlier successional flora, with no late successional midgrass seeds to be found (pg. 20). This dearth of midgrass seeds impairs the rate of succession.

Satterlund, D. R. 1972. **Wildland watershed management**. Ronald Press, New York. 370pp.

Many grazing lands share common characteristics and water quality problems (pg. 289). The main impacts of grazing are removal of organic matter at the soil surface and compaction of the soil through trampling. In the eastern U.S., trampling during wet weather may cause more harm than removal of organic matter, while in the semi-arid West the situation is reversed. Also, animals are affected by topography. A steep, south facing slope may be avoided by cattle except in the spring, when it warms before other pastures and becomes wet, luring cattle to the first spring growth when the slope is most likely to erode. By the time erosion becomes obvious, it may be too late for inexpensive control (pg. 291). Range plans are cost effective when they prevent erosion through prudent livestock management.

Warren, S. D., W. H. Blackburn, C. A. Taylor, Jr. 1986. **Soil hydrologic response to number of pastures and stocking density under intensive rotation grazing**. Journal of Range Management 39:500-504.

Proponents of intensive rotational grazing have touted high stocking rates and large numbers of smaller pastures as a solution to low infiltration and high runoff. This study found that pastures with the highest stocking density (.68ha/animal unit) had the lowest infiltration rate, and that the best way to increase rest periods (which improves infiltration) is to have few, larger pastures, instead of many smaller ones.

# VII. Riparian Issues in the Western United States

Armour, C. L., D. A. Duff, W. Elmore. 1991. **The effects of livestock grazing on riparian and stream ecosystems.** Fisheries 16(1):7-11.

This position statement of the American Fisheries Society defines the issue of livestock grazing, explains the impacts to streams, and lists 13 actions that should be taken to remedy the situation. The society feels that grazing can be used as a tool to rehabilitate stream banks but that some public policy changes and educational outreach are needed for any widespread rehabilitation programs to be successful.

Armour, C. L., D. A. Duff, W. Elmore. 1994. **The effects of livestock and grazing on Western riparian and stream ecosystems**. Fisheries 19(9):9-12.

The American Fisheries Society "regards livestock grazing on western ecosystems as a practice to be permitted only when careful analyses have shown that it is compatible with other uses, including the protection of natural ecosystems" (pg. 11). Ten policy changes are suggested, while the grazing fee issue is relegated to a separate paper.

Belsky, A. J., A. Mamzke, S. Uselman. 1999. **Survey of livestock influences on stream and riparian ecosystems in the Western United States**. Journal of Soil and Water Conservation 54: 419-431.

This paper documents the effects of livestock grazing in the riparian West in tabular form. All effects were found to be negative, with the suggested remedy of cattle removal from riparian areas throughout the West for an extended period.

Bronson, A., G. F. Gifford, K. G. Renard, R. F. Hadley. 1981. **Rangeland Hydrology.** Kendall Hunt, Dubuque, Iowa. 339pp.

Increasingly, range managers are looking for information on how to better manage their water resources. This book reviews arid and semiarid rangeland hydrology studies, focusing on, "1) runoff or water yields from watersheds, and 2) erosion and sedimentation" (pg. 1).

➔ Of interest are the sections, "Infiltration in natural rangeland plant communities as influenced by grazing" (pg. 61), and "Influence of grazing on runoff" (pg. 85) as well as, "Erosion, sediment yields and water quality" (pg. 111-155). Extensive bibliographies are included with each chapter.

Bureau of Land Management. 1994. **Rangeland reform '94: draft environmental impact statement**. Department of the Interior, Washington D. C. 273pp.

In the Western United States, riparian communities are the most negatively affected ecosystem with 70 to 90% lost due to human activities (pg. 3-29). Five management alternatives are proposed for Forest Service and BLM grazing lands and the impacts to many environmental features (including riparian areas) are outlined. The goals of rangeland reform are to: "1) manage public rangelands in a manner that is compatible with principles of ecosystem management, 2) accelerate the restoration and improvement of public rangelands, 3) streamline BLM and Forest Service grazing administration and reduce administrative costs, and 4) establish a fair and equitable grazing fee" (pg. 6). It is interesting to note that by implementing the most restrictive management alternative (5: no grazing), this EIS proposes that "in the long term 65% of BLM riparian areas would be properly functioning" (pg. 44).

