Western Watersheds Project

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Working to protect and restore Western Watersheds and Wildlife

July 5, 2016

BY EMAIL AND ONLINE SUBMISSION

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Re: Colville Forest Plan Revision, Comments on DEIS and Draft Forest Plan

Dear Colville Forest Planners:

Thank you for the opportunity to comment on the Forest's Draft Land and Resources Management Plan revision and Draft EIS. Please accept the following comments on behalf of Western Watersheds Project (WWP). Since the comment period extends until July 5, 2016, these comments are timely.

WWP works to protect and conserve the public lands, wildlife, and natural resources of the American West through education, public policy initiatives, and litigation. WWP and its staff and members use and enjoy the public lands in Washington—including those within the Colville National Forest—and its wildlife, cultural, and natural resources for health, recreational, scientific, spiritual, educational, aesthetic, and other purposes.

Please add WWP to the mailing/contact list for this Plan Revision, as we wish to receive all future notices of planning documents and environmental analyses.

No Grazing Alternative

It is well established that the Forest must consider a no-grazing alternative, as well as reduced grazing alternatives. The DEIS fails to do so because it specifies that under each alternative all allotments will continue to be available to grazing under the Revised Plan.

Grazing Permit Retirement

The DEIS should include alternatives that would provide for non-use (vacancy) of grazing allotments during the life of the Forest Plan when a permittee decides to voluntary relinquish the associated grazing privileges or permit. The Plan should then adopt appropriate language enabling that to occur.

In a hypothetical case, a third party may provide compensation for permittee's decision to waive a grazing permit back to the Forest Service provided the Forest Service agrees not to offer the permit to another party, instead allowing the allotment where the permittee held preference to be rested. The permittee's choice whether to relinquish grazing privileges is entirely voluntary.

Grazing permit retirement is increasingly provided for in forest plans, BLM RMPs, monument plans, and other programmatic management plans across the West. It is widely regarded as a "win-win" both for conservationists and native species and for livestock operators. The Colville Forest Plan should allow this opportunity through its plan revision process.

Bighorn Sheep and Disease Transmission

We strongly urge you to retain FW-STD-WL-12 in the final Forest Plan.

The Forest should also act quickly to analyze the risk of contact to bighorn sheep from domestic sheep that are authorized anywhere on the Colville National Forest. Because of the natural inclination of bighorn sheep to foray large distances, domestic sheep may pose an unacceptable risk to bighorn populations even if they are authorized outside of bighorn sheep source habitats or in areas not directly adjacent to source habitat.

In the Final EIS, please provide mapping at a scale and quality that clearly shows 1) bighorn core herd home ranges; 2) potential bighorn sheep habitat; 3) all domestic sheep grazing allotments, pastures, and driveways on the Colville National Forest; and 4) mapping showing the risk of contact between bighorn sheep and domestic sheep authorized on the Forest.

The Forest Plan should also specify that affected domestic sheep AUMs or Head Months would be cancelled outright instead of being converted to permitted/authorized use for other classes of livestock, or in other areas.

If the authorized use for sheep is converted to cattle or other classes of livestock, it should not be a 1:1 conversion of AUMs, and must take into consideration that domestic sheep use the landscape differently than cattle: they utilize steeper areas; are less dependent on riparian areas; make use of browse more than cattle; and are far more mobile than cattle. Thus, any conversion of use to cattle from sheep must be at a fraction of the AUMs authorized for sheep in order to prevent new impacts on riparian areas and other resources.

Grazing in Research Natural Areas

WWP supports your proposed decision not to allow new or additional grazing within RNAs. However, we urge you to also eliminate current grazing in these special areas. RNAs comprise only 5,904 acres (.5% of the Colville National Forest), but are disproportionately important for protection of biodiversity and other public values. Such small but important areas could be removed from areas available to livestock without discernible effect to grazing overall. The Forest Service should require this.

Capability and Suitability

Please include the mapping and underlying data from this exercise, and include the results in Tables 2, 6, and 11 in the FEIS. Currently livestock grazing is permitted on much of the Colville National Forest, but the Range Suitability Determination shows that only 363,000 acres (33% of the forest) are suitable for cattle grazing. Cows are the main class of livestock authorized. Does the Forest Service authorize grazing on land that it has found unsuitable for grazing? Do the results of the analysis dictate that any areas currently authorized for livestock use be made unavailable to livestock grazing under the Revised Plan?

Climate Change and Grazing

Except for one paper, the Range Specialist Report cites only studies that find grazing *increases* carbon sequestration and *reduces* greenhouse gases. In fact, there is an ever-growing body of literature[1] suggesting the opposite, which the Forest must consider. In the Final EIS, please provide more complete analysis of the effects of livestock grazing on climate change.

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[1] *See e.g.* Beschta, R. L., Donahue, D. L., Dellasala, D.A., Rhodes, J. J., Karr, J. R., O'Brien, M. H., Fleischner, T. L., & Deacon-Williams, C. (2012) Adapting to Climate Change on Western Public Lands: Addressing the Ecological Effects of Domestic, Wild, and Feral Ungulates. Environmental Management.

Dong Wang, Gao-Lin Wu, Yuan-Jun Zhu, Zhi-Hua Shi. 2014. Grazing exclusion effects on above- and below-ground C and N pools of typical grassland on the Loess Plateau (China). Catena 123 (2014). http://lab.yangling.cn/UploadFile/ea_201482785433.pdf.

Lei Deng, Zhinan Zhang, Zhouping Shangguan 2014. Long-term fencing effects on plant diversity and soil properties in China. Soil & Tillage Research 137 (2014) 7–15.

Wu Xing, Li Zongshan, Fu Bojie, Lu Fei, Wang Dongbo, Liu Huifeng, Liu Guohua 2014. Effect of Grazing Exclusion on Soil Carbon and Nitrogen Storage in Semi-arid Grassland in Inner Mongolia, China. Chin. Geogra. Sci. Bol 24 No. 4 pp. 479 –87.

Xing Wu, Zongshan Li, Bojie Fu, Wangming Zhou, Huifeng Liu, Guohua Liu. 2014. Restoration of ecosystem carbon and nitrogen storage and microbial biomass after grazing exclusion in semi-arid grasslands of Inner Mongolia. Ecological Engineering, Volume 73, Pages 395-403.

Aquatic and Riparian Resources

According to the Draft Plan, the majority of watersheds on the Forest are functioning at risk or non-functional. Grazing is a widespread cause of degradation of the watersheds and persistence of degraded conditions, as well as a threat to native fish and other species. Since the Plan Revision intends to replace INFISH, the aquatic strategy that the Forest implements in its place should be at least as protective of riparian resources and species as INFISH.

Measurable Use Standards

Draft Plan Guideline MA-GDL-RMA-09 should be retained, but modified in several ways. First, it should be included as a standard rather than a guideline. This includes modifying the permissive language so that it is mandatory (change “should” to “shall”). Second, the footnote allowing the numeric values of use levels to be made less protective based on site-specific conditions should be removed.

- The 6”–8” stubble height currently contemplated is appropriate and should not be subject to modification.

- However, the use standard for streambank alteration is too high, and should be changed to a lower value that is supported in the scientific literature. For example, the INFISH RMO for bank stability (which has an inverse relationship to bank alteration) is 80% percent. Thus, a 25% bank alteration standard would be less protective than the current bull trout objective. A breadth of other available literature shows that 25% bank alteration is above or at the upper extreme of appropriate levels for fish-bearing streams.[2] At a minimum, the Forest should adopt the 20% bank alteration standard in the proposed action alternative.

Adequate replacement for INFISH STD GM-1 needed

Under current management according to INFISH, Standard GM-1 provides for modification of grazing practices that retard or prevent attainment of RMOs or negatively affect native fish. There appears to be no equivalent analyzed in the DEIS. The FEIS should include such a standard, which the Plan should ultimately adopt to ensure that grazing is reduced when it leads to stagnation of poor conditions and lack of recovery.

Impacts to spawning salmonids

Draft Plan Standard MA-STD-RMA-11, which would prohibit livestock access to federally listed threatened or endangered fish redds, should be extended to apply to all reaches of stream where native fish species are known or expected to spawn during spawning periods, *but also through the time of incubation and emergence*. Spawning fish are at risk of harassment from wading livestock while they are staging and actively spawning. However, incubating eggs and

[2] *See* Bridger-Teton National Forest Streambank Alteration whitepaper (describing ranges within 10–20% for fish-bearing streams depending on channel type) (attached).

emergent juveniles still within substrate gravels are also vulnerable to trampling. [3] For bull trout, this likely means excluding livestock from August to April or later. For interior redband and cutthroat trout, spawning occurs in the spring and the season of use restrictions should be implemented accordingly.

