Special Report 994
September 1998

A Catherine Creek Study—Perspectives, 1995–1998

Agricultural Experiment Station
Oregon State University

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Preface

The Oregon Agricultural Experiment Station publication you have in your hands comprises three manuscripts, including one by Douglas Johnson and three co-authors entitled, "Mapping and Analysis of Catherine Creek Using Remote Sensing and Geographic Information Systems (GIS)." The Johnson et al. article was first published as a part of Special Report 951, July 1995, *Eastern Oregon Agricultural Research Center Field Day Annual Report, 1995*. Its publication three years ago began a debate among some scientists at or associated with Oregon State University. This article then drew attention of the popular press which tended to oversimplify certain conclusions of the research. The scientific debate widened, sometimes prompting interested scientists and others not directly associated with the University to express their views to the authors and to the College of Agricultural Sciences administration.

After Special Report 951 was published containing the Johnson et al. study, another group of scientists affiliated with Oregon State University proposed publication of a second article, this one addressing the methodology and conclusions of the first. It concerned me and certain other administrators in the College of Agricultural Sciences that in articulating such distinctly different views on this matter, our scientists should find their information being used out of context by advocates on one side or another of the continuing debate around cattle grazing, water quality, and management. I encouraged efforts to bring the principals in this scientific debate together at least enough that they might jointly develop a manuscript that—in one document—explicated their points of view. Despite what I believe were well-intended efforts by the men and women whose judgments differed on this science, my hope for a synthesis of views was unfulfilled. Unfortunately, what did result was delay after delay in any action that would move this matter forward. This had several consequences. It eroded confidence in a system through which scientific papers are published by the Oregon Agricultural Experiment Station. Parties to what was essentially a legitimate difference of scientific opinion became increasingly frustrated with what they saw as administrative roadblock. Communication among the parties was impeded or failed altogether. I take responsibility for this and would today choose a different course. For the delays caused by this effort to publish a single, integrated report, I apologize to the scientists involved and to others who have followed the progress of this debate.

What we now have published, however, are three papers.

- "Mapping and Analysis of Catherine Creek Using Remote Sensing and Geographic Information Systems (GIS)" by D.E. Johnson, N.R. Harris, S. du Plessis, and T.M. Tibbs, (Department of Rangeland Resources, Oregon State University).
- "The Relationship of Cattle and Salmon Redds at Catherine Creek: A Scientific Assessment" by H.W. Li, J.B. Kauffman (both of the Department of Fisheries and Wildlife, Oregon State University), R.L. Beschta (Department of Forest Engineering, Oregon State University), and B.A. McIntosh (Department of Forest Science, Oregon State University).
- "An Update on the Catherine Creek Riparian Study" by D.E. Johnson, N.R. Harris, and T.M. Ballard (formerly Tibbs).

As noted earlier, the first was published in connection with a Field Day in 1995 at the Eastern Oregon Agricultural Research Center; this paper is reproduced as originally published. The second, a critique of the first, was proposed for publication in January 1996 but was delayed, mostly by administrative intent noted above; the second paper was revised and updated during the delay. The third paper is a current response by the authors of the original paper to the assessment tendered by the authors of the second. All are contained here.

I have directed that these papers be published together in a consecutively numbered Special Report of the Oregon Agricultural Experiment Station so that the reader may have, conveniently, the full record of this professional debate. For those who want definitive answers now, this will disappoint, but for those who understand the way ideas are tested in science, these papers are a case study. Aside from how the issues are presented and challenged, I call the reader's special attention to the concluding sections of each paper in which the authors propose directions they think this pursuit of understanding must follow. Within these summaries lie the components of a yet undevised research strategy that will give us still greater understanding of an unimaginably complex system.

The evolution of this particular scientific debate taught me some lessons and reminded me of the nature of a Land Grant university. It taught me that, in a matter as complex and value-laden as this, there is need for careful, regular, documented communication about administrative intent. The experience also taught me that, as fellow faculty members, we must be better practiced than we are in handling our scientific differences.

Within a Land Grant university community, the people we serve often are necessarily impatient about ongoing scientific debate. Driven by realities of being competitive and profitable, addressing pressing public problems, or making public policy decisions, they want answers. Clear, definitive answers: the "truth." We, as administrative leaders, feel the pressures these expectations bring. Our faculty members, interacting as many do with people in business and public life, feel the same pressures to deliver "science that works." Faculty members, invested in their disciplines and their own works, are understandably passionate about what they have learned. Coupling the pressures of public expectations with passion for one's own research findings sets up at least some of our faculty for disagreement with each other around the meaning and applicability of research results.

Fundamentally, this is healthy. Profound insights have been driven by rigorous debate and testing. But, in today's litigious and media-intensive society, what begins as differing points of view, as legitimate differences in interpretation or distinctions drawn by disciplinary tradition, can easily escalate into public dispute and personal enmity. Instead, we must seek problem-solving good.

I hope the publication of this compendium of views is a step toward productive articulation of the issues, with passion but without rancor. Beyond that, however, I urge the scientists involved to consider the potential inherent here for teaching and learning. Oregon State University President Paul Risser has challenged us all to assure each student at Oregon State a "compelling learning experience." No higher purpose could be served than to afford these students opportunities to engage with the parties to this debate—together in the same room—exploring the differing perspectives. These student-citizens deserve such a compelling learning experience to help them understand what is fair and reasonable to expect of science.

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August 1998

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Review

The first two papers were peer reviewed according to Agricultural Experiment Station policy by reviewers affiliated with the University or the wider scientific community. The third paper, a response to the second, was reviewed by faculty members within the College of Agricultural Sciences.

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

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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.

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.

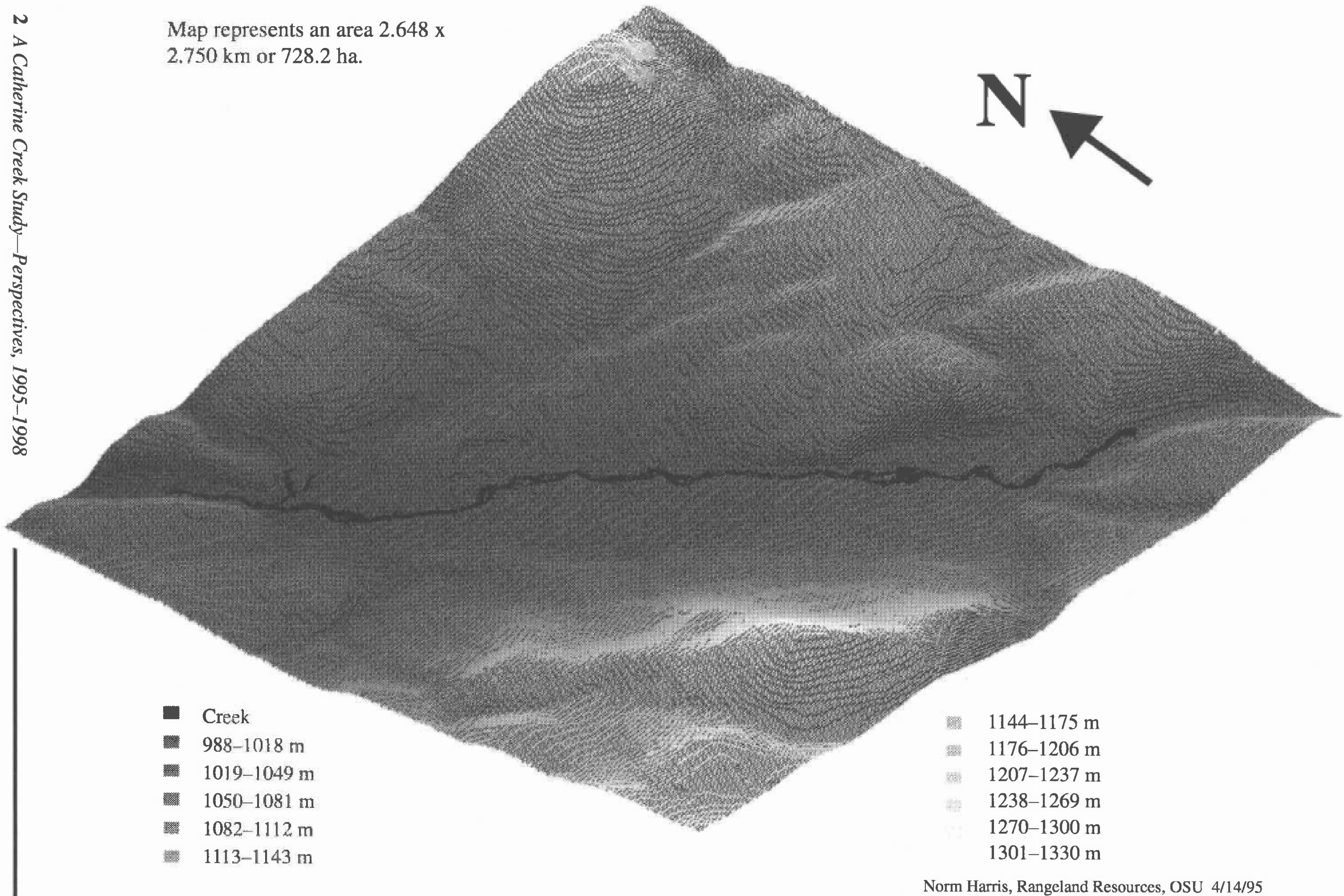

Figure 1. Orthographic view of the Hall Ranch, Union, Oregon. The outline of Catherine Creek as it was in 1994 is superimposed on the map.

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 U.S. Department of the Interior, Geological Survey (GS), 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.

Outlines of each experimental unit were geopositioned, 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 15 x 15 cm for the lowest photographs and 30 x 30 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 GS 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 x 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.

