STATEMENT OF PERMISSION TO COPY

In presenting this paper in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this paper for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this paper for financial gain shall not be allowed without my written permission.

Signature Lester A. Fish

Date 6-2-81

MITIGATION OF LIVESTOCK INFLUENCES ON RIPARIAN ENVIRONMENTS THROUGH GRAZING MANAGEMENT

by

LESTER ALLEN KISH

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Range Science

Approved:

Brian W. Sindelar
Chairman, Graduate Committee

Arthur C. Linster
Head, Major Department

Michael Malone
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

June, 1981

TABLE OF CONTENTS

	Page
VITA	ii
LIST OF TABLES	iv
LIST OF FIGURES	v
ABSTRACT	vi
INTRODUCTION	1
ROLE OF RIPARIAN VEGETATION	4
LIVESTOCK GRAZING EFFECTS ON THE TERRESTRIAL-RIPARIAN ENVIRONMENT	7
LIVESTOCK GRAZING EFFECTS ON THE AQUATIC-RIPARIAN ENVIRONMENT	14
RECOVERY RATES OF RIPARIAN AREAS DISTURBED BY GRAZING	18
GRAZING MANAGEMENT PRACTICES	22
Kinds of Livestock	22
Livestock Numbers	24
Season of Livestock Use	26
Distribution of Livestock	27
GRAZING SYSTEMS	32
GRAZING MANAGEMENT CONSIDERATIONS	38
SUGGESTIONS FOR FUTURE RIPARIAN RESEARCH	43
SUMMARY-CONCLUSIONS	46
LITERATURE CITED	49

LIST OF TABLES

Table		Page
1.	Function of riparian vegetation as determined by location within the riparian zone	6
2.	An evaluation of grazing systems and riparian aquatic conditions resulting from their use	33

LIST OF FIGURES

Figure		Page(s)
1.	Cattle grazing effects on riparian habitat conditions	8-9
2.	Major effects of overgrazing on terrestrial and aquatic environments, and the resulting effects of changes in these features on stream biota	16
3.	Future riparian research areas	45

ABSTRACT

The recent interest in riparian zones and their management has been generated by realization of the numerous resource values possessed by those areas. Livestock grazing and wildlife use are primary values of riparian areas. Presently, land managers are hampered in the decision making process by a lack of research data pertinent to riparian environments.

Livestock grazing can influence both the terrestrial and aquatic components of riparian envrionments either indirectly (through their presence in watersheds) or directly (through the actual use of streamside areas). Management of grazing is difficult as livestock tend to congregate in riparian areas. However, grazing management tools such as changing the season of livestock use, controlling livestock stocking rates, manipulation of the kind of grazing animal, and distribution of animals over the range may lessen livestock impacts in riparian areas, especially when they are used in conjunction with a grazing system.

INTRODUCTION

Riparian environments are typified by plant communities which rely on high water tables for their existence (Brown, Brinson, and Lugo 1978). Riparian zones derive water and soils from the drainage and erosion of adjacent uplands and/or from periodic flooding from aquatic ecosystems (Hirsch and Segelquist 1978; McCormick 1979). Vegetation types in riparian zones are variable, and may therefore be of a tree (Tuinstra 1967), shrub (Smith n.d.a), or meadow (Johnson 1978; Speck 1981) aspect. Thomas, Maser, and Rodiek (1979) indicated that riparian zones in western rangelands commonly possess the following characteristics:

1. They create well defined habitat zones within the much drier surrounding areas.
2. They make up a minor proportion of the overall area.
3. They are generally more productive in terms of biomass (plant and animal) than the remainder of the area.
4. They are a critical source of vegetation diversity within rangelands.

The importance of riparian habitats has been widely recognized (Carothers 1977; Fox 1977; Hubbard 1977; Odum 1978; Sands 1979; Smith n.d.a; U.S.D.I. 1978; U.S.D.I. 1980). Lea (1979) indicated that riparian zones were important for fish and wildlife values, recreation, livestock grazing, are often productive timber sites, provide scenic diversity to landscapes, are excellent sources of rock and aggregate, and are good road construction sites. Of these values, the importance

for fish and wildlife values has perhaps received the greatest acknowledgement. This may be attributed to the fact that wildlife use and dependance on riparian habitats is disproportionately greater than for any other habitat type (Thomas et al. 1979; Warner 1979a). For example, Smith (n.d.a) found that riparian zones in southwestern Wyoming were a crucial habitat element for 75 percent of all wildlife species occurring in the sagebrush-steppe environment and 60 percent of all species residing in forested montane habitats.

Due to the ubiquitous nature of livestock on rangelands, and their tendency to congregate in riparian areas, livestock grazing has been implicated as the force most destructive of riparian zones (Behnke 1977; Leopold 1975). Considerable conflict exists regarding the compatibility of livestock grazing and the maintenance of stable riparian ecosystems. Ames (1977) indicated that no known system of livestock management will provide adequate protection to the riparian zone. Others (Claire and Storch in press; Kimball and Savage 1977; Myers 1981) have demonstrated positive responses in riparian habitat conditions when livestock were properly managed.

Federal programs advocating intensified multiple use management on western rangelands can be expected in the future (Lea 1979). Therefore, user demands and conflicts can also be expected to intensify (Rupp 1979). In response to the predicted increased demand, range, wildlife, and watershed scientists, conservationists, government

agencies, and livestock producers have focused their attention on the management of riparian habitats (Roath 1980). The livestock industry and environmental groups in particular have become involved in the management controversy. The controversy focuses on the compatibility of livestock grazing with the maintenance of stable riparian environments.

At present, few studies are available which detail grazing-riparian relationships and grazing management practices which might be used to mitigate livestock grazing impacts on riparian environments. Also, much of the literature which has been generated is not readily accessible and cannot be retrieved through normal literature review. Thus, to date, range managers have had few data and limited information available upon which to base riparian habitat management decisions.

The purpose of this paper is to review and summarize accessible literature directly pertaining to grazing-riparian relationships and livestock grazing management methods by which livestock grazing effects in riparian environments might be mitigated. Secondly, to suggest alternative livestock grazing management practices. Thirdly, to discuss future considerations in riparian research.

ROLE OF RIPARIAN VEGETATION

Streambank vegetation maintains the integrity of the terrestrial-aquatic interface. The roots of riparian vegetation act to stabilize streambanks (Meehan, Swanson, and Sedell 1977; Winegar 1977) thus making them less vulnerable to erosion (White and Brynildson 1967) and trampling damage by livestock (Myers 1981). Riparian vegetation confines flowing water, thus resulting in the development of a deeper stream channel (Marcuson 1977). Simultaneously, the water table in the adjacent lowlands may rise (Winegar 1977), thereby producing a mesic environment which is relatively larger and favors development of a larger riparian community (Smith n.d.a). Streamside vegetation not only shades the stream and reduces water temperatures (Armour 1977; Bowers, Hosford, Oakley, and Bond 1979; Platts 1978a), but also provides shelter for trout at the water's edge in the form of overhanging banks (Armour 1977; Meehan et al. 1977; White and Brynildson 1967). Thomas et al. (1979) indicated that riparian vegetation produces a microclimate differing from surrounding rangelands due to increased humidity, higher transpiration rates, more shade, and increased turbulence.

Riparian vegetation maintains water quality by filtering sediments (Winegar 1977). Smith (n.d.a) reported that spring runoff water containing 1400 mg/l suspended solids had its sediment load reduced by 90 percent to 168 mg/l after flowing through five miles of land with well developed riparian habitat and frequent beaver dams. However, upon leaving this area and flowing through only one and one half miles

of pasture with declining riparian conditions and little or no beaver activity, the sediment load increased to 1150 mg/l (Smith n.d.a).

Meehan et al. (1977) and Odum (1978) suggested that the riparian zone acted as a buffer and filter between man's urban and agricultural development and his most vital life support resource, water. Riparian plants also hold soils and supply and retain organic matter to maintain the productivity of aquatic communities on a sustained basis (Jahn 1978). Riparian vegetation directly controls the food chain of the stream ecosystem by providing organic detritus (Cummins 1974; Likens and Bormann 1974), shading the stream, and by providing insects for stream organisms to feed upon (Meehan et al. 1977). Table 1 lists the functions of the various components of riparian vegetation.

Table 1. Function of riparian vegetation as determined by location within the riparian zone (from Meehan et al. 1977).

Site	Component	Function
Above the stream channel	Canopy and stems	1. Shade-controls temperature and stream primary production. 2. Source of large and fine plant detritus. 3. Source of terrestrial insects.
In channel	Large debris derived from riparian vegetation	1. Control routing of water and sediment. 2. Shape habitat-pools, riffles, and cover. 3. Substrate for biological activity.
Streambanks	Roots	1. Increase bank stability. 2. Create overhanging banks-cover.
Floodplain	Stems and low lying canopy	1. Retard movement of sediment, water, and floating organic debris.

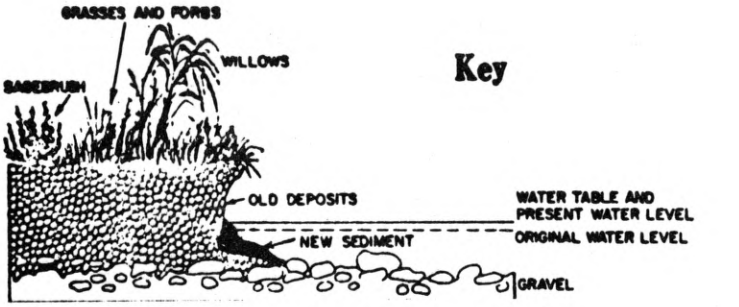
LIVESTOCK GRAZING EFFECTS ON THE TERRESTRIAL-RIPARIAN ENVIRONMENT

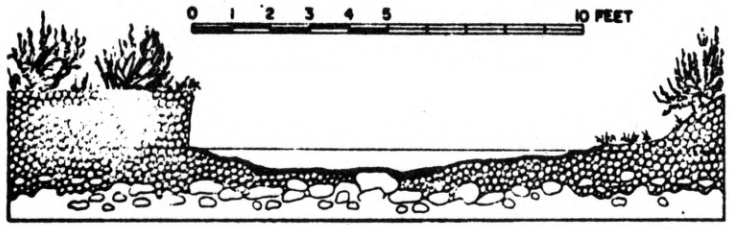
Roath (1980) divided the influences of animals on riparian areas into three principal categories. They were: utilization of herbaceous vegetation, utilization of woody vegetation, and physical damage to the site by trampling.

