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# AQUATIC HABITAT CONDITION INDEX, STREAM TYPE, AND LIVESTOCK BANK DAMAGE IN NORTHERN NEVADA[1]

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ABSTRACT: The quality of stream habitat varies for a variety of natural and anthropogenic reasons not identified by a condition index. However, many people use condition indices to indicate management needs or even direction. To better sort natural from livestock influences, stream types and levels of ungulate bank damage were regulated to estimates of aquatic habitat condition index and stream width parameters in a large existing stream inventory data base. Pool/riffle ratio, pool structure, stream bottom materials, soil stability, and vegetation type varied significantly with stream type. Pool/riffle ratio, soil and vegetation stability varied significantly with ungulate bank damage level. Soil and vegetation stability were highly cross-correlated. Riparian area width did not vary significantly with either stream type or ungulate bank damage. Variation among stream types indicates that riparian management and monitoring should be stream type and reach specific.

(KEY TERMS: stream morphology; stream stability; riparian vegetation; livestock grazing impact; fish habitat; aquatic ecosystems; watershed management; wildland hydrology.)

## INTRODUCTION

The quality of stream ecosystems for fish depends partially on channel morphology as well as the quality and type of riparian vegetation. Riparian vegetation affects stream habitats by moderating temperature fluctuations (Brown and Krygier, 1967), limiting suspended sediment loads and providing necessary organic matter for heterotrophic streams (Knight and Battorff, 1981). Stream morphology affects cover, feeding, resting, rearing, and spawning habitat (Platts, 1979).

Riparian ecosystems are also important for man. The beauty and diversity of riparian areas, as well as the fishing and hunting opportunities, attract more recreational use than any other type of habitat. A diversity of economic uses includes livestock grazing. Livestock concentrate in riparian areas for a variety of reasons including abundance and an extended season of high quality forage, water, shade, and ease of access. The first recognition of damage to streams by livestock use occurred in the early 1900s (Bryan, 1925; Duce, 1918; Leopold, 1946). Concentrated and prolonged use continues to degrade stream and riparian areas (Bryant, 1985). Most previous studies of the effect of livestock management centered on one or two streams comparing habitat conditions between livestock exclosures and grazed reaches (for example, Hubert *et al.*, 1985). We are aware of no studies relating habitat conditions to stream morphology over a wide range of streams.

Rosgen (1985) introduced a stream classification system based on stream and floodplain morphology and geologic parameters. This classification system is currently used by stream survey teams of the Nevada Department of Wildlife with assistance from the U.S. Forest Service (USFS) and Bureau of Land Management while collecting data concerning the habitat condition index (HCI), riparian area width, stream stability (Myers, 1990), and level of ungulate bank damage. HCI is from the General Aquatic Wildlife System (GAWS) in Region 4 of the U.S. Forest Service Handbook (USFS, 1985). Aquatic habitat is expected to differ naturally among stream types as is the effect of livestock grazing on this habitat.

The purpose of this research is to relate HCI parameters to stream type and level of ungulate bank damage. This research expands the comparison of livestock management effects to a large data base of streams as well as relating the livestock effects and habitat conditions to stream classification.

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## METHODS

### *Data Base*

Stream survey crews collected and measured the data used in this analysis in the Carson, Toiyabe, and Sweetwater Ranges of western Nevada from 1978-1981 and in the Santa Rosa Range of northern Nevada from 1986-1988. This time spans a variety of flow conditions including drought and a series of three wet years (1982-1984) with prolonged high flows and extensive channel erosion. The crews measured pool/riffle ratio, percent pool structure, percent stream bottom, percent soil stability, and percent optimum vegetation type for the entire period, and percent vegetation stability from 1986-1988. Also they measured the width of the riparian area and determined stream type in the Santa Rosa Range. Ungulate bank damage levels were determined for the entire period. Each sampling unit is a 200-foot stream reach divided into five equally spaced transects perpendicular to the stream thalweg. Conditions of the watershed above the sampling unit could not be examined due to time and cost limitations and the goal of building a large data base of site specific conditions. The stream type (described below) is a representation of the basin geomorphology and, to a lesser extent, the management of the basin. Sites with beaver dams of anthropogenic effects (such as abandoned cars or roads in the streams) not accounted for in the ratings were removed from the database. The following paragraphs describe the parameters for which more detail may be found in the U.S. Forest Service Handbook *Fisheries Habitat Surveys Handbook*.

Pool/riffle ratio is the percentage of stream area at current flow (generally this is after the peak of spring flow) that is a pool. Pool/riffle ratio was not converted into a rating of its proximity to 50/50 for this part of the study as normally done for the HCI evaluation. For these surveys, a pool was defined as any portion of a stream cross-section that has a measured surface velocity less than one foot per second.

Percent pool structure is the percent of pools that are high quality. These are pools rated 1, 2, or 3 (out of a possible five levels) by the procedure of the handbook (USFS, 1985). For the purpose of this analysis, a high quality pool is at least deeper than the average stream depth and longer or wider than the average stream width or equal to the average stream width with intermediate or better shelter. By definition, pools with intermediate shelter have cover over at least one quarter of the perimeter of the pool (USFS, 1985). The pool structure rating parameters do not vary with stream size.