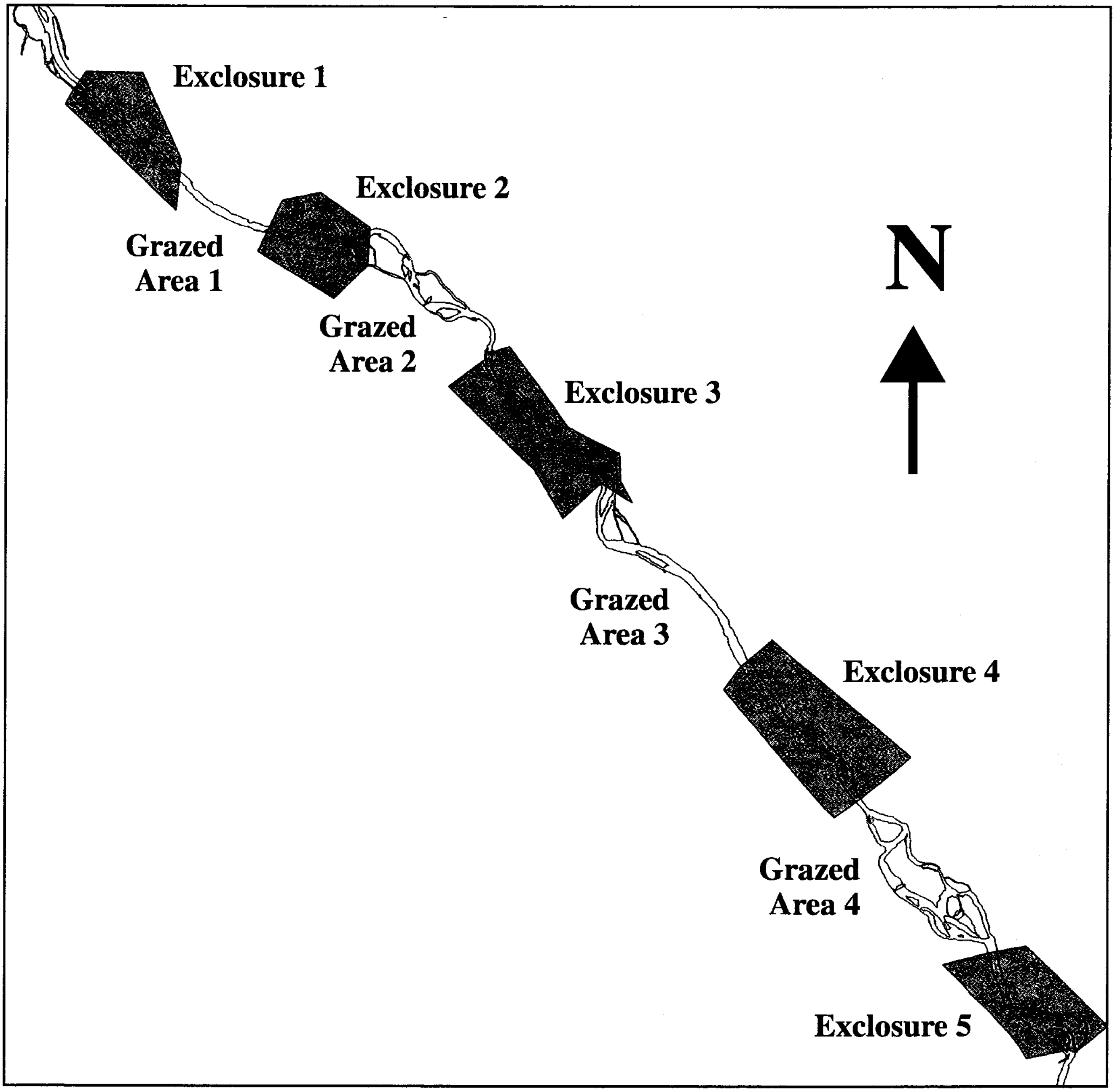
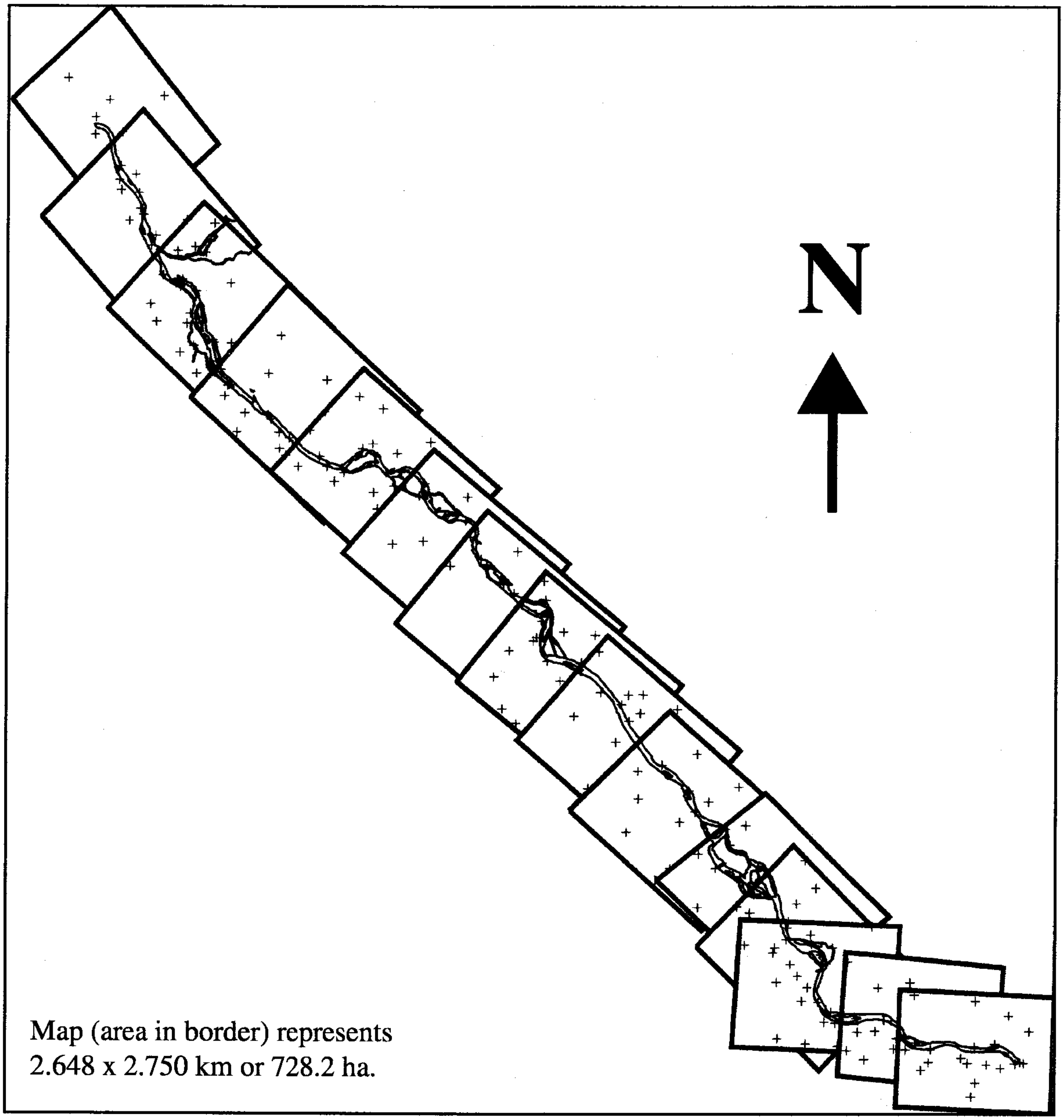


Figure 2. Layout of the experimental units on the Hall Ranch, Union, Oregon. Outlines of the 1994 channel of Catherine Creek are superimposed.



Norm Harris, Rangeland Resources, OSU 4/14/95

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.

Figure 3. The positions of the fifteen aerial photographs of the 1994 flight line superimposed on the outline of Catherine Creek on the Hall Ranch, Union, Oregon.

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

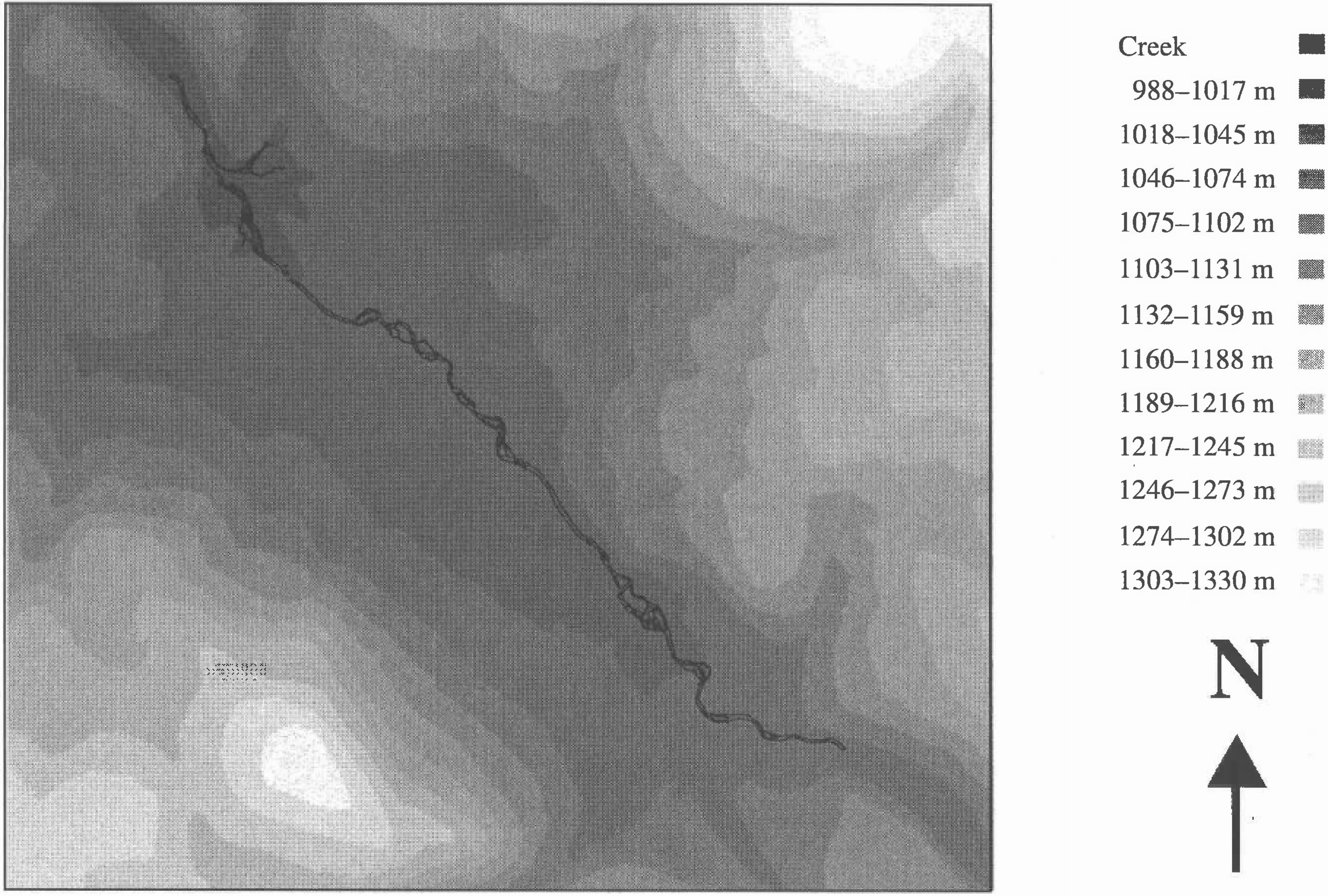
Year	Date of Aerial Photography	Stream Flow m^3/sec	(ft^3/sec)
1979	June 28, 1979	5.664	(200)
1983	July 10, 1983	4.361	(154)
1988	August 1, 1988	0.821	(29)
1989	June 16, 1989	10.506	(371)
1993	July 26, 1993	2.152	(76)
1994	July 12, 1994	1.359*	(48)*

* Data acquired from GS August 1998.

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	Percentage 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.



Map represents 2.648 x 2.750 km or 728.2 ha.

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Figure 4. Digital elevation model (DEM) of the Hall Ranch superimposed with the 1994 outline of Catherine Creek.

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 x 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 GS. 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.

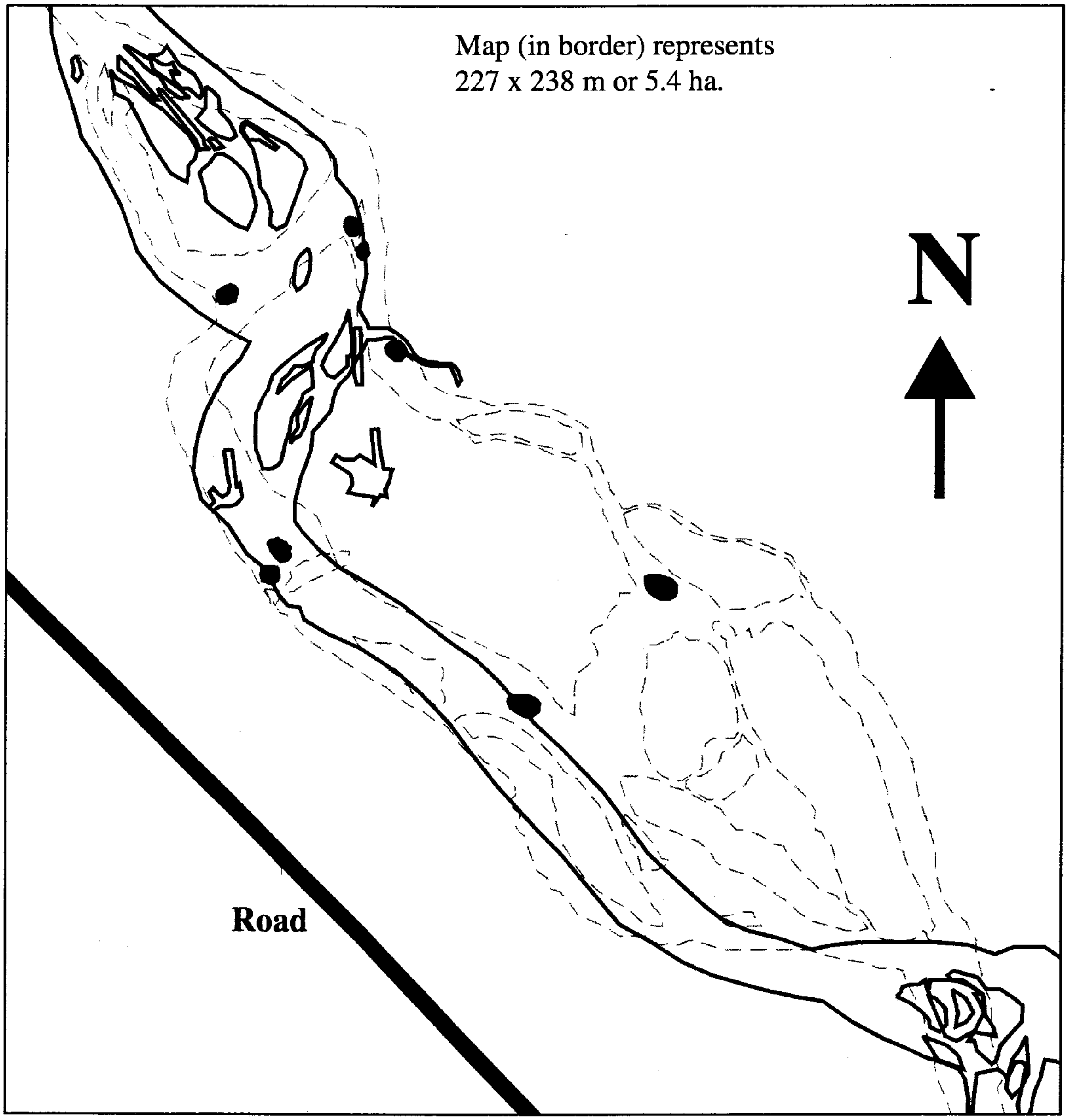
Area of 1994 Stream .... 32,575 m^2
Area of 1994 Stream
  Under water in 1979 .... 20,109 m^2
Area of 1994 Stream
  Above water in 1979 .... 12,364 m^2

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



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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.