Excessive utilization of herbage in riparian zones may result in changes in plant community species composition (Claire and Storch in press; Hayes 1978; Tuinstra 1967; Vogler 1978). Claire and Storch (in press) indicated that repeated annual use of vegetation which exceeded the tolerable physiological limits of the plants resulted in a change from a desirable, highly productive stand of grasses and grasslike plants to a plant community of lower productivity. Tuinstra (1967) documented successional changes on grazed and ungrazed floodplains. Heavy grazing was found to eliminate the low and tall shrub strata, and radically alter the species composition of the field layer (Tuinstra 1967). Trampling of plant roots and crowns can upset plant community integrity by creating vacant niches for invasion by weedy plants (Roath 1980). The U.S.D.I. (1978) presented a diagrammatic representation of riparian-stream conditions that resulted from various intensities of livestock grazing (Figure 1).

Decreased productivity has been noted in overgrazed riparian areas. Claire and Storch (in press) reported that some streamside plant communities which had been clipped to determine forage production were producing forage at only 35 percent of their potential as a result of

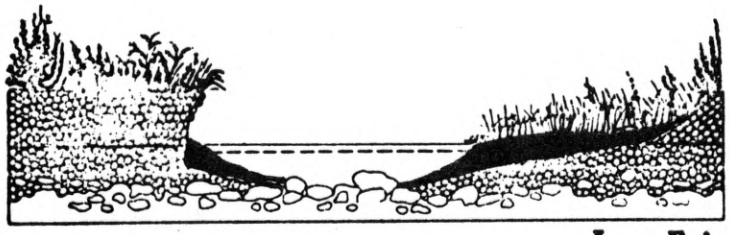
Figure 1. Cattle grazing effects on riparian habitat conditions. (from U. S. D. I. 1978).





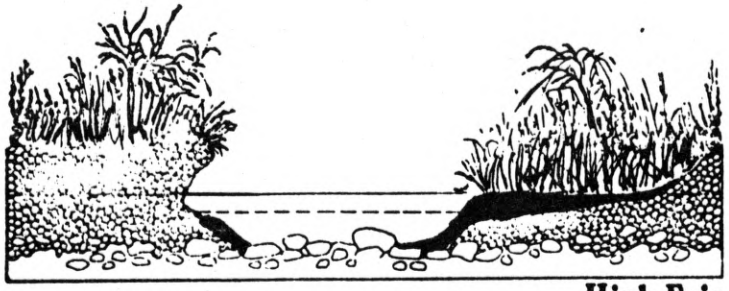
Poor

Channel wide, shallow and easily warmed by full exposure to solar radiation. Low bank stability with active bank erosion. Riparian vegetation quite limited, sagebrush to the streambank in many areas. Low riparian water table. Bottom sediment approaches 60%+, smothering gravel deposits. Habitat for aquatic or terrestrial wildlife essentially nil. Similar to conditions of heavy grazing impact.



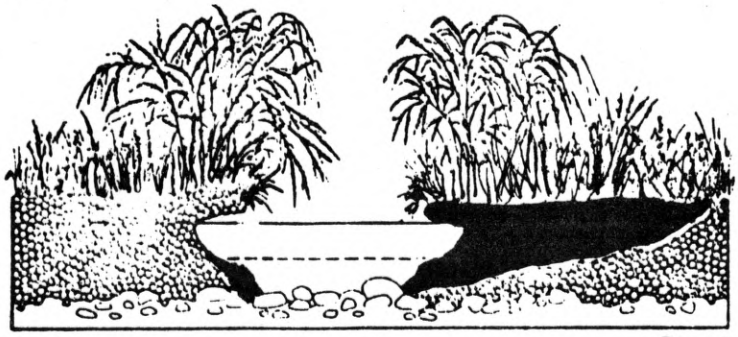
Low Fair

Riparian vegetation begins to form on silted bars and banks forming a sediment trap which builds up banks and begins to confine the channel. Water surface still fully exposed to warming, but level begins to rise, forcing out riparian sagebrush and bringing back riparian vegetation. As flow becomes confined, sediment is reduced to 40-60%. Conditions similar to those of moderate grazing pressure. Willow growth depressed. Habitat value to aquatic or terrestrial wildlife is still quite limited.



High Fair

Semi-confined by development of riparian vegetation with dense root mass. Banks stabilized by vegetation and bottom sediment reduced to approximately 20-30%. Rising water table is reducing sagebrush in favor or riparian grass shrubs. Stream continues deepening as bank resistance to erosion increases. Pools and riffles for fisheries are improving as more gravel is exposed. Representative of light grazing pressure.



Good

Confined-deep channel, elevated riparian water table, fully developed vegetation in riparian zone stabilizing cutbanks, deposited sediment and over hanging banks. Physical cover highly developed for both aquatic and terrestrial organisms. Bottom gravels clean with only 10-15% sedimentation. Reduced water temperatures due to 40-60% shading of surface area. Similar to conditions of very limited grazing or protected areas.

Figure 1. (Continued).

past overgrazing. The U.S.D.I. (1978) suggested that utilization of riparian vegetation may decrease productivity as a result of "salting out" through increased evaporation from the soil. Smith (n.d.a) in a study conducted on Huff Creek in southwestern Wyoming, indicated that overgrazed riparian areas produced 2,000 pounds per acre less forage than areas rested from grazing for two years. It was noted that the same stream contained only one acre of riparian vegetation per stream mile when overgrazed. After two years of rest from grazing, the same mile of stream may support three to five acres of riparian habitat (Smith n.d.a) which would mean an additional 6,000 to 10,000 pounds of forage per mile.

Although "light" browsing may stimulate sprouting in some riparian species such as willows (Salix spp.) (Vogler 1978), several authors (Boldt, Uresk, and Severson 1978; Davis 1977) have reported that excessive livestock use depresses or eliminates the reproduction of woody riparian vegetation. In time, this is reflected by an uneven distribution of the age classes of trees on floodplains, resulting from lack of representation of the younger age classes (Tuinstra 1967). The ramifications of hampered tree reproduction include the eventual elimination of the tree overstory (Crouch 1979). The U.S.D.I. (1978) observed that livestock browsing of current year's willow growth results in a dieoff back to the previous year's growth with little or no production or growth accumulation on grazed stems. In addition, studies of the regrowth rates of heavily browsed leaders indicate that during

the following growing season, willow leader regrowth may be reduced to 50 percent of the new year's growth of ungrazed stems (Smith n.d.a; U.S.D.I. 1978).

Marcuson (1977) noted differences in soil profiles on grazed and ungrazed sections of Rock Creek in Montana. The ungrazed area was characterized by a more developed soil profile with greater amounts of silt and plant roots. Soils in the grazed area were less developed and exhibited a sandy-cobble texture which was relatively less stable than the finer textured soils on the ungrazed area. Also, grazed area soils were drier due to their coarser texture, and provided a less favorable environment for riparian plant growth due to the relatively lower soil water holding capacities exhibited by these sites (Marcuson 1977).

Roath (1980) indicated that perhaps the greatest potential physical impact of cattle in riparian areas was soil compaction resulting from trampling. Meadows are especially vulnerable to compaction when wet (Roath 1980). Orr (1960) found that grazed Kentucky bluegrass (Poa pratensis) streambottoms had higher soil bulk densities and less pore space than soils in ungrazed bottoms. The U.S.D.I. (1979) suggested that light to moderate intensities of grazing will not damage infiltration rates during unsaturated soil conditions. However, livestock concentrations resulting from any phase of a grazing system which encourages high intensity grazing is likely to significantly reduce the potential rate at which rainfall or snowmelt can infiltrate into the soil (U.S.D.I. 1979).

Several factors may influence streamside vulnerability to trampling damage (Cooper 1979; Hayes 1978; U.S.D.I. 1978). Hayes (1978) indicated that a combination of high forage removal, high amount of livestock foraging time along streambanks, and high amounts of bank vegetation composed of palatable sedges resulted in increased streambank vulnerability to trampling damage and erosion. Streambanks high in sand content are particularly vulnerable to livestock pressure and are highly susceptible to vegetation cover loss due to bank shearing and livestock trampling (U.S.D.I. 1978). Streambanks lacking large amounts of log debris, dense woody vegetation, and/or considerable bank rock content are sensitive to trampling (Cooper 1979). In general, as bank rock content declines, a more vigorous vegetation cover is required to stabilize streambanks (U.S.D.I. 1980).

Livestock grazing within watersheds affects the riparian zone, especially the aquatic component. Heavy livestock grazing on uplands and in valleys reduces vegetation cover (Behnke and Raleigh 1978; Davis 1977; Glinski 1977; Winegar 1977). As a result, runoff from the watershed intensifies (Behnke and Raleigh 1978; Lusby 1970; Winegar 1977) and results in gullying (Winegar 1977) or stream channel braiding (Behnke and Raleigh 1978). The erosive forces resulting from increased runoff may lower water tables by cutting through soft streambeds (Berry 1978; Winegar 1977). When this occurs, plant communities may change from the original wet meadow types to more xeric vegetation types such as sagebrush (Artemisia spp.) and rabbitbrush (Chrysothamnus spp.) (Behnke and

Grazing in riparian environments may reduce wildlife habitat values. The importance of riparian areas for birds has been well documented (Anderson, Higgens, and Ohmart 1977; Hehnke and Stone 1978; Stevens, Brown, Simpson, and Johnson 1977). Lower structural diversity through the removal of the various shrub strata by grazing may reduce bird species diversity (Stauffer and Best 1980). Changes in the structure of riparian communities may also alter small mammal species composition (Geier and Best 1980). Boeer and Schmidley (1977) indicated that comprehensive studies of riparian mammals were lacking. However, numerous game, furbearing, and nongame animals are known to utilize riparian areas (Claire and Storch in press). It is not within the scope of this paper to detail habitat relationships of riparian wildlife species. However, it is reasonable to expect that grazing within the riparian zone will in some way influence the wildlife species which utilize that habitat. Future research with respect to livestock grazing and resulting effects on riparian wildlife is recommended.