Percent stream bottom is the percent of stream cross-sections with stream bottom materials of gravel and/or cobbles that are considered to be preferred rearing or foraging habitat for salmonids. Gravel and cobbles include particle diameters from 0.3 to 30 centimeters (USFS, 1985). Clay, silt, sand, boulders, and bedrock decrease the suitability of the stream bottom.

The definition of percent soil stability changed during the years of survey. Initially, the crews rated a streambank as unstable if there was evidence of erosion within the previous year (as in Platts, 1979). The reported value was the percent of streambanks at the five transects within a sampling unit that did not have recent erosion. This definition prevailed in the surveys in the Carson, Sweetwater, and Toiyabe Ranges (the southern ranges). In the recent period, crews rated streambanks on a scale of 1 to 4 representing poor to excellent conditions, respectively. The basis for these conditions is the density of plants with deep roots, the size, shape, and frequency of rocks, and existing signs of erosion (USFS, 1985). The reported value is a percent of optimum for the 10 stream banks. Optimum is a value equal to 40 (10x4), thus the rating ranges from 25 to 100 percent. This definition prevails in the data base for the Santa Rosa Range. The differing definitions are not compatible for analysis, so separate analyses and interpretation are performed.

Crews determined percent vegetation stability only in the Santa Rosa Range. This parameter rates the coverage of the bank by riparian vegetation and other nonerodible bank covers on a scale of 1 to 4 for poor to excellent conditions, respectively. Vegetation or other nonerodible bank material covers less than 25, 50, 80, or 100 percent of streambank surfaces for poor, fair, good, and excellent conditions, respectively. Calculation of the percent value is as described for percent soil stability.

Vegetation type for a sampling unit is the most common type observed. Crews rate each bank of a unit as follows: 1 for bare ground; 2 for grass and forbs; 3 for trees; and 4 for shrubs. For this analysis, the value analyzed is the mode, or the most commonly occurring value for the sampling unit. On units with two types being equal in occurrence, the choice is the higher value.

The HCI is a mean of the six parameters. All parameters are used as they were described in previous sections except pool-riffle ratio. Pool-riffle ratio is converted into a rating that must be 50/50 to be 100 percent and declines as pool area goes down or up from 50 percent of stream surface area.

Riparian area width is the width of the riparian zone including the stream at a representative location along the sampled stream reach. The width includes all vegetation that, obviously, depends on the moisture of the stream.

The level of ungulate (predominately cattle) bank damage described in Table 1 is based on observed signs of grazing, trampling, and trailing. Banks rate 1 for excessive damage, 2 for high damage, 3 for moderate damage, and 4 for light to no damage. The bank damage level does not represent previous damage indicated by increased channel width and downcutting unless part of ongoing direct effects. No attempt was made to correlate these ratings to actual numbers of animals or other grazing management practices because of the impossibility of obtaining meaningful data. While actual dates vary, grazing seasons are generally in summer due to the harsh winter climate. To a limited degree, wildlife, such as deer, could have made some of the bank damage; however, elk are not present in any of these ranges. The ratings also are qualitative and subjective as they depend on an observer's experience and judgment. These levels are used as a predictor to explain the variation in HCI parameters. Figure 1 shows the distribution of bank damage levels among the 721 study area stream reaches.

The stream type (Rosgen, 1985) represents the stream and floodplain morphology at the stream reach. The stream type classification uses hydraulic gradient, bed material size, width/depth ratio, sinuosity, valley confinement, and landform feature erodibility. Crews have typed the units only in the Santa Rosa Range. The first author visited the units in the southern ranges to assign stream types, and more than 50 units in the Santa Rosa Range to spot check the types determined by the crews. Stream type is used in the analysis as a predictor to explain variation in habitat condition parameters. Table 1 describes briefly each of the stream types found in this study. The stream type name is composed of a

TABLE 1. Stream Types and Levels of Ungulate Bank Damage in This Study.

| Type | General Description of Stream Type |
|---|---|
| A2 | Stable, steep (≥ 0.04) boulder and cobble channel in depositional landforms with steep side slopes, very deep, and very well defined. |
| A3 | Erodible, steep (≥ 0.04), coarse-grained channel with some fines in coarse depositional landforms with steep side slopes, very deep, and very well confined. |
| A4 | Erodible, steep (≥ 0.04) fine-grained channel in very steep depositional landforms, very deep, and very well confined. |
| B1 | Stable moderate-gradient (0.025-0.04) small boulder channel in stable coarse-grained landforms, moderately entrenched and confined. |
| B2 | Stable moderate-gradient (0.015-0.04) cobble and coarse gravel channel in moderately steep coarse depositional landforms, moderately entrenched and confined. |
| B3 | Unstable moderate-gradient (0.015-0.04) cobble-bed channel with a mixture of gravel, sand, and small boulders in coarse, depositional landforms with unstable banks, moderately entrenched, and well confined. |
| B4 | Unstable moderate-gradient (0.015-0.04) gravel, sand, and silt channel in fine-textured noncohesive depositional landforms, |
| C3 | Low-gradient (0.005-0.01) gravel-bed channel with low terraces and fine-textured unstable banks, moderately entrenched, and slightly confined. |
| C4 | Low-gradient (0.001-0.005) sand-bed channel with low terraces and depositional fine-grained banks, moderately entrenched, and slightly confined. |
| **Level** | **General Description of Ungulate Bank Damage** |
| 1 | Excessive damage – 76-100 percent bank damage, severe erosion and sloughing over entire bank because of completely damaged vegetation, no recovery, erosion constant. |
| 2 | High damage – 51-75 percent damage from heavy ungulate use, moderate to high bank erosion and sloughing, grazing does not allow plant biomass recovery to 50 percent bank stability. |
| 3 | Moderate damage – 26-50 percent ungulate damage, some erosion and sloughing, < 1/2 of potential plant biomass remains. |
| 4 | Light to no damage – partial or no evidence of bank damage, 0-25 percent ungulate use, little or no erosion or sloughing, near natural vegetation. |