The mode of excluding livestock is also important. Temporary and even permanent fencing is often ineffective at preventing livestock from accessing these sensitive areas, and has many negative consequences to wildlife, as well as inhibiting recreation. Consequently, livestock should be excluded through season of use restrictions at the pasture level to prevent impacts to redds. This is also critical because, apart from direct impacts to redds from trampling, incubating salmonid eggs are at risk from sedimentation caused by grazing in accessible upstream reaches and uplands.[4]

Wildlife/predator killing

The DEIS and Draft Plan do not appear to address wildlife killing by Wildlife Services on National Forest lands. This is a very important issue for a forest that provides actual or potential habitat for each of these species: grizzly bear, gray wolf, Canada lynx, Wolverine, American Marten, and fisher, which can be incidentally taken through various means even if not directly targeted. What are potential indirect and cumulative effects to these and other species from wildlife killing by Wildlife Services and how, when, and where does the Forest authorize these actions?

Old Forest Structure

WWP recommends designation of large areas of the Forest for emphasis on old growth-dependent species and old forest structure. Of the alternatives considered, this is best represented by Alternative R, which implements a large-scale reserve approach for this type of forest habitat (51%). This alternative also represents a passive management approach, which recognizes that manipulation by humans is not required for properly functioning ecosystems.

Wilderness

WWP supports adoption of—at a minimum—the wilderness recommendations under Alternative B. This alternative is the best of those analyzed in the DEIS because it recommends the greatest percentage of the forest for wilderness designation, while designating the lowest percentage of the forest as "backcountry" areas, in which mechanized recreation is allowed. Alternative B is preferable to Alternative R with respect to wilderness because it designates less backcountry, which is a watered-down designation that does not provide either the

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[3] *See* Thurow, R. F. The Camas Creek Watershed: Its Native Fish Populations, Aquatic Habitats, Landscape Processes, Scientific Values, Human Activities, and Limiting Factors and Threats, pp. 23-29 (attached).

[4] *See* Doumitt, Theresa and Laye, Doug, Assessing the Effects of Grazing on Bull Trout and Their Habitat p. 19 (attached) (noting that "effective [grazing] management of salmonid habitat begins at the ridgeline (watershed boundary) and not at the streambank").

environmental preservation or primitive recreational experience of actual wilderness. For similar reasons, WWP supports recommendation for actual wilderness designation of the Kettle Crest instead of creation of the Special Interest Area.

There is no shortage of areas allowing mechanized and motorized travel on public lands in the West, but wilderness areas comprise only a small percentage of public lands and are increasingly in demand by the public. Even under the most restrictive alternative, 73% of the Colville National Forest would still allow roads. The Forest Plan should recommend at least 220,330 acres (20%) of the Forest as suitable for wilderness, as contemplated in Alternative B.

Thank you for considering these comments. Please contact me if you have any questions.

Sincerely,

s/Paul Ruprecht
Staff Attorney
Western Watersheds Project

Copy: Travis Bruner, WWP

Streambank Alteration Measurement and Implementation
Bridger-Teton National Forest
Final
November 5, 2008

Ronna Simon
Forest Hydrologist

INTRODUCTION

Importance of bank alteration in the context of channel function

It is widely known that bank alteration by trampling, shearing, and exposure of bare soil can be an important source of stream channel and riparian degradation (e.g., Clary and Webster, 1989, 1990; Overton et al., 1994; Belsky et al., 1999). Impacts may include channel widening (and loss of ability of flood flows to access floodplains), loss of riparian vegetation (which then makes banks more vulnerable to further erosion), localized lowering of water tables in riparian areas (and loss of water storage in floodplains and stream channels), and changes in sediment transport capacity of stream channels.

Researchers have also reported that channel degradation from alteration may occur before utilization or stubble height requirements are met. In a personal communication to Ronna Simon on 1/31/08, Tim Burton (Idaho BLM State Office Fisheries Biologist and co-developer of MIM—see references to MIM that follow) stated that a test site that had received less than 5% streambank alteration for several years in a row had 47% bank alteration in 2007; this was accompanied by a decrease in bank stability from 86% to 30%, while a stubble height standard of 4 inches was still met. As a result, his office will be replacing the stubble height trigger for moving livestock with one for bank alteration. Bengeyfield (2006) also reported that trampling limits were exceeded before stubble height requirements were met.

Channel recovery is often slower than vegetative recovery. Kondolf (1993) found that channels in California that had been excluded from grazing for 24 years had not returned to their pre-disturbance morphology despite the growth of lush streambank vegetation. Clary and Webster (1989) provided information from other studies in their paper. They stated that "[w]hile Skovlin (1984) suggested that vegetation recovery after release from excessive grazing generally can occur within 5 to 15 years, Platts and Raleigh (1984) pointed out that impacts on fishery environments go far beyond the riparian vegetation. Channel and bank morphology, instream cover, and water flow regimens are important factors. Little is known about the recovery time for these factors in different environments." Magilligan and McDowell (1997) described geomorphic channel adjustments after more than 14 years of grazing exclusion in eastern Oregon. They concluded that 14 years might not be sufficient time for all variables to adjust. They also cite other studies' findings that "…for exclosures less than approximately five to ten years old, little geomorphic difference exists despite noticeable differences in riparian vegetation".

Given this knowledge, it is evident that bank alteration is an important factor to consider when evaluating stream channel and riparian area conditions in grazing allotments. Some researchers have concluded that bank alteration, taking natural channel stability into account, is the most important factor to consider in evaluating physical stream channel conditions and impacts from land use (Bengeyfield, 2006).

This paper provides a method for determining if streambank alteration is at acceptable levels for maintaining or improving channel stability. The information in this paper is not meant to imply that riparian vegetation is not important in maintaining riparian and stream channel conditions. This paper is addressing just the physical streambank conditions: a broader evaluation that includes vegetation is beyond the scope of what is presented here.

DEFINITIONS

Bank Alteration: The change in streambank form resulting from large herbivores' walking along or crossing a stream during the current grazing season. Shearing and trampling by animals' hooves results in direct breakdown of the streambank, channel widening, exposure of bare soil, and may cause soil compaction. The definition of streambank alteration provided by Burton, Cowley, and Smith (2007) is used to determine what constitutes bank alteration.

Disturbance: Disruption or perturbation of normal or pre-existing conditions. In the context of this document, disturbance refers to disruption of channel form—mainly streambanks.

Greenline: "The first perennial vegetation that forms a lineal grouping of community types on or near the water's edge" (Burton et al., 2007). It can also consist of patches of vegetation on bars and other areas where vegetation is becoming established.

Recovery Potential: Ability of a stream channel to return to its pre-disturbance physical form and/or condition without external (e.g., structural) measures, once the cause of instability is corrected.

Sensitivity: Ease with which a channel's form may be altered in response to disturbance; susceptibility of a given channel type to disturbance.

Shearing: One form of bank alteration (see above). Deformation of a streambank where one portion of the bank is shifted downward in response to direct hoof pressure, parallel to the remaining section of bank (i.e., shear stress is applied). Shearing is recognized by a shear plane associated with hoof marks on the streambank.

Stability: The persistence of a physical system in its existing equilibrium form when undisturbed, or only slightly disturbed. A streambank is stable if it lacks fractures, slumps, or sloughs. A steep bank (within 10 degrees of vertical) that is actively eroding is unstable.

Trampling: Treading heavily or destructively; beating down with hooves so as to adversely affect streambanks.

RATIONALE

Need for this protocol, including need for change

Current Forest Plan guidance on either streambank stability or alteration is contained in the Streambank Stability Guideline, which states that "[a]t least 90 percent of the natural bank stability of streams that support a fishery, particularly [TES] and all trout species, should be maintained. Streambank vegetation should be maintained to 80 percent of its potential natural condition or an HCI rating of 85 or greater. Streambank stability vegetation and fish numbers and biomass should be managed by streamtype." (p.126)

This guideline has proven difficult to interpret for field personnel; determining the natural stability of streams is difficult, especially given our limited database. The guideline mentions managing by stream type and this idea should be retained in the revised Forest Plan. Conducting surveys to determine stream type can be time-consuming, and has not been done on many streams across the Forest. This task is being emphasized in recent NEPA project work for a variety of projects, and more stream typing is continually being done by Hydrology personnel. The HCI is a Habitat Condition Index used by Fred Mangum of BYU to measure stream health using aquatic invertebrate assemblages.

Livestock permittees accompanied Forest personnel on one allotment in summer 2006, and during discussions of riparian conditions and the methods used to evaluate them it became evident that lack of clear direction on bank alteration was making it difficult for Rangeland Management Specialists and permittees to judge the point at which bank alteration by livestock – and wildlife – was a problem. Permittees and Range personnel have pointed out the need to recognize that wildlife can contribute to alteration levels, and in some areas their impact is sizable. The question of when to evaluate conditions, and annual variability in amounts of alteration, were also problematic. This paper—developed with input from Range personnel, hydrologists, and other resource specialists -- is intended to address these concerns.

The measures described in this document have been developed to provide for determination of allowable amounts of induced streambank alteration-- taking natural channel sensitivity (via channel type) into account-- that would still allow stream channels to function properly. Where stream channels are degraded, the allowable amount of disturbance would lead to an improvement in conditions. These measures also seek to take into account the ability of a stream to recover from disturbance. This would be used to assist livestock managers and Rangeland Management Specialists in managing livestock to protect or improve stream channel conditions. It may also be useful for evaluating impacts from other uses (e.g., recreation). This protocol would be incorporated by reference into the revised Bridger-Teton Forest Plan.