Several factors can complicate the assessment of livestock grazing impacts in riparian environments. Knight (1978) and Roath (1980) both studied grazing riparian relationships in Oregon. They indicated that pocket gopher disturbances in meadows could obscure livestock grazing effects. Soil compaction effects under light grazing may not be noticeable after one year as soil bulk densities generally decrease over winter due to frost heaving and wetting and drying of the soil (Knight

1978). The presence of humans and their associated activities may also result in impacts similar to those attributed to livestock (Busby 1979; Settergren 1977), thus further complicating the assessment of livestock grazing impacts in riparian zones.

LIVESTOCK GRAZING EFFECTS ON THE AQUATIC-RIPARIAN ENVIRONMENT

Livestock may drastically alter the stream environment in a relatively short period of time through streambank trampling and by removing vegetation while foraging (Duff in press). Behnke (in press) suggested that livestock grazing effects on aquatic ecosystems may be gradual and cumulative. This may be attributed to the "assimilation capacity" of the stream which reflects the ability of a stream to hide or avoid short term effects (Likens and Bormann 1974).

Physical damage to the riparian environment results from the trampling of streambanks and associated vegetation. Riparian vegetation which has been trampled loses its ability to maintain streambank integrity, thus affecting the aquatic environment. Streambank erosion increases (White and Brynildson 1967; Platts 1978b) under grazing pressures; consequently stream channels lose stability (Gunderson 1968; Marcuson 1977). Streams in grazed areas are characterized by a constantly shifting thalweg (Marcuson 1977) and a more braided channel network (Behnke 1977; Marcuson 1977). Streams in grazed areas are typically wider and shallower (Armour 1977; Duff in press; Gunderson 1968; U.S.D.I. 1980b; White and Brynildson 1967) and tend to have higher

temperatures (Armour 1977; Berry 1978; Bowers et al. 1979; Storch 1979) due to decreased vegetal shading (Claire and Storch in press) which increases the amount of stream surface exposed to solar radiation (Bowers et al. 1979; Brown and Krygier 1967; Greene 1950). Gunderson (1968) and Marcuson (1977) in studies conducted on Rock Creek in Montana found ungrazed stream sections to have 76 percent and 82 percent, respectively, more cover (in the form of undercut banks, debris, and overhanging brush) than did grazed sections. A diagrammatic representation of the major effects of overgrazing on terrestrial and aquatic environments is presented in Figure 2.

Among the most critical of livestock grazing effects is the increase in sediments added to streams (Armour 1977; Duff 1979). Sediments decrease stream productivity in several ways. Increased turbidity may decrease stream productivity by reducing photosynthetic rates of aquatic vegetation (Berry 1978; Cordone and Kelley 1961). More important perhaps is the impact of sedimentation on the reproduction of fish. Gebhards (1970) noted that turbid water during trout spawning periods may result in mortality of trout eggs. This occurs when sediments settle and coat stream gravels. Armour (1977) indicated that trout embryos suffocate because sediments reduce the exchange of oxygen between the eggs and the environment. Metabolic wastes also tend to accumulate around the embryos, thus contributing to higher mortality rates (Armour 1977).

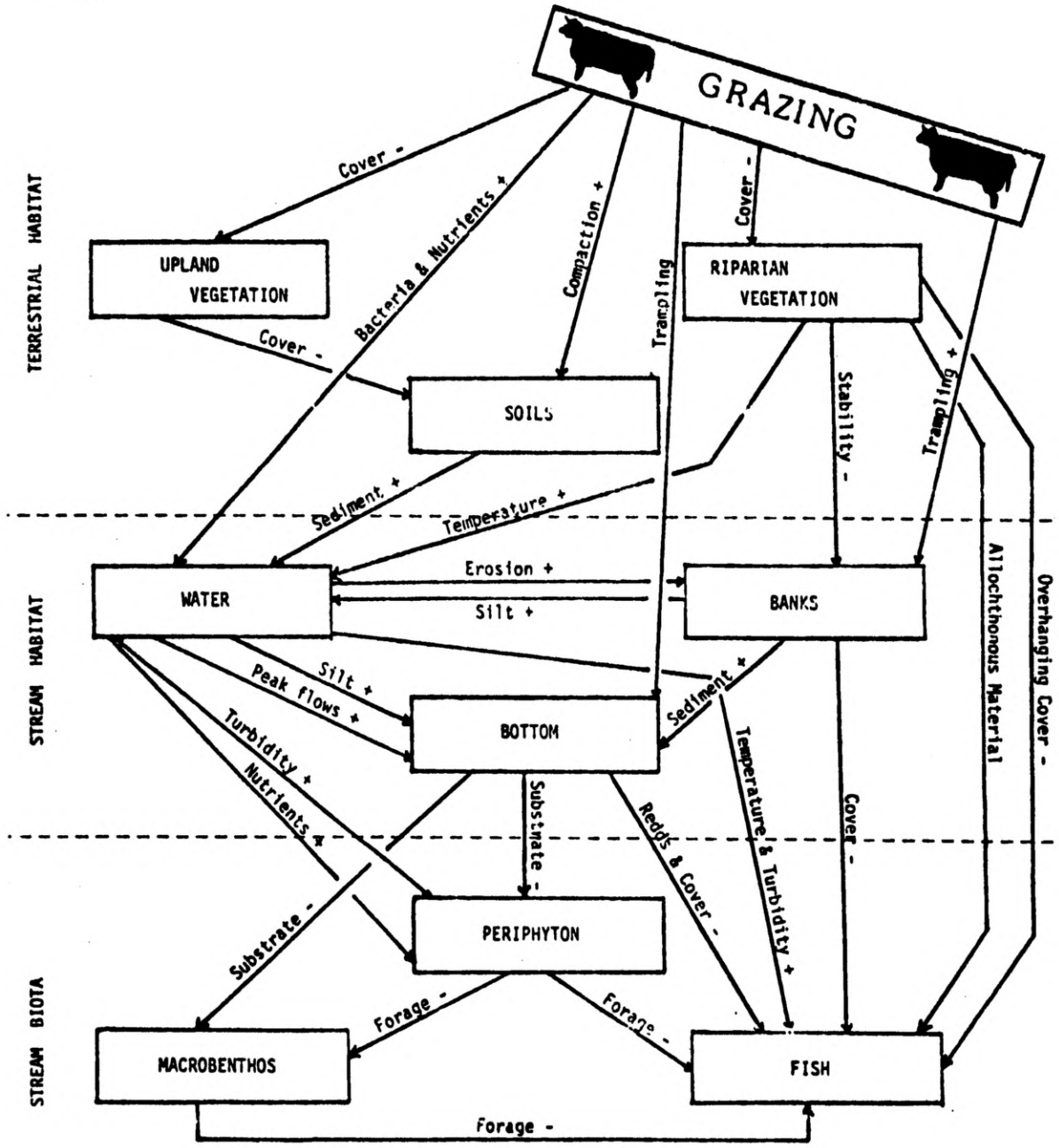


Figure 2. Major effects of overgrazing on terrestrial and aquatic environments and the resulting effects of changes in these features on stream biota. (from Berry 1978).

Cordone and Kelley (1961) reviewed the effects of inorganic sediments on stream biota. Among their conclusions were:

1. Sedimentation is one of the most important factors limiting the natural reproduction of salmonids in streams.
2. Sedimentation may destroy populations of aquatic invertebrates by eliminating clean, gravel substrates.
3. Organic inputs and sediments may alter water chemistry, particularly the dissolved oxygen content.
4. Sediment deposition between boulders reduces shelter for trout.

Livestock can also impact stream water quality. Significant increases in total coliforms, fecal coliforms, and fecal streptococci (Darling and Coltharp 1973; Speck 1981) and in natural fertilizers such as nitrogen and phosphorus (Johnson, Gary, and Ponce 1978) may be noted in watersheds grazed by livestock. Although plant growth and fish production may be stimulated by nutrient inputs (Johnson et al. 1978), excessive nutrient loading may result in eutrophication (U.S.D.I. 1979). The addition of pathogenic bacteria to streams may cause human health problems for considerable distances downstream from the point of input (Darling and Coltharp 1973; Johnson et al. 1978). However, Johnson et al. (1978) found no significant evidence of major long term cumulative impairments of water quality due to past grazing practices. The U.S.D.I. (1979) indicated that the evaluation of non point source pollution and transport effects was confounded by an interaction between land

characteristics (edaphic, geologic, and vegetal), natural wildlife populations, local hydrology, and present and past climatic conditions. Knight (1978) found that seasonal variation and natural variability in streambank vulnerability can obscure grazing effects on sediment production, bank cutting, and stream profiles. Hayes (1978) indicated that streambank sloughing was greater in some ungrazed than grazed meadows.

Several authors (Claire and Storch in press; Smith n.d.B) have indicated that game fish production can be used as a biological indicator of the quality of land management within the watershed and/or at the streamside. In general, ungrazed streams tend to be more productive in terms of game fish than streams experiencing grazing pressures. For example, Gunderson (1968) noted that the estimated number and weight of brown trout (Salmo trutta) per acre of stream was greater under ungrazed conditions. Marcuson (1977) on the same stream, found brown trout biomass to be 3.4 times greater in the ungrazed section of the stream.

RECOVERY RATES OF RIPARIAN AREAS DISTURBED BY GRAZING

The majority of studies to date have compared recovery of riparian areas under grazed vs. ungrazed conditions (Dahlem 1979; Duff in press; Keller, Anderson, and Tappell 1979; Van Nelson 1979; Winegar 1977). Fewer studies are available which document riparian zone recovery under various levels of livestock use.