Figure 5. 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 x 0.5 m 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 1*	3556	1762	-1794	-50.45	399	0	-399	-100.00	3157	1762	-1395	-44.19
Grazed Plot 2*	7811	8110	299	3.83	2892	4487	1595	55.15	4919	3623	-1296	-26.35
Grazed Plot 3*	6481	7080	599	9.24	665	2260	1595	239.85	5816	4820	-996	-17.13
Grazed Plot 4*	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

* In Johnson et al. (1995), Table 3 incorrectly listed these as Grazed Plot 6, 7, 8, and 9. Plots numbers corrected for Johnson et al. (1998 [1995]).

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, 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 survival 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	Percentage of Redds in 1993	Percentage 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		

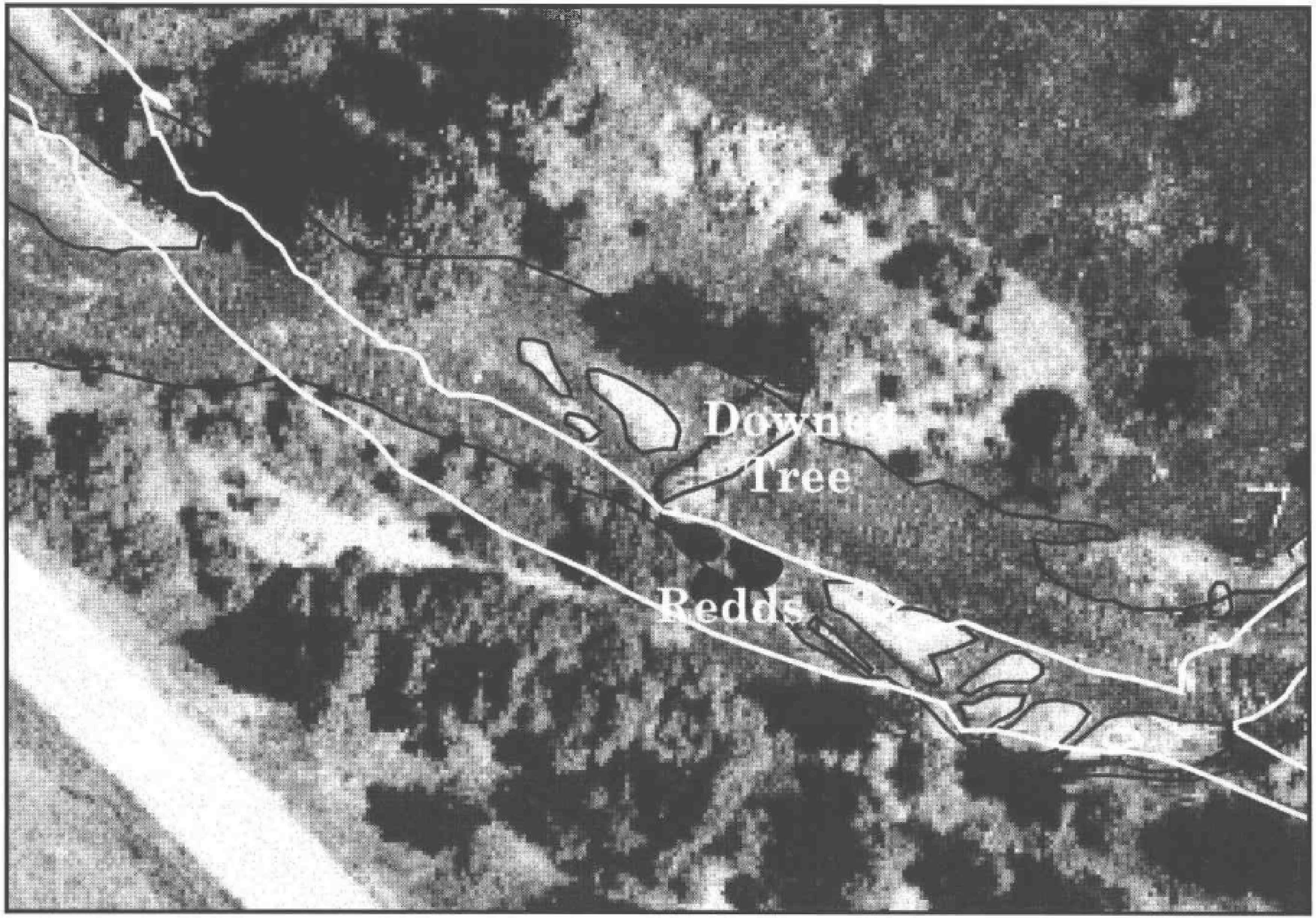

Photo shows area 151.8 x 106 m or 1.61 ha.

Norm Harris, Rangeland Resources, OSU 4/14/95

Figure 6. 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.

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The Relationship of Cattle and Salmon Redds at Catherine Creek: A Scientific Assessment

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Abstract

A recent paper by Johnson et al. (1995) reported higher densities of salmon redds in livestock-grazed riparian reaches than in ungrazed reaches of Catherine Creek, a tributary of the Grande Ronde River Basin in northeastern Oregon. By logical extension, one might infer that cattle have a positive influence on salmon spawning areas. After reviewing Johnson et al. (1998 [formerly 1995]), we concluded that their analysis was unsupportable because of an inappropriate study design and flawed statistical analysis. Repeated annual measures cannot overcome the inadequate study design, leaving any interpretations regarding the effects of livestock grazing on the density of salmon redds invalid. In addition, there were omissions of pertinent data concerning the study area, its biological features, and current land use. For instance, livestock use on the Catherine Creek study area was moderate in meadow communities and light in the streamside tree/shrub communities. Livestock utilization in the streamside tree/shrub communities is at the lowest levels of detectability, and these levels are not representative of most grazed streams in eastern Oregon. We present additional information needed to interpret the effects of grazing on Catherine Creek, suggest appropriate methods to test for grazing effects on spawning salmonids, and propose that interdisciplinary research be conducted on this issue.

Introduction

The paper, "Mapping and Analysis of Catherine Creek Using Remote Sensing and Geographic Information Systems (GIS)," presented information on the presence of spring chinook salmon redds in a stretch of Catherine Creek in the Grande Ronde River Basin of eastern Oregon (Johnson et al., 1998 [formerly Johnson 1995]). The stated 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" (p. 1 [12]). The authors conclude that theirs was "a preliminary study of livestock grazing *effects* (our italics) on stream morphology and resultant salmonid habitat" (p. 11 [23]). This conclusion went beyond the stated objectives and capabilities of the study design described by Johnson et al. (1998 [1995]). The study design was appropriate for the study of riparian vegetation (Kauffman et al., 1983a; Green and Kauffman, 1995) but inadequate for studying the effects of livestock grazing on salmon spawning. Subsequently, the interpretations of Johnson et al. (1998 [1995]) may have confused the public and led the media to misinterpret or extend the implications beyond the limits of the study (Anderson, 1995; Oregon Farm Bureau News, 1995). While Johnson et al. (1998 [1995]) did not provide specific conclusions regarding grazing impacts on salmon spawning habitats, misinterpretations by readers of the Johnson et al. (1998 [1995]) paper were the consequence of a study design inappropriate to the conclusions made, flawed data analysis, and unclear interpretations of the results. The objectives of our paper are to present a scientific review of the Johnson et al. (1998 [1995]) study, to provide additional information relevant to the interpretation of livestock influences, and to suggest scientifically sound strategies to assess the influence of grazing on salmonid habitats.

Since 1978, scientists have been conducting riparian ecology research along Catherine Creek in northeastern Oregon. The study site is located on lands managed by Oregon State University's Eastern

Oregon Agricultural Research Center (EOARC) in the Wallowa Mountains of northeastern Oregon. Catherine Creek is a third-order tributary to the Grande Ronde River. Elevation of the site is approximately 1030 m. Mean annual discharge is 3.4 m^3/sec with peak flows occurring from April to early June (Green, 1991). Kauffman's initial study (1982) established five livestock exclosures, and the objectives were to examine the influences of late-season livestock grazing on plant community composition, wildlife communities, and streambank erosion. Ongoing, long term studies of Catherine Creek have focused on the composition and structure of the riparian ecosystem (Kauffman, 1982; Kauffman et al., 1985; Green, 1991; Case, 1995), wildlife communities (Kauffman et al., 1982), livestock influences on streambanks (Kauffman et al., 1983b), livestock influences on plant communities (Kauffman et al., 1983a; Green, 1991; Korpela, 1992; Green and Kauffman, 1995) and the biogeochemistry of riparian zones (Green and Kauffman, 1989; Green, 1991).

Adequacy of Study Design

Johnson et al. (1998 [1995]) took advantage of the existing study design of exclosures and grazed plots used previously to examine the effects of livestock grazing on the riparian zone (Kauffman et al., 1983a; Green and Kauffman, 1995). While the study design was appropriate for the study of riparian vegetation, it was entirely inadequate for studying the spawning preferences of salmon for five reasons:

1. The study design of Johnson et al. (1998 [1995]) was statistically flawed because none of the treatment replicates (i.e., grazed and exclosure) were independent. In other words, the results were not influenced by the treatments alone. Experimental upstream plots can affect downstream plots through influences on the movements of water, sediments, and organic matter. In addition, downstream factors such as dams, land use activities, and other physical or chemical blocks to fish passage or survival can influence upstream plots and fish movements. No amount of randomization or interspersion of experimental stream units can correct for this problem. Repeated measures annually would not overcome the inadequacies of the study design. The lack of independence associated with the small exclosures and grazed plots precluded any attempts at a valid or meaningful statistical analysis. While the downstream/upstream interactions were not likely as strong of an influence on vegetation responses to grazing, it is of utmost importance for studies of livestock influences on salmon spawning.
2. Because of the lack of independence among replicates, the study lacked true replication; it was pseudoreplicated *sensu* Hurlbert (1984). The Johnson et al. (1998 [1995]) study was conducted at the wrong spatial scale; the unit of replication should have been the stream basin (e.g., Catherine Creek), with each stream basin being a replicate. Designing a study such as this at the basin-scale would eliminate the upstream-downstream problem of confounding influences by examining the full range of spawning habitats in each stream.
3. The original study design of Kauffman (1982) did not consider differences in channel morphology, stream gradient, substrate, or spawning gravels in the placement of exclosures because these factors did not bias that study of plants. By adopting Kauffman's design uncritically, Johnson et al. (1998 [1995]) introduced biases at the stream-reach scale because the plots were not adequately stratified to address the effects of cattle upon salmon redds.
4. Returning salmon show high fidelity to parental sites of spawning (Groot and Margolis, 1991). This behavior can confound differences in site selection for redds in damaged streams. Because of traditional behavior, an adequate site close to the natal origin of a fish may be chosen over an optimal site further away. Again, this points out the need to conduct an experiment using entire watersheds as the unit of replication.
5. The upper Grande Ronde watershed was an inappropriate place to conduct the study because spring chinook salmon populations (a Federally listed endangered species) were so

low that it was impossible to get an adequate statistical "signal" from any stream within the basin. We do not imply that this was due entirely to the ecological condition of the riparian zone and upland ranges; other factors such as negotiating passage through eight mainstem dams in the Columbia and Snake rivers were also confounding influences.

Analytical Rigor

Statistical Analysis

Johnson et al. (1998 [1995]) recognized several statistical shortcomings of their study. They noted that "it is difficult to separate livestock effects on the stream because excluded areas are relatively small and closely associated with grazed parcels" (p. 8 [20]). However, after providing this cautionary statement, they conducted an analysis that appeared to show a greater number of redds in the grazed areas than in the excluded areas and that these differences were statistically significant. The generally held scientific standard is to place a level of statistical significance at $P < 0.05$ (although a level of $P < 0.10$ is often presented in the literature as significant). Johnson et al. (1998 [1995]) chose less rigorous levels of statistical significance ($P = 0.29$ in 1993, $P = 0.12$ in 1994) when testing for differences of redd density/ha of water between grazed and ungrazed areas. This analysis is irrelevant because an inappropriate study design and a low sample size made statistical tests meaningless.

