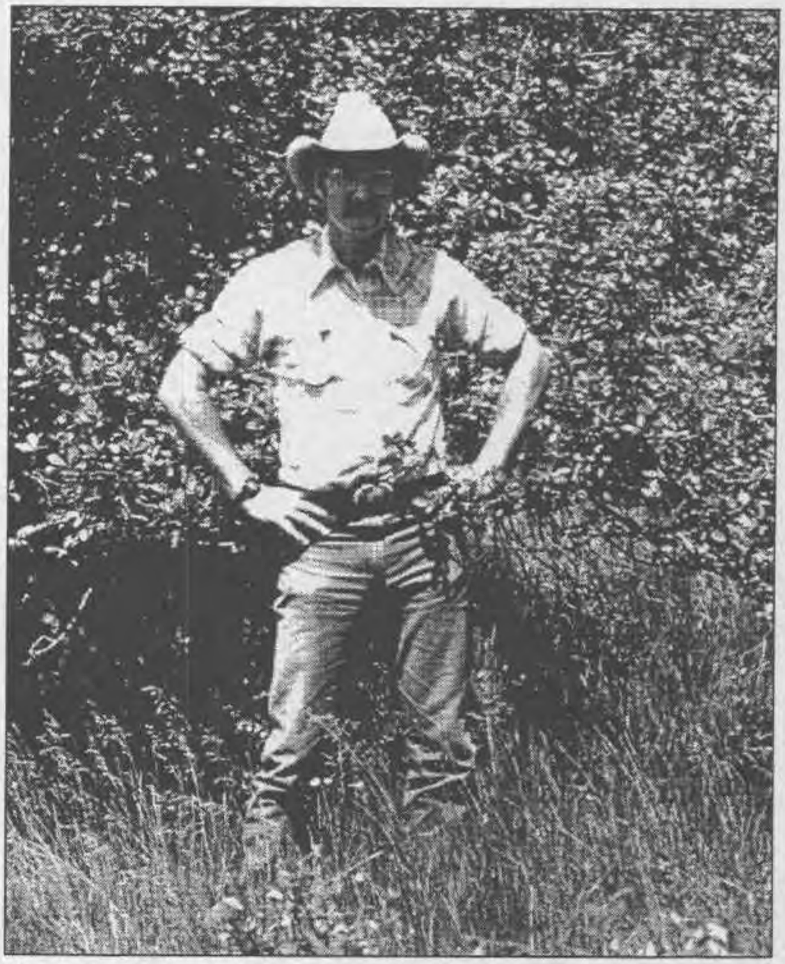
Special Report 951
July 1995

Eastern Oregon Agricultural Research Center Field Day Annual Report, 1995



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This special report is a cooperative effort of the Department of Rangeland Resources at Oregon State University and the Eastern Oregon Agricultural Research Center. Any mention of commercial products does not constitute endorsement by Oregon State University. The Eastern Oregon Agricultural Research Center, which includes the Burns and Union Stations, is jointly operated and financed by the Oregon Agricultural Experiment Station, Oregon State University, and the U.S. Department of Agriculture, Agriculture Research Service. We wish to thank Carol McDonald and Carol Savonen for their help in preparing and editing this report.

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Influence of Electronic Diversion from Riparian Areas on Livestock Grazing Behavior, Nutritional Physiology, Stress Physiology, and Performance

Teena M. Tibbs, T. DelCurto, M. McInnis, A.R. Tiedemann, and T.M. Quigley

SUMMARY

A challenge facing public land managers and beef cattle producers in the western United States is distribution of livestock relative to sensitive riparian areas. Tools used in the past, such as corridor fencing, are not as readily accepted due to concern over wildlife, recreation, and aesthetic values. As a result, beef cattle producers and range managers need tools which may replace traditional fencing to control livestock movement and distribution.

One potential tool involves the use of radio transmitters and receivers to control livestock movement and distribution (Quigley et al., 1990). The concept of the transmitters and receivers is similar to a shock collar used for training dogs. The cattle wear a radio receiver eartag that is the size of a small transistor radio and weighs 3.5 oz. A battery operated transmitter is placed in an area of desired livestock exclusion and is manually set to send out a signal that creates an exclusion zone to the animals wearing the eartag receivers. When an animal wearing an eartag receiver approaches the signal boundary from the transmitter (exclusion zone), the animal receives an audio signal and, if they do not return to the grazing zone, a maximum of four electrical signals. If the animal leaves the exclusion zone before receiving four electronic signals, the signals will stop, but, if they ignore the signals and remain in the exclusion zone, they will receive the audio and four electronic signals. The signal from the transmitter and subsequent stimulus received by the eartag will then train the animals to avoid exclusion areas (Figure 1).

Objectives

The objectives of the following study were to determine the effects of electronic diversion from riparian areas on beef cattle health, nutrition, and performance.

EXPERIMENTAL DESIGN

Thirty-six yearling heifers (avg. wt = 656 lb) and eight rumen fistulated steers (avg. wt = 554 lb) were stratified by weight and, within stratum, randomly allotted to 6 pastures (3 blocks, 2 treatments) with 6 heifers per pasture and 2 steers in 4 of the 6 pastures. The treatments consisted of three control pastures where animals had free access to the entire pasture, and three pastures where animals were diverted from the riparian areas by wearing electronic eartags that emitted audio and electrical stimulus when they entered the exclusion zone (Figure 2).

Body weight and condition of the heifers was measured on day 0, 28, and 56 after being off water and feed for 16 hours. Blood samples were obtained at the same times, with an additional sample taken on day 14 of the study period to look at the physiological stress occurring, if any, to the animals. Rumen fistulated steers were used to obtain fecal output measurements and rumen evacuation samples that determined diet quality and animal performance.

RESULTS

The heifers with free access to the entire pasture performed better than the heifers diverted from the riparian area. Average daily gain (ADG) was 18.8 percent greater in control heifers verses the treatment heifers diverted from riparian areas with both groups still maintaining a positive ADG. In contrast, body condition was not influenced by treatments (Table 1).

The blood samples taken at trial initiation (day 0), day 14, day 28, and day 56 (early trial termination) suggests that no physiological stress occurred with heifers that received electronic stimuli. Blood samples were assayed to measure plasma cortisol, a primary indicator of stress in the circulatory system, and T3/T4 levels. The measurements indicated no influence by treatments, thus suggesting that heifers were not significantly stressed by electronic eartags. In addition, serum urea nitrogen N levels tended to be higher in control heifers verses treated heifers. The differences in serum urea may be explained, in part, by the heifers with access to the riparian area selecting a higher quality of diet (Table 1).

Crude protein (CP) content of diets were higher in the steers with free access to the riparian area verses the steers diverted from the riparian area. In contrast, no differences were observed in the fibrous constituents of treatment and control diets. Thus confirming that animals diverted from the riparian area selected a lower quality of diet due to their altered distribution (Table 1).

DISCUSSION

The ability to control livestock movements and distribution relative to riparian areas with electronic diversion would provide livestock producers and public land managers an alternative tool to use in addressing the issues they are facing today. The potential benefits in the ability to electronically divert livestock from sensitive areas are: 1) modifying livestock distribution, 2) providing a tool to use in multiple-use rangeland resource management, and 3) providing an economical alternative to corridor fencing of riparian areas. When diet quality was analyzed it appeared the animals diverted from the riparian area consumed a lower quality of diet. The lower quality of diet consumed suggested the grazing behavior had been altered and, as a result, influenced animal performance.

This study indicated that no significant signs of physiological stress were put on the animals from electronic stimuli being received by their ears when they entered the exclusion zone. There was, however, physical damage that occurred to the ears from the eartag being too heavy (3.5 oz). This damage to the ears necessitated early termination of the study (day 56, rather than the planned day 84). The patent is pending on this electronic diversion system, but when the patent is granted a company can purchase the rights to the system and improve upon the technological problems. Problems, such as making the eartag smaller and controlling the exclusion zone boundary, need to be addressed before the potential use of this tool can be realized.

LITERATURE CITED

Quigley, T.M., H.R. Sanderson, A.R. Tiedemann, and M.L. McInnis. 1990. Livestock Control with Electrical and Audio Stimulations. Rangelands 12:152-155.

Table 1. Influence of Electronic Diversion From Riparian Areas on Livestock Grazing Behavior, Nutritional Physiology, Stress Physiology and Performance

Item	Treatment[a]	Control[b]	SE	P-Value
Wt. Gain, lb/day	1.46	1.76	0.09	0.02
BC Change	1.05	0.86	0.11	0.23
Intake, lb/day	14.12	15.12	0.58	0.19
Distance Traveled, mi/day	3.23	3.51	0.31	0.53
Grazing Time, hr/day	7.26	7.68	0.40	0.60
Diet Composition (% of OM)				
CP, %	13.40	16.90	0.74	0.03
ADIN, (% of total N)	24.70	22.30	1.97	0.43
NDF, %	66.60	68.20	0.89	0.28
ADF, %	41.80	41.30	0.66	0.60
Physiological Performance				
T3, ng/mL	1.62	1.62	5.37	0.96
T4, ng/mL	55.00	53.00	0.12	0.33
CORT, ng/mL	57.50	51.30	0.69	0.59
SUN, mg/dL	12.05	13.18	0.40	0.19

[a] Treatment = animals diverted from riparian areas by electronic stimulation.

[b] Control = animals with free access to entire pasture including the riparian areas.