Generally, riparian zones protected from grazing quickly recover to pregrazing conditions. Dahlem (1979) noted significant improvement in stream bottom composition, streambank stability, and vegetation cover after two years of protection from livestock grazing. Nine years after fencing Camp Creek in Oregon, Winegar (1977) indicated substantial improvement in plant species composition, larger and more diverse wildlife populations, and improved stream conditions as reflected by deeper stream channels and more stable streambanks. In Nebraska, Van Nelson (1979) noted lower average stream temperatures one year after fencing. Willows increased in prominence and most streambanks had stabilized. Average stream width decreased and water velocities increased, thus flushing sand and silt from stream gravels. Favorable responses were also noted in fish species composition as rainbow trout (Salmo gairdneri) achieved dominance (Van Nelson 1979). Keller et al. (1979) indicated that streambank vegetation had stabilized previously eroding banks on Summit Creek in Idaho after two years of protection from livestock grazing. Simultaneously, the stream became narrower and deeper (Keller et al. 1979). Substantial increases in mats of aquatic vegetation were observed. Algae (Nitella spp.) and buttercup (Ranunculus aquatillus) harbored an abundance of mayflies, stoneflies, caddisflies, freshwater shrimp, and other important trout foods (Keller et al. 1979). Trout habitat was believed to have improved as a result of increased vegetation and instream cover (Keller et al. 1979).

Marcuson (1977) suggested that it would take 25 years of protection from grazing and destructive floods in order to develop a young forest ecosystem on the Rock Creek, Montana floodplain. However, areas less severely disturbed could be restored much sooner (Marcuson 1977; Tuinstra 1967).

Smith (n.d.b) and the U.S.D.I. (1981) indicated that the restoration of riparian dry meadow sites could be accelerated through the use of fire and by one to two years of rest from grazing. Supplemental planting of rooted willow cuttings may also enhance the rate of willow recovery (U.S.D.I. 1981).

Smith (n.d.a) found that two years of rest from grazing were the minimum necessary before significant growth responses of heavily utilized willows could be observed. After three growing seasons of rest, streambanks were 90 percent stabilized, and dryland shrubs were in a downward trend. Also noted were decreases in soil compaction effects with concurrent increases in soil water holding capacity. Smith (n.d.a) concluded that in designing and monitoring livestock grazing systems, riparian soil compaction and willow growth rates were two significant criteria which could be used to determine the degree of riparian recovery, and effectiveness of the grazing system being applied.

The length of the rest period required for achieving improved productivity and diversity of riparian areas is contingent upon the intensity of utilization prior to initiation of the rest period (Smith

n.d.a). Smith (n.d.a) suggested that where riparian vegetation is utilized in excess of 100 percent, three to five years of rest from grazing may be required. At 75 percent utilization two years of rest may be required. At 50 percent, one year of rest, while at 25 percent or less it may be possible to implement a deferred rotation grazing system annually and still maintain multiple use objectives and riparian zone integrity (Smith n.d.a).

Orr (1960) studied soil porosity and bulk density on grazed and ungrazed bluegrass stream bottoms in the Black Hills of South Dakota. He noted that the difference in the magnitude of recovery from soil compaction was primarily related to soil texture, and not directly related to the length of time that livestock use was excluded. Therefore, finer textured soils were more prone to compaction and required more time to lower bulk density and recover large pore spaces. In general, more than one year of rest from grazing is necessary for improvement in soil pore space, infiltration capacities, and before decreases in summer runoff rates are noticed (Orr 1975). Often recovery continues for four to five years or more (Orr 1960; Orr 1975).

Several factors in addition to prior livestock use will influence the length of time necessary for regeneration of shrub communities in riparian zones. High streambanks with relatively low water tables may not be conducive to the development of riparian shrubs which require more mesic conditions (U.S.D.I. 1981). Dense stands of grasses

and forbs may competitively supress shrub regeneration (Boldt, Uresk, and Severson 1978; U.S.D.I. 1981). Also, wildlife attracted to the area as a result of lush vegetation may concentrate their browsing efforts on young shrubs (U.S.D.I. 1981).

At present, no studies are available which describe the retrogression process in stable, previously ungrazed riparian areas. However, Duff (1979) indicated that six weeks of trespass livestock grazing within an exclosure protected from grazing for four years had completely eliminated willows, and reduced the grass-sedge vegetation types to pre-exclosure conditions.

GRAZING MANAGEMENT PRACTICES

Kinds of Livestock

The manipulation of the kind of grazing animal is one aspect of riparian grazing management which has received inadequate consideration (Busby 1979). This is of particular importance as different kinds of stock possess adaptions which are reflected by the influence that the animal has on the range (Stoddart, Smith, and Box 1975). Unfortunately, in most instances the animal which may be best suited to the range biologically has often not been used due to economic or social reasons (Busby 1979; Stoddart et al. 1975). For example, some ranges are better suited to grazing by sheep, however cattle are used because they are more profitable (Stoddart et al. 1975). The U.S.D.I. (1978) indicated that major conversions from sheep to cattle operations, along

with anticipated long term increases in livestock use, and grazing systems designed around key upland forage species have been insensitive to the needs of aquatic habitats.

Little information is available in the literature with regard to the influence of different kinds of livestock on riparian environments. What little literature is available, deals with cattle and sheep. Documentation of use of riparian areas by horses and goats is lacking.

Cattle have been observed to cause much greater problems in riparian areas than sheep (Skeesick 1981). This may be attributed to the fact that sheep can be herded much more easily than cattle, and also have a greater ability to graze steep topography (Busby 1979). Therefore, by grazing the range with sheep, riparian environments may be avoided (Myers 1981; U.S.D.I. 1978). Impacts to riparian areas can also be reduced as a result of sheep herders selecting areas for watering (Busby 1979; U.S.D.I. 1978). Many sheepherders prefer herding sheep on open ridges as the animals are easier to handle (Myers 1981). Therefore, lambing and bedding activities can be directed to upland watering sites (Myers 1981).

Myers (1981) indicated that in areas with steep topography, yearling cattle tended to disperse away from streambottoms much more than cow-calf pairs. Others (Hedrick, Eller, McCarthur, and Petitt 1969; Young, McCarthur, and Hedrick 1967) have also reported better dispersal of yearlings than for cow-calf pairs. Such findings would suggest that

riparian environments might receive less use and therefore maintain more stable conditions when pastures are stocked with yearlings instead of cow-calf pairs.

Platts (1979) suggested that further research was necessary to determine which kinds of animals might be used to mitigate grazing impacts in riparian zones. In addition, Stoddart et al. (1975) indicated that even the breed of animal used may be an important determinant in how a range was used.

Livestock Numbers

Correctly determining stocking rates is of critical importance if riparian areas are to be maintained in a productive condition. Past stocking rates may have been adequate where the total amount of available forage was concerned. However, this practice may not account for livestock distribution problems and the higher utilization rates experienced by riparian vs. upland range types. In general, blanket application of a single utilization rate to all range types is unacceptable as upland ranges may not receive the desired amount of utilization, while riparian types, due to their attractiveness to stock may be utilized excessively.

Skeesick (1981) indicated that Region Four of the Forest Service authorizes grazing to the 50 percent utilization level. Often, riparian areas are grazed to a far greater percent utilization (Skeesick 1981).

Of the papers that I reviewed, terminology such as "light", "moderate", and "heavy" use were often encountered. Actual utilization

percentages were not reported. Therefore objective comparison of the various studies is difficult.

Severson and Boldt (1977) indicated that where hardwood draws occupied a small proportion of a pasture, chances were good that they would be overused by cattle, regardless of stocking rate. Cooper (1979) suggested that complete forage utilization was not necessary to damage sensitive streambanks. Greater numbers of stock may disproportionately accelerate damage to riparian areas (Cooper 1979). However, the premise that stocking rate reductions might reduce impacts on riparian areas is not entirely valid as fewer animals might spend a longer period of time grazing in the riparian zone (U.S.D.I. 1978).

Smith (n.d.a) indicated that stocking rate reductions might not be necessary if the productivity of the riparian zones can be restored. However, this would require two or more years of rest from livestock grazing (Smith n.d.a). This would also necessitate either the outright removal of livestock from pastures containing riparian habitat, or the use of intensive animal management practices which would keep stock out of the riparian areas.

The U.S.D.I. (1980a), using riparian condition rating criteria developed by Myers (1981), noted that the most successful grazing systems utilized light to moderate stocking rates. However, it must be realized that sensitive streambanks may not be protected by simply reducing livestock numbers (Cooper 1979). Also, where economics is to be a consideration, the right number of cattle might be too low (Cooper 1979).

Season of Livestock Use

Grazing during the proper season is particularly important if riparian soils and vegetation are to receive adequate protection. Determination of proper season of use should consider the physiological requirements of the riparian vegetation and the vulnerable periods of the physical environment as well.

Severson and Boldt (1977) noted that season long summer grazing was most detrimental to woody riparian habitats in the western Dakotas. Myers (1981) indicated that more than one "hot" season (July 10-September 1) use out of four resulted in lower habitat ratings for woody riparian zones in southwestern Montana. Various degrees of lighter use during the cool seasons can be tolerated in combination with one heavy "hot season" use treatment (Myers 1981). Martin (1979) indicated that cattle began browsing tree reproduction late in the spring and were especially attracted to shrubby vegetation once leaves were present. Browsing damage could be reduced by removing animals before or soon after palatable species of shrubs develop leaves. Also, removing cattle at "leaf out" for several consecutive years would allow tree reproduction to develop to the point where it is no longer vulnerable to livestock damage (Martin 1979).

Roath (1980) suggested that the management plan which would benefit shrubs most (i.e. grazing early in the season) would have the greatest potential for damaging the herbaceous vegetation. Conversely, late season grazing would minimize impacts on the herbaceous vegetation, but

would increase shrub utilization (Roath 1980).