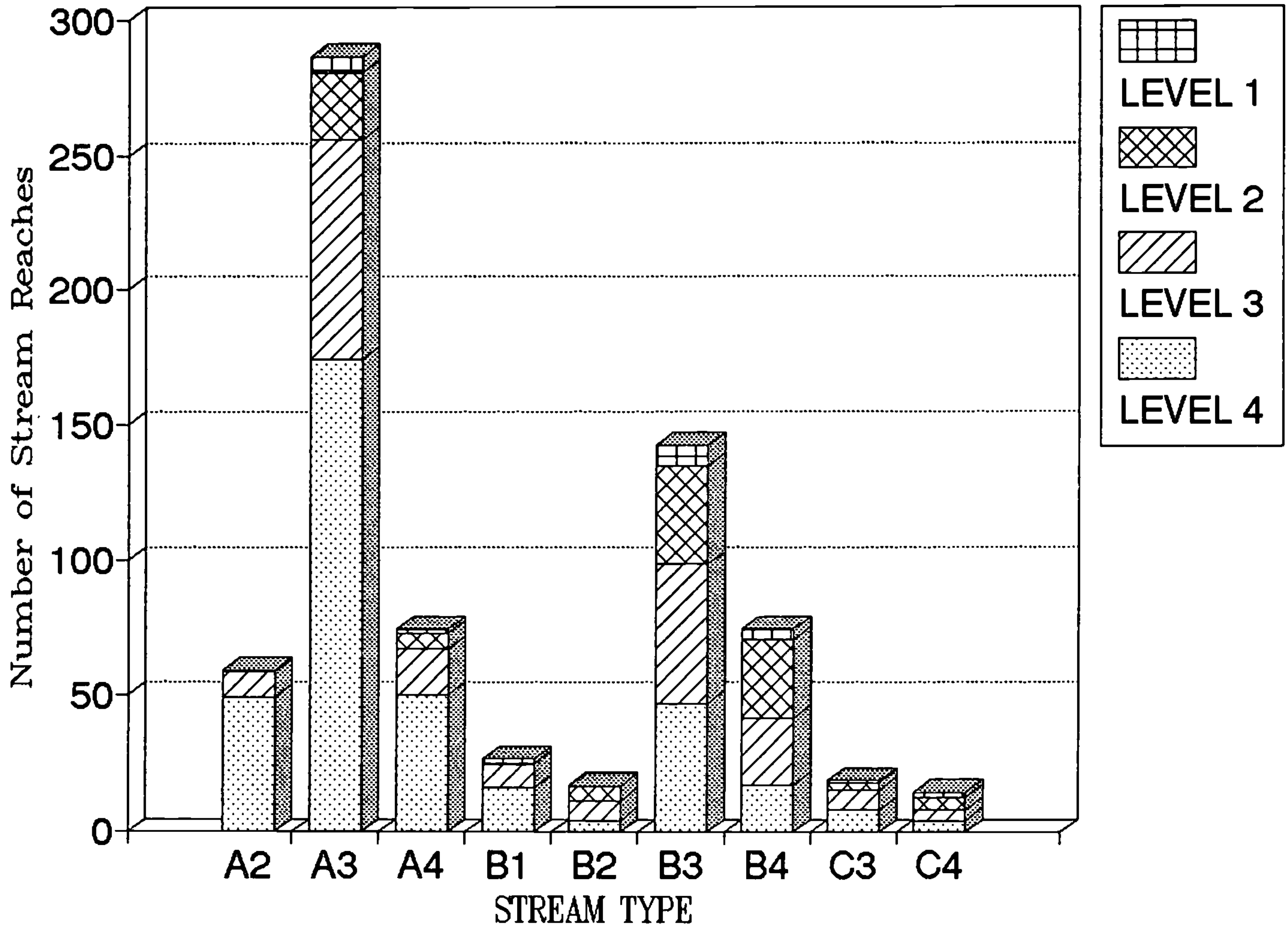

Figure 1. Distribution of Stream Types and Bank Damage Levels Among the 721 Analyzed Stream Reaches (4 = light to none, 3 = moderate, 2 = high, and 1 = excessive).

letter A, B, C, etc., and a number 1-6. In general A_ streams are steep and well confined, B_ streams are moderate in gradient, and C_ streams have a low gradient and high sinuosity. Also, _1 and _2 stream channels are dominantly boulders and cobble; whereas _3 and _4 stream channels are dominately gravels and sands. Figure 1 shows the frequency of occurrence of these stream types.