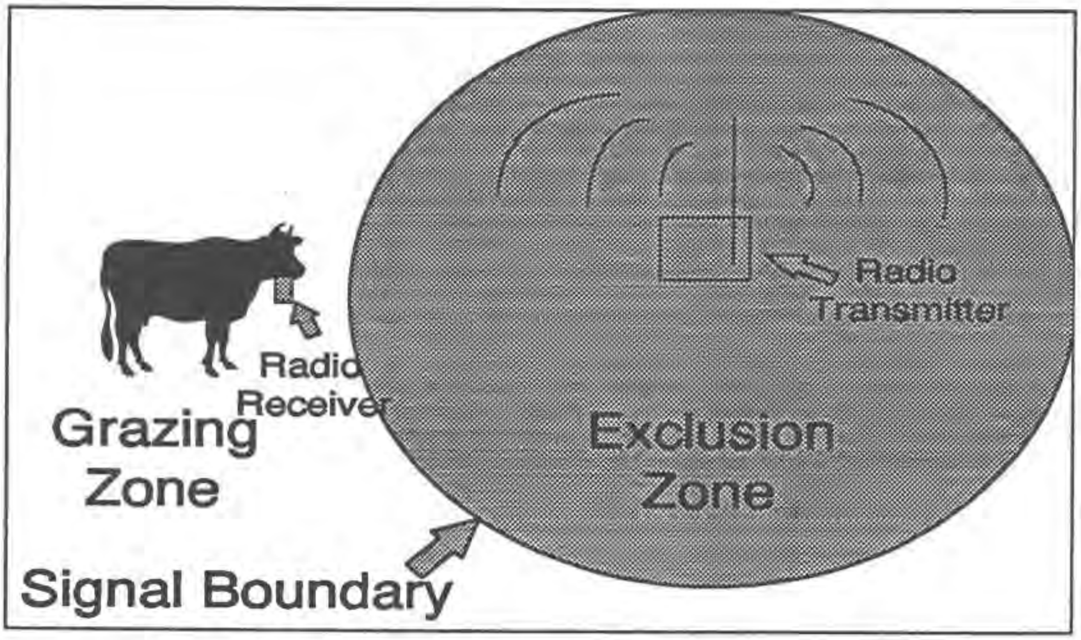

Figure 1. Animal with eartag approaches boundary of signal from transmitter that describes the exclusion zone and receives an audio warning tone. If the animal ignores audio warning it receives electrical stimulus and it turns into the grazing zone and the stimulus stops. If the animal ignores the electrical stimulus the eartag will lock up after four stimuli.

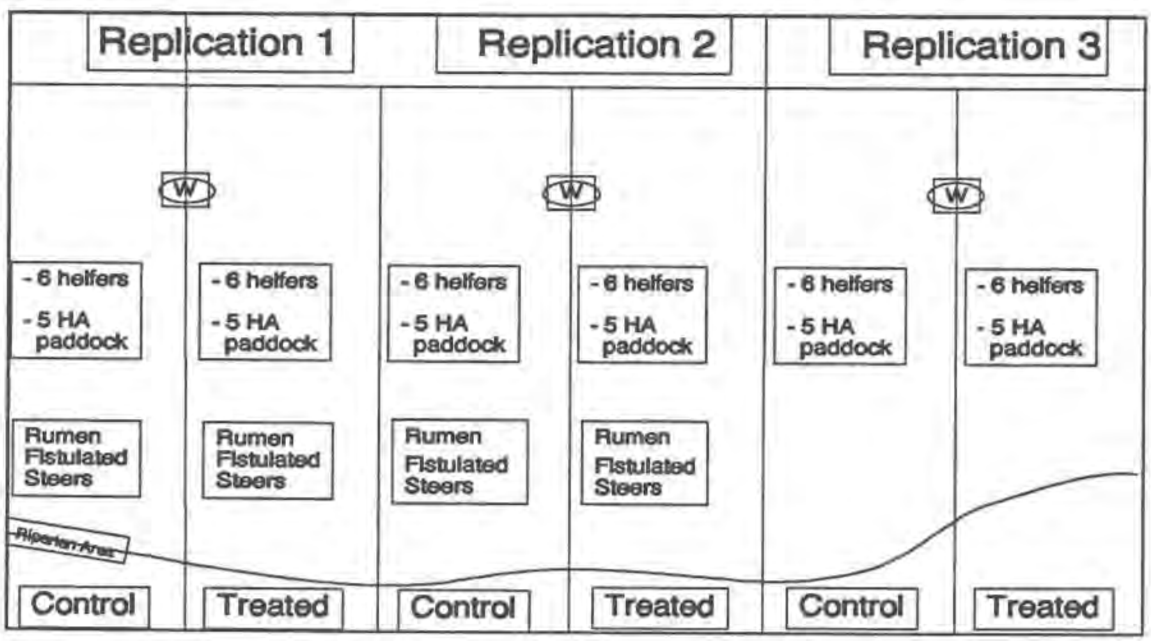

Figure 2. Experimental Design and Physical Layout of the Study Plan. Animals were rotated among pastures within replication every 14 days. Water tanks (W) will be available away from riparian areas for all treatment groups. Diet quality and intake estimates will be determined in replications one and two using the rumen/esophageal steers.

Mapping and Analysis of Catherine Creek
Using Remote Sensing and Geographic Information Systems (GIS)

by

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INTRODUCTION

Geographic Information Systems (GIS) are organized procedures that process spatially referenced data to yield insight on structure and function at a locale or across a region. Data sets or layers that contain information, such as soils, vegetation, topography, precipitation, geology, etc. can be superimposed or combined in a logical fashion to yield new information. Aerial photographs, satellite images, and other remotely sensed information are particularly helpful and have been widely used in GIS analysis.

By combining existing information, other parameters can be determined. These include slope and aspect which are derived from elevation models, erosion hazards from soils and topography, and habitat suitability generated from vegetation, topography, and cover layers. A myriad of other parameters can be produced if base maps or appropriate data layers exist. These systems facilitate the interpretation of data. They have revolutionized the analysis of landforms and can improve monitoring, interpretation, analysis, and management of landscapes.

Fine scale monitoring of streams and their associated watersheds can be executed by aerial photography, videography, or radiometry coupled with ground measurements. Areas of special interest can be photographed in scales up to 1:1000 for detailed work from fixed-wing aircraft. Blimp-borne photographic platforms have also been used for even higher resolution images. Both color and infrared photographic films are used if vegetative parameters such as cover (by species or class), biomass, or areas devoid of vegetation are to be determined.

Individual trees, shrubs, rivulets, and channels can be monitored and quantified over time by repetitive overflights which provides unprecedented analytical power to researchers and managers, especially when detailed ground surveying and measurement of the sites is done in conjunction with photography.

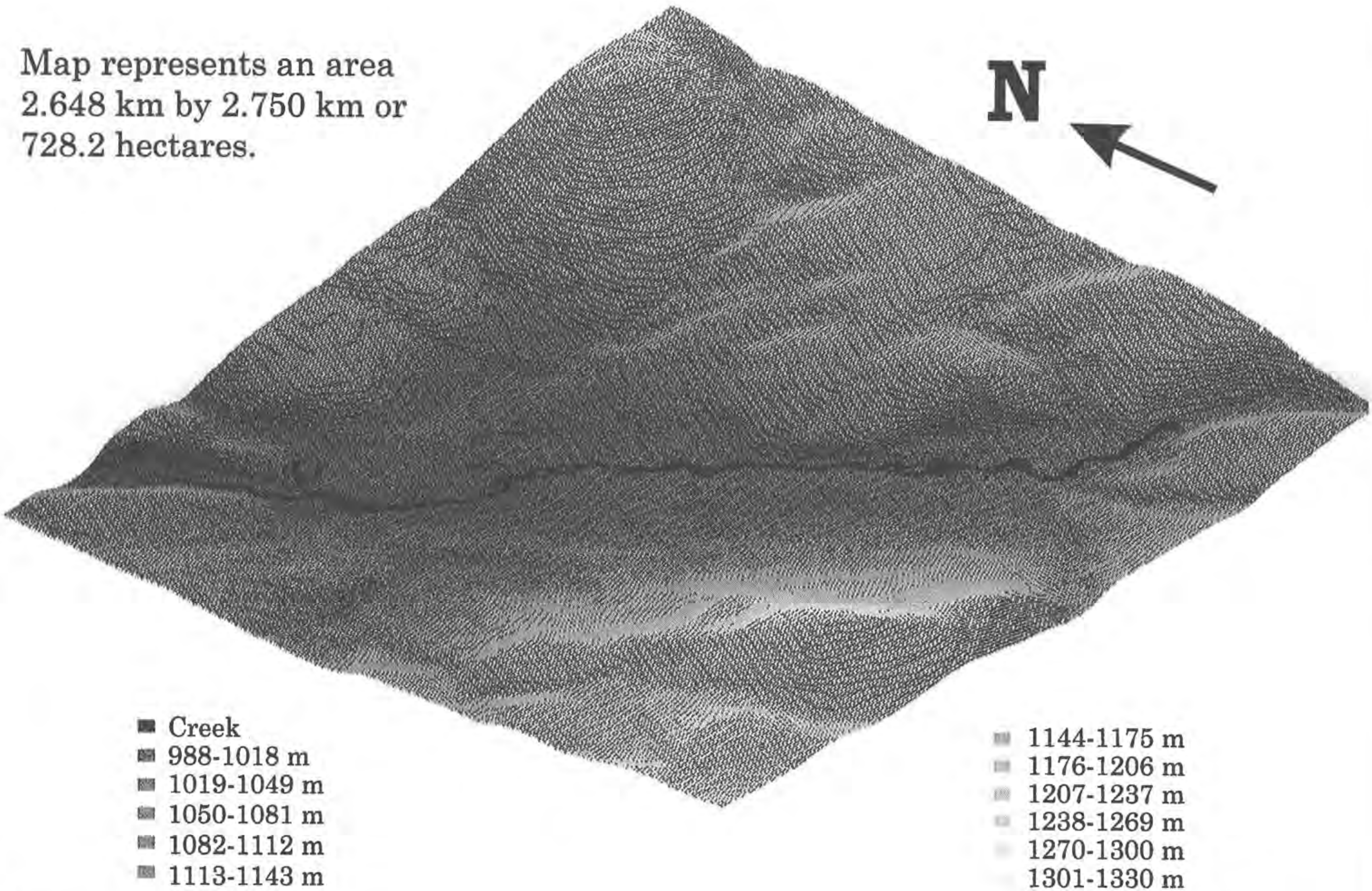

Figure 1.

Orthographic View of the Hall Ranch, Union, Oregon. The outline of Catherine Creek as it was in 1994 is superimposed on the map.