The presence of livestock in riparian areas during the winter months can also result in impacts. Supplemental feeding of stock in riparian areas may result in local deterioration because livestock tend to remain on feed sites (Severson and Boldt 1977). However, in most cases, winter grazing does not seem to be particularly harmful to deciduous shrubs (Severson and Boldt 1977) as they are in a dormant state. Myers (1981) indicated that during the fall and winter months, forage was generally more available on uplands and south facing slopes. Temperature inversions and snow accumulations tend to discourage stock use of riparian zones during the winter (Myers 1981). However, it must be noted that stock will utilize riparian areas for shelter when windy conditions prevail (Ames 1977).

Proper season of use to protect against soil compaction should consider soil moisture conditions. Gradwell (1968) and Orr (1960) indicated that livestock soil trampling effects were greatest during wet seasons. Orr (1960) noted that dry soils were generally highly resistant to compaction.

Improving Distribution of Livestock to Reduce Impacts on Riparian Areas

Obtaining proper distribution of livestock appears to be the greatest problem confronting range managers and livestock producers. Proper distribution of livestock on the range is important in order to insure that certain sites are not used excessively, while also insuring that

forage is not wasted on underutilized sites (Stoddart et al 1975).

Livestock, especially cattle, tend to congregate in riparian areas (Behnke and Raleigh 1978; Cook 1966; Cooper 1979; Dahlem 1979; Stoddart et al 1975). This preferential use may be attributed to the fact that riparian zones provide most if not all of the habitat elements sought by livestock. Riparian areas typically provide forage of relatively higher palatability (than the surrounding ranges), shade, and water (Ames 1977; Boldt et al 1978; Dahlem 1979; Severson and Boldt 1977) and relatively level terrain. Use and grazing impacts on riparian environments increase with the progression of the grazing season as surrounding ranges become dessicated (Behnke and Raleigh 1978; Hayes 1978), or with movement from wetter to drier rangeland environments (Myers 1981). Martin (1979) found that cattle began grazing slopes and browsing riparian tree reproduction mainly after forage on the flatter ridges had been consumed or had decreased in palatability. Cook (1966) evaluated 21 variables known to influence livestock utilization on mountainous ranges. Of these, the most important were:

1. Percent slope at site.
2. Percent slope adjacent to water.
3. Percent slope from site to water.
4. Distance to water below.
5. Percent maximum slope between site and water.
6. Percent palatable plants on site.
7. Thickness of brush around site.

8. Percent slope from site to salt.

Importantly, no one factor can be used as a reliable index to predicting use (Cook 1966).

Roath (1980) and Martin (1979) indicated that cattle tend to form home ranges. Animals whose home ranges include riparian areas would be more problematic as they would be less responsive to distribution improving practices.

Several management practices are available to the range manager to improve livestock distribution. Of these, salting, herding, fencing, and developing upland stock watering facilities have been advocated (Claire and Storch in press; Severson and Boldt 1978).

Distance to water ultimately controls the limit of vegetation utilization when other factors do not influence cattle distribution (Roath 1980). Where riparian habitat offers the only sources of shade and water, dispersal of stock is poor and could account for poor riparian zone management (Myers 1981). Development of alternate sources of stock water is desirable, but it should be done in conjunction with other distribution improving practices. McIlvain and Shoop (1971) indicated that the combined use of several livestock distribution tools was always more effective in promoting uniform forage use than was their use singly. Water location was the single most effective stock attractant, followed by supplemental feeding away from water and artificial shade development (McIlvain and Shoop 1971).

Salting should be used as a means of drawing livestock out of riparian environments (Myers 1981). Roath (1980) demonstrated that salt was used more heavily in wet than dry years. In years when vegetation remained succulent later into the growing season, and water was more widely distributed, cattle often bedded and remained near salt areas for several hours (Roath 1980). Therefore, it appears that moisture conditions on the range strongly influence the effectiveness of salt in promoting good livestock distribution. Success in distributing animals may decline with progressively drier environmental conditions.

Herding of animals may be used to improve distribution on ranges and thus reduce impacts on riparian zones. Workman and Hooper (1968) indicated that where slopes adjacent to bottoms were less than 35 percent, herding could increase forage utilization by 20 percent. Storch (1979) noted that livestock herding by permittees was a most successful management practice. Where permit holders herded livestock on a somewhat daily basis, the number of livestock visiting stream bottoms was successfully limited (Storch 1979). Roath (1980) however indicated that herding animals with home ranges established in riparian areas might not be worthwhile as they would tend to return to these areas. In such cases, animals would require constant tending, a practice which might not be practical in all cases (Storch 1979).

The development of alternate shade sources appears to be a promising practice for relieving animal pressures in riparian zones. McIlvain and Shoop (1971) indicated that development of artificial shade structures

in underutilized areas could be used to reduce localized damage. Shade was utilized by steers having access to it, while steers in adjacent pastures spent the hot part of the day near water (McIlvain and Shoop 1971). Cooper (1979) observed that in northern Idaho, shaded, sensitive streambanks with unpalatable forage usually sustained little damage, while in Wyoming, shaded sensitive streambanks with unpalatable forage often sustained significant damage. The degree of bank damage was contingent upon the amount of shade present in the pastures (Cooper 1979). On the Idaho study area, shade was well distributed, whereas in Wyoming, shade was limited to the immediate stream vicinity, thus attracting and concentrating livestock (Cooper 1979). Myers (1981) observed that stock continued to use riparian areas for loafing and watering even after the herbaceous vegetation had been removed.

Fencing to exclude livestock use from riparian areas has been suggested (Hormay 1976 in Armour 1977; White and Brynildson 1967). Hormay (1976) in Armour (1977) stated:

> "Vegetation in certain areas such as meadows and drainage ways is invariably closely utilized under any stocking rate or system of grazing. Such use may be detrimental to wildlife, esthetic, recreational, or other values. Where this is the case, about the only way to preserve values is to fence the area off from grazing. Reducing livestock or adjusting the grazing season will not solve such a problem."

Fencing has been recognized as being costly and therefore practical only when areas containing other high priorities were to be managed for specific uses (Behnke and Raleigh 1978; Bowers et al. 1979). However,

Olson and Armour (1979) conducted an economic analysis of benefit cost ratios resulting from fencing riparian areas and managing them as corridors for fish and wildlife values. They indicated a minimum return of $1.66 for each dollar invested. Where management plans did not include permanent exclusion of livestock, economic benefits associated with improved riparian zones could be more pronounced (Olson and Armour 1979).

Other practices which may improve livestock distribution have been suggested. Among these were: building trails to areas containing adequate forage, shade, and water (Roath 1980; Workman and Hooper 1968) and, seeding of logged over areas with palatable grasses (Storch 1979) to draw livestock out of riparian areas.

GRAZING SYSTEMS

The use of grazing systems in the management and improvement of riparian habitats has received considerable scrutiny in recent years. There is some doubt as to the utility of such systems in protecting the needs of riparian areas (Ames 1977; Platts 1978a). Recently, progress and promising results have been derived from grazing systems which considered the needs of riparian soils and vegetation.

Platts (1978a) evaluated several grazing systems with respect to the resulting riparian habitat conditions (Table 2), however, no scientific support was provided. The U.S.D.I. (1978) and U.S.D.I. (1980a) provide additional information on riparian responses to various grazing treatments.

Table 2. An evaluation of grazing systems and riparian aquatic conditions resulting from their use. (from Platts 1978a).

System	Condition of the riparian-aquatic habitat
Yearlong grazing	poor
Season long grazing	poor
Deferred grazing	poor to fair
Rotation grazing	poor to fair
Deferred rotation grazing	poor to fair
Rest rotation grazing	poor to variable*
Short duration-high intensity grazing (HILF)	variable*
No grazing	Good to excellent

* Resource damage, especially bank cutting within heavy use limits may not be repaired within the grazing cycle.

Season long grazing by livestock generally does not achieve multiple use stream management objectives (Storch 1979). Season long grazing in mountainous areas increases meadow use, and especially streambank use into the latter part of the grazing season (Johnson 1965 in Hayes 1978). Continuous and repeated annual grazing of meadows during these critical times may result in a high probability of bank degradation as streamside vegetation is not rested or allowed to regain vigor (Hayes 1978).

Deferred and deferred rotation systems may also be inadequate in achieving stream management objectives (Platts 1978a; Storch 1979). Severson and Boldt (1977) indicated that two and three pasture deferred rotation systems did not appear to benefit woody vegetation. However, Speck (1981) on a high mountain watershed in Wyoming noted that a four pasture deferred rotation system produced desirable responses in the riparian zone. Improved bank stability, a 76 percent increase in undercut banks, decreased silt deposition resulting in cleaner stream gravels, and a higher proportion of renewable cover expressed as overhanging vegetation were among the improvements (Speck 1981). Counts of bacterial indicator groups were variable, but in general were lower in deferred pastures than in pastures grazed season long (Speck 1981).

Several individuals have indicated the importance of allowing riparian areas to stabilize prior to grazing system implementation (Bowers et al 1979; Kimball and Savage 1977; Smith n.d.b). Generally, exclusion of livestock grazing for two to five years will be sufficient for riparian recovery (Smith n.d.b). Once stabilized, these areas

can be managed with less restrictions on grazing as they are less vulnerable to degradation (Myers 1981). Allowing riparian areas to stabilize and regain productivity will make them more valuable for future livestock use as riparian areas which receive adequate protection are generally of greater acreage and produce more forage (Smith n.d.A).

The most promising riparian responses have resulted from the implementation of rest rotation grazing systems. These systems avoid streambank damage by the removal of animals prior to reaching critical animal concentration periods (Hayes 1978). Claire and Storch (in press) indicated that rotation systems which included one year of rest out of three were generally successful in achieving streamside management objectives in Oregon. However, Storch (1979) noted that the recovery of herbaceous vegetation was not realized within the desired time frame. In southwestern Montana, Myers (1981) suggested that pastures containing woody riparian habitats could not be grazed during the summer more than once per four years if high riparian conditions were to be maintained. Kimball and Savage (1977) demonstrated that three pasture rest rotation systems resulted in significant improvement in streambank stability and pool areas, improved plant species composition and ground cover, resulted in an upward trend in soil and forage condition, and increased numbers of game fish. Alternately grazed two pasture rest rotation systems are inadequate in protecting streambank stability and aquatic habitat due to the intensity of grazing received by each pasture every other year (U.S.D.I. 1978).