➔ Some mention in Appendix A is made of using cattle as tools for habitat reconstruction (but no details are suggested).

Butler, L.D., J.B. Cropper, R. H. Johnson, A.J. Norman, and P.L. Shaver. 2002. **National Range and Pasture Handbook.** United States Department of Agriculture. Natural Resources Conservation Service. Grazing Lands Technology Institute, Fort Worth, TX. 472 pp. Accessed at: <www.ftw.nrcs.usda.gov/pdf/NRPH.PDF>.

Developed as the basic policy handbook for NRCS to assist farmers and ranchers in planning and applying resource conservation practices on rangelands, this document also serves as a detailed guide to the management and ecological assessment of rangelands. Chapters cover the inventory of grazing land resources, management of grazing land, livestock nutrition, husbandry, and behavior, rangeland and pastureland hydrology and erosion, and wildlife management on grazing land.

➔ Evaluation documents include detailed checklists of resource indicators including those for riparian health and a decision support guide for considering riparian areas for grazing.

Chaney, E., W. Elmore, W. S. Platts. 1990. **Livestock grazing on western riparian areas.** Northwest Resource Information Center, Eagle, Iowa. 43pp.

Although livestock grazing has had detrimental effects on western riparian areas, 11 case studies outline how these negative effects can be remedied with good grazing management. Also mentioned are strategies that resulted in increased pasture production along with a healthier riparian ecosystem.

Clary, W. P. and D. E. Medin. 1990. **Differences in vegetation biomass and structure due to cattle grazing in a Northern Nevada ecosystem.** USDA Research Paper INT-427. 8pp.

The plant biomass and structure of an area that had not been grazed for 11 years was compared to an area seasonally grazed by cattle. The grazed area had less grass biomass and height, and more non-willow large shrub biomass and soil compaction. Heavy grazing may short-circuit the aspen development, beaver arrival and felling of aspen, drowning of aspen stands, loss of beaver, and development of aspen cycle (pg. 6).

Clary, W. P. and B. F. Webster. 1989. **Managing grazing of riparian areas in the intermountain region.** USDA Forest Service Intermountain Research Station Technical Report INT-263. 11pp.

Level of utilization, season of use, and the requirements of riparian plants and animals should be the primary considerations that managers look at along with the needs of their cattle. Five grazing management recommendation are included with the most important being that residual stubble should measure four to six inches high.

➔ Appendices may also prove useful: Appendix I, general review of grazing systems; Appendix II, current information on grazing riparian areas; Appendix III, calculating ecological status and resource value ratings in riparian areas.

Clary, W. P. and B. F. Webster. 1990. **Riparian grazing guidelines for the intermountain region.** Rangelands 12:209-212.

Western riparian areas should be protected by guaranteeing that grazing animals leave a stubble height of four to six inches on stream banks. Time of year and grazing duration should also be carefully controlled.

➔ A set of initial actions for determining the sensitivity of a specific riparian area is outlined.

Fleischner, T. L. 1994. **Ecological costs of livestock grazing in western North America**. Conservation Biology 8: 629-644.

Although 70% of the western U.S. is grazed, this fact is not reflected in the extent of research performed on grazing impacts to western ecosystems. This article serves as a review of available research and the author encourages conservation biologists to weigh in more often on the debate over rangeland use and grazing issues.

Gardner, J. L. 1950. **Effects of thirty years of protection from grazing in desert grassland.** Ecology 31:44-50.

The study was conducted on a 320 acre desert grassland in New Mexico at an elevation of 5,600 ft. Grass density was 110% higher in the ungrazed area than in the grazed area, with minimal differences in species composition between the two (pg. 49). Soil composition was the same in both areas with greater erosion in the grazed area.

Gifford, G. F., R. H. Hawkins. 1976. **Grazing systems and watershed management: a look at the record.** Journal of Soil and Water Conservation 31:281-283.