Catherine Creek and associated pastures on the Hall Ranch have been well documented both from low-level aerial photographs and ground measurements since the late 1970s. Management actions are recorded and numerous graduate students and professors have carried out research projects on the stream and associated riparian systems. In 1994, the Oregon Agricultural Experiment Station provided a special grant to begin GIS analysis of the Catherine Creek watershed and its relation to the Hall Ranch. This paper represents preliminary results from the analysis.

OBJECTIVES

The objectives of this study were to quantify the surface hydrology of Catherine Creek on the Hall Ranch of northeastern Oregon as it relates to livestock grazing and salmon spawning. We employed aerial photographs to define the morphology, size, and change in stream channels which occurred between 1979 and 1994. This reach of stream is important because spring-run Snake River chinook salmon (*Onchorhynchus tschawytscha*), a fish recently added to the Federal Endangered Species List, spawn on the ranch and management actions are well documented.

MATERIALS AND METHODS

Study Area

The study area on Catherine Creek is located 15 km southeast of Union, Oregon, on the Hall Ranch, operated by the Oregon State Agricultural Experiment Station. Elevation of the stream and its associated meadows is approximately 990 m as it courses through 3 km of State property (Figure 1). A stream gauging station (Number 13320000) operated by the US Geological Service, Water Resources Division, is located approximately 1 km below the ranch. This station has relatively continuous flow records beginning in 1911.

Ground Data

Five plots, fenced to exclude livestock, were constructed in 1978 (Figure 2). These plots alternate with areas that are open to grazing by livestock and wildlife, so the linear-run of the main channel on the Hall Ranch was divided equally between grazed areas and exclosed areas. Using 1979 aerial photographs, we calculated the linear distance of the main creek channel by digitizing thalweg, or center-lines. There were 1,190 m of 1979 creek channel split between five exclosures. Grazed areas between these exclosures totaled 1,139 m of thalweg distance. Therefore, a total of nine experimental units or plots cover the creek as it passes through the ranch. Plots varied in size from 138 m to 359 m of thalweg distance. We should note that this design essentially doubles the livestock impact per linear unit of each grazed stream reach since animal access to the stream is restricted.

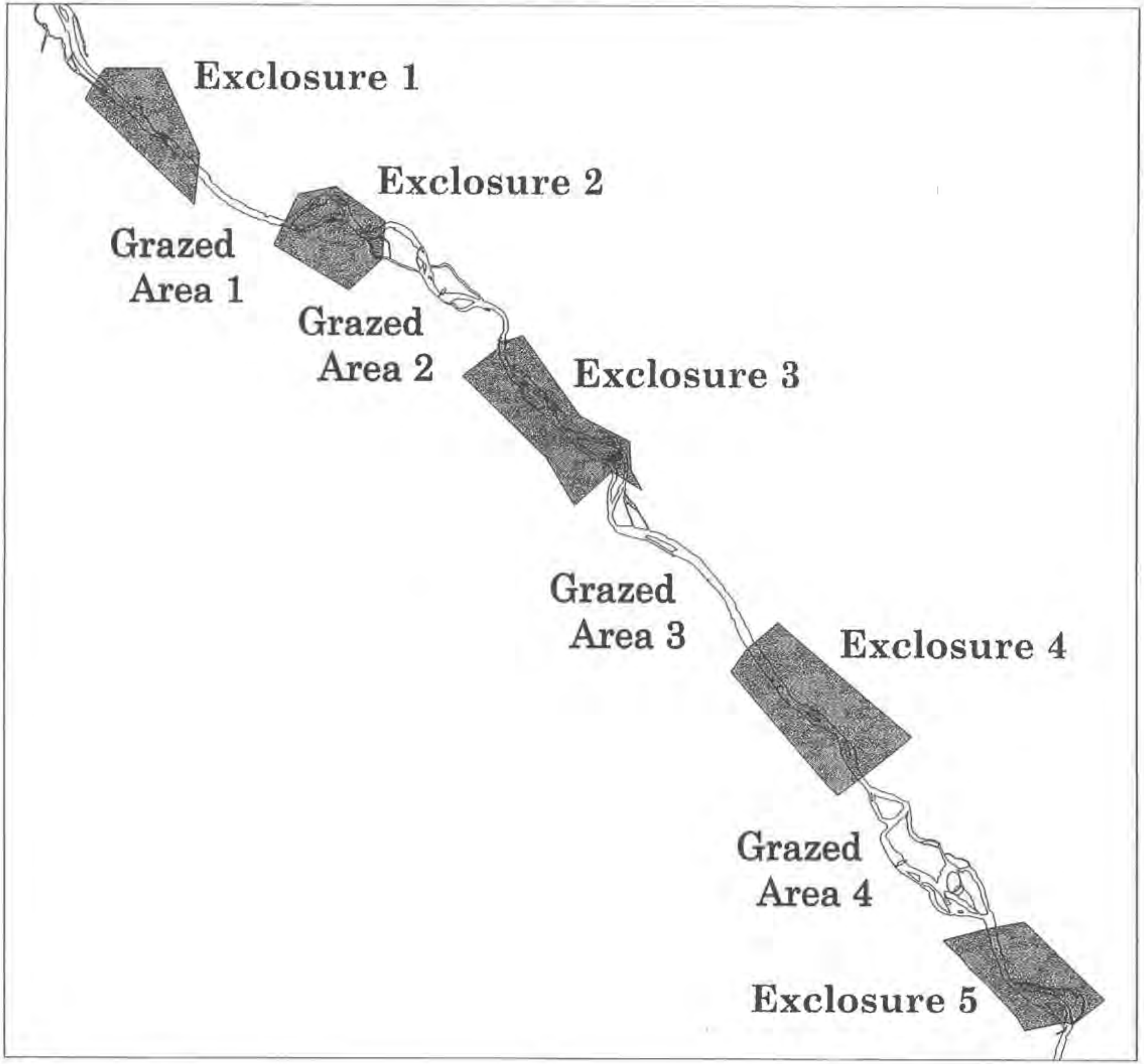

Figure 2.
Layout of the experimental units on the Hall Ranch, Union, Oregon. Outlines of 1994 channel of Catherine Creek are superimposed.

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Outlines of each experimental unit were geo-positioned, as were "ground control" reference points, by collecting 180 locational fixes at each point using a Trimble Pathfinder[1] global positioning unit. Data points were differentially corrected using the BLM/Forest Service Base Station at Burns, Oregon, which provided positional accuracy of field locations within 3 meters. In addition, position of salmon redds were monitored and outlined daily on aerial photographs during the 1993 and 1994 spawning seasons by Teena M. Tibbs, Faculty Research Assistant. These outlines were digitized into a georeferenced data layer which was used in analysis.

Aerial Photography

On the dates listed in Table 1, aerial photographs were taken with a Hasselblad camera fitted with an 80 mm lens using color negative film. Flight altitude varied from 400 m to 700 m above the creek depending upon weather conditions.

Photographs were scanned on an Epson ES-300C flat-bed color scanner providing an electronic image with pixel resolution of 15x15 cm for the lowest photographs and 30x30 cm for the highest. Images were geo-corrected using 202 ground control points so that areas and distances could be accurately determined.

Figure 3 shows the layout of photographs taken in 1994 superimposed on the stream channel. This image also indicates that two passes were flown while obtaining the photographs.

Three bands of information were generated from photographic films: red, green, and blue. Each picture element or pixel has a Digital Number (DN) from 0 to 255 indicating intensity of that band. These Digital Numbers can be processed and mathematically manipulated to accentuate differences between plant species, stream surface, and soils.

Digital Elevation Model

A Digital Elevation Model (DEM) was constructed for the Hall Ranch region by digitizing elevational contours from 7.5 minute USGS quad maps, transferring vectors to raster format and interpolating between contour lines. The interpolation algorithm employed uses north-south, east-west, and diagonal profiles across the image to estimate elevation of the profile for each cell. This procedure produced a digital map where a pixel or cell represents an area measuring 10 m by 10 m or 100 m^2. The elevation model for the region including the Hall Ranch is shown in Figure 4.

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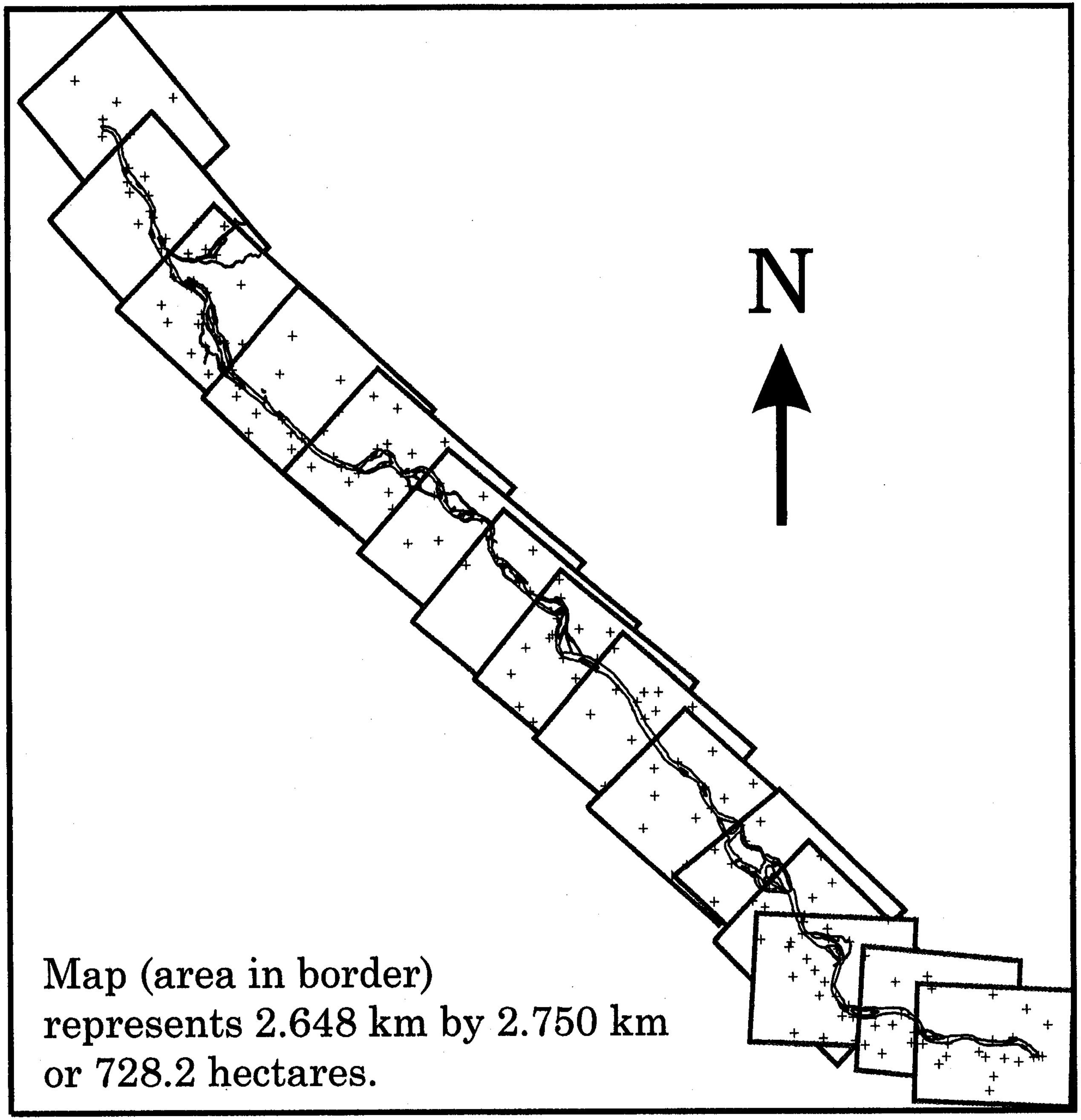
[1] Use of trade names is for the benefit of the reader and does not constitute endorsement by Oregon State University or the Oregon Agricultural Experiment Station.