Desired Conditions

Alluvial stream channels (i.e., those not formed in bedrock) are considered to be physically functioning properly when they can adjust their form and gradient, over a period of time, to transport the water, wood, and sediment being delivered to them. They are resilient to disturbance. When desired conditions are achieved, channel form is generally maintained, even with lateral migration of the channel, i.e. channels have the stream type that would exist in the absence of grazing or other land use impacts.

For fisheries, the assumption is that if the desired conditions described above are met, fisheries habitat will also be in its desired condition. Fish are mobile in a stream system and, like riparian vegetation, may experience an initial increase in numbers as a stream recovers from disturbance.

DEVELOPMENT OF METHODOLOGY

Summary of other guidance

It is instructive to see what other Forests and Regions are using for allowable streambank alteration and streambank stability guidelines, and the basis for those guidelines. Following is a summary of what some other units are using.

Caribou-Targhee: Riparian Grazing Implementation Guide Version 1-2

- Stratify by stream type: damage potential, recovery potential, vegetation influence.
- It appears that inherent, undisturbed bank stability of channels functioning at full potential ranges from about 70 percent to 100 percent, depending on channel type and streamside vegetation.
- Finer-grained materials are more sensitive to disturbance. Depends on vegetation, too.
- Tables 5, 5A, 7: recommended guidelines by channel type

Channel types (Rosgen)	Bank Disturbance/Alteration	Bank Stability (cumulative)
A1, A2, A6, B1, B2, B3, C1, C2, F1, F2,G1, G2	15-25% (depends on PFC rating)	75-85% (depends on PFC rating)
A3, A4, A5, B4, B5, B6, F3	15-20% (ditto)	70-80% (ditto)
The rest	10-15% (ditto)	65-75% (ditto)

Region 2 (USFS R2, 1996): Standard says "Maintain the extent of stable banks in each stream reach at 80% or more of reference conditions. Limit cumulative stream bank alteration (soil trampled or exposed) at any time to 20-25 percent of any stream reach."

Helena NF: Annual bank disturbance (percent) depends on resiliency of sites [can relate to channel types] and PFC (Functionality)/Similarity of site to conditions that are conducive to sustainable function. Simplified version of Table 4, Annual Bank Disturbance:

Resiliency	Functionality / Similarity		
	FAR/Mod	**FAR/Low**	**NF/Low**
High	30-40 / 20-25	20-30 / 15-20	15-20 / 10-15
Mod	25-30 / 15-20	15-25 / 10-15	10-15 / 5-10
Low	10-15	5-10	5-10

Tonto NF: (cited in Lewis and Clark NF, Sheep Creek Range analysis): Bank alteration standard limits physical impacts by livestock to 20% of alterable bank features or the greenline.

Beaverhead-Deerlodge NF: Based on PFC and still under development. SWCP 17 (17.05, in particular, dated 4/95) provides guidance, with "similarity" (how similar the existing reach conditions are to potential natural conditions), resiliency to impacts, and sensitivity to impacts taken into account. The Lewis and Clark Sheep Creek Range analysis states that the B-D's interim riparian guidelines allow between 19 and 51 percent total bank alteration (including natural) for inherent stabilities between 70 and 90 percent, and desired management levels between 70 and 90 percent of maximum.

Bengeyfield and Svoboda (1998) described four steps in the process of developing use levels for specific riparian areas on the B-D:

1. Set a Desired Future Condition (DFC) for a riparian area;
2. Choose a sensitivity level (I-III, based on IDT input and consideration of resource values in a watershed);
3. Determine the inherent stability of the stream channel type and vegetative communities present; and
4. Assess parameters important to attaining/maintaining DFC.

Acceptable amounts of streambank alteration were determined via comparison with reference reaches—i.e., streams that appear to be at, or near, DFC, and are relatively unaltered by land use.

Idaho Watersheds Project vs. Owyhee Resources (9th Circuit, 2002): The Court imposed an interim measure proposed by BLM of "Streambank damage attributable to grazing livestock will be less than 10% on a stream segment".

Lewis and Clark NF: 20% bank alteration is recommended as a starting point for developing a set of standards. Type of fisheries is used to vary from the 20% level:

Beneficial Use	Allowable Livestock Disturbance
Westslope CTT (where competing brook trout are also present)	10%
Fish (including streams where Westslope CTT are the only trout present)	20%
Non-fish	30%

These are regardless of similarity and resiliency: different rates of improvement would occur. Long-term trend monitoring is incorporated and adaptive management used to refine these.

Malheur NF: (Draft 5/16/2005) General starting points, to be adjusted as more site-specific information is gathered:

Desired Riparian Objectives: Mean bank stability: >80% (based on Kershner et al., 2004)
End-point indicators: Bank alteration: <5-20% (Cowley 2002, Bengeyfield and Svoboda, 1998)

Region 4 RO Guidance: Following is the text of an e-mail from Rick Hopson, Regional Hydrologist, in response to a request from the Bridger-Teton NF for input on the question of acceptable bank alteration. His response includes input from Cynthia Tait (Regional Aquatic Ecologist) and Rick Forsman (Regional Rangelands Program Lead):

> There is not any one scientifically valid criteria available. However, there is information available to help determine threshold values (see attached example from the BLM). Unless your Forest Plan provides specific direction, we recommend each Forest design criteria which best fit your specific resource conditions and needs. This should be done using an interdisciplinary team. Example - for PIBO streams on BLM lands in Idaho they are using a 10% threshold for streams with T&E listed species, and 20 value for all other streams. This latter 20% value can be adjusted based on site specific conditions. This is only one example and not to be considered direction from the Regional Office. What we do recommend is to use information which best fits your field conditions, determine in an interdisciplinary fashion specific threshold criteria, and document at the appropriate level (NEPA decision, AMP, etc.).

(Note: The referenced "attached example from the BLM" is the Cowley document, Guidelines for Establishing Allowable Levels of Streambank Alteration, dated March 2002).

As can be seen from the above information, there is no standard method for assigning allowable bank alteration. A number of Forests and BLM use PFC as their starting point, relating allowable bank alteration to some combination of similarity, functionality, and sensitivity. Others relate allowable alteration directly by Rosgen type, while the Tonto uses a straight 20%. Values for allowable bank alteration generally vary between 10% and 25%, with some outliers at both ends of the range.

Research summary

Research literature was also reviewed for information on bank alteration and channel stability; a summary of some literature found in a fairly brief search follows.

Overton et al., 1995: Mean inherent stability for "A" channels = 97%, for "B" channels = 87%, for "C" channels =85%. This was in the Salmon River drainage, and geology was described. (cited in C-T GIG)

Geology in the drainage is mostly granitics. Bengeyfield and Hickenbottom (2005) found that there was little variation in particle size distributions among geologies under reference conditions in the Greater Yellowstone area. Granitics and volcanics were in the middle of the range of particle sizes of various geologies under reference conditions. The authors stated, however, that "as disturbance and the possibility of sediment delivery increases, it is likely geology becomes a more important factor in determining the particle size distribution in streams".

Overton et al., 1994: Bank stability and width/depth ratios were recommended as the indicators to be used for assessing habitat conditions in a study stream. Ungrazed banks for stream reaches in granitic geologies from Idaho "C" type channels had a combined mean of 90% stable. An interim DFC of greater than 80% stable was recommended for these streams. Bank stability and width/depth ratios appeared to be correlated.

Cowley, 2002: Overton (pers. comm.) found that over 2/3 of low-gradient meadow type stream reaches in Idaho had streambank stabilities greater than 95%. Four-fifths exceeded 80% stability. Eight percent had bank stabilities less than 50%.

Based on his literature review, "it appears that 70 percent unaltered streambanks (i.e., 30 percent altered streambanks) is the minimum level that would maintain stable conditions. All of [the] authors consider both natural and accelerated alteration in the totals".

Cowley suggested that 80% unaltered streambanks should allow for "making significant progress" toward stream channel improvement, and that this value should be the maximum allowable streambank alteration.

In a personal communication regarding this paper (1/31/08, to Ronna Simon), Tim Burton cautioned against using 10% as a criterion and suggested 15 or 20% as a starting point for bank alteration.

Hockett and Roscoe (1993): Maximum allowable bank disturbance of 10% or less for sensitive streams and 10-25 percent for moderate to low sensitivity streams. (cited in C-T GIG)

Platts, 1981: Past sheep driveway use, especially where meadows had been used for forage and bedding while awaiting shipment, was evaluated for impacts on a stream channel. Significant differences in channel morphology between a fenced area that experienced light grazing and the unfenced, heavily-grazed, meadow were reported. Natural streambank alteration was about the same for both areas (3.5% +/- 1.4 in the lightly grazed area; 5.8% +/-1.4 in the heavily grazed area). Alteration from streambank trampling was 86.1% (+/-4.2) in the heavily used portion of the meadow. The fenced area that experienced light grazing had 5.7% (+/-4.2) bank alteration.