### *Statistical Analysis*

Habitat condition parameters, expressed as a percent, are analyzed for variation with stream type and level of ungulate bank damage with multiple regression analysis. The technique of indicator variables (Neter *et al.*, 1985; Draper and Smith, 1981) in a multiple regression analysis of variance model is used to determine variation with qualitative data. An indicator variable simply "indicates" whether a sampling unit is a given stream type or ungulate bank damage level with binary coding of 0 for no and 1 for yes. The fitted model follows:

$$Y = b0 + b1*A3 + b2*A4 + \ldots + b8*C4 + b9*L3$$

$$+ b10*L2 + b11*L1 + b12*A3L3 + b13*A3L2$$

$$+ \ldots + b34*C4L1$$

The dependent variable Y is the habitat parameter being fitted. Constants b0 to b34 are regression coefficients. Independent variables A3, A4, B1, B2, B3, B4, C3, and C4 are indicator variables for the given stream type and equal 1 if the sampling unit is the given stream type and 0 is not. Independent variables

L3, L2, and L1 are indicator variables for the ungulate bank damage level. Independent variables A3L3 through C4L1 are indicator variables representing the interactive effect of the given stream type and level of ungulate bank damage. The variable equals 1 if both are 1. Several interactive terms contain two or less observations and were dropped from the analysis because of multicollinearity. These were A2L2, A2L1, A4L1, B1L2, B1L1, B2L1, C3L1, and C4L1.

The regression model provides an analysis of variance model of the means of the given HCI parameter being fitted over stream type and level of ungulate bank damage. Stream type A2 and ungulate bank damage level 4 are the basis for analysis. The coefficients and their significance probabilities represent variation from these base levels. The results are an analysis of variance among stream type, ungulate bank damage levels, and interactive effects. The effect is accepted as significant at less than 10 percent probability of insignificance. Tables of mean values for each stream type, ungulate bank damage level, and combination are presented to aid interpretation of the analysis of variance from the multiple regression. The mean values are compared for significant differences ($p<0.1$) using the t-test for planned comparisons (Sokal and Rohlf, 1981). The relatively high p value was selected to balance the Type I and Type II errors, and to expose potential relationships for future investigation.

Vegetation type is a qualitative rating that cannot be analyzed using regression analysis. Three-way and two-way contingency table analysis (Fienberg, 1981; Everitt, 1977) is used to determine interactions among observations for stream type, level of ungulate bank damage, and vegetation type. Stream type and level of ungulate bank damage are explanatory variables, and vegetation type is a response variable (Fienberg, 1981, pg. 15).

## RESULTS AND DISCUSSION

### *Pool/Riffle Ratio*

Analysis of variance results indicate that pool/riffle ratio varies as a function of stream type and level of ungulate bank damage ($p<0.01$). Table 2 shows that pool/riffle ratio variation occurs among groups of stream types. Pool/riffle ratio generally increases significantly as the gradient decreases from A_ to C_ streams as expected because velocity depends on gradient which is a stream type parameter. Based on the groups of means in Table 2, most of this increase occurs on stream types without ungulate bank damage. Variation of pool area reflects the requirement of streams to balance pools and riffles within geologic constraints (Yang, 1971). Because there is less energy to disperse as high velocity riffles, more of the lower gradient C_ streams are low velocity pools.

The variation with ungulate bank damage level is significant because the mean of the parameter increases significantly as the level changes among 4,

TABLE 2. Pool/Riffle Ratio Means (percent) for Stream Types and Levels of Ungulate Bank Damage.
(Pool riffle ratio is expressed as a percent of stream surface area that is in a pool.)

| | Level | | | | |
|---|---|---|---|---|---|
| **Type** | **4 (light to none)** | **3 (moderate)** | **2 (high)** | **1 (excessive)** | **Average** |
| A2 | 32.5Aa | 49.0Ab | – | 25.9* | 34.6A |
| A3 | 38.4Ba | 48.9Ab | 57.0Ab | 26.8Aa | 42.5B |
| A4 | 32.9ABa | 46.5Ab | 51.9Ab | 40.7Aab | 38.1AB |
| B1 | 55.4Ca | 50.6Aa | 64.2* | 8.7Aa | 53.1CDE |
| B2 | 55.9BCa | 65.4ABa | 61.1Aa | – | 61.2DE |
| B3 | 44.2Ba | 49.1Aab | 55.1Ab | 32.0Aa | 48.0C |
| B4 | 55.1Ca | 54.1Aa | 52.4Aa | 56.9Aa | 53.8E |
| C3 | 56.4Ca | 66.8Ba | 70.9ABa | 26.4* | 61.5F |
| C4 | 65.9Ca | 41.0Aa | 83.4Ba | 100.0* | 64.7F |
| **Average** | **40.0a** | **50.5b** | **56.2c** | **38.8a** | **45.4** |

NOTES:

1. Pool/riffle ratio is expressed as percent of stream surface area that is a pool.
2. Upper case letters indicate means that are not significantly different ($p>0.1$) among stream types (down columns), and lower case letters indicate means that are not significant different ($p>0.1$) among levels of ungulate bank damage (across rows). * indicates mean that cannot be compared because of insufficient observations ($n=1$).

