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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

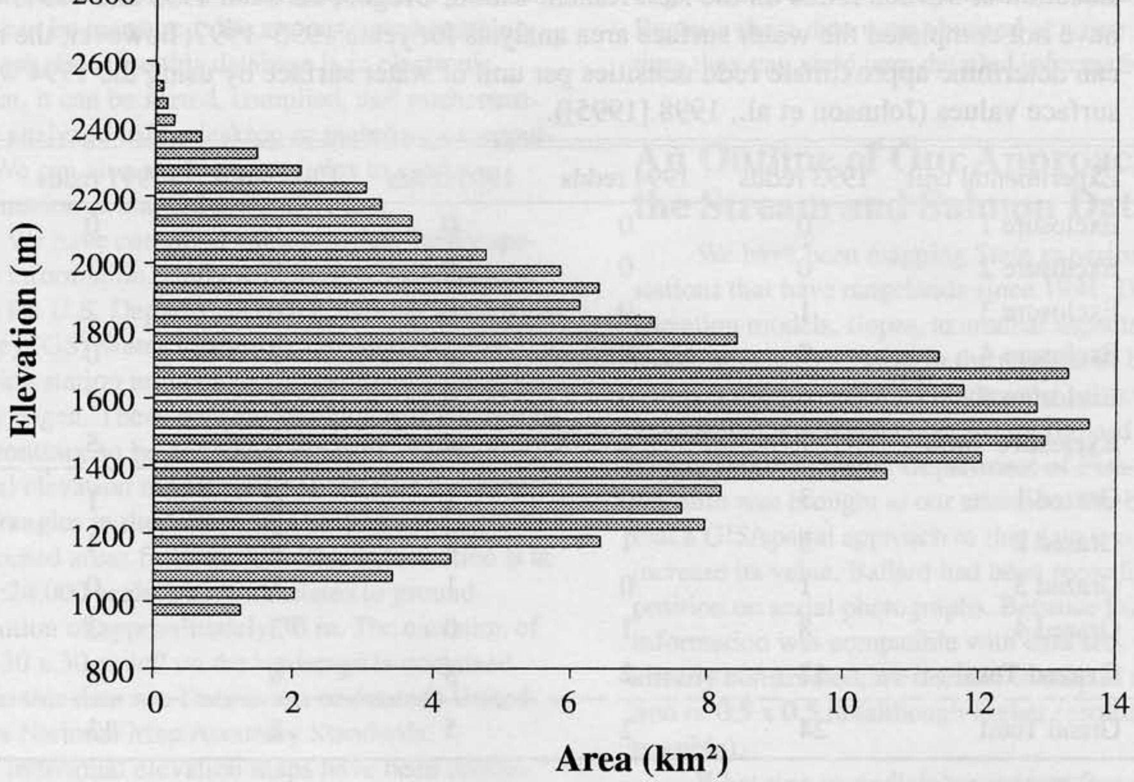

Figure 1. Elevational distribution of land in the upper Catherine Creek watershed above the Hall Ranch, Union, Oregon.