Dallas, 1997: In southwestern Montana, stream channels narrowed and deepened when streambank disturbance from cattle did not exceed 30 feet per 100 feet of stream reach. (cited in Mosley et al., 1997)

Bridger-Teton National Forest

Natural channel characteristics-- Rosgen

It is important, first, to distinguish between natural stream *sensitivity/stability* and induced *bank alteration*: channel stability is a long-term characteristic of a stream while streambank alteration is a short-term impact to a channel that may induce changes in stability. A major question that arises in regard to stability is the following: what level of bank stability can realistically be achieved, given the natural characteristics of the stream? It is also important to think about the ability of the stream to recover from disturbance once there are impacts. This can be related directly back to Rosgen type (Rosgen, 1996). Rosgen types are assigned based on a number of measurable channel attributes (entrenchment, bankfull width/depth ratios, substrate, etc.). In his book, Rosgen provides information on various characteristics of the different stream types: sensitivity to disturbance, recovery potential, sediment supply, streambank erosion potential, and vegetation controlling influence (Table 8-1).

To stratify streams on the Bridger-Teton NF, a table/matrix was made of the first two characteristics – sensitivity to disturbance and recovery potential – with respect to different stream types. These two characteristics are the most important ones in assessing the impact of bank alteration on channel form and function: as stated in Rosgen (1996), "The greatest response in riparian and stream condition would come from placing the highest priority on developing grazing management strategies for those streams that are most sensitive to grazing disturbances and have the highest recovery potential." (p.8-10) The same categories as Rosgen's were used (i.e., sensitivity ranging from Extreme to Low; recovery potential ranging from Excellent to Very Poor) and stream types were assigned their respective place in the table (Table 1):

Table 1: Sensitivity and recovery potential for various stream types

	Recovery Potential	EXC	V.GOOD	GOOD	FAIR	POOR	V.POOR
Sensitivity to disturbance							
V. LOW		A1, A2, B1, B2					
LOW		B3	C1, C2,	G1	F1, F2		
MOD		B4, B5, B6		C3	G2	F3	
HIGH				E3		D6	A6
V. HIGH				C4,C6, E4, E5, E6	C5, F6	D3, D4, D5, F5, G3, G6	A3

EXTREME						F4	A4, A5, G4, G5

Heavy black lines were drawn in Table 1 to separate the various stream types into groups as a starting point for assessment. Those streams that are least sensitive and that have the highest recovery potential are in the upper left portion of the table. The most sensitive streams having the lowest recovery potential are in the lower right corner. The upper right corner contains stream types that are not especially sensitive to disturbance, but that have low potential for recovery once they are disturbed. The lower left corner contains stream types that are very sensitive, but that recover well (the highest priority for development of grazing strategies, according to Rosgen). In this table, moderately sensitive streams are included with the more sensitive streams. This was based on input from several hydrologists, and it makes sense given the data that are available. The position of stream types in the table may be adjusted later, if needed, as more information becomes available.

Streambank erosion potential is also shown in Rosgen's Table 8-1, as mentioned above. These ratings tend to closely follow the ratings for "sensitivity to disturbance", with occasional minor deviations (e.g., B4 streams are considered to have moderate sensitivity to disturbance, and low streambank erosion potential). Sensitivity is a reasonable surrogate for streambank erosion potential.

Field Verification

In summer 2006, Bridger-Teton National Forest staff evaluated a number of streams in grazing allotments to see if Categorical Exclusions were appropriate NEPA tools for reissuance of grazing permits. In evaluating riparian and stream channel conditions, Hydrology personnel measured or collected visual observations of the following parameters on representative reaches of channel:

- Channel and floodplain dimensions
- Stream gradient
- Substrate composition
- Vegetative composition, shrub use, and bank cover
- Streambank stability
- Recent bank shearing (alteration)
- Land use impacts

Streambank stability and bank alteration data were collected based on the Multiple Indicator Monitoring (MIM—Burton et al., 2007) and PACFISH/INFISH and the Biological Opinions (PIBO) protocols. Range specialists were consulted for information on channels and riparian areas before Hydrology crews went to the field; due to time and personnel constraints, priorities for field surveys were based on this information, along with information obtained from topographic maps and air photo interpretations. Survey channel reaches were chosen to be representative of overall channel types and conditions, in adjustable channels (i.e., not in bedrock- or boulder-dominated channel reaches): as much of the channel as could be accessed was walked before choosing a reach for survey. Fencelines and areas of isolated heavy impacts were avoided (although the latter were recorded in field notes where they were deemed important impacts to channel function). Other features that might have contributed to impacts on channel conditions were noted (e.g., roads), and beaver dams were evaluated for their effects on channel conditions. Reaches having beaver dams were generally not measured due to the dams' effects on channel features-- e.g., changes in water surface gradients and channel widths where there were active dams; changes in amount of exposed banks and headcutting where dams had blown out—but effects of livestock use were noted.

For this paper, field data from 2006 and 2007 were examined to see how observed conditions agreed with the information from Rosgen; results are summarized in Table 2. Where detailed channel surveys were conducted, measured channel parameters were compared with reference values and percent alteration was measured. Methods for assessing bank stability had been refined over the course of the field season, and values of "percent stable" are shown for the streams where this value was measured. Verbal descriptions of conditions from these streams (e.g., "good") are an overall impression, based on measured values or observed conditions. Where no formal channel survey was conducted, overall channel conditions were described based on ocular estimates of conditions by Hydrology personnel after having walked as much of the stream as possible. Degree of bank alteration, amount of unstable banks, riparian vegetation condition, and general channel characteristics were used as the basis of the description: detailed descriptions in field notes took the place of in-depth surveys due to time and personnel limitations.

Data gathered on "reference" reaches were also examined. These are reaches of streams that were surveyed in 2002 by a crew that worked throughout the Greater Yellowstone Ecosystem (GYE) They appeared to be at "proper functioning condition" (PFC) and did not have significant management impacts to them. Channel stability was evaluated on the reference streams using the Pfankuch method, which provides a qualitative assessment of channel stability; no channel alteration data were collected. Table 2 summarizes these results as well.

Table 2: Summary of 2006 and 2007 field data, and GYE-wide averages (reference reaches are in gold)

Stream	District	Type	Current Condition/ Bank Stability	% alteration (where measured)
Sheep	3	B3	good	
Sweeney	7	B3c	good to v. good (98% stable)	12
Indian Cr	1	B3 or B4	good	
Devils Hole	1	B3 or B4	fair to good	

NF Elk	1	B3 or B4	fair to good	
W. Fk. Hams Fk	1	B3 or B4	good	
Little Cliff	2	B4c	v. good (87% stable)	6
Willow	7	B4c	Good (80% stable)	33-38
Stewart	3	B4c	40-98% stable (fair overall)	0-4
S. Fk. Little Greys	3	B4	78-82% stable (good overall)	6-10%
Box (reference strm)		B3	poor stab	
Clear (reference strm)		B4a	poor stab	
GYE-wide Average (reference strms)		B3	fair stab	
GYE-wide Average (reference strms)		B4	fair stab	
Greys River (portions)	3	C3	fair to good	
Cliff (lower)	2	C3, C4	fair	
Sheffield (reference strm)		C3b	poor stab	
S.Fk Buffalo Fk (reference strm)		C3	good stab	
GYE-wide Average (reference strms)		C3	good stab	
Hams Fk nr CG	1	C4	good	
Hams Fk nr CG	1	C4	good	
Little Sweetwater	7	C4	fair	
E. Squaw (portions)	7	C4?	good	
Dutch Joe	7	C4c-	Unsure (48-80% stable)	10-34
Clear (reference strm)		C4	good stab	
Slate (reference strm)		C4	fair stab	
GYE-wide Average (reference strms)		C4	good stab	

E.Sweetwater	7	C5	fair to good (82% stable)	17
Irish Canyon	7	C5 or C6	fair to poor	high
Moose (reference strm)		E3a	good stab	
GYE-wide Average (reference strms)		E3	good stab	
Spruce	1	E4	v. good	
Middle Fk Squaw	7	E4	good to fair (85% stable)	22
Spring-fed stream, Patrol Cabin elk feedground	State land	E4	72 – 80% stable (fair)	8 - 20
Tepee (reference strm)		E4	good stab	
Horsetail (reference strm)		E4b	good stab	
Mill (reference strm)		E4b	good stab	
GYE-wide Average (reference strms)		E4	good stab	
GYE-wide Average		E5	ref	fair stab
Muddy	2	Likely F4, F5, or F6	Poor (50-52% stable)	56-80
Clark Draw	2	F4?	fair to poor	

Referencing the field information in Table 2 to the sensitivity and recovery potential information in Table 1 results in the following observations:

B3 and B4 streams: Including the GYE-wide reference streams, there is quite a bit of scatter in conditions, so it is reasonable to move the B4 streams to below the dark line in Table 1. It is not known why the two reference streams from the B-T rated out as "poor"; no information is provided on the field data forms. B3 streams may need to be moved down, but they can be left where they are for now and reassessed when more information is available.

C3 streams: These are quite variable, so it was decided to move the horizontal dark line up in Table 1, which would incorporate more streams in the "intermediate" category (vs.

the category with low sensitivity to disturbance). This was also suggested by Rick Hopson and several of the Greater Yellowstone hydrologists.

<u>C4 streams:</u> These are also somewhat variable, so their position on the table is appropriate.