Digitized Channel Outlines and 202 "Ground Control" Points (small x's) are also shown.

Ground control points are easily identifiable photo objects that are georeferenced using a Global Positioning System.

This instrument uses 5 navigational satellites to obtain a position accurate to within 2 meters.

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Figure 3.

The positions of the fifteen aerial photographs of the 1994 flight line superimposed over the outline of Catherine Creek on the Hall Ranch, Union, Oregon..

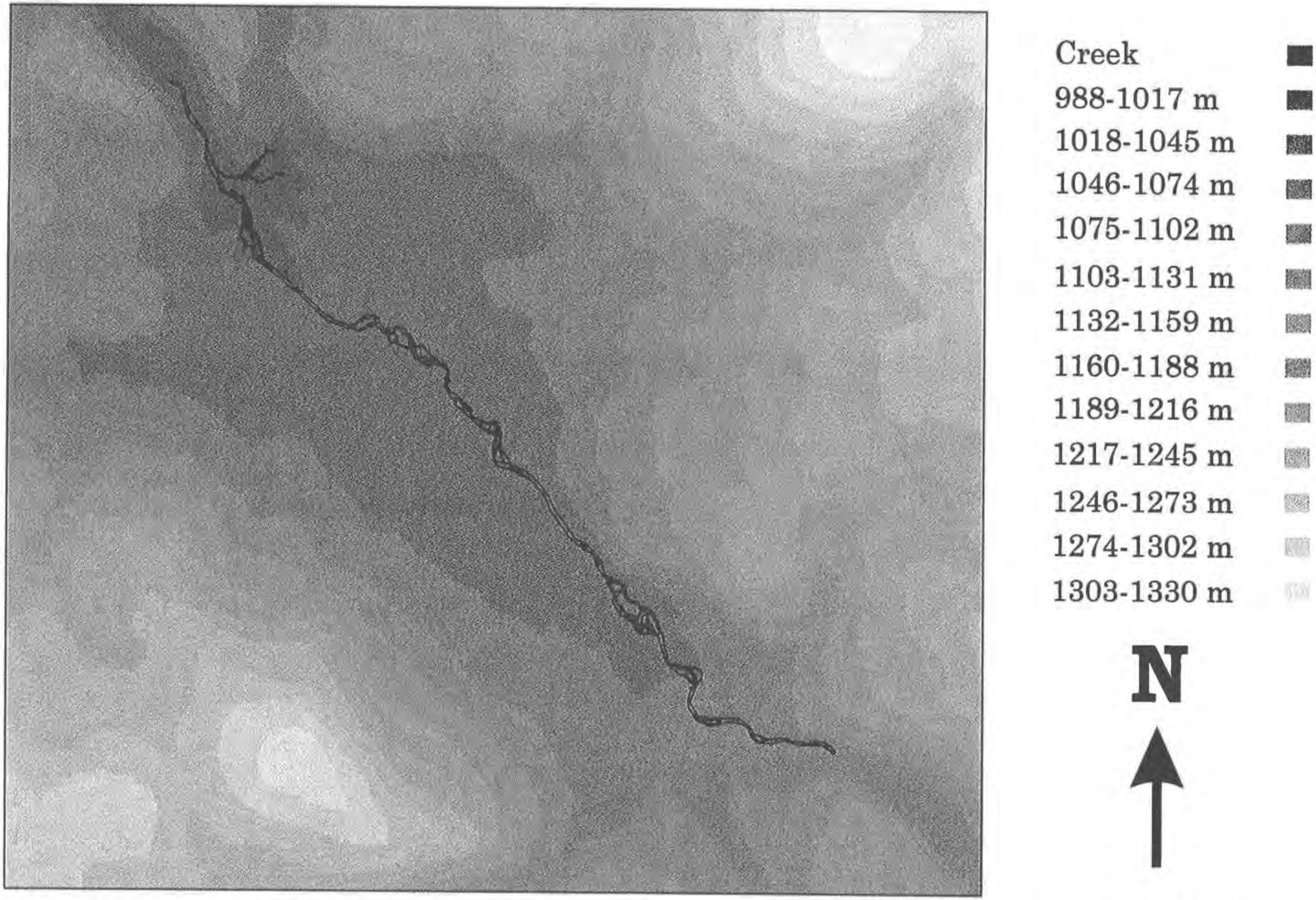

Figure 4. Map represents 2.648 km by 2.750 km or 728.2 hectares.
Digital elevation model (DEM) of the Hall Ranch superimposed with the 1994 outline of Catherine Creek.

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Table 1. Dates of photographic overflights and stream flow of Catherine Creek as measured at Water Resources Division, U.S. Geological Service, Stream Gauging Station Number 13320000. This station is approximately 1 km below the Hall Ranch, Union Co. Oregon.

Year	Date of Aerial Photography	Stream Flow m^3/second (ft^3/second)
1979	June 28, 1979	5.664 (200)
1983	July 10, 1983	4.361 (154)
1988	August 1, 1988	0.821 (29)
1989	June 16, 1989	10.506 (371)
1993	July 26, 1993	2.152 (76)
1994	July 12, 1994	*

* Data not yet acquired from USGS

Table 2. Annual flow on Catherine Creek in cubic meters for the period October 1978 through October 1993. Stream flow of Catherine Creek is measured at Water Resources Division, U.S. Geological Service, Stream Gauging Station Number 13320000. This station is approximately 1 km below the Hall Ranch, Union Co., Oregon.

Water Year	Total Annual Flow in millions of meters^3	Percent of Mean Annual Flow for this Period
Oct. 1, 1978 to Sept. 30, 1979	102	95.8
Oct. 1, 1979 to Sept. 30, 1980	93	88.0
Oct. 1, 1980 to Sept. 30, 1981	96	90.4
Oct. 1, 1981 to Sept. 30, 1982	120	112.8
Oct. 1, 1982 to Sept. 30, 1983	126	118.2
Oct. 1, 1983 to Sept. 30, 1984	161	151.7
Oct. 1, 1984 to Sept. 30, 1985	94	88.5
Oct. 1, 1985 to Sept. 30, 1986	116	109.4
Oct. 1, 1986 to Sept. 30, 1987	---	---
Oct. 1, 1987 to Sept. 30, 1988	71	67.0
Oct. 1, 1988 to Sept. 30, 1989	114	107.6
Oct. 1, 1989 to Sept. 30, 1990	100	94.1
Oct. 1, 1990 to Sept. 30, 1991	105	99.4
Oct. 1, 1991 to Sept. 30, 1992	65	61.1
Oct. 1, 1992 to Sept. 30, 1993	123	115.9
Mean annual flow for this period	106	

* Data for October 1, 1986 to September 30, 1987 is not available.

Digitization from Photographs

Stream channels were digitized on-screen from the center of each photograph where distortion from camera lens was minimal. Subsequent sections of the stream were joined until the entire stream channel including islands within the stream were mapped. In this fashion a geographically correct vector map of the stream and its islands was produced.

Stream vectors were rasterized to maps with a cell size of 0.5 by 0.5 m for surface analysis. All estimates of bank-to-bank stream, island, and water surface areas were obtained from raster maps with this resolution. Bank-to-bank area is measured from the edge of the stream on one side to farthest opposite bank. This represents water surface area and any included islands.

RESULTS AND DISCUSSION

Stream Dynamics

Catherine Creek has changed its course substantially in the years between 1979 and 1994 (Figure 5, Table 3). The 1994 thalweg measurements showed an increase of 330 m of channel length in grazed areas with 282 m of this increase occurring in grazed plot #2 (Table 4). Increased thalweg distances in some exclosed plots were partially offset by decreases in others resulting in an overall increase of 13 m by 1994.

Water surface area in late June of 1979 was approximately 43,000 m^2 when flow was 5.664 m^3/sec (Table 3). On 12 July 1994 water surface area was approximately 32,500 m^2 on the ranch which was a 24.1 percent reduction from the 1979 area. This change in surface area could result from a lower discharge rate or a deepening of the channel. Discharge data for Catherine Creek during 1994 is not yet available from the USGS. However, we estimate that it will be approximately 1.7 m^3/second (60 ft^3/second). This estimate is based upon examination of 1993 and 1994 aerial photographs.

Bank-to-bank surface area was remarkably stable over this time period, approximately 54,000 m^2. Similarly, the perimeter of the stream or the linear distance along both the eastern and western banks also is quite similar, 6,226 m in 1979 and 6,260 m in 1994. These parameters are apparently modified only when major storm or runoff events change the course of the stream.