This literature review of the effects on vegetative cover near waterways highlights continuous grazing, deferred grazing, deferred-rotation grazing, and rest-rotation grazing. The review found that: 1) none of these grazing systems shows increases in plant or litter cover on watersheds, 2) grazing systems are species specific, 3) no reliable research has been done on this topic, 4) no information is available on the impact compared to initial range conditions (pg. 282). Present use of intuition and faith to justify grazing systems is insufficient

Graf, W. L. 1985. **The Colorado River: instability and basin management.** Association of American Geographers, Washington, DC. 86pp.

Many principles of natural and social science can be learned from observations of the Colorado River Basin. It is a system in constant change and one cause of that change has been overgrazing (pgs. 20,30,36). Topics covered in relation to grazing include flooding, riparian vegetation, arroyo development, channel migration, dams, chemical instability, and futures for the Colorado River Basin.

Hadley, R. F. 1974. **Sedimentation and land use in southwest United States.** International Association of Scientific Hydrology Publication 113:96-98.

A reduction in livestock grazing the Colorado River Plateau rangeland has reduced the sediment load entering the Colorado River by 50% between 1926 and 1960.

Herrick, J.E., J.R. Brown, A.J. Tugel, P.L. Shaver, K.M. Havstad. 2002. **Application of soil quality to monitoring and management: Paradigms from rangeland ecology.** Agronomy Journal 94: 3–11.

An analysis of soil quality indicators for rangelands is presented. Authors recommend the following indicators of upland range conditions: plant cover, species richness or diversity, plant productivity, soil density measured by penetrometer, and water infiltration. Riparian indicators include channel vegetation and channel profile. Authors also recommend analyzing indicator data across a watershed to identify spacial variability, a measurement that provides insight into ecological processes and thresholds.

Kauffman, J. B., W. C. Krueger, M. Vavra. 1983. **Effects of late season cattle grazing on riparian plant communities**. Journal of Range Management 36:683-685.

"Late in the grazing season, vegetation growing in riparian areas generally is more palatable and of higher nutritive quality than vegetation in upland plant communities" (pg. 683). Late season grazing can have a large impact on some species of riparian plants over time. It is recommended that riparian areas be fenced separately so that they can be grazed separately from upland areas. In this way riparian plants are utilized without jeopardizing their future use.

Krausman, P. R. , R. W. Mannan, F. D. Hole. 1985. **Animals and soil in Arizona.** Pp. 55-62. In Arizona Soils. D.M. Hendricks (ed.). University of Arizona, Tucson, Arizona.

The effects of animals on soil and soil on animals (in Arizona and elsewhere) are large and diverse. There are 751 vertebrate species and more than 20,000 invertebrate species that affect the topographic, hydrologic, pedogenic, climactic, and biotic elements of soil. A site disturbance index (SDI) can help to measure the effects of animals including cattle, by measuring moisture vulnerability, mean force exerted by hooves on soil, daily range of animal, relative activity, and range shift.

Li, H. W., G. A. Lamberti, T. N. Pearsons, C. K. Tait, J. L. Li, J. C. Buckhouse. 1994. **Cumulative effects of riparian disturbances along high desert trout streams on the John Day Basin, Oregon.** Transactions of the American Fisheries Society 123:627-64.

Grazing is the most obvious human disturbance in the John Day River Basin, and trout populations have declined precipitously because of it. Despite studies showing that reduced abundance and distribution of riparian vegetation can have a positive effect on salmonids by stimulating the autotrophic food base, this research found that a reduction in stream side vegetation caused higher water temperatures, which fatally stressed native fish. Silt from eroding stream banks caused by grazing, also added to the degradation of trout habitat. Documenting these disturbances should help range and fisheries managers enact new policies to protect stream reaches from cattle.

Lusby, G. C. 1970. **Hydrologic and biotic effects of grazing versus nongrazing near Grand Junction, Colorado.** U. S. Geological Survey Professional Paper 700-B:B232-B236.

Measurements of precipitation, runoff, erosion, and vegetation were measured for 14 years in four pairs of watersheds. One watershed of each pair was grazed by cattle and sheep and one was left ungrazed (by domestic livestock). The grazed watersheds experienced an increase in bare soil, 30% more runoff, and 45% more sediment yield than ungrazed watersheds. "Runoff is directly related to the percentage of base soil present" (pg. B232).