<u>C5 and C6 streams</u>: Only two of these streams have been found on the Forest thus far, so they will be left in their current position in Table 1. There is only one C5 reference stream in the GYE dataset, and it rated as "good" (it is a spring-fed stream, which acts differently than snowmelt-dominated streams).

<u>E3 streams</u>: There was only one on the B-T, and it was a reference stream (and was not a "pure" E3), so it is left in its current position in Table 1. GYE E3 reference streams were also generally in good condition.

<u>E4 streams:</u> These appear to generally be in good condition, but they are sensitive to disturbance, which is reasonable with respect to their position on Table 1.

<u>E5 streams:</u> No E5 streams have been surveyed to date on the Bridger-Teton NF. GYE surveys averaged out as "fair" for this type so it will remain in its current position.

<u>F streams:</u> These streams definitely all belong in the lower right hand corner of Table 1. They are entrenched, highly sinuous streams that are very dynamic.

Other stream types have not been sampled on the Forest, and other types were not sampled in the GYE-wide reference stream surveys, so their position on Table 1 cannot be assessed at this time.

<u>IMPLEMENTATION</u>

Several people, including Pete Bengeyfield (B-D Hydrologist, retired) and Tim Burton caution against using 10% as a criterion for allowable streambank alteration because it is unrealistically low (Pete). In a recent e-mail, Tim suggested using 15 or 20% as a starting point: this conflicts with information in Ervin Cowley's 2002 paper, but is based on more recent MIM results.

For the above reasons, and based on information described in the "Summary of other guidance" and "Research summary" sections of this paper, the following percentages are the allowable amounts of streambank alteration for the current season of use:

Table 3. Allowable bank alteration by channel type

LOCATION IN TABLE 1	**ALLOWABLE PERCENT BANK ALTERATION**
Upper left corner	25
Upper right and lower left corners	20
Lower right corner	15

Where stream types have not been assigned	20

These amounts of bank alteration—at least initially-- would address physical channel impacts, and using Rosgen as a basis also takes channel sensitivity and recovery potential into account. Values are to be adjusted if field data show that adjustments are needed. Guidance from other Forests seems difficult to implement; the method presented in this paper is a straightforward way to start measuring impacts to channels, to keep management impacts in line with Forest Plan guidance, and to start speaking with permittees about amounts of bank alteration that are acceptable.

Field methods

MIM direction for evaluation of streambank alteration and channel stability will be followed. At the time the initial drafts of this document were prepared, the 2007 version of Burton et al. was in use, but this version has already been superseded by an April 2008 version of MIM. The most recent version should be used.

1. Selection of survey reach:

MIM guidance for selecting sample reaches (called Designated Monitoring Areas, or DMAs) is as follows: (Burton et al., 2007)

> • DMAs represent riparian areas **used** by livestock (or other use). Select the site based on the premise that if proper management occurs on the DMA, the remainder of the riparian areas within a pasture or use area will also be managed within requirements.
> • Select sites that are representative of use, not an average for the stream within the pasture or allotment. For example, if livestock use one-half mile of a stream reach in the pasture and one mile is not used because it is protected by vegetation, rock, debris, or topography, the DMA location should represent the stream reach that livestock actually use.
> • Monitoring sites should have the potential to respond to and demonstrate measurable trends in condition resulting from changes in grazing management. Livestock trails associated with livestock use of the riparian area may be included in the DMA.
> • Avoid selecting sites where vegetation is not a controlling factor, such as cobble, boulder, and bedrock-armored channels.
> • Do not place DMAs in streams over four percent gradient unless they have distinctly developed flood plains and vegetation heavily influences channel stability.
> • Avoid putting DMAs at water gaps or locations intended for livestock concentration, or areas where riparian vegetation and streambank impacts are the result of site specific conditions (such as along fences where livestock grazing use is not representative of the riparian area). These local areas of concentration may be monitored to address highly localized issues, but they should not be considered

as representative of livestock grazing management over the entire riparian area within the grazing unit, and are therefore not generally chosen as DMAs.

DMA selection is meant to occur in an interdisciplinary team setting. If this is not possible, locations of DMAs are to be shared with ID team members who have a vested interest in their selection.

2. Stability and alteration assessments:

Channel stability reflects long-term channel conditions while bank alteration reflects short-term impacts that may lead to long-term changes in stability. The MIM stability assessment protocol includes a procedure for assessing streambank stability that incorporates observations of both bank cover and stability (Burton et al., 2007). The PIBO procedure for assessing streambank stability is identical to the MIM method, except that a sampling frame is not used with PIBO (Kershner et al., 2004). MIM includes a procedure for measuring bank alteration, while PIBO does not, for two reasons: (1) PIBO crews may be onsite before livestock have come onto a given pasture, and (2) PIBO is more interested in long-term channel conditions than annual conditions.

Channel stability

Protocol

1. Evaluation is conducted along the entire study reach, which is approximately 110m in length. Pacing is used to establish sample site spacing within the study reach; figure out the number of paces between observations sites needed to provide at least 40 observation points along each bank to cover the entire reach (observation spacing is 2.75m—this usually requires 4 or 5 steps between observation sites). Avoid fence boundaries where livestock tend to congregate. Begin pacing at the downstream left end of the reach (looking upstream), work upstream along that bank, cross over, and work downstream along the other bank.
2. At each site, determine if the bank is depositional (e.g., point bar on the inside of a channel bend) or erosional.
3. Evaluate stability within a rectangle defined laterally by the width of the measuring frame (50 cm). The lower limit of the rectangle is the scour line, and the upper limit is the elevation defined by the top of the point bar or, on erosional banks, the lowest terrace. The scour line is defined as the elevation of the ceiling of undercut banks or, on depositional banks, the lower limit of sod-forming or perennial vegetation.
4. A "covered" bank is one that has at least 50% of the area within the rectangle covered by any of the following:
    - perennial vegetation
    - cobbles (greater than 6 inches in diameter)
    - anchored large wood (diameter at least 4 inches)
    - a combination of the above.
5. A "stable" bank lacks fractures, slumps, or sloughing within the rectangle. A steep or bare/eroding bank is considered to be unstable, as is a depositional site that is bare of vegetation. If any of the signs of instability are present within the rectangle, the site is considered unstable.

6. Record each observation in one of the following 6 categories. Categories are various combinations of stability and cover, with added categories for "false" banks and unclassified features, following MIM (and PIBO) guidelines:

* Covered, stable
* Covered, unstable
* Uncovered, stable
* Uncovered, unstable
* False bank (past slumped banks, now stabilized)
* Unclassified (side channels, tribs, springs, etc.)

Tally left and right banks separately, keeping track of each observation; a suggested data sheet is provided separately (Excel spreadsheet).

Because channel stability reflects long-term conditions, these assessments would be done approximately every 5 years, on average.

<u>Streambank alteration</u>
According to MIM, impacts must be the obvious result of current season use and are considered streambank alteration when:

• Streambanks are covered with vegetation and have hoof prints that expose at least 12 mm (about ½ inch) of bare soil (include both the depression and soil pushed up as a direct result of hoof action);
• Streambanks exhibit broken vegetation cover resulting from large herbivores walking along the streambank and have a hoof print at least 12 mm (½ inch) deep. Measure the total depression from the top of the displaced soil to the bottom of the hoof impression; and/or
• Streambanks have compacted soil caused by large herbivores repeatedly walking over the same area even though the animal's hoofs sink into and/or displace the soil less than 12 mm (½ inch). Animal trails are included; roads are NOT included.

Protocol

1. Observations are made at each of the observation points described under #1, under the channel stability protocol.
2. Place the centerline of the sampling frame beginning at the toe of the boot, along the ***greenline.*** Evaluate the presence of streambank alteration within the entire 42 x 50 cm plot of the sampling frame. Determine the number of lines on the frame (zero to 5) that intersect areas of streambank alteration within the plot (if there are multiple shears along a given line, count them as one intersection). The first and last lines are the inside of the sampling frame bars. Record the number (0 to 5): a suggested format for a datasheet is available, separately (Excel spreadsheet).

3. When the greenline is on the top of a high steep bank, record shearing on the face of the bank and trampling within the frame along the edge of the stream. Do NOT count trampling on the top of a high terrace above the active floodplain that is upslope from the greenline.
4. When the greenline is more than about 6m or 20 feet away from the stream channel or terrace wall, streambank alteration is read along the edge of the terrace wall or along the top of the streambank. If there is not a visible terrace, alteration is read 6m from the water's edge.

Channel alteration should be evaluated annually, if possible, when it is deemed near time to move livestock. It may also be advisable to evaluate alteration before livestock come onto a pasture if wildlife use (or another type of use) is high, or if there is a desire to evaluate changes over the grazing season.

For streambank alteration, the **greenline** is to be used instead of bankfull level as an index of impacts, even though it is not a good indicator of true channel function: bankfull should be used to assess stream channels. Greenline, however, is easier to identify than bankfull and, as a result, measurements are more easily replicated; this is the reason that greenline is used in MIM. Bankfull-based measurements will be used for long-term monitoring by Hydrology crews to evaluate channel conditions.