Areas covered by the stream in 1979 can either still be stream in 1994 or they can be land. Similarly, the stream in 1994 could either have been stream in 1979 or dry land. Roughly, half of the cells or pixels covered by the stream in 1979 was dry land on 12 July 1994 as shown below:

Area of 1979 Stream	42,806 m^2
Area of 1979 Stream **Under** water in 1994	20,109 m^2
Area of 1979 Stream **Above** water in 1994	22,602 m^2

Two thirds of the 1994 stream was under water in 1979, with the remaining area as dry land. This implies that substantial deposition or movement of material has taken place leading to channel changes.

Area of 1994 Stream	32,575 m^2
Area of 1994 Stream **Under** water in 1979	20,109 m^2
Area of 1994 Stream **Above** water in 1979	12,364 m^2

In some places channels have moved 18 m or more laterally. This movement occurrs when there is rapid runoff during spring. Major change occurred in the spring of 1984 (Dr. Marty Vavra, personal communication). As would be expected, during years with below average precipitation, little change was observed in the channel.

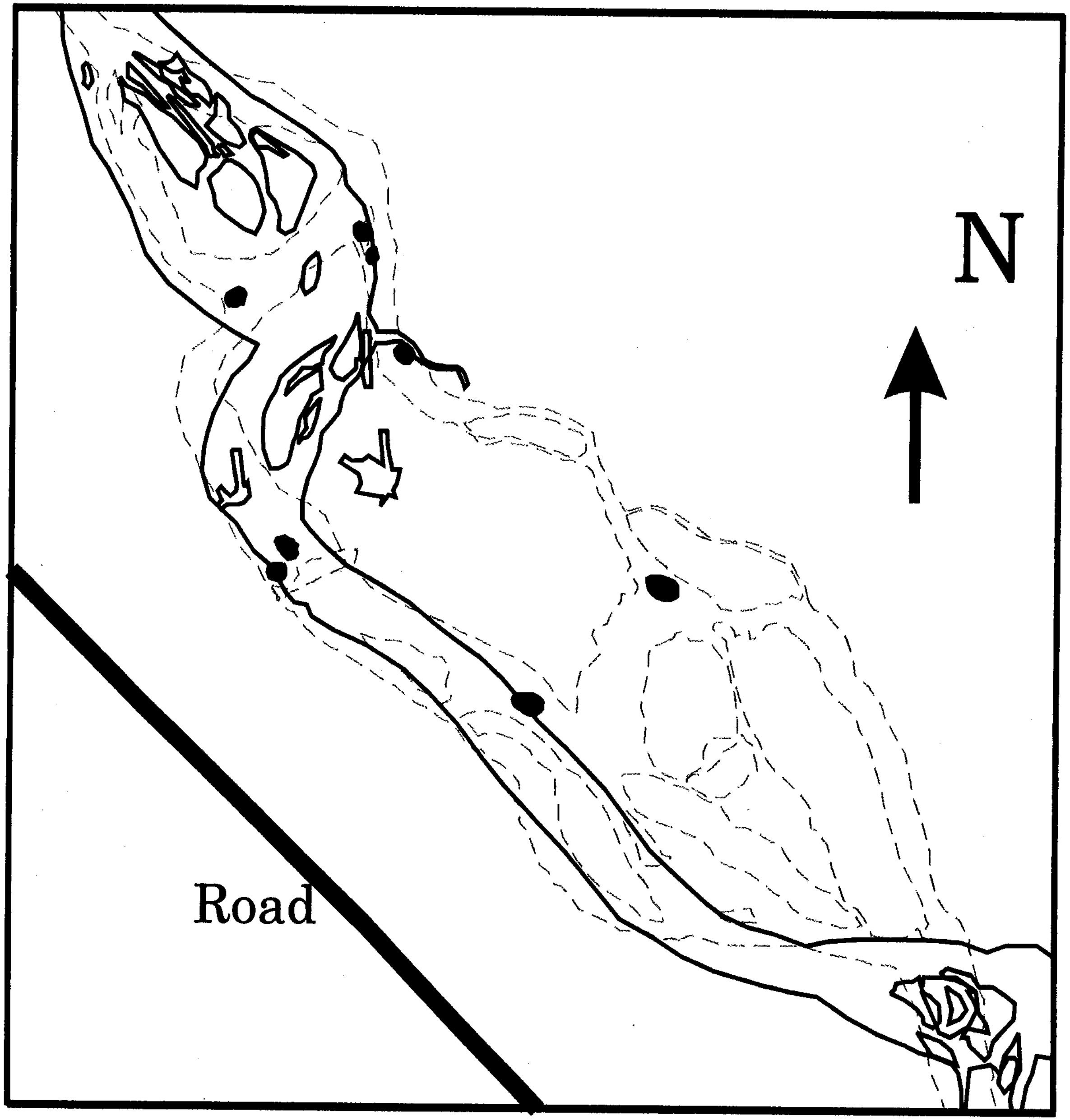
Effects of Livestock Grazing on Salmon Spawning

It is difficult to separate livestock effects on the stream because excluded areas are relatively small and closely associated with grazed parcels. However, both exclosed and grazed areas had smaller water surface areas in 1994. There was a 33.8 percent reduction in water surface area in the exclosed plots compared to 12.8 percent reduction in grazed plots from 1979 to 1994. Flow is lower in 1994 than in 1979 which accounts for some of this change. This also suggests that the channel is deepening more rapidly in areas left ungrazed. Total island area of exclosures increased by 2 percent (Table 3) while bank-to-bank surface area decreased by 25.7 percent.

Total water surface area of grazed plots decreased by 2,590 m^2. Grazed areas seem to be where most braiding of channels is taking place. Areas grazed by livestock increased their bank-to-bank area by 7,400 m^2 or 30 percent in 15 years. This results from substantially more island area which increased 208 percent from 4,820 to 14,890 m^2 (Table 3). Deposition of sediments may also be greatest in these areas. If future aerial photographs can be taken when stream discharge is similar to the level in 1979 then interpretation will be easier and clearer. We will complete this analysis when flow data for 1994 becomes available.

Salmon Redds

Most of the spawning sites for salmon occurred in grazed portions of the stream in 1993 ($P = 0.17$) and 1994 ($P = 0.09$) (Table 4). Lowest numbers of salmon redds were in exclosures 1, 2, and 4 during 1993. Of the ungrazed plots, exclosure number 5 had 6 redds,



Approximate age of Redd formations can be estimated from placement of Redds on creek channel.

1979 Channel shown by solid black outline.

1994 Channel shown by dashed gray outline.

Eight 1993 Redds shown as black polygons.

Woody debris and downed trees are also outlined.

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Figure 5. Map (in border) represents 227 m by 238 m or 5.4 hectares

Overlays showing the position of Catherine Creek in early summer of 1979 and 1994. Also shown on this image is the location of some salmon redds in 1993. This indicates the dynamic nature of the stream channel in these meadows

Table 3. Surface measurements for Catherine Creek on the Hall Ranch near Union, Oregon. Surface areas were calculated from geo-corrected low altitude aerial photographs taken in 1979 and 1994 that were digitized on-screen. Vectors were transferred to raster format and analysis completed with 0.5 by 0.5 meter pixels.

	Bank-to-Bank Area				Island Area				Water Area			
	1979 (m^2)	1994 (m^2)	Change (m^2)	% Change	1979 (m^2)	1994 (m^2)	Change (m^2)	% Change	1979 (m^2)	1994 (m^2)	Change (m^2)	% Change
Exclosure 1	5683	2293	-3390	-59.65	931	233	-698	-74.97	4752	2060	-2692	-56.65
Exclosure 2	4819	4986	167	3.47	1529	2293	764	49.97	3290	2693	-597	-18.15
Exclosure 3	6381	5950	-431	-6.75	731	2127	1396	190.97	5650	3823	-1827	-32.34
Exclosure 4	4387	3689	-698	-15.91	0	166	166	---	4387	3523	-864	-19.69
Exclosure 5	7910	4753	-3157	-39.91	3390	1895	-1495	-44.10	4520	2858	-1662	-36.77
Grazed Plot 6	3556	1762	-1794	-50.45	399	0	-399	-100.00	3157	1762	-1395	-44.19
Grazed Plot 7	7811	8110	299	3.83	2892	4487	1595	55.15	4919	3623	-1296	-26.35
Grazed Plot 8	6481	7080	599	9.24	665	2260	1595	239.85	5816	4820	-996	-17.13
Grazed Plot 9	7179	15556	8377	116.69	864	8143	7279	842.48	6315	7413	1098	17.39
Exclosed Total	29180	21671	-7509	-25.73	6581	6714	133	2.02	22599	14957	-7642	-33.82
Grazed Total	25027	32508	7481	29.89	4820	14890	10070	208.92	20207	17618	-2589	-12.81
Grand Total	54207	54179	-28	-0.05	11401	21604	10203	89.49	42806	32575	-10231	-23.90

which was substantially higher than any other plot. No salmon spawned in exclosures during 1994. Overall, there were an average of 4.68 redds/exclosed plot in 1993 compared to 7.41 redds/plot on grazed areas.

Salmon spawning was more uniform across grazed plots in 1993 varying from a low of 1 to a high of 8 (Table 4). When all plots were examined on a per unit surface area of water basis, densities for 1993 varied from 0 to 21 redds/ha of water. Exclosures averaged 4.68 redds/ha of water while grazed plots averaged 9.65 redds/ha of water. Redd density per ha of water was different between grazed and ungrazed areas at $P = 0.29$ for 1993 data and $P = 0.12$ for 1994.

Salmon redds were significantly fewer in 1994 than in 1993 ($P = 0.02$). Twenty-four redds were observed in 1993 contrasted with only three in 1994. The density of redds was reduced from 7.41 redds/ha of water to only 0.62 in 1994 ($P = 0.02$).

Exclosure number 5 is somewhat different than other exclosed plots. It is the first plot as the creek flows onto the ranch. The stream at this point is sharply diverted by rip-rap protecting the road. It widens inside the exclosure and we suspect water velocity is dissipated. The stream in this area therefore would be more dynamic than in other exclosures. We speculate that the stream is more acceptable to salmon for spawning habitat because of the deposition of coarse gravels.