3, or 2. Stream types A2, A3, A4, B3, and C3 especially reflect this trend, although it is not always significant because of small numbers of observations. Because this trend is consistent, the effect does not manifest itself in the interactions which are insignificant (p=0.52). This indicates that stream bottom features that cause riffles are less abundant in heavily grazed streams. Physical damage by frequent grazing evidently does not allow the stable stream bottom features responsible for pool/riffle sequences (Yang, 1971) to form.

### *Percent Pool Structure*

The analysis of percent pool structure includes only sampling units with pools so the number of cases decreases to 641. Analysis of variance results indicated that it varied significantly (p<0.01) with stream type, but not with level of ungulate bank damage (p=0.34).

Table 3 shows that pool structure improves significantly from the A_ to C_ streams which corresponds with decreasing gradient. The improvement is probably due to increased overhangs and greater variation in width because there is more opportunity for lateral migration with the decreased confinement of C streams. These factors of stream type are presumably more important than ungulate bank damage levels, which were insignificant.

### *Percent Stream Bottom*

Analysis of variance results indicate that percent stream bottom (of gravels and cobbles) varied significantly with stream type (p<0.01) and interactions (p=0.012). Comparison of the means reported in Table 4 reveals some patterns. First, the B_ streams appear to have the highest percent stream bottom, while the C_ streams appear to have the lowest. A2 percent stream bottom is also low, but this is probably due to boulders; whereas, A3, A4, B4, C3, and C4 are probably low due to sands and silt. Second, two of the three number 4 types (B4 and C4) have the lowest values in their letter class. These apparent patterns simply indicate that low-gradient streams, which are most prone to sediment deposition, and streams with fine bank and bottom materials, have the smallest amount of suitable bottom materials.

The ungulate bank damage level was insignificant (p=0.28), but the interactions were significant because the groups of similar means among levels of ungulate bank damage appear to differ among stream types. This indicates that level of ungulate bank damage may affect the bottom structure differently among stream types. Types A2, A4, B3, and C4 are significantly affected by livestock grazing. Table 3 shows that Type A3 is similar to A4; percent stream bottom increases as ungulate bank damage increases. In Type A3, the increase is consistent, but not significant. In A4, the increase is significant between Level 4 and 3, but not consistent among Levels 3, 2, and 1.

TABLE 3. Percent Pool Structure Means for Stream Type and Levels of Ungulate Bank Damage.

| | Level | | | | |
|---|---|---|---|---|---|
| **Type** | **4 (light to none)** | **3 (moderate)** | **2 (high)** | **1 (excessive)** | **Average** |
| A2 | 22.0Aa | 37.9ABb | – | 0.0* | 23.7A |
| A3 | 29.1Ba | 33.2Ab | 26.8Ab | 29.0Ab | 30.0B |
| A4 | 29.8ABa | 24.3Aa | 24.4Aa | 60.0Aa | 29.1ABC |
| B1 | 27.3ABa | 50.7Cb | 43.0* | 48.7Aab | 35.6CD |
| B2 | 35.3ABCa | 13.3Aa | 42.5Aca | – | 31.0ABCD |
| B3 | 37.5Ca | 44.7Bab | 49.3Cb | 25.4Aa | 42.5D |
| B4 | 44.5Ca | 40.7Ba | 34.5ABa | 26.2Aa | 38.5D |
| C3 | 39.7BCa | 61.1C | 46.1ABCa | 100.0* | 53.0E |
| C4 | 56.2BCa | 56.7BCa | 81.2Da | 0.0* | 58.4E |
| **Average** | **30.6**[+] | **38.6** | **38.4** | **31.8** | **34.0** |

NOTE:

1. Upper case letters indicate means that are not significantly different (p>0.1) among stream types (down columns), and lower case letters indicate means that are not significant different (p>0.1) among levels of ungulate bank damage (across rows). * indicates mean that cannot be compared because of insufficient observations (n=1).

[+] Significance is not indicated for level average because p>0.1 in the analysis of variance.

TABLE 4. Percent Stream Bottom Means for Stream, Type, and Level of Ungulate Bank Damage.

| | Level | | | | |
|---|---|---|---|---|---|
| **Type** | **4 (light to none)** | **3 (moderate)** | **2 (high)** | **1 (excessive)** | **Average** |
| A2 | 55.4Bb | 43.0Aa | – | 43.0* | 53.5B |
| A3 | 66.4Ca | 68.3Ba | 71.5Aa | 79.7Aa | 67.6E |
| A4 | 53.6Ba | 72.5BCb | 65.4Ab | 74.0Ab | 59.6C |
| B1 | 71.5Ca | 66.2BCa | 76.0* | 70.0Aa | 70.3EF |
| B2 | 66.3BCa | 65.0BCa | 78.2Aa | – | 70.8EF |
| B3 | 74.7Cb | 77.8Cb | 67.6Aa | 72.8Aab | 74.2F |
| B4 | 65.3Ca | 65.6BCa | 66.1Aa | 61.0a | 65.4DEF |
| C3 | 58.0BCa | 69.8BCa | 50.0a | 45.0* | 61.5CD |
| C4 | 18.3Aa | 39.0Ab | 32.3a | 0.0* | 28.0A |
| **Average** | **64.0+** | **69.3** | **67.0** | **69.8** | **66.0** |

NOTE:

1. Upper case letters indicate means that are not significantly different (p>0.1) among stream types (down columns), and lower case letters indicate means that are not significant different (p>0.1) among levels of ungulate bank damage (across rows). * indicates mean that cannot be compared because of insufficient observations (n=1).