Channel morphology surveys, pebble counts, channel typing:
This will be done by Hydrology personnel. Relevant work will include assessment of bankfull channel dimensions and gathering of other channel information that will allow for assessment of long-term channel conditions and trends (in addition to channel stability, although this information may also be gathered).

CONCLUSION

This document provides a method for measuring streambank alteration and channel stability on streams in the Bridger-Teton National Forest. It also provides implementation direction for determining if alteration is exceeding amounts that allow for maintenance, or reestablishment, of channel stability. To be an effective tool, these assessments will need to be conducted at the appropriate time on grazing allotments. The question of who conducts the assessments needs to be discussed among Forest staff and personnel, and it may vary across the Forest. This method is also useful for evaluating the impacts of other Forest activities on stream channels, and should be used as a tool for this purpose.

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The Camas Creek Watershed:
It's Native Fish Populations, Aquatic Habitats, Landscape Processes, Scientific Values, Human Activities, and Limiting Factors & Threats

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INTRODUCTION

This report attempts to synthesize existing knowledge of the Camas Creek watershed. Camas Creek flows within the Middle Fork Salmon River basin (MFSR) in central Idaho. First, the importance of Camas Creek within the context of the overall Columbia River basin is addressed. Next, a brief history of anthropogenic activities within the Camas Creek watershed is provided. This is followed by a description of Camas Creek's aquatic resources (with a focus on native fishes), and its aquatic habitats. A chronology of aquatic research and a description of key research findings are then described. The next section summarizes the most recent Chinook salmon Status and Recovery planning documents prepared by the NOAA Fisheries. Finally, factors limiting the productivity and persistence of natal habitats and fishes are discussed with recommendations for future conservation and restoration actions.

CONTEXT

From 1994 to 1997 the Aquatic Science and Science Integration Teams for the Interior Columbia River basin Ecosystem Management Project (ICBEMP) were charged with developing an assessment of the distribution, status, and ecology of native fishes in the Interior Columbia River basin and portions of the Klamath River and Great basins (CRB), an area encompassing 58.3 million ha and portions of six western states. In 1997, the native fish assessment represented the most comprehensive and spatially explicit evaluation ever attempted in the Intermountain and Pacific Northwest.

As reported in Lee et al. (1997) and subsequent publications (Thurow et al. 1997; Rieman et al. 2007; Thurow et al. 2000); throughout most of the CRB, the distribution and status of native salmon and trout had declined; in some cases dramatically. Chinook salmon (*Oncorhynchus tshawytscha*), for example, had been extirpated from more than 70% of their historical range and steelhead (*Oncorhynchus mykiss)* from more than 50% of their historical range. In 1997, the number of subwatersheds (6^{th} code hydrologic units) supporting six or more native salmonid taxa was about 25% of the potential historical distribution and the number of subwatersheds supporting two or more native salmonid taxa was about 50% of the potential historical distribution. We concluded that many systems were remnants of what were once larger, more complex and diverse, connected systems.

Despite these widespread declines, we also confirmed that key areas remain for maintaining and restoring the biological diversity associated with historical aquatic communities. The Salmon River drainage in central Idaho, including Camas Creek and the MFSR basin, represent the core of one of these key areas. Ancestors of the Northern Shoshone and Nez Perce occupied the Salmon River drainage for more than 10,000 years. Shoshoni descendants called the river Agaimpaa (Big Fish Water) and Nez Perce descendants named it Natosoh Koos (Chinook-Salmon-Water) (Thurow et al. 2000). Members of the Lewis and Clark expedition were the first non-natives to record the abundant salmon runs and by 1810, maps of the drainage labelled it the Salmon River.

Within the CRB today, the Salmon River basin represents one of 3 large networks of contiguous and clustered subwatersheds supporting key habitats for native salmon and trout (Lee et al. 1997). Salmon River basin key habitats, including Camas Creek, are disproportionately important for anadromous fish and trout. Central Idaho contains 30% of the subwatersheds in the potential historical range of spring/summer Chinook salmon and supports 48% of the subwatersheds currently occupied by Chinook salmon. Similarly, central Idaho contains 27% of the subwatersheds in the potential historical range of steelhead and supports 40% of the subwatersheds currently occupied by steelhead. Central Idaho is also critical for native trout; the Salmon River contains 26% of the subwatersheds in the potential historical range of bull trout (*Salvelinus confluentus*), and supports 53% of the subwatersheds currently occupied by strong populations of bull trout. Similarly, central Idaho contains 30% of the subwatersheds in the potential historical range of westslope cutthroat trout (*Oncorhynchus clarki lewisi*) and supports 40% of the subwatersheds currently occupied by strong populations of westslope cutthroat trout.

The central Idaho Mountains also provide a stronghold for wild, genetically intact stocks of salmon and trout. Wild, indigenous, stream-type Chinook salmon and summer steelhead populations like those in Camas Creek and the MFSR are rare; Thurow et al. (2000) reported their presence in 4% and 10% of the potential historical range, respectively, and 15% and 22% of the current range, respectively, in the CRB. Most other wild populations in the CRB were either extirpated or have been supplemented with hatchery-reared fish. MFSR Chinook salmon are especially unique because they spawn at the highest elevations of any spring/summer Chinook salmon population in the world (Crozier et al. 2008).

The MFSR drainage, including Camas Creek, represents the core of the Central Idaho key habitat. Most of the MFSR drainage has been relatively undisturbed by anthropogenic activities so habitat quality is good to excellent. Its protected status also enables natural processes to function relatively unimpeded across this extensive wilderness landscape. As a result, natural processes such as fires, floods, debris flows, and snow avalanches recruit wood and sediments to streams. These processes create and maintain a dynamic mosaic of landscape conditions which support diverse, high quality, and connected habitats. These habitats provide a physical template essential to the expression of native species life history and genetic diversity. The MFSR basin, including Camas Creek, contains some of the highest quality, most diverse, and most functional natal, wild salmon, steelhead, and trout habitats in the entire Columbia River basin. Although past land use degraded habitat in isolated areas, since wilderness designation, many past perturbations have been eliminated. With additional land-use constraints to protect species listed under the Endangered Species Act (ESA), many other degraded habitats are recovering. Nevertheless, anthropogenic activities continue to degrade some watersheds, including Camas Creek.

As a result of its large size, functioning natural processes, and the diverse, high quality, connected habitats they create, a nearly complete native species assemblage persists in the MFSR; only grizzly bears and indigenous people are absent (Thurow 2015). The Salmon River basin represents a large block of critical habitat with opportunities to maintain existing native salmon, trout, and other aquatic species and to rebuild a larger network of complex and connected habitats. The large wilderness and roadless portions of the central Idaho Mountains (72% of the subwatersheds), retain the potential to maintain natural landscape processes and serve as refugia for native aquatic species. The high diversity of native salmon and trout taxa and the fact that populations are genetically intact suggest that the core for maintaining and restoring biological diversity still exists in these watersheds. Achieving a larger goal of rehabilitating the integrity of entire aquatic ecosystems will require the rehabilitation of a network of well-connected, high-quality habitats that support diverse native species, the full expression of life histories and dispersal mechanisms, and the genetic diversity necessary for long term persistence in a variable environment. The Salmon River basin, including Camas Creek, represents one of few areas where such efforts are feasible.

STUDY AREA

Camas Creek is a major tributary to the eastern edge of the MFSR and flows through the heart of the above-referenced key, core habitat in the Salmon River basin. Camas Creek drains approximately 1,036 km^2; the lower 13 km and its headwater reaches are within the Frank Church River of No Return Wilderness.