Marlow, C. B. and T. M. Pogacnik. 1986. **Cattle feeding and resting patterns in a foothills riparian zone.** Journal of Range Management 39:212-217.

Cattle prefer to use upland areas to feed and rest in June and July, and then to spend more time in riparian areas

in August and September. In dryer years they spend more time in the riparian zone, spending nights in upland areas only if insects are a problem. Stocking rate adjustments should be made based upon moisture patterns and climactic changes as well as forage quality.

Marlow, C. B., T. M. Pogacnik, S. D. Quinsey. 1987. **Streambank stability and cattle grazing in southwestern Montana.** Journal of Soil and Water Conservation 42:291-296.

Cattle grazing is considered the biggest threat to stream health in the western United States. This four-year grazing study found that, "stream bank alteration may result from a combination of high soil moisture levels, high stream flow, and cattle use" (pg. 295). Changes in channel profile could not be contributed to cattle use alone.

Marston, R. A. 1994. **River entrenchment in small mountain valleys of the western USA: influence of beaver, grazing and clearcut logging.** Revue Geographie De Lyon 69:11-15.

A brief review of pertinent literature and concepts explains how grazing in the West can cause river entrenchment.

McInnis, M.I. and J. McIver. 2001. **Influence of off-stream supplements on stream banks of riparian pastures.** Journal of Range Management 54(6): 648–652.

Placement of feed supplements and water away from riparian areas on western rangelands decreased the cattle trampling and congregration in riparian areas. This resulted in a significant reduction in the amount of uncovered and unstable stream banks in these pastures compared to those without supplements. However, the authors note that the degree to which livestock can be attracted away from riparian areas depends on season, topography, vegetation, and weather.

Minshall, G. W., S. E. Jensen, W. S. Platts. 1989. **The ecology of stream and riparian habitats of the Great Basin region: a community profile.** U.S. Fish and Wildlife Service Biological Report 85 (7.24). Washington D. C.

Since cattle were introduced to the West during the Civil War, their numbers have steadily increased. Mormon settlers grazed their herds in the daytime and brought them home each night, causing riparian areas near settlements to be degraded. Later, ranchers used the Spanish system of free ranging cattle without fences, allowing them to invade areas that had not been intensively grazed since the close of the Pleistocene era.

➔ Along with history, this research review includes outlines of different riparian ecosystems of the area, water chemistry parameters, and biological parameters

Ohmart, R. D. 1996. **Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats.** Pages 245-279. In: Rangeland Wildlife. P. R. Krausman (ed.). The Society for Range Management, Denver, Colorado.

Riparian areas have resource values that far exceed the 1% of land they cover. Overgrazing has seriously degraded most of these areas, leaving siltation, loss of tree canopy, lowered water tables, high coliform counts, and huge fish and wildlife reductions in its wake. Three phases of degradation are outlined along with estimations of how long it takes for each one to occur, and how long it may take to remedy the situation. Limited season livestock grazing is one recommended remedy. Our challenge as resource managers, citizens, and landowners is to repair western riparian areas before more species are lost and the land becomes unfit for any grazing animal.

Ordho, A. B., M. J. Trlica, C. D. Bonham. 1990. **Long-term, heavy-grazing effects on soil and vegetation in the Four Corners region.** Southwest Naturalist 35:9-14.

Fifty years ago Chaco Culture National Historical Park was fully fenced off from surrounding grasslands. The study sites included a hilltop, hillside, and a swale. The previously heavily-grazed area had a reduced shrub population, while grasses have completely recovered (pg. 9). Greatest compaction occurred at the hilltop and the whole area still had reduced litter cover.

Platts, W. S. 1981. **Effects of sheep grazing on a riparian stream environment.** Forest Service Intermountain Forest and Range Experiment Station Research Paper INT-307.