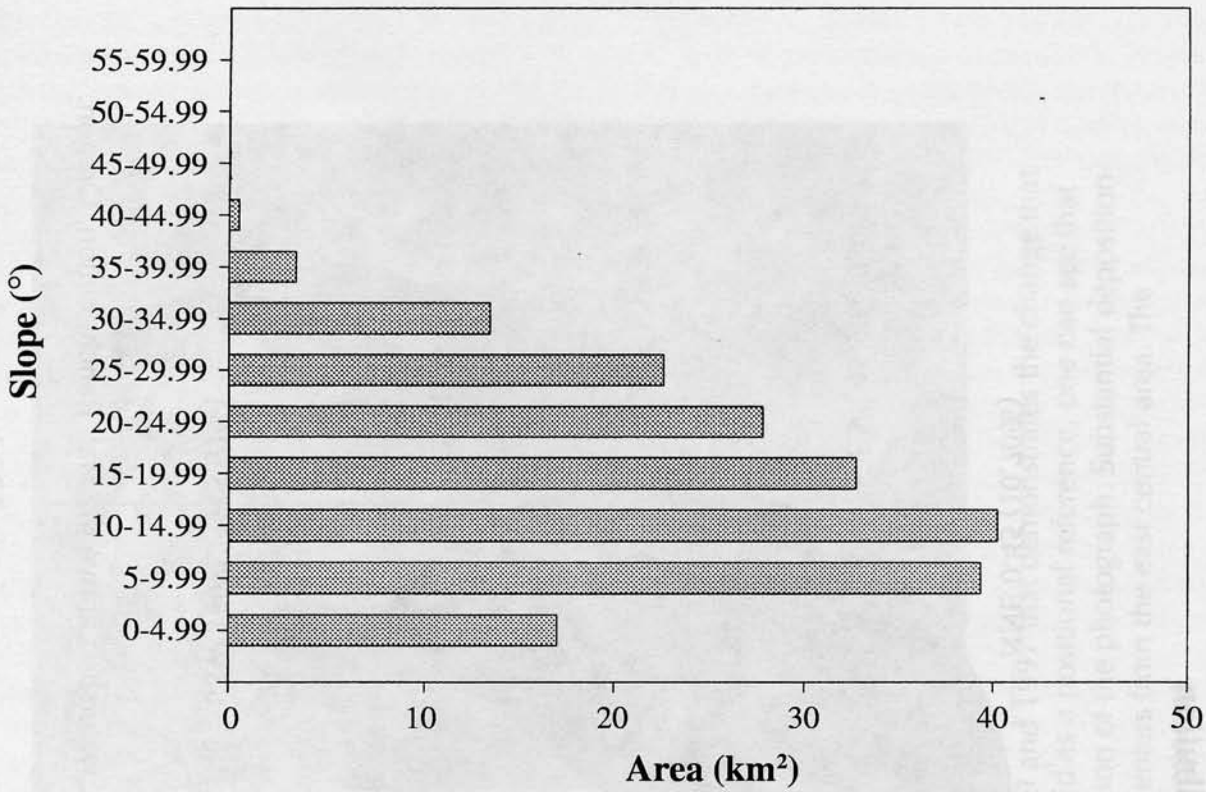

Figure 2. Slope distribution of land in the upper Catherine Creek watershed above the Hall Ranch, Union, Oregon.

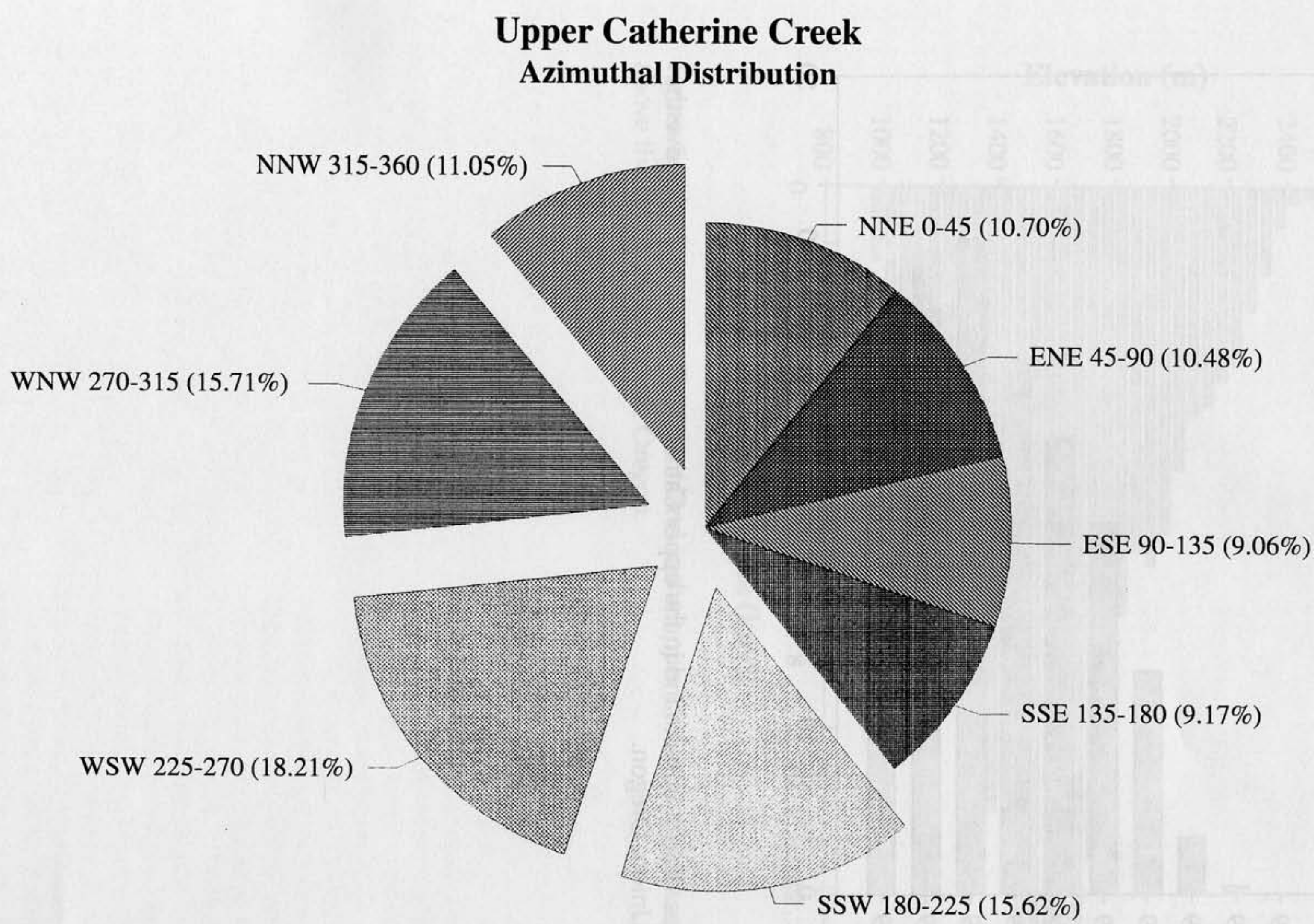

Figure 3. Azimuthal distribution of land in the upper Catherine Creek watershed above the Hall Ranch, Union, Oregon.