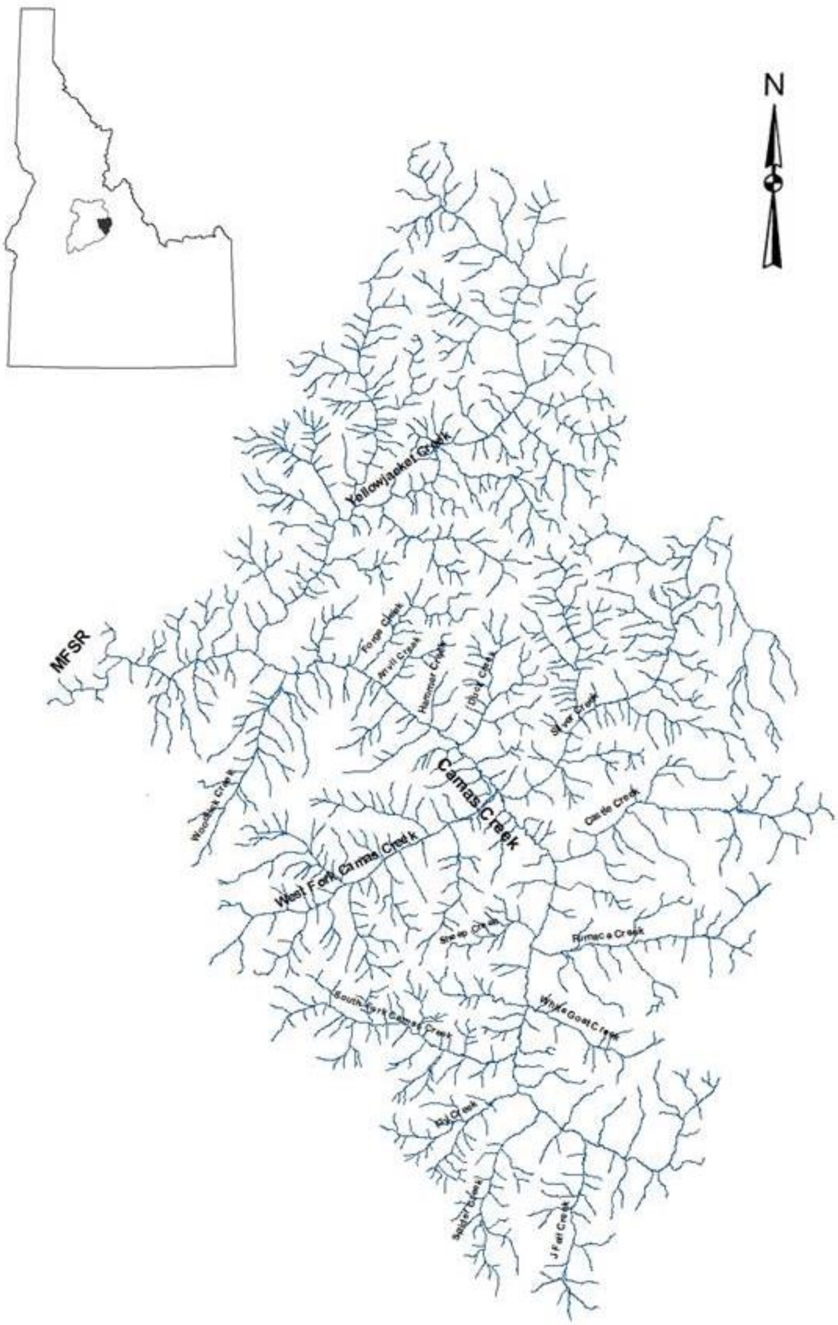

Figure 1. The Camas Creek watershed in the Middle Fork Salmon River basin, Idaho.

OVERVIEW of CAMAS CREEK RESOURCES

The MFSR drainage, including Camas Creek, supports 15 native fishes, including seven salmonid forms: westslope cutthroat trout, bull trout, mountain whitefish (*Prosopium williamsoni*), redband trout, which include both resident and anadromous (summer steelhead) stocks, and spring and summer Chinook salmon (Thurow, 1985). Many redband trout less than 230 mm (9 in) are actually juvenile steelhead that will migrate to the ocean after physiologically transforming to a smolt. Healey (1991) categorized juvenile Chinook salmon that migrate seaward after one or more years as stream-type. MFSR stream-type Chinook salmon include both spring- and summer-run fish (Fulton, 1968; Gebhards, 1959; IDFG, 1992; Parkhurst, 1950). Spring Chinook salmon cross Bonneville Dam on the Columbia River from March to May, summers from June to July, and falls from August to September (Burner, 1951; Matthews and Waples, 1991). Other native fishes include Pacific lamprey (*Lampetra tridentatus)*; three sculpin species; torrent (*Cottus rhotheus*), mottled (*C. bairdi*), and shorthead (*C. confusus*); speckled (*Rhinichthys osculus*) and longnose (*R. cataractae*) dace; largescale (*Catostomus macrocheilus*) and bridgelip (*C. columbianus*) suckers; redside shiner (*Richardsonius balteatus*); and northern pikeminnow (*Ptychocheilus oregonensis* (Thurow, 1985). The latter four species are predominately found in the mainstem MFSR and the lower portions of larger, lower elevation tributaries. Introduced fishes are uncommon in the MFSR and most tributaries. Only brook trout (*Salvelinus fontinalis*) are locally abundant in a few streams and they tend to be patchily distributed (Gamett and Bartell, 2011), primarily in road-accessible, meadow streams. Gamett and Bartell (2011) did not detect brook trout in any of the sites they sampled in Camas Creek from 2002-2008.

Camas Creek supports three species of fish that are federally listed as Threatened or Endangered under ESA: spring/summer Chinook salmon, summer steelhead, and bull trout. Camas Creek also supports three recently Federally de-listed species (peregrine falcon, bald eagle, and gray wolf). A host of USDA Forest Service Regions 1,4-Sensitive Species (Pacific lamprey; westslope cutthroat trout; inland redband trout; Columbia spotted frog; black-backed and American three-toed woodpeckers; boreal, flammulated, and great gray owls; spotted and Townsends big-eared bats and fringed myotis; harlequin duck; northern goshawk; and several sensitive native plants) occupy the MFSR basin (Thurow 2015) and most are likely present within the Camas Creek watershed.

ANTHROPOGENIC ACTIVITIES

Native Americans inhabited Camas Creek and other portions of the MFSR and utilized its fisheries resources for at least 10,000 years (Knudson et al. 1982). Mountain Shoshoni (Sheepeaters) were the principal inhabitants and they shared fishing grounds and traded with neighboring Flathead and Nez Perce tribes (Liljeblad 1957; as cited in Smith 1973). The Mountain Shoshoni lived in some of the best fishing areas of Idaho and it was their habit to construct weirs and dams to catch the salmon (Smith 1973). They were considered the most skilled hunters on foot of all Idaho native people, using excellent bows of laminated horn of bighorn sheep, light snowshoes in winter, and dogs trained for the chase (Liljeblad 1957). Numerous archeological sites within Camas Creek, including pictograph panels and campsites, confirm the use of the watershed by indigenous people.

Similar to other parts of Idaho, the first non-natives to arrive in the Camas Creek watershed were likely explorers searching for fur trapping areas. They were soon followed by fur trappers and miners. In 1869, gold was discovered in quartz deposits near Yellowjacket Creek (Mitchell 1997). In 1879, the murder of Chinese on nearby Loon Creek precipitated the Bannock War, despite evidence suggesting white miners were guilty (Carrey and Conley 1977). During the war, Captain Bernard scouted northeast as far as Meyers Cove on Camas Creek (Smith 1973). In 1882 a stamp mill operated via a water wheel was constructed on Yellowjacket Creek and the water wheel was powered by water stored behind a 2 m dam near Trail Creek (Mitchell 1997). In 1893, the dam height was increased to 4 m and a spillway was installed to carry ice off the pond (Mitchell 1997). These dams likely blocked anadromous fish access to spawning areas upstream from Trail Creek. Mitchell (1997) reported that from 1910-1969, nearly 12,400 tons of ore, tailings, and gravels were processed to find 223.8 pounds of gold; about .28 ounces of gold per ton of material. Farmers, stockmen and businessmen soon followed the miners and the towns of Salmon and Challis were founded in 1866 (Smith 1973) and 1878, respectively.

Smith (1973) reported a road constructed to the Yellowjacket mine in 1928 and another down Silver Creek to Meyers Cove before 1930. In 1942 fluorspar deposits were discovered near Duck Creek, and as part of the wartime fluorspar investigations by the US Geological Survey, Cox (1954) mapped and studied the deposits in 1943 and 1944. In 1943 the USFS built a graded road from Meyers Cove to Fluorspar Gulch and in 1943-1944 Chamac Mines Company extended the road an additional 3 km down Camas Creek (Cox (1954).

Pack trails on Camas Creek have been used for decades (Carrey and Conley 1977) and in 1950 and 1953, new pack bridges were built at the mouth of Yellowjacket Creek and the mouth of Camas Creek, respectively (Smith 1973).

From 1930-1980, remote areas of Camas Creek were managed in “Primitive Area” status (USFS 1998). In 1980, the Central Idaho Wilderness Act established the 906,136 hectare wilderness that remains the largest contiguous wilderness in the lower 48 states and the largest in the National Forest system. In 1984, the current name was adopted in honor of the late Senator Frank Church’s efforts to secure wilderness designation (Thurow 2000).

Approximately 418 km of perennial streams drain the Camas Creek watershed, with 402 km administered by the USFS Salmon-Challis National Forest and the remaining 16 km on private lands (SR 2014). Private lands occur on Silver, Duck, and Castle creeks, upstream from Hammer Creek, and near White Goat Creek.

CHRONOLOGY of AQUATIC RESEARCH

Most of the Camas Creek watershed is relatively intact, with functioning natural processes that are relatively unimpeded by humans. As a result, Camas Creek contains high quality, diverse and connected aquatic habitats which support the diversity of fauna described above. These qualities provide a reference-condition river-floodplain ecosystem with native fauna that jointly present excellent opportunities for research.

Below is an incomplete list of past and current aquatic research in the Camas Creek watershed. In addition to the work described below, Idaho Department of Fish and Game (IDFG) and USDA Forest Service (USFS) Salmon-Challis National Forest biologists have surveyed Camas Creek for decades and additional data are located in agency files. For example, Gamett and Bartel (2011) described results of aquatic surveys in more than 20 sites in the Camas Creek drainage.

1.) In 1951, IDFG began surveying Chinook salmon redds and monitoring salmon angler harvest in Camas Creek and other MFSR tributaries. Hauck (1953a, 1954) reported that more than 32 km of Camas Creek were surveyed with fixed-wing aircraft (a Stinson 140) and aerial counts in some reaches were compared to ground-based counts from 1951-1954. A creel census was conducted to estimate angler effort and harvest (Hauck 1953b, 1954).