Platts (1978.a) indicated that short duration high intensity grazing (HILF) might be used in riparian zone management. This method was developed in Africa (Goodloe 1969) and supposedly can be implemented in any range situation (Savory n.d.). HILF systems are comprised of numerous pastures which are grazed at high intensities for short periods of time (Goodloe 1969; Savory 1980). Range condition and animal production per acre have been found to improve considerably, although stock condition is slightly less than under continuous selective grazing (Goodloe 1969). Presently no information is available as to the utility of HILF in maintaining riparian values. Further evaluation of this method is desirable.

Several factors may influence the success of grazing systems in riparian zone management. Severson and Boldt (1977) suggested that the percentage of the pasture occupied by wooded areas influenced the relative amount of degradation. Where livestock have more available riparian areas, localized concentrations are not as great as stock have relatively more riparian zone over which to distribute themselves (Severson and Boldt 1977). Myers (1981) indicated that the success of grazing systems in southwestern Montana may be attributed to the extended summer green season. Areas characterized by hot, dry summers, and where succulent forage is limited to riparian areas may require more restricted grazing management. However, grazing managment in more mesic areas is probably more successful with less intensive management (Myers1981).

Condition of the riparian zone prior to grazing system implementation is important in determining grazing system success. Storch (1979) noted that the composition, density, and age-class variation of riparian vegetation were critical condition factors. Generally, where vegetation is in good condition, rest rotation systems maintain or improve vegetation condition (Storch 1979). Also, where adequate forage and water are available away from streams, streamside areas improve in condition (Storch 1979).

The U.S.D.I. (1980a) suggested that the following points be considered where grazing systems were to be implemented in riparian habitats:

1. Natural bank vulnerability.
2. The amount of riparian habitat in managed pastures.
3. The abundance of other shade and water sources.
4. Stocking rates.
5. The density of woody species relative to stock movements.
6. Streamside topography.
7. Class of livestock.
8. Upland range conditions.
9. Salting and fence locations.
10. The condition of the riparian habitat before management plan implementation.

Grazing systems which protect riparian habitats possess the following characteristics (U.S.D.I. 1980a):

1. They are lightly to moderately stocked.

2. They include not more than one "hot" season of use each three years.
3. They contain ample riparian habitat so as not to create excessive stock concentrations.
4. Fences are properly dispersed from streams.
5. They contain streambanks that are not excessively frail.

GRAZING MANAGEMENT CONSIDERATIONS

Armour (1977) indicated that range specialists have three alternatives for the management of degraded trout streams, they are:

1. Permit existing grazing conditions to prevail and risk additional deterioration.
2. Manage exclusively for quality fish habitat.
3. Implement a livestock management program which will help improve the stream to some acceptable level of trout production.

Although these suggestions are fisheries oriented, the literature supports the fact that quality fisheries are often indicative of good riparian conditions (Smith n.d.b). As the public's environmental awareness increases, it will be unreasonable to expect that alternative number one will be viable. Alternative two, although popular with certain special interest groups, is neither practical nor economically feasible. Management exclusively for quality fisheries habitat will only be realized in situations where the management of unique and exception-

ally high quality fisheries is such high priority so as to preclude all other possibly conflicting uses. As multiple use demands increase, it is likely that alternative three will prevail. In most cases, it will be desirable to manage ranges to produce as many resource values as possible. We cannot afford to exclude livestock from our rangelands. However, we can ill afford to degrade our riparian areas and lose some of their associated values. Therefore, livestock grazing management practices which are more compatible with the requirements of riparian habitats will have to be implemented. Grazing management alternatives have been derived from the literature reviewed in this paper. They are:

1. Consider conversion to kinds of stock which graze more compatibly with the needs of riparian areas (i.e. sheep). Where this conversion is acceptable to livestock operators, riparian conditions may improve.
2. Graze during the proper season(s). For woody riparian areas this generally means exclusion or infrequent summer use (Myers 1981). Herbaceous riparian zones can best withstand use after the growing season (Pond 1961).
3. Since cattle are more attracted to shrubby vegetation once leaves are present, browsing damage may be reduced by removing animals prior to leaf development by palatable woody species (Martin 1979).
4. Graze after soils are no longer vulnerable to compaction

(i.e. after drying out).

5. Avoid winter feeding of stock in riparian areas.
6. Utilize practices in combination, which improve livestock distribution by drawing them out of riparian areas. For example, where shade and water are limited on ranges, they should be developed in close proximity to each other in order to increase their effectiveness (McIlvain and Shoop 1971).
7. Consider fencing riparian areas, allowing them to regain productivity, and then using them as separate pastures in a grazing management system.
8. Do not turn stock into riparian areas when first introducing them into the pasture as this may result in the entire herd using the riparian zone at the initiation of the grazing season (Roath 1980).
9. Consider culling animals from the herd which have established home ranges within riparian zones (Roath 1980).
10. Consider using animals with no previous grazing experience on a given allotment, and behaviorally bonding them to under-utilized areas (outside of the riparian zone) (Roath 1980). Success will be contingent upon the presence of water, forage, shade, and salt in the new area (Roath 1980).
11. Stock should be physically moved between pastures, and gates closed, as allowing for natural drift between pastures often

results in both being used, therefore increasing use on riparian areas (Myers 1981).

One might question the compatibility of some of the suggested alternatives as some appear to be mutually exclusive. When considered individually, this may be true. However, when these alternatives are considered as part of a grazing management system, they might be implemented compatibly. For example, on allotments that are part of a deferred or rest rotation system which includes pastures composed of upland areas and other pastures composed of riparian zones and some uplands, it may be possible to graze upland pastures while allowing the soils in pastures containing riparian habitat to dry out. It would appear that allowing for the drying out of riparian soils prior to turning in stock and, the removal of stock prior to leaf development by woody riparian vegetation would be mutually exclusive. Or, at least this practice would only allow for a very short use period for riparian areas during the spring. However, if woody riparian areas can be grazed once every three summers while still maintaining good riparian conditions, then these two considerations might not be mutually exclusive. In general, it is repeated annual summer use rather than periodic use of woody riparian vegetation that is detrimental.

The practicality of behavioral bonding of animals to underutilized habitats might also be questioned. However, this alternative might also be implemented as part of a grazing management system. New animals

might be introduced to an allotment during a year in which upland pastures are being used, and pastures containing riparian habitat are being rested. Thus, if behavioral bonding is feasible, the stock may become accustomed to foraging on upland areas. This alternative is at present only a suggestion; experimentation regarding its feasibility is necessary. However, if it can be successfully implemented, it would be of tremendous utility in protecting the riparian environment from grazing by livestock.

SUGGESTIONS FOR FUTURE RIPARIAN RESEARCH

In reviewing literature concerning riparian zones it was evident to me that few practical management oriented studies have been conducted. Although there is considerable documentation of livestock impacts in riparian areas, little information is available regarding the amount and timing of livestock use necessary to produce a certain ecosystem impact. Several authors (Platts and Meehan 1977; Smith n.d.b; Warner 1979b) have indicated the need for a systematic approach to the management of riparian habitats. Since riparian zones are a part of a larger ecosystem (i.e. watershed), it would be unreasonable to conduct impact related research on anything less than the watershed level. Likens and Bormann (1974) stated:

> "Most environmental problems have a biospheric perspective, undesirable pollutants may be widely transported by moving components-air, water, and animals, and they may accumulate in remote areas. Problems of this kind cannot realistically be considered on a scale smaller than the range of these vectors, i.e. airsheds, watersheds, or migratory ranges. Legislation which ignores the biospheric perspective or the complexity of the landscape is ultimately naive."

A systems approach to riparian research will be of particular utility to individuals attempting to formulate multiple use oriented management guidelines. Presently, most research is of a fragmented nature with research being limited to the monitoring of selected parameters (i.e. water quality, fish production, vegetation cover, etc.). In addition, these studies have been conducted in a number of different environments. Synthesis of these study results for the derivation of a

common set of management guidelines may not be valid as the study results have been generated from different environments and by different scientists.

A systematic research program will be of greatest utility to land managers as a number of environmental parameters will be evaluated in a specific watershed. The results from such a study may then be used to construct an ecosystem model from which land managers can predict the effects of various levels of grazing on the riparian zone.

Roath (1980) indicated that baseline studies which monitored vegetation, classified riparian habitats, and obtained data on soils and water quality prior to the introduction of livestock onto a given allotment were mostly unavailable. Skovlin, Meehan, Buckhouse, and Vavra (in press) prepared a study outline which monitored the parameters outlined by Roath (1980) and attempted to determine livestock grazing influences on riparian environments. More studies of such comprehensive nature would be particularly valuable.