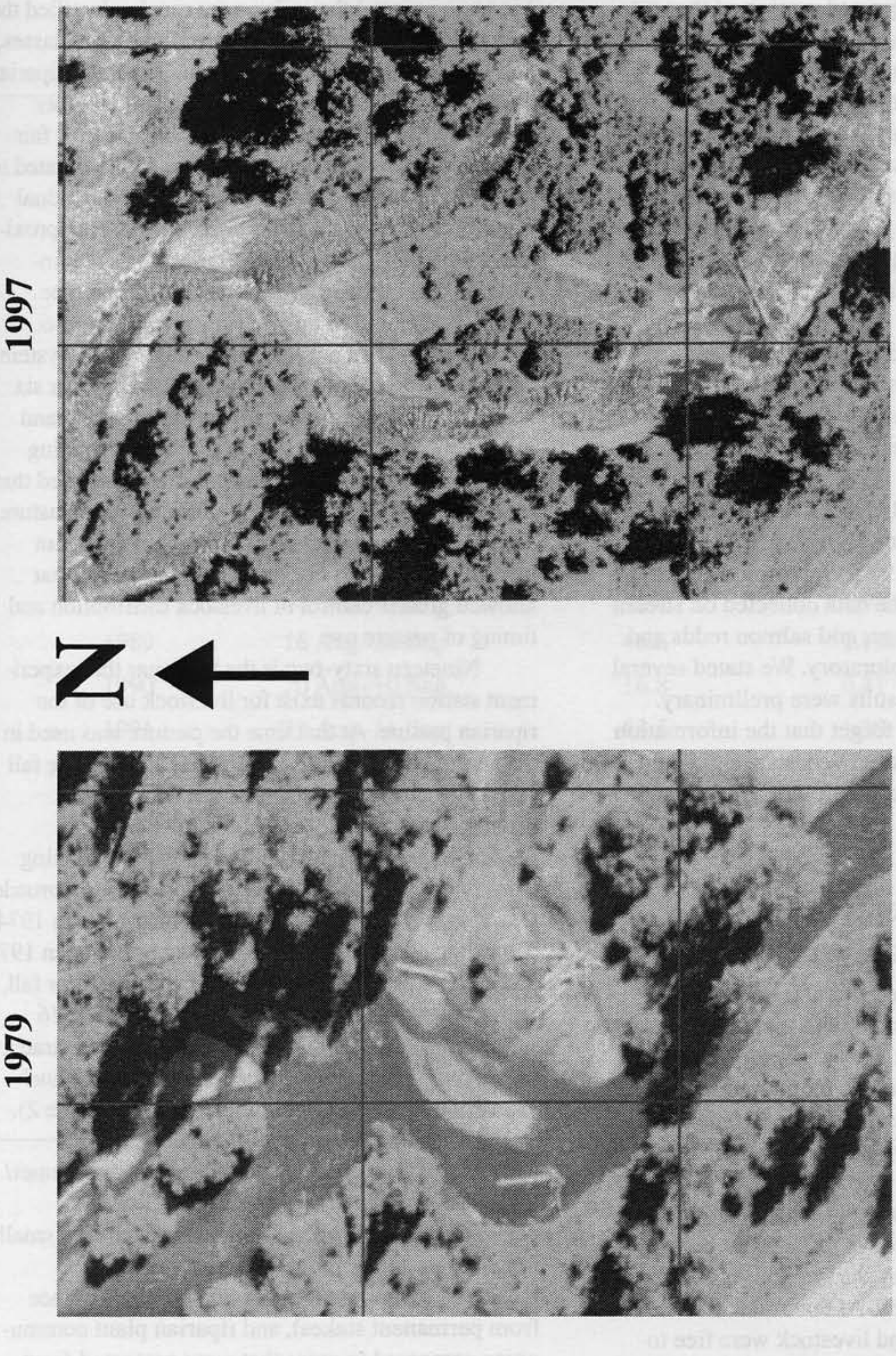

Figure 4. Geocorrected color aerial photograhs from 1979 and 1997 that demonstrates the change that has occurred at this location in grazed unit 4. Using the grid as a positional reference, one can see that there has been erosion of the bank in the south-center portion of the photograph. Substantial 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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