Stream Age and Salmon Redds

We also examined the relation between the age of the stream and number of redds observed (Table 5). In 1993, twelve redds (50.0 percent) were found in areas of the stream that had been under water less than 15 years (Figure 6). This is somewhat higher than would be expected since 38% of the stream channel is 15 years or younger. In 1994 again we found half of the redds were in areas of the stream that were younger than 15 years. It appears, however that the age of the stream does not preclude its acceptability as spawning habitat.

Future Research

This is a preliminary study of livestock grazing effects on stream morphology and resultant salmonid habitat. Many more questions remain to be answered. For example, grazing effects on suvival of salmon eggs, rearing, and offspring mortality were not examined in this study but are obviously important. We plan to continue to monitor salmon spawning and changes in this stream channel. A logical follow-up study would be to examine other stream systems with different grazing intensities and/or seasons of use.

Table 4. Linear run of main channel (Thalweg distance) and number of islands in 1979 and 1994, and the number and density of salmon redds in 1993 and 1994 in each experimental unit on the Hall Ranch, Union Co. Oregon.

Experimental Unit	1979 Thalweg Distance	1994 Thalweg Distance	1979 Islands	1994 Islands	1993 Redds	1994 Redds
	meters	meters	Number	Number	No.	No.
Exclosure #1 (N)	233	203	10	2	0	0
Exclosure #2	159	195	7.5	4.5	0	0
Exclosure #3	274	320	8	10.5	1	0
Exclosure #4	301	274	2	2	0	0
Exclosure #5 (S)	223	211	9.5	3	6	0
Exclosure Total	1190	1203	37	22	7	0
Grazed #1 (N)	138	158	6.5	1	3	0
Grazed #2	285	567	5	9.5	5	1
Grazed #3	359	375	3	4.5	1	0
Grazed #4 (S)	357	369	15.5	14	8	1
Grazed Total	1139	1469	30	29	17	2
Grand Total	2329	2672	67	51	24	2

Table 5. Age of Catherine Creek channels that contained salmon redds in 1993 and 1994 on the Hall Ranch and on immediately surrounding area.

Age of Channel	Number of Redds in 1993	Number of Redds in 1994	Percent of Redds in 1993	Percent of Redds in 1994
2 - 5 Years	2		8.3	
6 - 9 Years	4		16.7	
10 - 14 Years	6	1	25.0	50.0
15+ Years	12	1	50.0	50.0
Total	24	2		

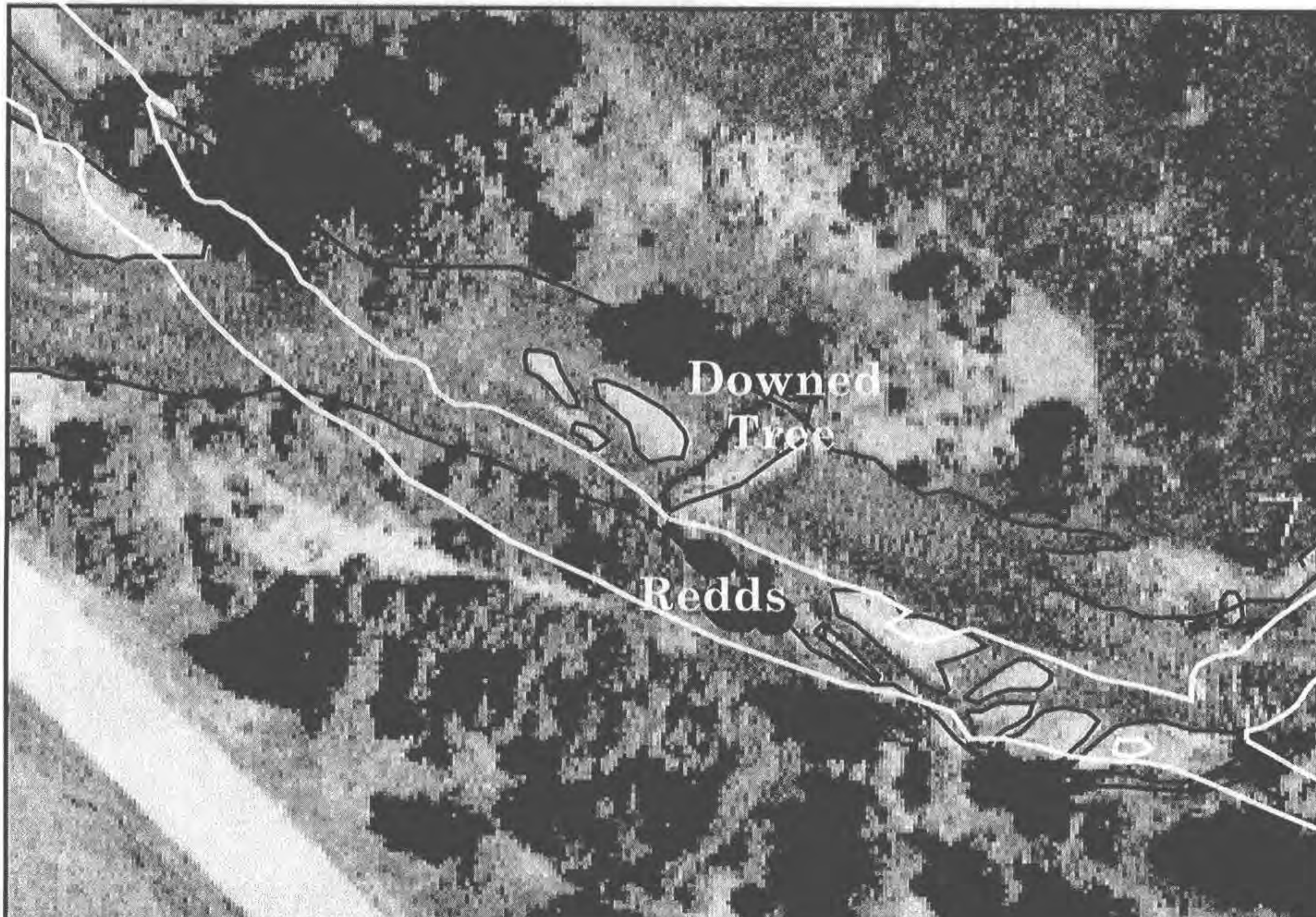

Figure 6. Photo shows area 151.8 m by 106 m or 1.61 hectares.

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A 1979 aerial photograph of a portion of Catherine Creek with the 1994 channel outline superimposed. The position of three of the 1993 salmon redds are also indicated.

An Ecological Basis For the Management and Recovery of Riparian Zones

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INTRODUCTION

Riparian zones are likely the most productive yet mismanaged, the most diverse yet degraded, and the most valuable, yet least studied of wildland ecosystems. Mismanagement has resulted in a precipitous decline in the ecological potential of western range riparian resources including values of terrestrial wildlife, native salmonids, forage, and water. These losses pose a tremendous challenge and opportunity for resource managers today. Ecological restoration will be necessary to recover these ecosystems. However, in many cases, the scientific understanding to effectively restore degraded ecosystems is limited or does not exist. Hence, there is a critical need for research so that sound ecological principals can be incorporated in the management of riparian zones.

An value of riparian zones lies in their inherently high levels of biological diversity that characterize them. For example, along a 3 km reach of Catherine Creek in Northeastern Oregon, more than 255 plant taxa have been identified (Green 1991). This is equivalent to ~17 percent of all species found in the 932,000 ha Wallowa Whitman National Forest. Along Meadow Creek, we identified more than 120 species of plants existing on gravel bars that were created by a flood three years prior to sampling. In addition to species diversity, there is a high level of structural diversity present within and among riparian plant communities (Kauffman et al. 1985 and Case 1995). Due to a diverse gradient of communities dominated by conifers, hardwoods, wet meadows, dry meadows, willows, other shrubs, and herbs that occur along the river continuum. Knowledge of the multitude of geomorphic, hydrologic, and biotic features that shape species and structural diversity of the riparian zone will be necessary for undertaking restoration.

The inherently high biotic diversity of riparian zones is related to frequent natural disturbance processes that create high levels of edaphic and hydrological diversity (i.e. the physical variables of ecosystem diversity). Of particular importance is the occurrence of seasonal high flows that vary in magnitude, timing, and duration from year to year. Recognition of the linkages and interrelationships between natural disturbances, physical diversity, and biotic diversity is necessary in the restoration of riparian ecosystems. In addition an understanding of how, and to what degree, human land use activities (e.g. cattle grazing) alter ecosystem attributes of composition, structure, and function is important.

ECOLOGICAL APPROACHES TO GRAZING MANAGEMENT

Management of riparian zones is reflective of societal values which, similar to natural ecosystems, are in a continual state of change and evolution. While human values change with time, basic ecological processes that influence riparian zone structure, composition, and function do not. The challenge among scientists and natural resource managers is to continually increase our understanding of the ecological, hydrological, and physical properties of riparian zones in order to maintain ecosystem integrity or restore degraded ecosystems. Clearly, we have much to learn.

To be successful, riparian management objectives must have an ecological basis from which to take appropriate actions (Table 1). For example, on lands where livestock production is the primary management objective, an ecological approach to the optimization of net productivity of desirable plant species should be implemented. A knowledge of the inherent productivity of the land and plant species as well as the ecological impacts of herbivory on the environment is necessary. Management strategies must include not only the direct effects of grazing (e.g., defoliation, trampling, soil compaction, etc.) but also the indirect and long-term effects (e.g., influences on riparian vegetation structure, vegetation competition, changes in fire patterns, and influences on hydrology, streambank morphology, and biogeochemistry). From this knowledge-base, managers could develop grazing prescriptions that are specific to the biotic composition and soil/geomorphological features of the ecosystem.