Data Presentation

We found the presentation of data in Table 4 of Johnson et al. (1998 [1995]) was misleading. The five cattle exclosures and four grazed areas of Catherine Creek are very different in size (Kauffman et al., 1985). However, redd counts were presented as raw counts for each grazed or exclosed plot and were not standardized by water area. We standardized the data by water area to remove the bias of areal differences, and the resulting rankings of the experimental plots by redd densities changed (Table 1). When raw counts are used, the ranking of experimental plots in descending order of redd numbers is as follows: grazed plot 4, exclosure 5, grazed plot 2, grazed plot 1, a tie between grazed plot 3 and exclosure 3, and tied rankings among exclosures 1, 2 and 4 (Table 1). However, when standardized by water area, the ranking shifts to the following in descending order of redd density: exclosure 5, grazed plot 1, grazed plot 2, grazed plot 4, exclosure 3, grazed plot 3 and tied rankings among exclosures 1, 2 and 4 (Table 1). Based on redd density there was no significant statistical difference ($P = 0.29$) between grazed and exclosed areas; again, flaws in the statistical design and small sample size make any analysis irrelevant.

Livestock Utilization at Catherine Creek

Johnson et al. (1998 [1995]) did not report the levels of livestock utilization, providing little context for interpreting potential influences of livestock on the ecosystem. It is a standard practice in range management research to report the timing and degree of utilization in order to ascertain the influences of livestock on the ecosystem (J. Boone Kauffman, 1995, personal communication). Such information facilitates comparisons with grazing approaches used in other areas. The livestock grazing strategy of the EOARC reach of Catherine Creek has normally been late-season grazing for 13 to 28 days (mid-August to mid-September, file data, Eastern Oregon Agricultural Research Center). Only large wild ungulates and trespass cattle grazed within the exclosures. Kauffman (1982) reported that 85 to 104 spring-calving, cow-calf pairs annually grazed the 41.3 ha experimental riparian zone during 1978 to 1981. This is equivalent to 64 to 78 AUM (or 0.53 to 0.64 ha/AUM). An AUM is the amount of forage or feed required for one mature cow or equivalent for one month based on a daily consumption rate of 11.4 kg/day for 28 days. From 1987 until 1994, stocking rates ranged from 17 to 65 AUMs. Stocking rates during the 1993 and 1994 sampling period reported by Johnson et al. (1995) were 48 and 22 AUMs respectively or 28 to 75 percent of the grazing level reported by Kauffman (1982) and Kauffman et al. (1983a). These levels of livestock utilization were not representative of the much higher rates of utilization that normally occurs throughout riparian zones on western rangelands (Kauffman et al., 1983b; Green and Kauffman, 1995).

Within any given year, livestock utilization was not uniform among the various riparian plant communities. In the Catherine Creek study area, cattle showed a high initial preference for meadow-dominated communities and very little preference for ponderosa pine, black cottonwood, thin-leaf alder, or snowberry-Wood's rose-dominated communities (Kauffman et al., 1983a; Green, 1991; Korpela, 1992; Green and Kauffman, 1995). Utilization under the higher stocking rates reported by Kauffman et al. (1983a) and Green (1991) was 48 to 73 percent in meadow-dominated communities. In contrast, utilization was 10 to 27 percent in ponderosa pine, 14 to 16 percent in thin-leaf alder, 15 percent in snowberry-Wood's rose, and 1 to 11 percent in black cottonwood-dominated communities. These livestock utilization levels were at the lowest limits of detectability.

Johnson et al. (1998 [1995]) presented a map of a grazed plot showing locations of the salmon redds (reproduced in this paper as Figure 1A). Data gathered from Kauffman et al. (1985) were used to construct a map of community vegetation of the same area (Figure 1B): this map further elucidates potential livestock effects on the stream reach. Along this reach, the streamside plant communities are dominated by Ponderosa pine, black cottonwood, thin-leaf alder, and snowberry-Wood's rose. These communities were among the least utilized by livestock (utilization was 1 to 27 percent, Table 2). Given that utilization was at the lower limits of detectability, it was highly likely that the influence of livestock on these stream reaches was minimal. Areas with the highest densities of salmon redds (i.e., exclosure 5 and grazed areas 1 and 2) also coincided with streamside vegetation communities of similar composition (Kauffman et al., 1985). This suggests that salmon redds are associated more with site influences such as spawning gravels than the minimal livestock effects that occurred under this grazing strategy.

Channel System

The results presented in Johnson et al. (1998 [1995]) provided observations and interpretation of stream channels from aerial photography with no on-the-ground assessment of stream bed morphology or channel-shaping processes. Our ground-truthing indicated that there were major differences between grazed areas and exclosures in channel characteristics (widths, depths, sinuosity, gradient, channel diversity, and connectivity with riparian vegetation) independent of the grazing treatments. For example, the two most upstream treatments, (grazed area 4 and exclosure 5) occupy a reach that is currently locally aggrading and storing gravels in the channel. These two adjacent experimental units are typified as low gradient, shifting, braided, and unconstrained reaches with an abundance of gravel bars and, in all likelihood, an abundance of interstitial (hyporheic) flow. These characteristics are typically associated with high abundances of redds (e.g., Collings, 1972; Thompson, 1972; Healy, 1991). These two areas accounted for nearly 60 percent of all spawning redds in 1993 (total redds = 24) and 50 percent in 1994 (total redds = 2), but comprised only 25 percent of the stream length.

Although Johnson et al. (1998 [1995]) provide limited information on human modification of the stream channel, additional human modification of the channel could further account for the lack of salmon redds in exclosed reaches of stream. Further downstream of Grazed Area 4 (see Figure 2, Johnson et al., 1998 [1995]) the channel of Catherine Creek becomes more simplified (i.e., less sinuous, less channel braiding, and deeply incised in its historical floodplain). The simplicity of the channel in exclosure 1 was largely due to mechanical channelization by the Oregon Department of Transportation in 1989 in an attempt to protect State Highway 203 immediately downstream (J. Boone Kauffman, 1995, personal communication). Given this severe impact to this exclosure we were not surprised that no salmon redds occurred here in 1993 and 1994. Thus, while the reported treatments by Johnson et al. (1998 [1995]) were "grazed and excluded," there are other unreported channel features, channel alterations, and major differences in channel processes that confound any attempt at attributing the in-channel distribution of salmon redds to grazing practices on Catherine Creek. The study design and interpretability of the data are compromised when more than simple grazing differences exist between the study plots. Lack of information pertaining to stream gradient, geomorphology, vegetation, and management history represent severe shortcomings of the study because of their relevance to channel-forming processes and the creation and maintenance of spawning habitats.

Table 1. Salmon redd data from Catherine Creek, standardized by water area. Data are from Johnson et al. (1998 [1995]).

Experimental unit	1993 redd count	1994 wetted area (m^2)	Redds per ha of wetted area
Exclosure 1	0	2,060	0
Exclosure 2	0	2,693	0
Exclosure 3	1	3,823	3
Exclosure 4	0	3,523	0
Exclosure 5	6	2,858	21
Grazed Plot 1	3	1,762	17
Grazed Plot 2	5	3,623	14
Grazed Plot 3	1	4,820	2
Grazed Plot 4	8	7,413	11

Table 2. Community dominance and level of utilization for streamside plant communities along grazed area 4, Catherine Creek, OR. Plant community numbers correspond to those in Fig. 1B. Utilization data are from Kauffman (1982), Kauffman et al. (1983a), and Green (1991).

Community number	Dominant species	Utilization range (%)
66	alder (*Alnus rubra)*	14–16
67	cheatgrass (*Bromus tectorum)*	1–2
72	cottonwood (*Populus tricocarpa)*	1–11
78	Wood's rose (*Rosa* spp.)	15
81	Wood's rose (*Rosa* spp.)	15
82	cottonwood (*Populus tricocarpa)*	1–11
86	bluegrass (*Poa* spp.)	48–70
88	Wood's rose (*Rosa* spp.)	15
89	annual brome (*Bromus* spp.)	1–2
93	bluegrass (*Poa* spp.)	48–70
92	annual brome (*Bromus* spp.)	1–2
94	ponderosa pine (*Pinus ponderosa)*	10–27
102	snowberry (*Symphoricarpus* spp.)	15
103	sedge (*Carex* spp.)	59–73
104	cottonwood (*Populus tricocarpa)*	1–11

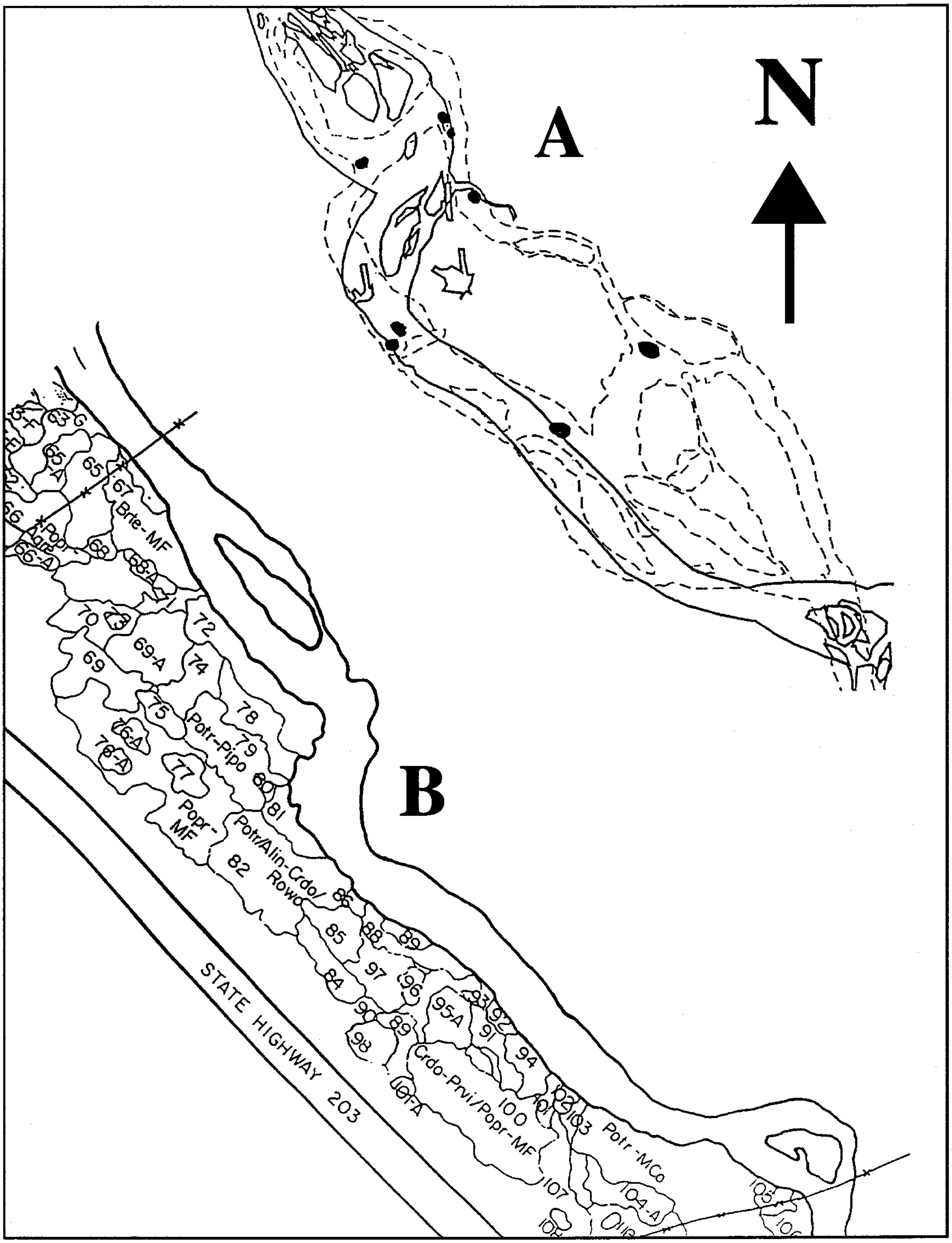

Figure 1. The top figure (A) is the location of salmon redds (large black dots), the 1979 channel (solid line), and the 1994 channel (dashed lines) of grazed area 4 from Johnson et al. (1998 [1995]). The lower figure (B) includes the associated plant communities along the south side of Catherine Creek (from Kauffman 1982, Kauffman et al. 1985). This entire reach is predominantly shrub- or tree-dominated; livestock utilization of these communities was 1 to 27 percent annually over the last 15 years. Plant community and range of utilization can be found in Table 2.