+Significance is not indicated for level average because p>0.1 in the analysis of variance.

This trend implies that increasing livestock use causes more gravel, a desirable stream bottom material, to enter the reaches of these types from the naturally unstable banks. Presumably, the migrations of gravel out of steep reaches causes a net decrease between disturbances. Percent stream bottom does not decrease significantly with ungulate bank damage for the steeper stream types (A_s) because fine-grained sediment inflow does not settle in the streams with steeper gradients. The increased fine sediment moves downstream to lower gradients where it settles and decreases the percent stream bottom without regard to local grazing conditions. The means of B_ and C_ streams do not show a consistent pattern with level, indicating dependence on upstream conditions.

### *Percent Soil Stability*

The definition of percent soil stability changed in 1986; therefore, two separate analyses were completed. Stream type and level of ungulate bank damage are significant in both the southern ranges (p<0.01 and p=0.02) (Table 5) and the Santa Rosa Range (p=0.07 and p<0.01) (Table 6). Interactions are significant in the Santa Rosa Range (p=0.02), but not in the southern ranges (p=0.41). Some stream types (_3 and _4 types) are inherently less stable, by definition, because channel and bank materials differ by stream type (Rosgen, 1985), and bank stability differs by particle size composition (Hooke, 1979).

The low probability values for significance of ungulate bank damage levels are expected. Livestock trample banks which increases erosion and instability. Increased bank damage corresponds with increased instability. The average stability in the southern ranges for heavy livestock damage (Level 1) is only 49 percent compared with 68 percent for excellent conditions (Level 4). The effect appears similar in the Santa Rosa Range where stability increases from 26 to 60 percent, respectively.

### *Percent Vegetation Stability*

Data for this parameter have been collected only since 1986 in the Santa Rosa Range; therefore, the analysis applies to this range only. The analysis of variance results indicate that percent vegetation stability varies significantly with level of ungulate bank damage (p<0.01) and interactions (p=0.77), but not with stream type (p=0.13) (Table 7). These results indicate that vegetation stability improves with decreased ungulate bank damage. Damage to vegetation is one of the indicators of level of ungulate bank damage. The interactions term is significant because stream types A4, B4, and C4 show a larger (significant) decrease in plant or other nonerodible bank cover with ungulate bank damage than do other types.

Simple regression between this parameter and percent soil stability shows a 76.8 percent correlation. The coefficient for vegetation stability was 0.91 with probability <0.01. This indicates that, for every 1 percent decrease in vegetation stability, there is a 0.91 percent decrease in soil stability. The high correlation

TABLE 5. Percent Soil Stability Means for Stream Type and Level of Ungulate Bank Damage (Southern Ranges).

| **Type** | **Level**<br>**4**<br>**(light to none)** | <br>**3**<br>**(moderate)** | <br>**2**<br>**(high)** | <br>**1**<br>**(excessive)** | **Average** |
|---|---|---|---|---|---|
| A2 | 85.0Da | 66.7Aba | – | 40.0* | 81.4B |
| A3 | 65.1ABb | 61.6Bb | 61.0Aab | 45.0Aa | 63.2B |
| A4 | 71.9BCa | 73.3Ba | 60.0* | 55.0Aa | 71.1B |
| B1 | – | 47.5Aa | – | 45.0Aa | 46.7A |
| B2 | – | 50.0* | 75.0Aa | – | 66.7AB |
| B3 | 86.0CDb | 44.0Aa | 55.0Aa | 50.0Aa | 54.0A |
| B4 | 52.9Ab | 48.6Aa | 58.6Aa | 43.3Aa | 52.1A |
| C3 | 100.0Db | 40.0Aa | 40.0* | 90.0* | 68.3B |
| C4 | 95.0Db | 40.0Aa | – | – | 67.5A |
| **Average** | **68.4b** | **55.1** | **58.4a** | **49.0a** | **63.9** |

NOTE:

1. Upper case letters indicate means that are not significantly different (p>0.1) among stream types (down columns), and lower case letters indicate means that are not significant different (p>0.1) among levels of ungulate bank damage (across rows). * indicates mean that cannot be compared because of insufficient observations (n=1).

TABLE 6. Percent Soil Stability Means for Stream Type and Level of Ungulate Bank Damage (Santa Rosa Range).

| **Type** | **Level**<br>**4**<br>**(light to none)** | <br>**3**<br>**(moderate)** | <br>**2**<br>**(high)** | <br>**1**<br>**(excessive)** | **Average** |
|---|---|---|---|---|---|
| A2 | 48.6Aa | 58.1BCDa | – | – | 50.2A |
| A3 | 58.4Bb | 59.8CDb | 50.7Aa | – | 58.2B |
| A4 | 72.9Cb | 51.9BCa | 47.5Aa | – | 61.1B |
| B1 | 50.4Aa | 87.5* | 55.0* | – | 53.1AB |
| B2 | 68.3BCDa | 68.3Da | 50.0Aa | – | 62.2B |
| B3 | 62.7BDa | 61.1Da | 59.3Ba | – | 61.4B |
| B4 | 66.9Db | 48.7Ba | 54.9ABa | 27.5* | 55.3AB |
| C3 | 63.8BCDa | 65.3Da | 37.5* | – | 62.8B |
| C4 | 77.5Db | 40.0Aa | 53.1ABa | 25.0* | 52.5AB |
| **Average** | **59.5c** | **58.7c** | **53.9b** | **26.2a** | **58.2** |