When formulating management or restoration activities, caution should be made to avoid implementation of projects which, rather than result in recovery, actually exacerbate ecosystem degradation. Based upon untested management paradigms, many riparian/aquatic enhancement attempts have increased the degree of riparian degradation rather than facilitated recovery (Beschta et al. 1991, Kauffman et al. 1993, Beschta et al. 1994). For example, managers in the past recommended clearing cottonwoods (*Populus trichocarpa)* and other streamside vegetation with the hope of increasing available forage or surface water. However, because the influences of riparian hardwoods on soil stability, channel roughness, microclimate, wildlife habitat, nutrient cycling, and channel function were ignored, their elimination resulted in dramatic declines in riparian productivity and biodiversity.

ECOLOGICAL APPROACHES TO THE MANAGEMENT OF FISHERIES AND WILDLIFE HABITATS

An ecological approach is also needed to restore or maintain riparian resources for terrestrial wildlife. At Catherine Creek, we quantified high levels of avian and mammalian diversity that are characteristic of intact riparian ecosystems for the upper Grand Ronde River (Kauffman et al. 1982). Given the importance of riparian zones for the vast majority of wildlife species in semiarid ecosystems, their restoration should be a major responsibility that range and other natural resource managers must not ignore or minimize. In later studies on Catherine Creek, we discovered that a complex suite of biotic, edaphic, and hydrological factors are responsible for the high levels of biological diversity on these sites (Green 1991 and Green and Kauffman 1989).

Thus, the challenge of the wildlife manager is to appreciate, approach, and implement management that will perpetuate those ecosystem processes that are responsible for the high levels of biotic diversity in the riparian zone. Ecosystem processes include the presence of frequent disturbances in riparian zones (e.g., fire and floods), and the complex interactions between groundwater, soils, and plants (e.g., redox processes, sedimentation, undercut formation, etc.).

Salmonid production has been among the most economically, socially, and spiritually valuable of range resources in the Pacific Northwest. Therefore, the restoration of anadromous and resident salmonids is among the most important challenges and responsibilities facing range and natural resource managers today. Many restoration attempts have failed to take an ecological approach resulting in minimal, if any, positive responses (Beschta et al. 1991, Kauffman et al. 1993, Beschta et al. 1994). Clearly, engineering approaches to stream restoration are no substitute for ecological functions provided by intact riparian ecosystems.

Management of salmonid habitats does not begin at the streambank, but rather at the ridgeline. A landscape approach that recognizes the linkages of the terrestrial, riparian, and aquatic components of fisheries habitats, natural disturbance regimes, and those anthropogenic factors that contribute to habitat decline or prevent recovery is needed to restore depleted salmonid populations (Beschta et al. 1995 and Kauffman et al. 1995).

Just as arboreal vegetation is critical habitat for terrestrial wildlife, so is it critical for salmon and trout populations in the semiarid west. Trees in the riparian zone influence the aquatic biota through the amelioration of temperatures, reductions in anchor ice formation, and in the provision of energy and nutrients that drive instream productivity. Trees also function in the provision of habitat structure in the form of coarse wood debris and roots, the entrapment of sediments during flooding events, and influences on water chemistry and quality (Gregory et al. 1991 and Li et al. 1994). Recently, we have quantified the biomass and ecosystem structure of riparian forests associated with headwater streams of the upper Grand Ronde River. Total above ground biomass of undisturbed headwater forests may exceed 300 Mg ha^{-1} (Case 1995). In contrast, biomass of unconstrained meadow-dominated reaches ranges from ~2 to 9 Mg ha^{-1} (Kauffman et al. 1983). The important functions of these headwater riparian forests as sources of the coarse wood and nutrients for downstream reaches, as well as their influence on water temperature underscores the need to maintain these reaches in an intact state.

While forested headwater streams provide much of the organic nutrients and large wood debris for riverine ecosystems, unconstrained stream reaches dominated by wetlands or meadow vegetation provide other critical habitat features for both juvenile and adult salmonids. In unconstrained stream reaches below the forest reaches we hypothesize that the complex interaction of wetland vegetation, groundwater, soils, and the soil biota dramatically influence stream nutrients, water quality, and ecosystem productivity. For example, anoxic or anaerobic conditions in wet meadows result in lower levels of nitrates which influence water quality and hence, instream oxygen concentration, and productivity (Green and Kauffman 1989). Recognition of the distinct function and interconnections of each type of stream reach with respect to their influences on the productivity and diversity of the entire river continuum is of importance if we are to restore or manage riparian/aquatic habitats and salmonid populations.

LIVESTOCK INFLUENCES AND MANAGEMENT FROM AN ECOLOGICAL PERSPECTIVE

The livestock and range management professions must recognize that many past and ongoing management approaches to cattle production are principal factors in the decline of riparian ecosystems throughout the world. Restoration of degraded riparian habitats or depleted salmonid populations will necessarily entail improved and innovative livestock management approaches. Rather than taking an advocates view, managers must view livestock impacts in an ecological context. As with any disturbance regime, livestock impacts can be quantified in terms of the severity of the disturbance, the areal extent of the disturbance, and the frequency of disturbance. Disturbances can also be viewed at several spatial and temporal scales. Management and research should view livestock impacts at landscape or ecosystem scales. The impact from a single cow walking through a riparian zone (while significant at microscales of individual plants or soil peds) is likely undetectable at the landscape level. Yet, the cumulative impacts of thousands of AUM's (animal unit months) over many years can be dramatic.

Influences of herbivory are not uniform on ecosystem components. Soils, plant communities, and associated biota are differentially influenced by grazing at different intensities and seasons of use. At moderate levels of utilization, the persistence of the herbaceous components of riparian zones is greater than that of cottonwoods and willows (Green 1991). For example, while late season grazing at moderate stocking levels had few influences on the productivity and structure of meadow communities at Catherine Creek, dramatic differences in the structure and development of adjacent alder (*Alnus incana*) and cottonwood communities was measured.

The basic principals of range management (i.e., the proper timing, season, distribution and utilization by grazing animals) have close parallels to managing the temporal, spatial, and severity components of disturbances. Recognizing the effects of livestock as a perturbation to ecological processes and functions will facilitate the innovation of improved approaches to grazing management. When livestock grazing occurs in areas where the restoration of riparian zones is a management goal, steps must be taken to ensure that their influences result in minimal disruptions to natural ecosystem processes (e.g., competition, succession, erosion, and hydrological processes). Here is where expertise and innovation in grazing management is needed. Successful grazing strategies will be those that result in the restoration and continuation of ecological processes necessary for proper ecosystem function. Included in the range of grazing management strategies are exclosures and rest; the most rapid recovery rates of degraded riparian zones have been in areas where livestock were excluded (Elmore and Kauffman 1994 and Beschta et al. 1995). For example, following two years of rest from livestock grazing on Meadow Creek, riparian shrub density increased (Case 1995).

Developing prescriptions for the restoration of riparian zones is not a simple nor linear process; riparian zones are not uniform in the structure, function, or response to anthropogenic activities. If livestock were the only influence on riparian vegetation, management might be reasonably straight-forward. However, other herbivores can influence riparian composition and structure and they must be considered when establishing allowable limits of utilization. Livestock impacts will be additive to those of native herbivores. In the upper Grand Ronde River, deer, elk, and beaver have been shown to significantly affect regrowth rates of riparian willows and cottonwoods. For example, following the cessation of livestock grazing on Meadow Creek, willow biomass increased 142 percent in two years. However, in areas protected from wild ungulates as well as cattle, shrub biomass increased 506 percent (Case 1995).

CONCLUSION

Our knowledge of the complex suite of ecological patterns and processes that are characteristic of intact functional riparian zones is limited. This limited research base is a significant barrier to the design and development of riparian restoration strategies. However, it is known that riparian vegetation has reproductive and morphological traits that facilitate persistence in an environment of frequent fluvial and other disturbances. The inherently high resilience of riparian vegetation to recover following disturbance suggests a potential exists for the recovery of riparian wildlife and fisheries habitats following decades of unsustainable or improper land use. The recognition of the inherent capacity for riparian ecosystem recovery, and how activities such as livestock, wild herbivores, channel manipulations, and revegetation programs influence natural recovery is an important first step in riparian rehabilitation. This will require an interdisciplinary approach where the contributions of specialists in vegetation, hydrology, fish, and wildlife resources is imperative.

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Table 1. The ecological context of riparian management objectives.

Riparian Management Objectives	Ecological Interpretation or Considerations
1. Increase forage production, availability, and quality for livestock	-Positively influence net primary production of herbaceous and shrub layers. -Encourage species diversity of herbaceous and shrub layers.
2. Restore, enhance or maintain terrestrial wildlife resources	-Manipulate plant species and structural diversity of riparian vegetation. -Wildlife habitats (food, nesting, and thermal cover, etc.) -Increase the juxtaposition of aquatic and terrestrial plant communities.
3. Restore, enhance, or maintain fisheries resources	-Focus on ecosystem processes responsible for high levels of habitat diversity -biotic, physical, hydrological. • Vegetation productivity - allocthonous inputs (fines to CWD). • Functional interactions among riparian zone features - riparian soils, ground water, water column, benthos, hyporheic (water chemistry nutrient spiraling). -Minimize anthropogenic increases in sedimentation, erosion losses, and influences on streambank integrity (structure, erosivity). These are best accomplished through intact vegetation assemblages and CWD dynamics. -Allow riparian zone to function as a thermal buffer of the aquatic system: • Interchange with groundwater, hyporheic zones; • Recovery of channel diversity and structure; • Natural levels of vegetation cover • Allow beaver populations to occur. -Influence base flow-hydroperiods: • Linkages with intact uplands • Floodplain storage, soil resources management
4. Improve water quality and quantity	-Dissipate energy of flood events, high flows by increasing roughness element of vegetation, streambanks. -Interchanges with ground water, riparian vegetation, hyporheic zones, and the stream channel.
5. Alter timing of discharge	-Recovery of natural dynamic peak flows and base flows. -Maintain or reconnect linkages with intact uplands. -Facilitate storage within the floodplain complex.
6. Decrease streambank erosion, floodplain losses, and loss of streambank integrity (channel bank structure); allow for channel recovery	-Increase vegetation cover and structural diversity to facilitate sediment trapping-streambank rebuilding. -Maximize channel roughness diversity, and sinuosity.
7. Decrease or eliminate negative effects or alterations associated with livestock in riparian zones or use them to modify the environment for some specified use.	-Minimize or eliminate livestock influences on natural ecosystem processes (ecological physical, and disturbance). -Minimize anthropogenic degradation of streambanks (e.g., trampling damage). • Grazing strategies - intensity and seasonal presence. • Kind and class of animals. • Rest, exclosures
8. Restore or conserve the biological diversity of the riparian/stream ecosystem	-All of the above.