Determining the complex relationships between salmon redds, vegetation, channel morphology, and grazing intensity will require a detailed long-term research effort. Simple observation of aerial photos clearly suggests that salmon redds occurred in those areas with the greatest channel diversity. Inputs of coarse wood debris to the stream (since 1978) coupled with low levels of livestock utilization (either short duration or exclusion in these studies) resulted in improvements in riparian vegetation and stream condition (Green and Kauffman, 1995). Johnson et al. (1998 [1995]) did not report the results of published research studies and graduate theses from Catherine Creek that confirm the vegetation and streambank responses to the management history of this stream reach.

Evaluation of Salmonid Habitats

The number and location of salmon redds, by themselves are not adequate measures of the overall habitat quality for salmonids. Bottlenecks to salmon survival may occur later in life because of other habitat inadequacies. Therefore, an evaluation of grazing activity must include impacts on habitats used during the entire freshwater life history of salmon (i.e., emergence from the gravels to their spawning activities). For example, large pools provide rearing habitat for juvenile fish, resting habitat for adjust fish (Bjornn and Reiser, 1991), and refugia for adults and juveniles from natural disturbances, such as drought, fire, and winter-icing (Sedell et al., 1990). Recent research (McIntosh, 1992; McIntosh et al., 1994b) found that the frequency of large pools (> 0.8-m deep) in the Grande Ronde Basin decreased by 66 percent from the 1940s to the present. In Catherine Creek, the large pool frequency decreased by 61 percent, and on the EOARC, large pools decreased by 47 percent (9.0 to 4.8 pools/km). The rearing and holding capacity of the EOARC has been greatly diminished since first measured in the 1940s.

When viewed from the scale of the entire stream basin, spring chinook salmon use more than the EOARC reach for spawning in Catherine Creek. Redd densities have been higher both upstream and downstream of the EOARC (file data, Oregon Department of Fish and Wildlife, La Grande, OR). Thus, choosing the appropriate spatial scale is important to understand the carrying capacity for rearing, summer-holding, and spawning of salmonids in individual streams. Researchers must assess the availability and quality of different habitats for entire streams (see Hankin and Reeves, 1988; McIntosh et al., 1994a; 1995). We must understand not only how livestock grazing affects the number of redds, but also the survival of eggs, fry, and smolts under grazed and ungrazed conditions.

Conclusions

1. Johnson et al. (1998 [1995]) provided observations regarding the occurrence of spawning redds on the EOARC portion of Catherine Creek. It is misleading to represent these observations as the results of an experiment that demonstrated positive influences of livestock on salmon redd densities. A flawed study design made any interpretations regarding the effects of livestock grazing on the density of salmon redds invalid, and the subsequent statistical analysis could not be supported. Repeated annual measure cannot overcome the shortcomings in the inherent study design.

2. The "grazing treatment" was not described by Johnson et al. (1998 [1995]); it was late season, of short-duration, and with low levels of annual utilization (not greater than 27 percent) over the past 15 years. During this period, riparian plant communities changed measurably in both grazed and ungrazed areas. Especially notable was an increase in woody species. Long-term grazing practices consistent with those applied during the past 15 years at the Hall Ranch would likely assist in improving salmon spawning habitat throughout much of the upper Columbia River Basin. Unfortunately, the ecological condition and livestock grazing approaches on Catherine Creek are not representative of most other Columbia Basin riparian zones.

Johnson et al. (1998 [1995]) apparently recognized some of the shortcomings in their study and accurately concluded that many questions remain to be answered regarding the direct and indirect effects of grazing on spawning success, rearing, and emergent survival. We suggest an interdisciplinary team of geomorphologists, hydrologists, rangeland grazing specialists, riparian ecologists, fisheries biologists, stream ecologists, and statisticians should conduct a cooperative study wherein competing hypotheses would be tested. Streams, rather than small reaches are the appropriate unit of study. Potentially powerful statistical designs include: (1) comparisons of streams where one set(s) is not grazed (a control), and the other set(s) is grazed at a prescribed level(s); (2) one could also choose to examine grazing impacts using a regression design. The relationship between redds per unit area and other parameters of anadromous salmonid life history with increasing levels of livestock utilization could be analyzed in this manner. Prior to experimentation, Principle Components Analysis or cluster analysis of the physical and biotic characteristics of candidate streams would be conducted to insure that "control" and "treatment" streams were similar (Newbold et al., 1980; Li et al., 1994; Tait et al., 1994). Controversy raises important issues and ideas. Resolving it objectively requires investment in the best possible research approach, study design, and scientific team.

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An Update on the Catherine Creek Riparian Study

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Introduction

We have reviewed "The Relationship of Cattle and Salmon Redds at Catherine Creek: A Scientific Assessment" (Li et al., 1998) which is a response to our report, "Mapping and Analysis of Catherine Creek Using Remote Sensing and Geographic Information Systems (GIS)" (Johnson et al., 1998 [1995]). There is an obvious difference of opinion as to the usefulness of the information available from the Catherine Creek Study and the potential for information yet to be collected. Hopefully, this paper will clarify the issues surrounding the study, provide insight, and lead to cooperation regarding this data set.

In this response, we review the information that has been collected to date, outline our approach of processing this information, and answer the criticisms that have been directed to our work.

The Experiment and Associated Data

In 1978 the riparian pasture that surrounds Catherine Creek on the Hall Ranch was divided into nine experimental units, five of which were fenced to exclude livestock. Four grazed riparian units exist between the exclosures. The grazed units are connected around the exclosures so a herd of cattle has access to all unexcluded portions of the pasture at one time. This very simple and straightforward experimental design has been used by several Ph.D. students and several Master of Science students to study vegetative communities, neotropical migratory bird populations, streambank erosion, and grazing animal behavior and diets. This plot layout continues to be used by graduate students. Since 1993, Ballard (formerly Tibbs) has also collected information on salmon spawning. She has mapped the location of each redd and is currently studying the behavioral interactions between cattle and salmon (Table 1). The Oregon Department of Fish and Wildlife and the OSU Department of Fisheries and Wildlife also collected information about salmon on the Hall Ranch.

Because the Hall Ranch is part of the Eastern Oregon Agricultural Research Center (EOARC) managed by Oregon State University (OSU) Agricultural Experiment Station, it has been closely monitored since 1978, and much historical information exists. Collected data included delineation and mapping of riparian vegetative communities, plant production, wildlife use, timing and level of livestock use, pattern of cattle use, livestock dietary selection, and other factors.

In addition to these quantitative measures, this stream section was aerially photographed at high resolution in 1979, 1983, 1988, 1989, 1993, 1994, 1995, 1996, and 1997. Near-earth photographic monitoring continues at fine scale: these photographs show features on the ground with a diameter of approximately 10 cm. To improve the value of the photographic record, we identified 202 objects that were visible in these photographs and geographically positioned them to an accuracy within 2 m during the summer of 1994. This "ground truth" information permitted us to rectify images by removing distortion arising from lens and topographic relief. It also permitted us to assign Universal Transverse Mercator or latitude-longitude locations to pixels or features visible in the image. Once corrected we geographically located features in the photos, calculated linear distances, surface areas, area-perimeter ratios, etc. at the resolution of the ground control network. These data can also quantify spatial relationships between ground features and landscape elements; for example, the distance between a salmon redd and the closest large woody debris or the distance between a cattle crossing and a salmon redd can be measured. We are just now beginning this task. Because this database is in electronic format, it can be sorted, compiled, and mathematically analyzed using desktop or mainframe computers. We can also apply geostatistics to spatial information contained in the data sets.

We have compiled other ancillary landscape-level information. Daily stream flow was obtained from the U.S. Department of the Interior, Geological Survey (GS) Water Resources Division, stream-gauging station number 13320000 since before this study began. These data are also in electronic format and continue to be collected. We have obtained digital elevation models (DEM) for all 7.5 minute quadrangles in the Catherine Creek watershed and associated areas from the GS. This information is at the 1:24,000 scale which translates to ground resolution of approximately 30 m. The elevation of each 30 x 30 m cell on the landscape is contained within this data set. Data meets or exceeds United States National Map Accuracy Standards.

Individual elevation maps have been concatenated and processed to delineate the Catherine Creek watershed. The digital elevation model of the watershed was further processed to yield slope and azimuthal aspect maps of this region. We also processed this information to quantify surface areas of the Catherine Creek watershed above the ranch by elevation, slope, and azimuth (Figures 1–3).

These data sets can also be used to compare this system to other systems to which it might be "paired". Our preliminary examination of this information leads us to the conclusion that no ideal candidate for exact pairing exists; however, there are some sites that show similarities to the Hall Ranch riparian pasture.

The point of the above discussion is that much information is available for this case study and site that is not available at other locations in the State, increasing the usefulness of data collected thus far and data that will be collected in the future. The near-earth, fine-scale, geocorrected images are especially valuable because they were repeated through time and can therefore be used to quantify stream and vegetative changes that have occurred since 1978 for this case study. They can also be used to map livestock trails, stream position, position of large woody debris, and dynamics of these features. Because these data were obtained at a fine resolution, they can yield very detailed information.

An Outline of Our Approach to the Stream and Salmon Data

We have been mapping State experiment stations that have rangelands since 1991. Digital elevation models, slopes, azimuthal aspects, soils, roads, streams, etc. were in the process of being mapped for the Hall Ranch when the salmon information that was being collected by Ballard (formerly Tibbs) and the Oregon Department of Fish and Wildlife was brought to our attention. We believed that a GIS/spatial approach to this data would increase its value. Ballard had been recording redd position on aerial photographs. Because this spatial information was compatible with data sets we had already constructed, we decided to map at a resolution of 0.5 x 0.5 m (although higher resolutions are possible).

What was immediately apparent from the data on spawning spring chinook salmon was that the preponderance of the redds occurred in grazed areas and in exclosure 5 (Table 1). Our first thought was to compare the length of stream and surface area of water between those portions that were grazed and those exclosed. That we did (Johnson et al., 1995). It also appeared from photographs of the stream that more complex areas, those with stream braiding, were more acceptable as spawning sites than were simpler stretches. The "islands" in the stream were therefore counted and the size of these "islands" computed (Johnson et al., 1995).

We then examined the change in the stream as determined from sequential aerial photographs. Some wetted portions of this 2.5-km length of stream have moved substantially since 1978 (Figure 4). Surface areas of water, linear run of the channel, and bank-to-bank (wetted edge-to-wetted edge) area were calculated. Because the redds were geographically positioned, we could determine if a spawning location (or any location for that matter) had been part of the stream during the previous summer seasons. We found that some of the 1993–1994 spawning locations were above the water level or adjacent to the stream in earlier photographs and had

Table 1. Location of salmon redds on the Hall Ranch, Union, Oregon, between 1993 and 1997. We have not completed the water surface area analysis for years 1995–1997; however, the reader can determine approximate redd densities per unit of water surface by using the 1994 water surface values (Johnson et al., 1998 [1995]).

Experimental unit	1993 redds	1994 redds	1995 redds	1996 redds	1997 redds
Exclosure 1	0	0	0	0	0
Exclosure 2	0	0	0	0	1
Exclosure 3	1	0	0	0	2
Exclosure 4	0	0	0	0	0
Exclosure 5	6	0	0	2	2
Exclosure Total	**7**	**0**	**0**	**2**	**5**
Grazed 1	3	0	1	0	1
Grazed 2	5	1	3	2	4
Grazed 3	1	0	1	1	0
Grazed 4	8	1	0	3	3
Grazed Total	**17**	**2**	**5**	**6**	**8**
Grand Total	24	2	5	8	13

previously supported typical riparian shrub/herbaceous communities. Our original report included in tabular form the data obtained during this analysis.

There is much that could be determined from this data set such as the juxtaposition of redds to each other (fidelity of spawning to specific sites), relationship of redds to large woody debris, shrubby overhanging vegetation, stream width, stream shape, etc. We believed that these data are of value to fisheries biologists, riparian ecologists, and hydrologists.