NOTE:

1. Upper case letters indicate means that are not significantly different (p>0.1) among stream types (down columns), and lower case letters indicate means that are not significant different (p>0.1) among levels of ungulate bank damage (across rows). * indicates mean that cannot be compared because of insufficient observations (n=1).

between these parameters is probably related to the great similarity in their definition. The high significance of the livestock term indicates that vegetation (and soil) stability closely relate(s) to grazing bank damage. However, the significance of the interactions term is that stream types respond differently to grazing bank damage. Especially for some stream types, improved conditions for vegetation will improve the soil stability. For example, this implies that improved flow conditions that improve riparian vegetation will provide an additional benefit of improving soil stability.

### *Vegetation Type*

Based on the expectation that stream type has the major effect on vegetation type, the three-way contingency table analysis (Table 8) model numbers 1, 4, 7, and 8 are the chosen hierarchy (Fienberg, 1981). Even though the difference in maximum likelihood values between Models 7 and 8 (19.87) is significant with nine degrees of freedom, Model 7 is the selected model (Fienberg, 1981, pg. 59) because the extremely high p value indicates the model provides an excellent fit to the observed data. Two-way contingency table analysis (not shown) tested independence between stream

TABLE 7. Percent Vegetation Stability Means for Stream Type and Level of Ungulate Bank Damage.

| | Level | | | | |
|---|---|---|---|---|---|
| Type | 4 (light to none) | 3 (moderate) | 2 (high) | 1 (excessive) | Average |
| A2 | 53.6Aa | 69.4Bb | – | – | 56.2 |
| A3 | 62.8Bb | 61.8BCb | 53.0Aa | – | 61.6 |
| A4 | 76.8Cb | 59.2ABCa | 55.8Aa | – | 67.0 |
| B1 | 53.6Aa | 72.5* | 52.5* | – | 54.8 |
| B2 | 74.2BCb | 74.2Cb | 49.2Aa | – | 65.8 |
| B3 | 66.4Bb | 63.0BCb | 59.3Ab | – | 63.8 |
| B4 | 68.3BCb | 55.7Aa | 59.8Aa | 27.5* | 59.9 |
| C3 | 66.2BCa | 61.2BCa | 45.0* | – | 62.2 |
| C4 | 77.5BCb | 42.5Aa | 53.1Aa | 35.0* | 54.2 |
| **Average** | **63.4b** | **61.5b** | **56.8b** | **31.2a** | **61.6** |

NOTE:

1. Upper case letters indicate means that are not significantly different (p>0.1) among stream types (down columns), and lower case letters indicate means that are not significant different (p>0.1) among levels of ungulate bank damage (across rows). * indicates mean that cannot be compared because of insufficient observations (n=1).

type and vegetation type for streams without ungulate bank damage (Level=4). The result was highly significant (p<0.01) with a maximum likelihood test statistic of 76.31 and probability <0.01. These results indicate that vegetation depends on stream type. For example, the data show that the highest frequency (25 percent) of shrubs occurs on stream types B3 and C4. The highest frequencies (20 percent) of trees occurs along stream types A3 and B3. It should be noted that bare ground is the dominant type on almost 50 percent of all sampling units. Stream type is probably significant because of differing soil types, floodplain morphologies (Harris, 1987), valley confinements, and elevation.

TABLE 8. Three-Way Contingency Table Analysis Maximum Likelihood Test Statistics ($\chi^2$) for Vegetation Type.

| Number | Model | $c^2$ | P | df |
|---|---|---|---|---|
| 1+ | [T] [L] [V] | 222.2 | <0.01 | 129 |
| 2 | [T] [LV] | 200.0 | <0.01 | 120 |
| 3+ | [L] [TV] | 149.8 | <0.01 | 105 |
| 4 | [TL] [V] | 142.7 | 0.01 | 105 |
| 5 | [TV] [LV] | 127.6 | 0.02 | 96 |
| 6 | [TL] [LV] | 120.5 | 0.05 | 96 |
| 7+* | [TL] [TV] | 70.3 | 0.80 | 81 |
| 8+ | [TL] [LV] [TV] | 50.5 | 0.97 | 72 |

NOTE:

1. [T], stream type; [L], level of ungulate bank damage; [V], vegetation type; combinations represent interactive effects.

+Chosen hierarchy.
*Chosen model.

## *Habitat Condition Index*

Components of the aquatic habitat condition index differ between the southern ranges and the Santa Rosas where percent vegetation stability was added. However, analysis of variance results indicated very similar habitat condition for the two study subareas. In both areas, level of ungulate bank damage was highly significant (p<0.01), and in neither was there significant interaction (p=0.88 for the southern ranges and 0.24 for the Santa Rosas). Stream type was significant (p<0.01) for the Santa Rosas, but not for the southern ranges (p=0.18).