Patton (1977) constructed a general conceptualized model of riparian research needs (Figure 3). More specifically, livestock management research in riparian areas should be directed toward the following areas:

1. Obtaining physiological and phenological data for riparian vegetation in order to determine proper season of livestock use.
2. Further evaluation of the compatibility of grazing systems

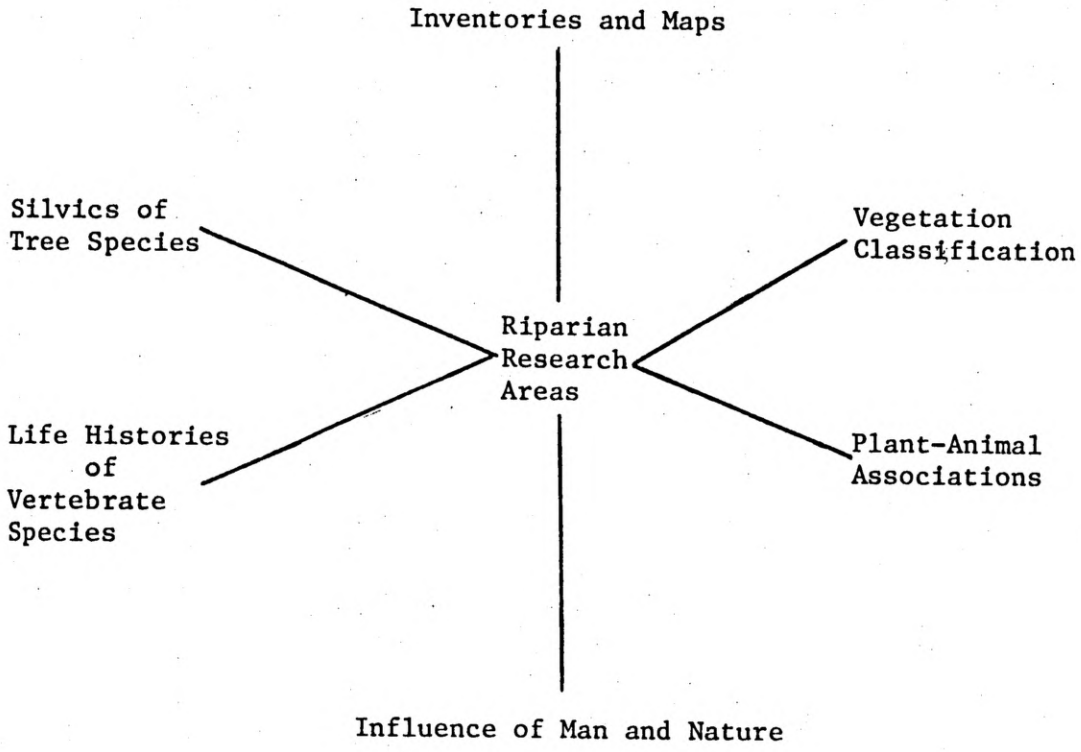


Figure 3. Future riparian research areas (from Patton 1977)

with fisheries (Platts 1979).

3. Determination of the type of management and the amount of time necessary to return streams altered by livestock grazing to near natural conditions (Platts 1979).
4. Determination of what natural conditions are (Leopold 1975).
5. Refinement of methodology used to assess impacts in order to segregate natural variation in riparian conditions from human or livestock induced variations (Platts 1978b).
6. Determining which kinds of livestock graze most compatibly with, and allow for the maintenance of stable riparian zones (Platts 1979).
7. Determine what the first indicators of stream improvement or livestock induced degradation are (Platts 1979).

SUMMARY-CONCLUSIONS

Livestock can and do influence the physical, chemical, and biological aspects of riparian environments. Unfortunately, the amount of stock use necessary to produce a certain level of ecosystem deterioration is not known. Regardless, it is encouraging to note that riparian areas rested from livestock grazing recover rapidly from the effects of overgrazing.

Many of the studies reviewed while writing this paper contained observations of various riparian components and their responses to livestock grazing. These observations were often used to make manage-

decisions. I do not question the validity of those decisions, especially when they are made objectively, and by individuals with range management experience. However, a problem exists in that many of the papers cited are not puplished in the refereed journals. Many of the studies present results which are derived from management oriented habitat analysis methodology. Some individuals might question the validity of management decisions based on those studies. However, I believe that management oriented studies are particularly useful as they are usually directed towards solving problems by the land manager; therefore they are practical. Comprehensive research studies such as those suggested in an earlier section of this paper are necessary. However, range managers cannot afford to wait for long term research results to become available. Livestock induced problems in riparian environments exist today, and should therefore be approached promptly. Fortunately range managers have a wealth of range management principles at their disposal which, with some modification, can be useful in solving riparian management problems. Application of these management principles will require that the range manager understand how livestock use a particular range unit as well as the problems resulting from such use. Records of past livestock use on grazing allotments should provide government land managers with grazing histories and problem areas.

An ideal grazing strategy for riparian areas would allow maximal livestock use and still maintain other riparian resource values. Rest

rotation grazing systems have produced the most desirable responses in riparian soils and vegetation, especially where riparian zones were allowed to regain stable and productive conditions through one to five years of rest from grazing. It must be realized that the success of any grazing system will depend on the manipulation of the kind of animal grazed, season of livestock use, livestock stocking rates, and livestock distribution. Failure to properly apply these management principles and recognize problems existing on grazing allotments will result in failure of the grazing system in meeting riparian requirements. In conclusion, Myers (1981) stated that the management of riparian zones is a learning experience--not a science.

LITERATURE CITED

Ames, C. R. 1977. Wildlife conflicts in riparian management: grazing. p.49-51. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Anderson, B. W., A. Higgins, and R. D. Ohmart. 1977. Avian use of saltcedar communities in the lower Colorado River valley. p.128-136. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Armour, C. L. 1977. Effects of deteriorated range streams on trout. U.S.D.I. Bureau of Land Management. Boise, ID. 7p.

Berry, C. R. 1978. Impact of sagebrush management on riparian and stream habitat. Ut. Coop. Fishery Unit, Ut. St. Univ., Logan, UT. 18p.

Behnke, R. J. 1977. Fish faunal changes associated with land use and water development. Great Plains-Rocky Mt. Geogr. J. 6(2):133-136.

Behnke, R. J. In press. Impact of livestock grazing on stream fisheries: problems and solutions. IN: J. Menke (ed.). Symposium on Livestock Interactions with Wildlife, Fish, and Their Environments. Sparks, NV. (May 1977). U. S. Dep. Agr. For. Serv. Pac. SW For. and Range Exp. Sta. Berkeley, CA.

Behnke, R. J. and R. F. Raleigh. 1978. Grazing and the riparian zone: impact and management perspectives. p.263-267. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

Boeer, W. J. and D. J. Schmidly. 1977. Terrestrial mammals of the riparian corridor in Big Bend National Park. p.212-217. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Boldt, C. E., D. W. Uresk, and K. E. Severson. 1978. Riparian woodlands in jeopardy on northern High Plains. p.184-189. IN: R. R. Johnson and D. A. Jones (tech, coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

Bowers, W., B. Hosford, A. Oakley, and C. Bond. 1979. Wildlife habitats in managed rangelands--The Great Basin of southeastern Oregon-Native Trout. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. PNW-84. Pac. NW For. and Range Exp. Sta. LaGrande, OR. 16p.

Brown, G. W. and J. T. Krygier. 1967. Changing water temperatures in small mountain streams. J. Soil and Water Cons. 22(6):242-244.

Brown, S., M. M. Brinson, and A. E. Lugo. 1978. Structure and function of riparian wetlands. p.17-31. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

Busby, F. E. 1979. Riparian and stream ecosystems, livestock grazing, and multiple use management. p.6-12. IN: O. B. Cope (ed.). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

Carothers, S. W. 1977. Importance, preservation, and management of riparian habitats: an overview. p.2-4. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Claire, E. and R. Storch. In press. Streamside management and livestock grazing: an objective look at the situation. IN: J. Menke (ed.). Symposium on Livestock Interactions with Wildlife, Fish, and Their Environments. Sparks, NV (May 1977). U. S. Dep. Agr. For. Serv. Pac. SW For. and Range Exp. Sta. Berkeley, CA.

Cook, C. W. 1966. Factors affecting utilization of mountain slopes by cattle. J. Range Manage. 19:200-204.

Cooper, J. L. 1979. A technique for evaluating and predicting the impact of grazing on small stream channels. Paper presented at the 32nd Annual Meeting of the Society for Range Management held at Casper, WY (Feb. 12-15, 1979). 13p.

Cordone, A. J. and D. E. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. CA Fish and Game. 47(2):189-228.

Crouch, G. L. 1979. Long term changes in cottonwoods on a grazed and an ungrazed plains bottomland in mortheastern Colorado. U. S. Dep. Agr. For. Serv. Res. Note RM-370. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO. 4p.

Cummins, K. W. 1974. Structure and function of stream ecosystems. Bioscience 24:631-641.

Dahlem, E. A. 1979. The Mahogany Creek watershed-with and without grazing. p.31-34. IN: O. B. Cope (ed.). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

Darling, L. A. and G. B. Coltharp. 1973. Effects of livestock grazing on water quality of mountain streams. p.1-8. IN: H. F. Mayland (ed.). Proceedings of the Symposium on Water-Animal Relations. U. S. Dep. Agr. Agr. Res. Serv. Kimberly, ID.

Davis, G. A. 1977. Management alternatives for the riparian habitat in in the Southwest. p.59-67. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

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

Duff, D. A. In press. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. IN: J. Menke (ed.). Symposium on Livestock Interactions with Wildlife, Fisheries, and Their Environments. Sparks, NV (May 1977). U. S. Dep. Agr. For. Serv. Pac. SW For. and Range Exp. Sta. Berkeley, CA.

Fox, K. M. 1977. Importance of riparian ecosystems: economic considerations. p.19-22. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Gebhards, S. 1970. The vanishing stream. ID Wildl. Rev. 22(5):3-8.

Geier, A. R. and L. B. Best. 1980. Habitat selection by small mammals of riparian communities: Evaluating effects of habitat alterations. J. Wildl. Manage. 44(1):16-24.

Glinski, R. L. 1977. Regeneration and distribution of sycamore and cottonwood trees along Sonoita Creek, Santa Cruz County, Arizona. p.116-123. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Goodloe, S. 1969. Short duration grazing in Rhodesia. J. Range Manage. 22(6):369-373.

Gradwell, M. W. 1968. Compaction of pasture topsoils under winter grazing. Trans. 9th Int. Congr. Soil Sci. 3:429-435.

Greene, G. E. 1950. Land use and trout streams. J. Soil and Water Cons. 5(3):125-126.

Gunderson, D. R. 1968. Floodplain use related to stream morphology and fish populations. J. Wildl. Manage. 32(3):507-514.

Hayes, F. 1978. Streambank stability and meadow condition in relation to livestock grazing in mountain meadows of central Idaho. M. S. Thesis. Univ. of Id. Moscow, ID. 91p.