We knew that many studies had been conducted throughout the Pacific Northwest and much information had been collected regarding salmon spawning. We also knew that factors such as streambed particle size, fish hiding cover, water depth, etc. would influence the selection of spawning sites. With this in mind, fish biologists in the OSU Department of Fisheries and Wildlife were contacted and shown the aerial images and given maps showing the outline of the channel and position of salmon redds. We agreed to work together on this data set. Several questions were immediately obvious. What were the streambed characteristics? How do they relate to spawning on this stream? What was the success of spawning? What are the cross-sectional and longitudinal profiles of the stream? Where are the areas of deposition and erosion along the stream? How did the channel morphology affect the fish? How did grazing and cattle-crossing points relate to redd location? Did the grazed areas have different stream characteristics than adjacent exclosed areas?

We can measure many physical characteristics of the stream from fine-scale aerial photographs and have done so for some parameters. However, we believed that characterization of habitat for salmon was best done by salmon biologists. Thus we have not attempted to extract habitat-specific themes from the aerial images nor have we tried to predict site selection.

Our report "Mapping and Analysis of Catherine Creek Using Remote Sensing and Geographic Information Systems (GIS)" (1998 [1995]) was fundamentally descriptive in nature. We accurately reported what had been observed on this stream. We chose to include as much of the raw data

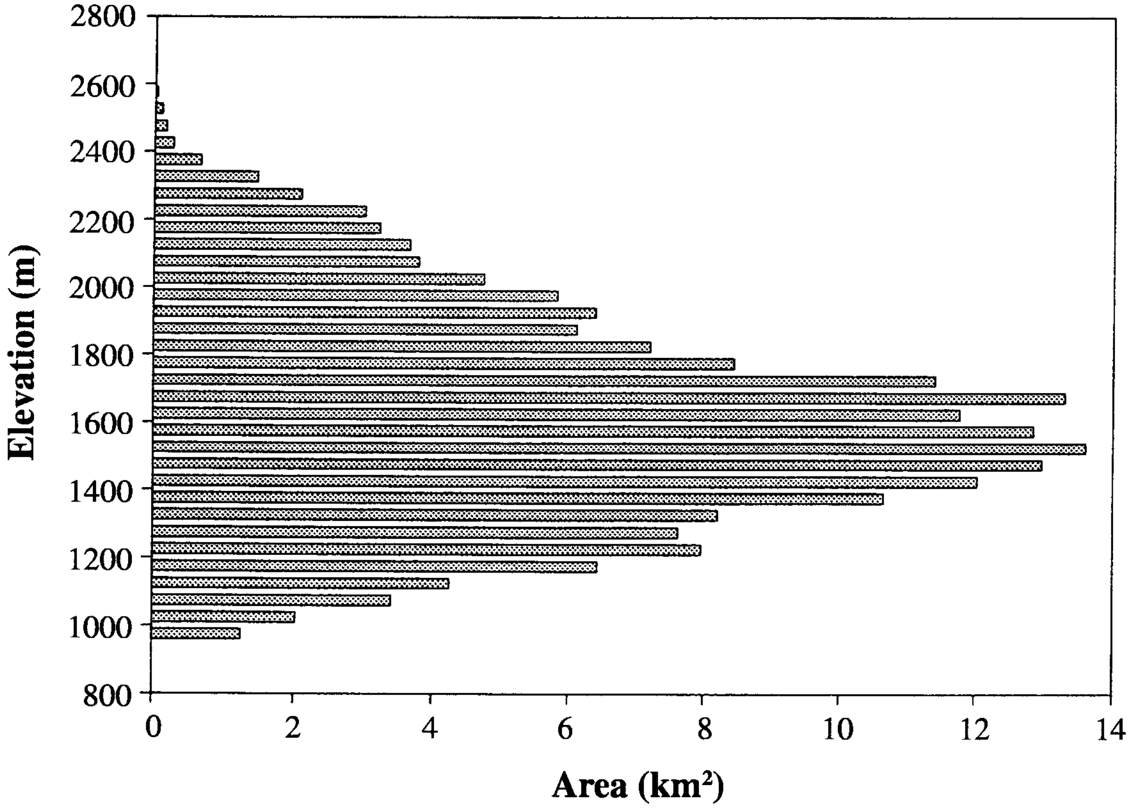

Figure 1. Elevational distribution of land in the upper Catherine Creek watershed above the Hall Ranch, Union, Oregon.

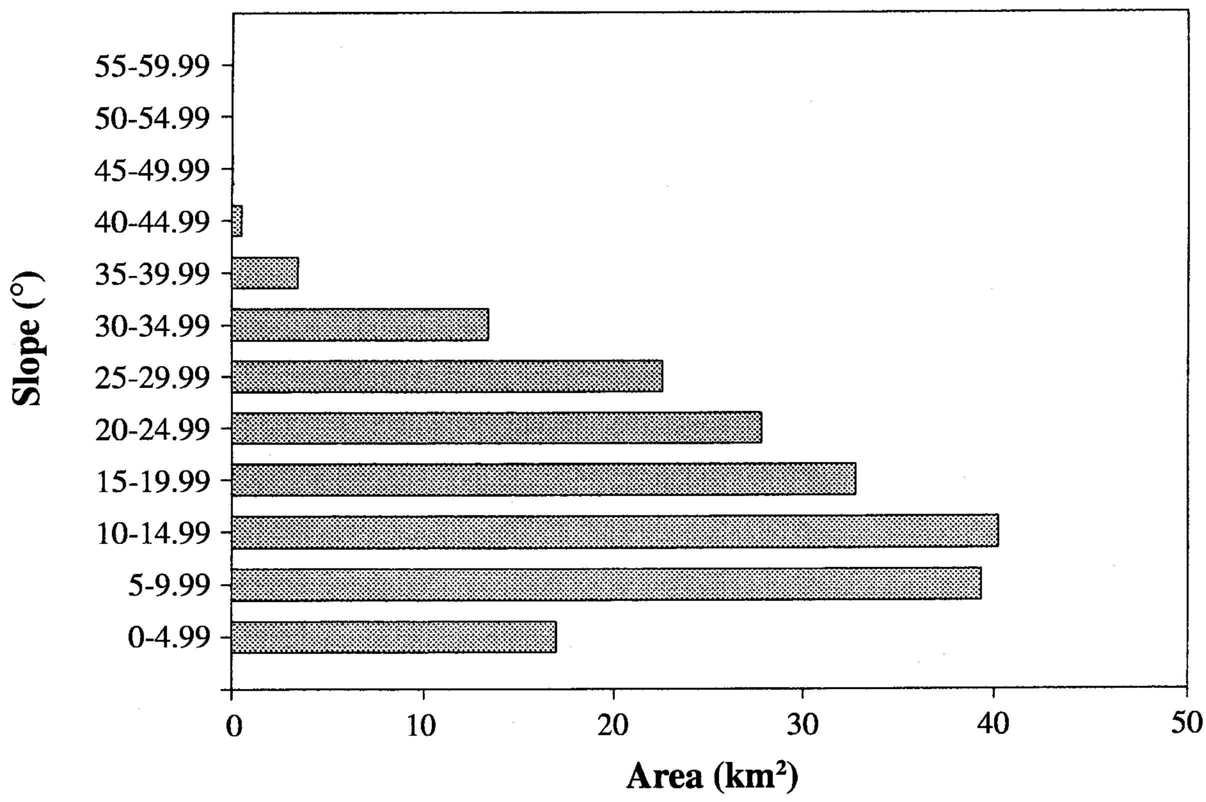

Figure 2. Slope distribution of land in the upper Catherine Creek watershed above the Hall Ranch, Union, Oregon.

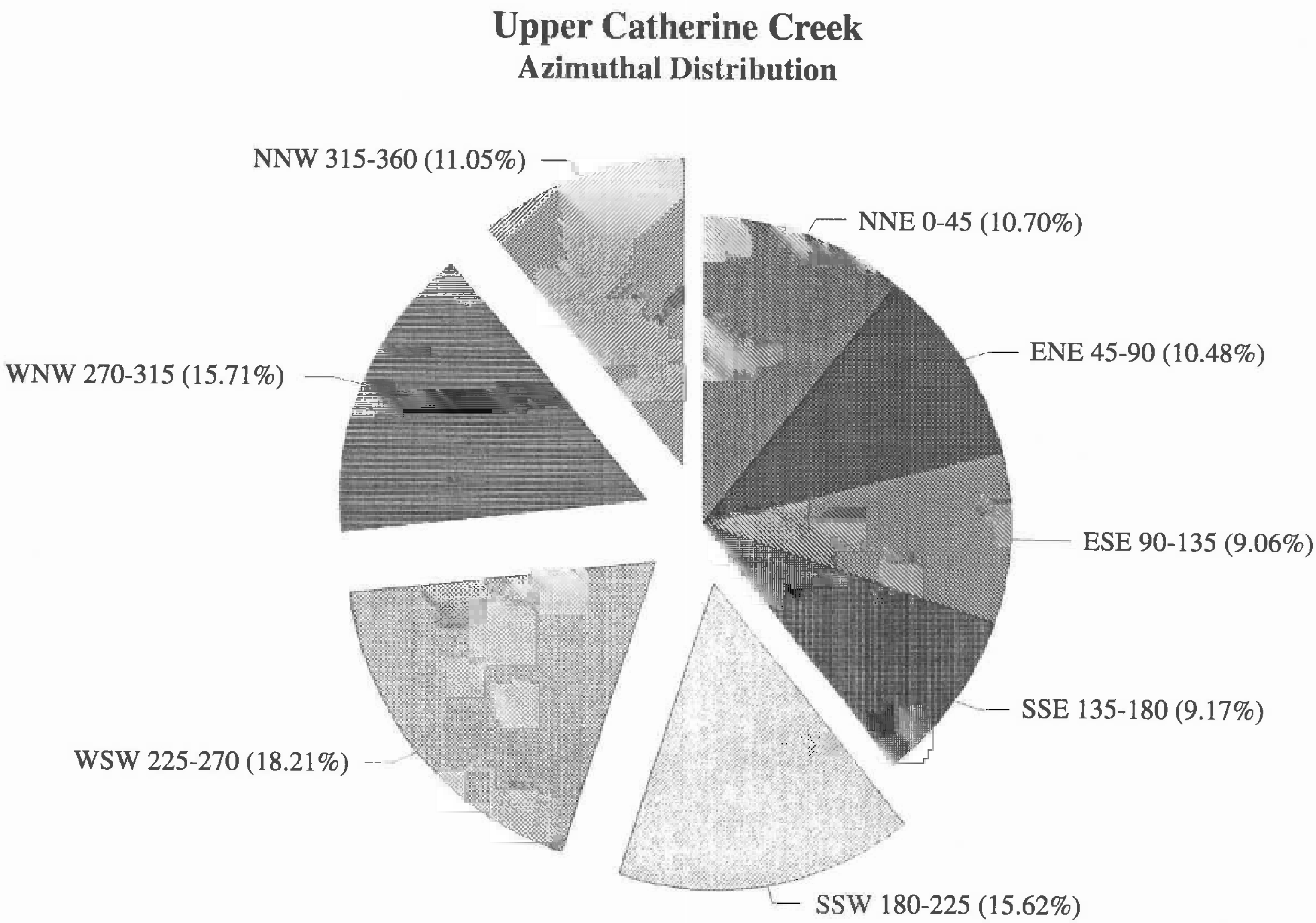

Figure 3. Azimuthal distribution of land in the upper Catherine Creek watershed above the Hall Ranch, Union, Oregon.