Because of this similarity and to save space, mean HCI ratings for stream type and level of ungulate bank damage are shown in Table 9 for the Santa Rosas only. The Santa Rosa data are shown because of the somewhat larger data set and the inclusion of all HCI variables. The significance of level of ungulate bank damage appears to be caused by only two reaches in Level 1. These usually low HCI ratings for one B4 and one C4 Level 1 stream reach may not represent a large enough sample size for interpretation. The other levels, each with 70 or more samples per level, are not significantly different. In the southern ranges, Levels 3, 2, and 1 are not different (55.3 = 58.3 = 55.4, respectively); where, Level 4 is lower (50.2). Apparently the effect of the lower pool-riffle ratio of the Level 4 reaches overcomes that of the higher soil stability.

Table 9 also shows few significant differences among stream types. Both C4 and A2 HCI values are lower than most others although probably for different reasons. The pool-riffle ratio and percent pool

TABLE 9. Habitat Condition Index Means for Stream Type and Level of Ungulate Bank Damage in the Santa Rosas.

| Type | Level<br>4<br>(light to none) | <br>3<br>(moderate) | <br>2<br>(high) | <br>1<br>(excessive) | Average |
|---|---|---|---|---|---|
| A2 | 43.3Aa[+] | 47.3ABa | - | - | 43.97B |
| A3 | 54.4Ba | 54.7ABa | 48.7Aa | - | 53.98C |
| A4 | 57.6Ba | 52.5ABa | 51.4Aa | - | 54.8CD |
| B1 | 51.2AB | 69.6* | 53.85* | - | 52.6ACD |
| B2 | 65.1Ba | 53.4ABa | 53.62Aa | - | 57.4CD |
| B3 | 58.6Ba | 57.0ABa | 56.97Aa | - | 58.0D |
| B4 | 60.8Bb | 51.2ABab | 50.71Aa | 23.03* | 52.7C |
| C3 | 56.0Ba | 61.6Ba | 41.85*a | - | 58.0CD |
| C4 | 51.7ABa | 39.1Aa | 48.43Aa | 14.17* | 43.3AB |
| **Average** | **54.7b** | **54.8b** | **51.8b** | **18.6a** | **54.1** |

[+] Upper case letters indicate means that are not significantly different ($p>0.1$) among stream types (down columns), and lower case letters indicate means that are not significant different ($p>0.1$) among levels of ungulate bank damage (across rows). * indicates mean that cannot be compared because of insufficient observations ($n=1$).

structure are very low for A2, and they are very high for C4; whereas, the percent stream bottom is just the reverse for these very different stream types. The tendency for different parameters of HCI to vary differently among stream types and levels of ungulate bank damage probably causes there to be fewer significant differences for the index than for the individual parameters.

### *Riparian Area Width*

Analysis of variance shows that riparian area width does not vary significantly with stream type ($p=0.22$), level of ungulate bank damage ($p=0.22$), or interactions ($p=0.62$). This is surprising because stream classification identifies differing landforms and because the vegetation type depends on the stream type. A_ streams, confined in the bottom of steep canyons, should have a narrower riparian zone than C_ streams with their flat, alluvial, meandering configuration. This analysis suggests that something other than confinement controls the width of riparian zones in flatter landforms. Perhaps the C_ streams are recharging the ground water; hence, the level of ground water decreases moving away from the stream (Ponce and Lindquist, 1990). Another possibility is that C_ streams are located in downcut reaches and have reclaimed only a relatively narrow floodplain. This could limit the width of the riparian zone in C_ streams.

## CONCLUSION

This research confirmed many relationships that have been understood intuitively, or from other riparian research, with more limited data bases. Pool/riffle ratio, percent pool structure, percent stream bottom, and percent soil stability were found to differ significantly with stream type as expected. Also, pool/riffle ratio and soil and vegetation stability varied significantly with the level of ungulate bank damage. Soil and vegetation stability were highly cross-correlated. Vegetation type was found to vary significantly with stream type with a strong interactive effect with livestock.

Because soil stability correlates with vegetation stability and both relate to ungulate bank damage, improvement of streambank stability depends on livestock management. Efforts at bank stabilization should include managing for vegetation. When selecting species objectives, a manager must consider site conditions as defined by stream type, climate, flow regime, and soil conditions on each fluvial surface (Kovalchik, 1987).

These results indicate that management must be stream type specific. By classifying stream reaches and studying the nature and response potential of different stream types, managers can write objectives that target specific attainable changes. Clear statement of attainable objectives is a fundamental first step to efficient riparian management. For example, when attempting to adjust pool/riffle ratios, managers must realize the limits. The gradient of A_ streams requires that much of the length of the stream must be high velocity to dissipate energy; therefore, more riffles are necessary. The gradient of C_ streams is low and there is insufficient energy for many riffles; therefore, the pool/riffle ratio is high.

The tables included in this paper provide land managers with expected habitat parameters from a large sample of streams representative of Great Basin rangelands. Because these surveys are ongoing throughout the West, the managers can determine how their surveyed streams relate to the results presented herein. As the database of stream surveys grows, more studies, such as this, should be completed so that variations across larger areas may be analyzed.

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