Hedrick, D. W., B. R. Eller, J. A. B. McCarthur, and R. D. Pettit. 1969. Steer grazing on mixed coniferous ranges in northeastern Oregon. J. Range Manage. 22(5):322-325.

Hehnke, M. and C. P. Stone. 1978. Value of riparian vegetation to avian populations along the Sacramento River system. p.228-235. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

Hirsch, A. and C. A. Segelquist. 1978. Protection and management of riparian ecosystems: Activities and views of the U. S. Fish and Wildlife Service. p.344-352. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

Hubbard, J. P. 1977. Importance of riparian ecosystems: biotic considerations. p.14-18. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Jahn, L. R. 1978. Values of riparian habitats to natural ecosystems. p.157-160. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

Johnson, S. R., H. L. Gary, and S. L. Ponce. 1978. Range cattle impacts on stream water quality in the Colorado Front Range. U. S. Dep. Agr. For. Serv. Res. Note RM-359. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO. 8p.

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

Kimball J. and F. Savage. 1977. Diamond Fork aquatic and range habitat improvements. U. S. Dep. Agr. For. Serv. Paper. Intermountain Region. Ogden, UT. 19p.

Knight, R. W. 1978. Streamside erosional response to animal grazing practices on Meadow Creek in northeastern Oregon. M. S. Thesis. Or. St. Univ. Corvallis, OR. 59p.

Lea, G. 1979. BLM management and policy for riparian/stream ecosystems. p.13-15. IN: O. B. Cope (ed.). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

Leopold, S. 1975. Research needs of an ecosystem. p.96-98. IN: W. King (ed.). Proceedings of the Wild Trout Management Symposium. Trout Unlimited. Denver, CO.

Likens, G. E. and F. H. Bormann. 1974. Linkages between terrestrial and aquatic ecosystems. Bioscience. 24(8):447-456.

Lusby, G. 1970. Hydrologic and biotic effects of grazing vs. non-grazing near Grand Junction, Colorado. J. Range Manage. 23:256-260.

Marcuson, P. E. 1977. The effect of cattle grazing on brown trout in Rock Creek, Montana. Mt. Dep. Fish and Game, Fish Div. Spec. Rep. Proj. No. F-20-R-21,II-a 26p.

Martin, S. C. 1979. Evaluating the impacts of cattle grazing on riparian habitats. p.35-38. IN: O. B. Cope (ed.). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

McCormick, J. F. 1978. A summary of the national riparian symposium: A proposal for a national riparian program. p.362-363. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

McIlvain, E. H. and M. C. Shoop. 1971. Shade for improving cattle gains and rangeland use. J. Range Manage. 24(3):181-184.

Meehan, W. R., F. J. Swanson, and J. R. Sedell. 1977. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. p.137-145. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Myers, L. H. 1981. Grazing management vs. riparian management in southwestern Montana. Paper presented at the 34th Annual Meeting of the Society for Range Management held at Tulsa, OK (Feb. 9-13, 1981). 14p.

Odum, E. P. 1978. Ecological importance of the riparian zone. p.2-4. IN: R. R. Johnson and J. F. McCormick (tech. coord.). Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

Olson, R. W. and C. L. Armour. 1979. Economic considerations for improved livestock management approaches for fish and wildlife in riparian/stream areas. p.67-71. IN: O. B. Cope (ed.). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

Orr, H. K. 1960. Soil porosity and bulk density on grazed and protected Kentucky bluegrass range in the Black Hills. J. Range Manage. 13:80-86.

Orr, H. K. 1975. Recovery from soil compaction on bluegrass range in the Black Hills. Trans. Am. Soc. Agr. Eng. 18:1076-1081.

Patton, D. R. 1977. Riparian research needs. p.80-82. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Platts, W. S. 1978a. Livestock (grazing) interactions with fish and their (aquatic and riparian) environments: a symposium summary. CA-NV Wildl. Trans. p.92-96.

Platts, W. S. 1978b. Livestock interactions with fish and aquatic environments: problems in evaluation. Trans. 43rd. N. Am. and Nat. Resour. Conf. p.498-504.

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

Pond, F. W. 1961. Effect of three intensities of clipping on the density and production of meadow vegetation. J. Range Manage. 14(1):34-37.

Roath, L. R. 1980. Cattle grazing habits and movements related to riparian habitats and forested ranges with inference to acute bovine dietary pulmonary emphysema. PhD. Diss. Or. St. Univ. Corvallis, OR. 134p.

Rupp, C. 1979. Management and policy for grazing riparian ecosystems on National Forest system lands. p.17-19. IN: O. B. Cope (ed). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

Sands, A. 1977. Riparian forests in California: Their ecology and conservation. Institute of Ecol. Pub. No. 15. Univ. of CA. Davis, CA. 122p.

Savory, A. and S. D. Parsons. 1980. The Savory grazing method. Rangelands. 2(6):234-237.

Savory, A. n.d. The Savory Grazing method. Range Sci. Dep. videotape. Mt. St. Univ. Bozeman, MT.

Settergren, C. D. 1977. Impacts of river recreation use on streambank soils and vegetation--state-of-the-knowledge. p.55-59. IN: Proceedings of the River Recreation Management and Research Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. NC-28. N. Central For. Exp. Sta. St. Paul, MN.

Severson, K. E. and C. E. Boldt. 1978. Cattle, wildlife, and riparian habitats of the western Dakotas. p.90-113. IN: Management and use of morthern Plains rangeland. Reg. Rangeland Symposium. Bismarck, ND.

Skeesick, D. G. 1981. AFS-USFS riparian ecosystem field tour. Western Div. Am. Fish. Soc. Newsletter. 6(2):1-6.

Skovlin, J. M., W. R. Meehan, J. C. Buckhouse, and M. Vavra. In press. Determining the influence of grazing on riparian and aquatic habitats in the Blue Mountains of northeastern Oregon. IN: J. Menke (ed). Symposium on Livestock Interactions with Wildlife, Fisheries, and Their Environments. Sparks, NV (May 1977). U. S. Dep. Agr. For. Serv. Pac. SW For. and Range Exp. Sta. Berkley, CA.

Smith, B. H. n.d.a. Riparian willow management: its problems and potentials within the scope of multiple use on public rangelands. (unpublished paper). U.S.D.I. Bureau of Land Management, Rock Springs, WY. 11p.

Smith, B. H. n.d.b. The ecosystem appraoch to stream habitat management. (unpublished paper). U.S.D.I. Bureau of Land Management, Rock Springs, WY. 4p.

Speck, J. E. 1981. A comparative study of the aspects of grazing systems on riparian vegetation, water quality, and stream morphology. Paper presented at the 34th Annual Meeting of the Society for Range Management held at Tulsa, OK (Feb. 9-13, 1981). 8p.

Stauffer, D. F. and L. B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44(1):1-15.

Stevens, L. E., B. T. Brown, J. M. Simpson, and R. R. Johnson. 1977. The importance of riparian habitat to migrating birds. p.156-164. IN: R. R. Johnson and D. A. Jones (tech. coord.). Importance, Preservation, and Management of Riparian Habitat: A Symposium. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta. Fort Collins, CO.

Stoddart, L.A., A. D. Smith, and T. W. Box. 1975. Range Management. McGraw-Hill Book Co. New York. 532p.

Storch, R. L. 1979. Livestock/streamside management problems in eastern Oregon. p.56-59. IN: O. B. Cope (ed.). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands--the Great Basin of Oregon-riparian zones. U. S. Dep. Agr. For. Serv. Gen. Tech. Rep. PNW-80. Pac. NW For. and Range Exp. Sta. LaGrande, OR. 18p.

Tuinstra, K. E. 1967. Vegetation of the floodplains and first terraces of Rock Creek near Red Lodge, Montana. PhD. Diss. Mt. St. Univ. Bozeman, MT. 110p.

U.S.D.I. Bureau of Land Management. 1978. Sandy Grazing Environmental Impact Statement. Rock Springs, WY.

U.S.D.I. Environmental Protection Agency. 1979. Livestock management and water quality protection. EPA 910/9-79-67. Seattle, WA. 147p.

U.S.D.I. Bureau of Land Management. 1980a. Mountain Foothills Grazing Management Program-Draft Environmental Impact Statement. Butte, MT. 308p.

U.S.D.I. Fish and Wildlife Service. 1980b. Streamside areas-management dividends. FWS-OBS-80-55. Washington, DC. 8p.

U.S.D.I. Bureau of Land Management. 1981. Thomas Fork Cooperative Aquatic Habitat Management Plan. Prog. Rep. (Feb. 1981). 23p.

Van Nelson, R. 1979. Effects of livestock grazing upon rainbow trout in Otter Creek. p.53-55. IN: O. B. Cope (ed.). Proceedings of the Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited. Denver, CO.

Vogler, J. P. 1978. Effects of grazing, clearing, and stream channelization on riparian and associated vegetation of Guthrie County, Iowa. M. S. Thesis. Ia. St. Univ. Ames, IA. 79p.

Warner, R. E. 1979a. Proceedings of a workshop on fish and wildlife needs in riparian ecosystems. U.S.D.I. Fish and Wildlife Service. Davis, CA. 53p.

Warner, R. E. 1979b. California riparian study program: background information and proposed study design. CA Dep. Fish and Game. Sacramento, CA. 177p.

White, R. J. and O. M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Dep. Nat. Resour. Div. Cons. Tech. Bull. No. 39. Madison, WI. 65p.

Winegar, H. H. 1977. Camp Creek channel fencing-plant, wildlife, soil, and water response. Rangemans J. 4(1):10-12.

Workman, J. P. and J. F. Hooper. 1968. Preliminary economic evaluation of cattle distribution practices on mountain rangelands. J. Range Manage. 21:301-304.

Young, J. A., J. A. B. McCarthur, and D. W. Hedrick. 1967. Forage utilization in a mixed coniferous forest of northeastern Oregon. J. Forest. 65:391-393.