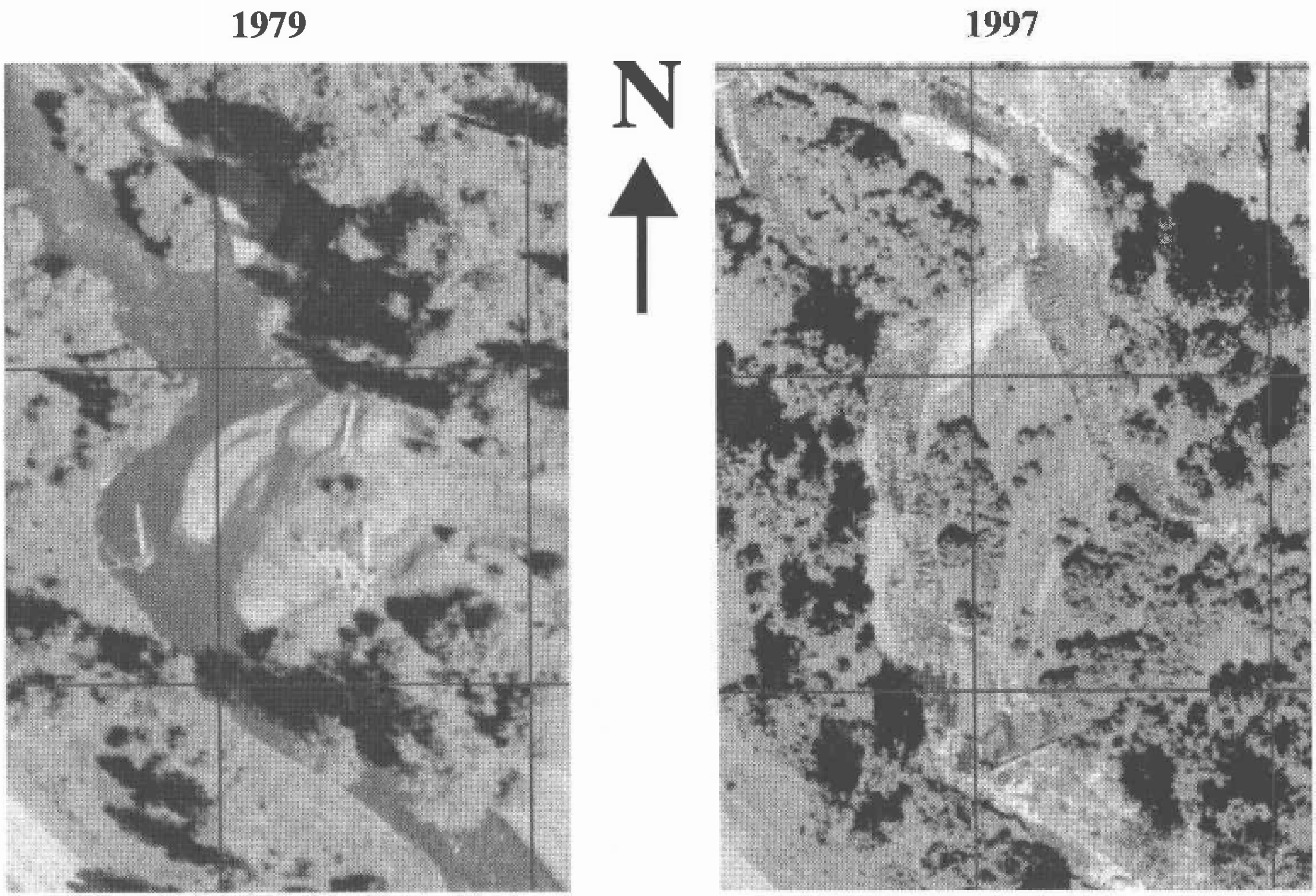

Figure 4. Geocorrected color aerial photographs from 1979 and 1997 that demonstrates the change that has occurred at this location in grazed unit 4. Using the grid as a positional reference, one can see that there has been erosion of the bank in the south-center portion of the photograph. Substantial deposition has occurred in the central area and a major channel now enters from the east central area. The development of shrubs both gravel bars and banks is also apparent.

as reasonable so that others would also have an opportunity to examine this information. Because the observed redd distribution was and continues to be predominantly in the grazed portion of the stream, we also included maps that showed the stream outline, relative position of the redds, and changes in the stream through time. This served as an example of the kind of data we possessed and suggested additional comparisons and analyses that could be made. We reported the data within the context of grazed and ungrazed treatments because one cannot ignore the superimposed grazing experiment begun in 1978. In fact, this may be one of the more fascinating aspects of the collected information. It should be stressed that each redd was spatially quantified and not simply counted as inside or outside a particular treatment. This means that the information can be examined in many different ways.

"Mapping and Analysis of Catherine Creek Using Remote Sensing and Geographic Information Systems (GIS)" (1998 [1995]) represented our preliminary analysis of the data collected on stream position, streambed change, and salmon redds and should be considered exploratory. We stated several times in the paper that results were preliminary. However one should not forget that the information contained within this data set was substantial and that areas that were grazed had more spawning salmon (Table 1).

Grazing Management on the Catherine Creek Riparian Pasture

Li et al. (1998) were critical because our progress report lacked a complete narrative describing the grazing treatment. As we mentioned in our paper, the grazing treatment is monitored by Oregon State University scientists. The following is a synopsis of what is known about grazing in this pasture.

The Hall ranch has a well-documented history that is in many ways reflective of lands in this region. This ranch was obtained by the Oregon Agricultural Experiment Station in 1939. At that time there was only perimeter fencing, and livestock were free to move across the ranch at will throughout the grazing season. In 1956, a team of specialists from Oregon State University (Don Hedrick, Chet Youngberg, Ellis Knox, J.A.B. MacArthur and others) and the USDA Soil Conservation Service (E. William Anderson, W.W. Hill, Rudy Mayko, Richard Savage, and Grant Lindsay) mapped the soils on the ranch, classified the vegetative communities, estimated condition classes, and developed a conservation plan. The East Riparian Pasture was rated in poor condition, and all other range sites on the station were in either poor or fair condition. The 1956 riparian pasture was estimated to have 41 AUMs available for livestock and residual standing vegetation with a stubble height of approximately 1 inch (Anonymous, 1956). It was recommended that all riparian pastures on the ranch be subdivided and used only in summer. It was also recommended that a rotated-deferred grazing system be implemented that permitted livestock use for six weeks between July 1 and August 15 in year 1 and July 15 to August 31 in year 2. Under this grazing strategy and with some reseeding it was believed that 100 AUMs could be produced in the riparian pasture. This conservation plan was not implemented, but interior fencing was constructed in the 1960s that allowed greater control of livestock distribution and timing of pasture use.

Nineteen sixty-two is the first year that experiment station records exist for livestock use of the riparian pasture. At that time the pasture was used in the spring as a breeding pasture and again in the fall when vegetative regrowth was grazed. Grazing usually began about May 15, but in some years grazing began as early as May 1. By 1960, fencing was completed and management options were broader (M. Vavra, 1997, personal communication.). In 1974, Vavra began managing the Hall Ranch. Between 1974 and 1977, this pasture was used in spring and/or fall, with grazing starting on May 20, except for 1976 when grazing began on April 27. The grazing strategy employed on the riparian pasture of the Hall Ranch changed in 1977 to a late summer system (Table 2).

In 1978, Krueger and Vavra designed an experiment to examine the effect of a late-summer/early-fall riparian grazing regime on livestock performance, neotropical bird nesting habitat, small mammal populations, streambank stability (as measured by undercut banks and stream distance from permanent stakes), and riparian plant communities compared to areas that were protected from livestock grazing. The riparian pasture that surrounds Catherine Creek was divided into nine

Table 2. Grazing intensity of the riparian pasture on the Hall Ranch, Union, Oregon, between 1977 and 1997.

Year	Grazing dates	AUMs consumed in pasture	Average AUM/ha consumed
1977	17 Aug–02 Sep	72.4	1.75
1978	23 Aug–09 Sep	63.8	1.54
1979	27 Aug–17 Sep	56.8	1.38
1980	23 Aug–16 Sep	90.0	2.18
1981	27 Aug–16 Sep	59.3	1.44
1982	26 Aug–15 Sep	40.7	0.99
1983	22 Aug–11 Sep	57.7	1.40
1984	23 Aug–13 Sep	63.8	1.54
1985	16 Aug–04 Sep	66.5	1.61
1986	15 Aug–03 Sep	67.9	1.64
1987	18 Aug–14 Sep	60.5	1.46
1988	23 Aug–20 Sep	43.5	1.05
1989	16 Aug–28 Sep	46.6	1.13
1990	20 Aug–10 Sep	16.8	0.41
1991	29 Aug–11 Sep	53.5	1.30
1992	22 May–01 Jun	9.0	
	06 Aug–19 Aug	56.0	
	Annual Total	65.0	1.57
1993	23 Aug–13 Sep	47.6	1.15
1994	17 Aug–12 Sep	22.3	0.54
1995	22 Aug–08 Sep	32.4	0.78
1996	13 Aug–09 Sep	50.0	1.21
1997	14 Aug–10 Sep	50.0	1.21
Mean		53.7	1.30

experimental units, five of which were fenced to exclude livestock. This fencing did not prevent wildlife or fish from using the exclosures. Four grazed riparian units exist between the exclosures. The grazed units were connected around the exclosures so a herd of cattle had access to all unexcluded portions of the pasture at one time. The areas were delineated by Kauffman, who was at that time a Master of Science student working on the project. He paced out linear lengths of the stream so about half the stream was excluded and half open to grazing by cattle. The intention of the researchers was to collect data from this pasture and follow the treatment as far into the future as possible (W.C. Krueger, 1998, personal communication).

This experiment was the outgrowth of observations that livestock gains on upland pastures were low in August/September while riparian vegetation was still relatively green and palatable. It was believed that livestock gains could be improved by rotating animals from upland pastures in late spring and early summer to the riparian pasture in the late summer/fall. It was also believed that ecosystem/riparian benefits accruing from complete exclusion of livestock in the riparian zone could also be realized by managed livestock use (M. Vavra, 1998, personal communication).

This experiment was to contrast change in a riparian zone without livestock to the same system with short duration-late summer grazing.

Estimation of use of Kentucky bluegrass communities by cattle in this grazing system were made by Kauffman (1982) and Korpela (1992). Kauffman (1982) estimated utilization in *Poa pratensis*-mixed forb communities at 44%, 70%, and 67% for 1978, 1979, and 1980, respectively. *Poa pratensis-Phleum pratense* communities had 66%, 73%, and 59% for these years. Korpela (1992) estimated utilization by weight of 88.7% and 78.7% in dry bluegrass meadows for 1984 and 1985 respectively. Moist bluegrass meadow utilization was measured as 48.5% and 53.5% for 1984 and 1985 (Korpela, 1992). Over the course of several years, it was observed that livestock would shift from foraging on Kentucky bluegrass to shrubs when the utilization of bluegrass reached approximately 70% as estimated by weight. Consequently, use of the pasture is now targeted to 70% on the Kentucky bluegrass communities (W.C. Krueger, 1998, personal communication). The grazing treatment is also responsive to climatic conditions. In drought years when forage in the riparian pasture was limited or very dry, livestock numbers or the duration of grazing was restricted (Table 2). This pasture has changed considerably since 1978 with both the grazed and exclosed areas recovering considerably (W.C. Krueger, 1998, personal communication).

The actual grazing use of the pasture is given in Table 2. An Animal Unit Month (AUM) is the amount of forage that is consumed by a 1,000-lb cow and her calf for 30 d and amounts to approximately 12 kg Dry Matter/d or 360 kgDM/mo. Use of this pasture was typically by Simmental crossbred cows and their calves. Cows have weighed between 1,100 and 1,300 lb and calves have weighed approximately 400 lb (M. Vavra, 1996, 1998, personal communication). Because these animals were large with correspondingly higher intake rates than a typical animal unit, consumption of vegetation was probably somewhat higher that the average AUM estimate of 360 kgDM/mo. For the last several years grazing in this pasture was by heifers, and stocking rates were adjusted to obtain a similar level of grass use (M. Vavra, 1996, 1998, personal communication).

Grazing by livestock is typically patchy in pastures where large shrubs or rough terrain occur (Stuth, 1991), with sites supporting preferred forage grazed more closely and utilized more than other locations. This pasture is no exception. That is why communities supporting streamside trees and shrubs were utilized less than bluegrass meadows. Animals preferred Kentucky bluegrass; therefore, they spent their time in plant communities dominated with this grass. This is the reason that bluegrass communities were "key" for management. The pattern of use in the riparian pasture is an expression of cattle behavior and preference. No attempt has been made to force livestock to use or to avoid streamside communities.

Overall utilization measurements can be misleading and must be examined in the context within which they are obtained. For example, if a portion of a pasture is not available because it is inaccessible, what appears as a low percentage of overall utilization may be heavy use of the accessible portion. This is the reason that "key" locations and "key" species are normally used to monitor grazing intensity. The grazing system used on the riparian pasture of the Hall Ranch was designed to utilize herbaceous vegetation while protecting shrubs (M. Vavra, 1998, personal communication). When herbaceous vegetation was limiting, the cattle were removed to prevent damage to shrubs (M. Vavra, 1998, personal communication).

Livestock influence pastures, wildlife, and streams in ways other than simply by removal of riparian zone forage (Holechek et al., 1995; Johnson, 1962; Rhoades et al., 1964; Rauzi and Smith, 1973; Gifford and Hawkins, 1978). Livestock trailing, watering, bedding, and other activities may influence vegetation, soils, erosion, and streams (Platts, 1991). Livestock presence at a location may discourage or encourage current or subsequent use of that site by wildlife species. Since approximately half of this stream is exclosed, livestock watering, crossing, and trampling of banks are concentrated in the remaining grazed units. Two studies are currently in progress on the Hall Ranch that assesses cattle behavior and use of pastures in a spatial context. These studies will indicate the distribution of cattle within the riparian pastures. A GIS data layer or theme with this information could provide insight on livestock impacts on streams. Behavioral interactions between livestock and spawning salmon are also being studied.