"A stream section in a meadow receiving high intensity grazing from sheep was almost five times as wide and

only one-fifth as deep (average) as an adjoining stream section where the meadow received light or no grazing" (pg. 1). Although sheep do not naturally congregate in riparian areas to the extent that cattle do, if they are fenced into a riparian area they will be detrimental to the riparian ecosystem.

Platts, W. S. and R. L. Nelson. 1985. **Stream habitat and fisheries response to livestock grazing and stream improvement structures, Big Creek, Utah**. Journal of Soil and Water Conservation 40:374-379.

Two sections of stream bank were compared, one that had livestock excluded for 11 years and one that included grazing livestock. The ungrazed portion showed significant vegetative improvement and some structural improvement. However, to improve fish populations it is assumed that a larger area of the stream will have to be rehabilitated.

Reed, M. J., R. A. Peterson. 1961. **Vegetation, soil, and cattle responses to grazing on northern Great Plains range.** USDA Technical Bulletin 1252. U.S. Government Printing Office, Washington, D.C. 79pp.

During the period from 1932 to 1946, rangeland was studied to determine a broad range of effects to three different cattle stocking rates. Four ranges were stocked year-long at 23.1 acres/breeding cow, four intermittently at 30.5 acres/breeding cow, and four lightest at 38.8 acres/breeding cow (pg. 68). Specific effects to many species of arid grasses and shrubs were outlined with the general conclusion that the heaviest grazing rate resulted in poor soil absorption and less litter cover and volume of roots. As a result, in the highest stocking rate areas, growth of cows was suppressed, growth of calves was retarded, and weights of all cattle on that range were lower throughout the year (pg. 70). The best way to ensure a healthy range, and in turn healthy cattle on the range, is to consistently monitor all plants and to make range management decisions in response to what one observes.

Sheridan, D. 1981. **Western rangelands: overgrazed and undermanaged.** Environment 23:14-39.

The symptoms of desertification include, "declining water tables, increased salinity of topsoil and water, reduction of surface waters, unnaturally high soil erosion, and loss of native vegetation" (pg. 15). The Navajo reservation, Rio Puerco Basin, and San Pedro/Santa Cruz Basins are three areas of the Western U.S. currently experiencing desertification from overgrazing. Unfortunately, many management proposals that include reduction of animal grazing numbers have met with severe opposition from ranchers who disagree with scientists about the state of rangelands.

Stolzenburg, William. 2000. **Good cow, bad cow, a two-headed question over cattle on the range.** Nature Conservancy July/August 12-19.

At Red Canyon Ranch, cattle are being trained to spend more time grazing away from stream banks. At the Grey Ranch in Arizona, grazing research plots of five square miles each are being used to study the interaction of cattle, fire, climate, and prairie dogs. The Nature Conservancy sees cattle as part of the solution to overgrazed stream banks in the West.

Tait, C. K., J. L. Li, G. A. Lamberti, T. N. Pearsons, H. W. Li. 1994. **Relationships between riparian cover and the community structure of high desert streams.** Journal of the North American Benthological Society 13:45-56.

In high-elevation streams, opening the canopy decreases salmonid density. This occurs despite additional aquatic insect biomass because higher incident radiation raises the water temperature to (30º C and higher) levels lethal to salmonids (pg. 53). However, with warmer reaches and more insects, warm water fish species thrive, and the result is higher overall fish counts.

Thurow, T. L., W. H. Blackburn, C. A. Taylor. 1986. **Hydrologic characteristics of vegetation types as affected by livestock grazing systems, Edwards Plateau, Texas.** Journal of Range Management 39:505-509.

This study assesses infiltration rate and sediment production in the following grazing systems: moderate continuous (MCG - 8.1 ha/au/yr), heavy continuous (HCG - 4.6 ha/au/yr), intensive rotational grazing (SDG - 4.6 ha/au/yr), and in a livestock enclosure (LEX). The grazers consisted of 50% cattle, 25% sheep, and 25% goats. Vegetation was oak mottes, bunchgrass, or sodgrass. Sediment production was significantly higher in HCG than in all other grazing systems, regardless of plant community. Generally, infiltration rates are highest in oak motte, followed by bunchgrass and then sodgrass for each grazing system. Total vegetative cover was strongly correlated with infiltration.