LESSONS LEARNED CONCERNING LIVESTOCK IN RIPARIAN ZONES AND THE ASSOCIATED UPLANDS OF RANGELAND WATERSHEDS

John C. Buckhouse

INTRODUCTION

The western United States has experienced a wide range of uses and impacts in the 150± years since the arrival of Europeans. Beaver trapping by the Hudson Bay Company and the American Free Trappers removed tens of thousands of beaver from the Intermountain and Pacific Northwest. With the loss of the beaver, subsequent washing out of dams and downcutting of valley bottoms, a path of destruction was initiated. Drovers arrived on the heals of the trappers with cattle, sheep, and horses. Closely following the livestock owners were homesteaders who enthusiastically plowed and grazed many fragile landscapes that were never ecologically suited for intensive use.

This early pattern of exploitive use of rangeland ecosystems caused numerous instances of retrogression in plant communities, soil stability, erosion, and watershed function. Fortunately, recent decades of research, thoughtful observation, and intensive management has redirected many ecological trends into positive directions. While all members of society would probably agree that there is still a distance to go, the observant individual can be heartened by the generally positive trend that the nation's rangeland watersheds are experiencing. Nevertheless, there are places where long-lived, invading or encroaching species are proliferating and cause for alarm is present.

In this paper, I will explore a number of opportunities where management can make a positive impact on the ecological, social, and economic realities of rangeland ecosystems.

NEGATIVE AND POSITIVE IMPACTS OF GRAZING

Negative

Herbivores, be they livestock or big game, in numbers exceeding carrying capacity, at times of the year when plant growth and physiology are most critical; or if their distribution patterns encourage congregation on critical sites, can be deleterious to those sites. History is replete with examples of streambank sloughing, dietary overlap and competition, nutrient loading, vegetation species composition changes, erosion, and pollution which was traced to herbivore excesses of one form or another.

Positive

Fortunately, as we have learned more about the ecological pieces in this managerial puzzle, it becomes apparent that management by objective and for sustainability is not only possible, but achievable. Here are a few examples.

Positive changes in species composition and community structure

Herbivores, particularly livestock, can be used as a biological tool to encourage succession. If, for instance, a site is heavily infested with invading annuals and/or noxious alien weeds, it may be possible to prescription graze the site at a time when the aliens are vulnerable in order to encourage the growth of remnant, native perennials.

By doing prescription grazing one can foster individual plant response, tillering, seed production, seedling establishment, and vegetation cover in order to enhance infiltration of precipitation at the point of origin. This in turn fosters soil moisture and nutrient cycling relationships

Wildlife habitat

A common perception among many people is that livestock and wildlife are in direct competition with each other for food and/or habitat. At abusive grazing levels this may indeed be true. At managed levels, however, quite the opposite is so. Following the lead of African researchers in the Serengeti, who established the interdependence of feeding guilds, rangeland managers are learning how to use "coarse" feeders such as cattle to foster forage and habitat for more "delicate" feeders such as elk or geese. In Oregon, and elsewhere in the West, cattle are used to "prepare" sites for wildlife. Without the coarse feeders, vegetation would be less succulent and palatable for the next guild. The ODFW elk pastures on the South Santiam and the migratory geese feeding stations in the Willamette Valley are good examples of where livestock have been used in conjunction with positive uses.

AMELIORATIONS

In riparian zones, particularly, concerns about improper grazing by livestock have created conflicts between and among natural resource groups. There are several opportunities for management that can enable the positive ecological and economic values of livestock production to be compatible with watershed, habitat, and wildlife values.

Livestock Behavior

By understanding livestock behavior, a host of potential prescriptions can be made. Roath and Krueger (1982) found that livestock demonstrate home ranges much like those shown by wildlife. This, of course, leads one toward the concept of culling animals on the basis of their habitat preference.

Miner et al. (1991) demonstrated that an off-site watering device used under winter-time conditions was able to reduce livestock time spent in the stream by 90 percent. Clawson (1993) using an off-site watering device was able to show a 20 percent reduction in time livestock spent near the stream even under summer conditions.

Chamberlain (1995) investigated technologies where off-site watering could be accomplished. Of the possibilities presented by stream-driven hydrologic ram pumps and/or animal activated (nose) pumps, he demonstrated the feasibility of using portable solar-powered pumps.

Clawson (1993) also investigated water gaps size and configurations to determine feasibility in using watergaps to reduce animal access and time spent in the riparian zone. He was following up on work which was later published by Larsen et al. (1994) which suggested that buffer strips of as little as one meter in width reduced the introduction of fecal-borne coliform bacteria into the stream by 90 percent. Clawson (1993) found that watergaps do, indeed, have a dramatic impact and was able to eliminate direct deposition of feces into the stream through a combination of watergap sizes and configurations.

Of course, centuries-old technologies of fencing and/or herding represent ways of controlling herbivores so that they graze riparian and upland watersheds by prescription, not by default. Tiedemann and Quigley (1993) have experimented with "fenceless fences" that employ electronic boundaries and deterrents to site-specific areas. Herding may be being re-discovered as well. Several studies contemplating such cost/benefit relationships are underway.

Grazing Strategies

Several studies have been done where grazing strategies have been employed to encourage specific plant community responses. Buckhouse and Elmore (1993) have constructed a matrix where they have compared natural stress against human-imposed response. Generally speaking one can classify these strategies in terms of plant growth/development and watershed response (Figure 1). This might be summed up as follows:

> Usually grazing on frozen ground when plants are dormant has minimal impact on either vegetation or infiltration, and may be used to foster woody vegetation.
>
> Early growth season grazing — as long as it is terminated before soil moisture is gone — seems to work well on well drained soils. One should be alert to potential compaction problems on poorly drained soils, however. Riparian grazing during the growing season (season-long grazing) tends to be detrimental in terms of plant and watershed responses.
>
> Post-reproductive stage grazing is a mixed bag. It tends to favor herbaceous vegetation at the expense of woody vegetation (on those streams which are classified as "sedge and rush dominated without a natural woody component" this may work well, however). This post-reproductive stage frequently is dry and therefore at minimal risk for compaction and additionally may have some wildlife benefits especially for sites used earlier in the growing season by ground-nesting birds.

As one attempts to balance a sustainable grazing system with a sustainable watershed, it becomes obvious that soil physics, watershed (especially infiltration), plant growth and development factors/responses, and animal behavioral responses all must be factored in. With care it can be done.

HOW DO WE GET THERE FROM HERE?

Wishful thinking isn't going to do it. A combination of approaches is necessary. I believe they are:

Site Classification

Before you can determine what you want your site to provide, you must know what it is capable of producing. Watershed classification (Swanson et al. 1988) makes sense.

Vision

Create a vision of what you want the area to be like. Without that mind's eye picture you will have trouble achieving success.

Goal Setting

Clear, written goals, then objectives, will enable you to establish the directions and time frames necessary for watershed planning.

Planning

Follow a standard planning outline to establish goals, objectives, alternatives, methods, and flexibility appropriate to your plan.

Monitoring

If you don't plan, you won't know where you are going. If you don't monitor, you won't know when you get there. Bedell and Buckhouse (1994) and Bauer and Burton (1993) give some sensible advice on watershed uplands and riparian zones, respectively.

CONCLUSION

Watershed-ecosystem management as espoused by the Oregon Cattlemen's Association, the Oregon Department of Environmental Quality, the U.S. Forest Service, and the Oregon State University Department of Rangeland Resources Extension Service is based upon ecological reality, social acceptability, and economic viability (Buckhouse 1995). This balancing act is complex and ever-shifting. But the stakes are too high to ignore. Sustainable ecosystems depend upon our diligent efforts to learn about and to manage our natural resources.

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MANAGEMENT STRESS		Low Steep, Low sediment load	Medium Steep, High sediment load	Medium Moderate, Low sediment load	Medium Moderate, High sediment load	Medium Flat, Low sediment load	High Flat High sediment load
Low	No Grazing	Shrubs ↑ Herbs ↑ Banks ↔	Shrubs ↑ Herbs ↑ Banks ↔ ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑
Low	Dormant Season	Shrubs ↑ Herbs ↑ Banks ↔	Shrubs ↑ Herbs ↑ Banks ↔ ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑
Low	Early growing season	Shrubs ↑ Herbs ↑ Banks ↔	Shrubs ↑ Herbs ↑ Banks ↔ ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑
Medium	Late growing season	Shrubs ↓ Herbs ↑ Banks ↔ ↓	Shrubs ↓ Herbs ↑ Banks ↔ ↓	Shrubs ↓ Herbs ↑ Banks ↔ ↑	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↓ Herbs ↑ Banks ↑
Medium	3-pasture Rest-rotation	Shrubs ↓ Herbs ↑ Banks ↔	Shrubs ↓ Herbs ↑ Banks ↔ ↑	Shrubs ↓ Herbs ↑ Banks ↔ ↑	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↓ Herbs ↑ Banks ↑
Medium	Deferred rotation	Shrubs ↓ Herbs ↑ Banks ↔	Shrubs ↓ Herbs ↑ Banks ↔ ↑	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↓ Herbs ↑ Banks ↑
Medium	Rotation	Shrubs ↓ Herbs ↑ Banks ↔	Shrubs ↓ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑	Shrubs ↑ Herbs ↑ Banks ↑
High	Season long	Shrubs ↓ Herbs ↓ Banks ↓	Shrubs ↓ Herbs ↓ Banks ↓	Shrubs ↓ Herbs ↓ Banks ↓	Shrubs ↓ Herbs ↓ Banks ↓	Shrubs ↓ Herbs ↓ Banks ↓	Shrubs ↓ Herbs ↓ Banks ↓

NATURAL CONDITIONS

↓ - decrease

↑ - increase

↔ - no change

Figure 6-4.—Generalized relationships among riparian vegetation response, grazing management practices, and stream system characteristics