Grazing Levels in the Region

Li et al. (1998) were critical of our report because they contended that grazing levels on the Hall Ranch riparian pasture were very light (a maximum of 27% overall utilization) and therefore "were not representative of the much higher rates of utilization that normally occurs throughout riparian zones on western rangelands" (p. 16). We have not attempted to quantify grazing strategies on individual farms and ranches in this region of the State or of the West. It is beyond the scope of our original paper. However, the U.S. Department of Agriculture, Forest Service's "Land and Resource Management Plan: Wallowa-Whitman National Forest" (USDA Forest Service, 1990) and the Oregon State University Extension Service in Wallowa County (J.D. Williams, 1996, 1998, personal communication) have provided some information.

Grazing management would vary considerably from location to location within this region of Oregon depending upon the size of the landholding, alternative grazing areas, importance of livestock to the owner, management skills of the rancher, and overall enterprise. Some lands would be grazed more heavily than the Catherine Creek riparian pasture, some more lightly, and some left ungrazed. Many of the meadows surrounding streams in this area are used for hay production and consequently would not be grazed, or they would be grazed after mowing and removal of the hay crop (J.D. Williams, 1996, 1998, personal communication).

Many private land holdings intermingle with public lands and would therefore be managed in accordance with federal guidelines (J.D. Williams, 1996, 1998, personal communication). The Forest Service is a major land manager in Baker, Union, and Wallowa counties (Table 3). According to "Land and Resource Management Plan: Wallowa-Whitman National Forest" (USDA Forest Service, 1990), grazing in riparian zones is monitored by examining the percentage of utilization of "key" plant communities in "key" areas. Under these regulations, grazing is permitted on areas in satisfactory condition to a maximum utilization level of between 40 and 50%, typically under 45% (USDA Forest Service, 1990). Utilization is based on percentage of annual production removed by weight (USDA Forest Service, 1990) but is estimated from stubble height and the proportion of plant mass in height increments. The targeted grazing intensity of 70% use of Kentucky bluegrass communities on the Hall Ranch riparian pasture is higher than permitted on Forest Service riparian zones today.

Adequacy of the Catherine Creek Study Design

We view the salmon spawning portion of Johnson et al. (1998 [1995]) from a different perspective than the authors of Li et al. (1998). The pattern of spawning that has been observed over the last several years is interesting, and because the quality and quantity of ancillary information about this site is so great, the potential for obtaining useful insight is high.

Table 3. Land ownership in percent for counties in extreme northeastern Oregon. Data is from the *Atlas of Oregon* (Loy et al., 1976).

County	U.S. Bureau of Land Management	U.S. Forest Service	State of Oregon	County	Private
Baker	18.7	32.8	0.6	0.2	47.7
Union	0.5	47.4	0.3	0.0	51.8
Wallowa	1.0	55.9	0.7	0.0	42.4

To us, this is an observational study of preference. Salmon enter this stream segment and can choose where they spawn. That decision, obviously, is based on a multitude of factors that the animal senses and processes. Redd site-selection is governed by the fish's instincts. Streambed composition, water depth, temperature, streamside vegetative and bank cover, flow characteristics, and other factors all play a part. The presence of livestock at the time of spawning and the effect of livestock on the stream from watering, crossing, etc. may also be important factors.

Because many of these factors can be measured, mapped, and incorporated into the database, the relative importance of measured factors to spawning site-selection can be assessed. For example, if salmon choose areas that are away from sites where cattle cross the stream or if areas close to pools are preferred, we should see this in the choice of spawning sites over time.

When we compared grazed sections to ungrazed sections of the stream, we were testing the strength of the pattern shown in Table 1. We were asking the question, "Is the spawning pattern shown in Table 1 the result of random chance?" The statistic used was Student's *t*-test, one of the oldest and simplest statistical tests. This is the same test that Kauffman (1982) used on this same experimental design to evaluate differences in undercut depths of streambanks and streambank disturbance. Kauffman (1982) also applied parametric statistics (those that contain assumptions of normality, homogeneous variances, and independence) to populations of neotropical migratory birds and mammals using the riparian corridor, a similar situation to the salmon. The *t*-test indicated that more fish spawn in the grazed areas than would be expected at the reported probability level. This does not mean that the grazing treatment is causing fish to spawn at these locations, but rather there are more there than expected.

Several other criticisms of this study have been raised by Li et al. (1998) which we here address:

1. "The study design of Johnson et al. (1998 [1995]) was statistically flawed because none of the treatment replicates (i.e., grazed and exclosure) were independent." Li et al. (1998, p. 15).

If a treatment is applied in such a way that it extends beyond the bounds of the treatment area or if other factors are influencing the results, then interpretation could be "biased" because the observed response in that experimental unit is not the result of the treatment (or lack of treatment). Obviously, the creek runs through this set of treatments and therefore an action in one may influence the downstream elements. For example, if sediment is lost at a greater rate from banks in grazed treatments it may be transported downstream and degrade gravels in an exclosure. With this in mind, we have begun to measure any areas of sediment deposition. Other factors that might also influence down-stream stretches should be identified and measured, and their relative influence assessed. Many factors that affect the fish are fixed in place, for example overhanging vegetation and undercut banks, and this design is appropriate to examine them. To automatically assume that controlling variables are biased and reject this information seems to us to be short-sighted. For this reason, we have continued to identify and measure both physical and morphological characteristics of this stream.

2. "Because of the lack of independence among replicates, the study lacked true replication; it was pseudoreplicated *sensu* Hurlbert (1984)" (Li et al., 1998, p. 15).

Pseudoreplication means that this study was not replicated or repeated in other locations throughout the State or in other watersheds. It is therefore a case study. That is how it was described and presented. Case studies can be very valuable and have been used extensively in both wildlife and range research.

3. "The original study design of Kauffman (1982) did not consider differences in channel morphology, stream gradient, substrate, or spawning gravels in the placement of exclosures because these factors did not bias the study of plants. By adopting Kauffman's design uncritically, Johnson et al. (1998 [1995]) introduced biases at the stream reach scale because the plots were not adequately stratified to address the effects of cattle upon salmon redds" (Li et al., 1998, p. 15).

Stratification in 1978 would have been desirable because it would have partitioned acceptable spawning sites into each experimental unit in equal numbers or area. This process would have ensured at the beginning of the study that the probability of spawning would be equal between experimental units. We agree that hindsight favors stratification at the time the study was initialized, but the lack of stratification did not render experiments or collected data meaningless. We believe that information should be collected on channel morphology, stream gradient, substrate, and spawning gravels, and have begun this work. Implicit within their argument is the assumption that the distribution of factors is not even between grazed and nongrazed areas and that favorable conditions predominated in grazed units not only in 1978 but also today. The task of classifying current conditions has not been completed to date, but we believe it will shed light on this question.

Another difficulty with *a priori* stratification of stream factors is that the position of the stream has changed in the last 18 years. Our preliminary analysis indicated that half of the 1979 stream was above the water level in 1994, and half of the salmon redds recorded in 1993 and 1994 were in positions outside the 1979 stream boundary. For these sites a 1978 classification would have been impossible.

4. "Returning salmon show high fidelity to parental sites of spawning (Groot and Margolis, 1991). This behavior can confound differences in site selection for redds in damaged streams. Because of traditional behavior, an adequate site close to the natal origin of a fish may be chosen over an optimal site further away. Again, this points out the need to conduct an experiment using entire watersheds as the unit of replication" (Li et al., 1998, p. 15).

To give an individual salmon a choice in spawning locations, the potential sites must be relatively close together. This implies that a preference study must be conducted over a relatively short reach. The suggested comparisons between watersheds would pose a number of problems—intrinsic differences between the watersheds, such as elevation, slope, aspect, soil, vegetation; past management; roads; dwellings; etc.,—that confound results and lead to high levels of internal variability. In addition, different cohorts of fish from the same watershed could suffer different mortality at oceanic or downstream locations which would tend to confound results.

Watershed scale treatments are also very difficult and expensive to apply. The Catherine creek watershed above the stream gauging station near Union, Oregon, has a surface area of 272 km^2 (105 mi^2). This land, principally forest and rangeland, is owned and managed by many different entities for many different purposes. Application of a single uniform treatment across this watershed scale is impossible.

5. "The upper Grande Ronde watershed was an inappropriate place to conduct the study because spring chinook salmon populations . . .were so low that it was impossible to get an adequate statistical 'signal' from any stream within the basin" (Li et al., 1998, p. 15-16).

We believe that spring chinook salmon populations in the Catherine creek drainage are important and information gathered from the Hall Ranch can contribute to the understanding of the interrelations between management actions, riparian/stream ecology, and salmonid biology. We encourage other researchers to study spring chinook salmon populations at other locations and at other scales.

6. Li et al. (1998, p. 14) also stated, "The study design was appropriate for the study of riparian vegetation. . .but inadequate for studying the effects of livestock grazing on salmon spawning."

This study design is appropriate to examine preferences of salmon at a local scale. There is no argument about the number or location of the redds. The fundamental question is why have the majority of these fish chosen the grazed sections as spawning sites (Table 1). What are the physical and biological factors that control acceptability? When we know what these factors are, we can determine how grazing in this pasture influences them.

7. "The Johnson et al. (1998 [1995]) study was conducted at the wrong spatial scale. . ." (Li et al., 1998, p. 15).

We believe that the scale argument hinges on what factors are being examined. If spawning site selection is being influenced by factors that operate at coarse scales across broad landscapes, then this argument has merit. If however, the causal factor operates at fine scale, then these plots are entirely appropriate. For example, the presence of grazing livestock near the stream is a localized, fine-scale phenomenon. Their presence may make no difference to a fish that cannot see or sense them from its position several meters away. Livestock crossings, effects of livestock on banks, effects of livestock on stream substrate, and the behavioral interactions between livestock and fish are all localized, fine-scale phenomena. This study design is entirely appropriate for these factors. We encourage other scientists to examine grazing/salmonid interactions at the landscape level, noting that inherent variability across landscapes would render this type of study very expensive and problematic. Insights can be gained from studies at a variety of scales.

8. "The generally held scientific standard is to place a level of significance at $P < 0.05$ (although a level of $P < 0.10$ is often presented in the literature as significant). Johnson et al. (1998 [1995]) chose less rigorous levels of statistical significance ($P = 0.29$ in 1993, $P = 0.12$ in 1994)" (Li et al., 1998, p. 16).

Thirty years ago, before the widespread use of computers, scientists relied upon printed tables to evaluate the results of *t*-tests. Tables for ten, five, or one percent levels were created to simplify and speed-up the evaluation process. The terms "significant" and "highly significant" were used to indicate the probability that a result occurred by chance alone are 5% or 1%, respectively. Today, one can easily calculate the probability that a specified comparison is different. We reported the probability values for all comparisons made. We left it to the reader to determine whether a particular probability level was important or not.

The Interdisciplinary Team Approach

We applaud the suggestion that an interdisciplinary team approach could be used to study competing hypotheses. Our data, digital aerial images, and maps showing the location of redds were shared and discussed with fisheries biologists from the OSU Department of Fisheries and Wildlife, scientists in the OSU Department of Animal Science, and an experiment station statistician. This information was generated with the idea that it would be shared, and we have tried to be as open and straightforward with this data set as possible. We distributed the information that was collected on the Hall Ranch and the watershed to other projects and scientists. We believe this information has value, that it can help direct future research, and that it should not be discarded.

Conclusions

We think that there is less disagreement than appears at first glance. All of us would probably agree that the primary factors controlling the stream morphology are topography and high flow in the spring. Conditions such as a heavy snow pack, rapid spring warming, or rain-on-snow in the spring can lead to substantial movement of soil and reconfiguration of the channel. Extremely high flow occurs periodically (with an interval of several-to-many years) which results in profound change. Also important is the presence of woody and shrubby debris, which deflects the stream and changes channel shape. Coupling analysis of what is visible in the photography with stream transects done today, should provide researchers insight as to how the stream has changed over the last 20 years and serve as a reference for change in the future.

It appears that the original project objective of improving riparian habitat for wildlife with this grazing system has occurred. Acceptable spawning sites exist within the grazed portions of this pasture. We encourage fisheries biologists to examine the success of spawning and of juvenile fish in this system. We also think that an examination of the mortality of spring chinook salmon populations from this reach at various stages of their life history is warranted. We believe a careful examination of this and other data can yield meaningful insights.

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