2.) In 1957, IDFG began consistently, annually counting Chinook salmon redds in index reaches of Camas Creek and other key MFSR tributaries (Hassemer 1993). Index reaches were selected based on concentrations of spawning Chinook salmon and redds were counted during "peak" spawning time periods. Two index reaches were selected and surveyed in Camas Creek: a.) Hammer Creek to Castle Creek and, b.) Castle Creek to South Fork Camas Creek. Initial counts were via fixed wing aircraft with ground-based counts applied for many years thereafter. These counts continue today and represent an invaluable 58 year database.

3.) In 1959, Mallet (1960) began a multi-year research project to investigate the life history and migrations of fluvial westslope cutthroat trout in Camas Creek, other MFSR tributaries, and the mainstem MFSR and Salmon River.

4.) In 1968, Corley (1969) evaluated the spring steelhead harvest at four locations in the MFSR drainage by conducting anger counts and completing a creel census.

5.) In 1981 IDFG biologists conducted an intensive investigation of steelhead and other native fishes within the MFSR basin, including Camas Creek (Thurow 1982). From 1981-1983, we surveyed and mapped the location of spawning steelhead, counted adults, and collected biological data on fish captured or observed (Thurow 1983). We established and snorkeled transects in lower, middle, and upper reaches of Camas and Yellowjacket creeks. To assess adult steelhead movements, we captured, tagged, and released adult steelhead. We conducted a creel census in the mainstem Salmon River to assess harvest of MFSR steelhead.

6.) The 1980's snorkel surveys led to expanded efforts by IDFG to estimate the distribution and abundance of wild Chinook salmon and steelhead parr and other salmonids in tributaries to the Salmon River. Kennedy et al. (2013) reported that current methods for monitoring Chinook salmon and steelhead trout parr were originally developed by Petrosky and Holubetz (1986) and this effort developed into the General Parr Monitoring program (GPM; Scully et al. 1990) that continues today.

7.) Since 1995, USFS- Rocky Mountain Research Station (RMRS) biologists have annually completed a continuous survey of all potential Chinook salmon spawning areas in Camas Creek and the entire MFSR basin (Thurow 2000). We have annually surveyed the entire Camas Creek drainage and georeferenced the location of all Chinook salmon redds. The primary method for counting redds has been low-level helicopter flights and we have supplemented aerial surveys with ground-based redd surveys in areas including the West Fork Camas Creek. In order to conduct a complete redd count, we wait until the end (not peak) of spawning in Sept to do the surveys. Twenty consecutive years of data have been collected to date and the goal is to continue these surveys for at least another decade.

8.) Also since 1995, we have georeferenced the location of all bull trout redds and mature adult bull trout staging areas incidentally observed in Camas Creek and other MFSR tributaries during salmon surveys.

9.) Redd counts are commonly used to monitor annual trends in Chinook salmon populations where total adult escapements are unknown. Despite the widespread use of redd counts to calculate measures of population performance, little is known regarding the accuracy of salmon redd counts or the factors that decrease precision and introduce bias. In 2000 we initiated new research to examine the probability of detecting Chinook salmon redds and the factors that influence accuracy and precision of redd counts. Our research addressed five objectives: 1) to census redds and develop an unbiased estimate of the true number of Chinook salmon redds within study reaches; 2) to use the redd census as a baseline for estimating the accuracy of aerial and ground based redd counts; 3) to evaluate the effectiveness of a mark-resight approach for measuring the accuracy and precision of Chinook salmon redd counts; 4) to quantify sources of error in ground based Chinook salmon redd counts; and 5) to evaluate the influence of environmental and habitat characteristics on sightability of Chinook salmon redds (Thurow and McGrath 2010). We surveyed reaches of six major MFSR tributaries, including two extensive reaches in Camas Creek. From 2002-2005 trained observers surveyed the reaches every 4-5 days in order to develop an unbiased estimate of the "true" number of redds in each reach. During these intensive surveys, we also collected data to assess the specific timing of staging and spawning by adult salmon and bull trout. After salmon spawning was completed, we measured a series of reach- and redd- based physical characteristics.

10.) During the temporally intensive ground-based redd surveys described in #9 above, we simultaneously collected tissue samples and data from Chinook salmon carcasses we encountered. These samples and the subsequent analyses have been used to describe a variety of the characteristics of the Camas Creek salmon run, including age, size, sex ratio, and genetic structure. Specifically, we collected dorsal fin ray sections for aging by IDFG biologists; otoliths for assessing origin, life history type and dispersal; and fin tissue for genetic analysis. We continue to work with collaborators from IDFG and the Nez Perce and Shoshone-Bannock tribes to annually collect all three types of tissue samples. All dorsal fin ray sections and genetic samples are delivered to the IDFG Eagle laboratory for archiving and storage. All otoliths are archived in the RMRS database and stored in a secure location. More than 4,000 otoliths have been collected between 1997 and 2014 from Camas Creek and four other major MFSR tributaries and the mainstem MFSR.

11.) RMRs fluvial geomorphologist John Buffington is leading research to understand geomorphic controls on the spatial distribution, routing, and quality of Chinook salmon spawning habitat in Camas Creek and other mountain catchments, and to predict how spawning habitat changes over space and time in response to basin disturbances (e.g., fire, debris flows, flooding). Three approaches are being used for modeling geomorphic controls on spawning habitat: a.) correlation of the observed location and quality of spawning sites with landscape features (geology, channel gradient and confinement, land use, etc.); b.) mechanistic prediction of the abundance and spatial distribution of spawning gravels as a function of channel type and associated hydraulics; and c.) development of a dynamic model for routing sediment through the river network as a function of basin hydrology and stochastic sediment inputs (floods, debris flows), allowing investigation of the spatial and temporal changes in spawning habitat availability.

12.) Dynamic landscapes are shaped by a variety of natural processes and disturbances operating across multiple temporal and spatial scales. Persistence of species in these dynamic environments is also a matter of scale: how do species dispersal and reproductive rates merge with the scales of disturbance? Across the Pacific Northwest, salmon populations have evolved with a complex set of natural disturbance patterns and processes creating and altering their essential habitats. In most watersheds, human activities have changed the disturbance regimes and compromised our ability to examine both the natural processes and salmon population responses. In contrast, the MFSR is a large wilderness basin where natural processes function relatively unimpeded by human activities. Recently, RMRS scientists have been applying redd distribution data to evaluate wild Chinook salmon responses to natural disturbance processes (fires, storms, debris flows, avalanches) in the MFSR.

13.) In 2006 and 2007, Idaho State University (ISU) scientists led by Colden Baxter investigated how stream geomorphology influences the structure and function of aquatic ecosystems. The researchers compared allochthonous inputs, aquatic primary producer and invertebrate production, stream retentive capacity, and aquatic invertebrate community composition in two types of stream channels. Five confined river segments were compared to five paired floodplain segments. River segments of both types were selected in Camas Creek which the researchers considered a stream relatively intact, reference-condition river-floodplain ecosystem that presented an excellent opportunity to evaluate ecosystem structure and community function in floodplain and confined river segments.

14.) In conjunction with the research described in #13 above, ISU scientists applied data collected in Camas Creek's reference-condition river-floodplain segments and other Salmon River basin streams to evaluate the impact of dredging on food resources for fishes in the Yankee Fork Salmon River. Segments were compared in terms of: a.) allochthonous inputs of organic matter and invertebrates, b.) the biomass of aquatic primary producers, and c.) the biomass and production of aquatic invertebrates.

KEY FINDINGS

Camas Creek provides essential habitats for each of the six sensitive native fishes described above (Chinook salmon; steelhead; Pacific lamprey; bull, cutthroat, and redband trout) during their complex life cycles. All life stages including: incubating eggs, hatched alevins or lamprey ammocetes, emergent fry, rearing juveniles, migrating juveniles, overwintering juveniles and adults, migrating adults, pre-spawn staging adults, spawning adults, and post-spawn migrating and rearing adults depend on critical Camas Creek habitats. Each of these species migrates extensively within and to and from critical habitats within the Camas Creek drainage. For example, anadromous Chinook salmon, steelhead, and Pacific lamprey mature in the ocean and migrate more than 1,100 km to rest in staging habitats prior to spawning in Camas Creek gravels. Non-anadromous adult bull, cutthroat, and interior redband trout persist as both resident and fluvial migratory forms. Fluvial forms may migrate more than 150 km from the mainstem Salmon River to access suitable spawning habitats in Camas Creek. Young-of-the-year salmonid fry or lamprey ammocetes emerge from redds and reside in Camas Creek or the MFSR for varying lengths of time (months to years) while feeding and growing. Some may migrate downstream immediately as newly emerged progeny, while others may rear in reaches of Camas Creek for multiple years before migrating as juveniles to downstream reaches of Camas Creek, the MFSR, and the mainstem Salmon River. These species also migrate extensively in the fall as water temperatures decline and they seek optimal overwintering habitats at lower elevations.

Camas Creek also supports a diversity of within-species life history strategies. Chinook salmon that migrate earliest and spawn earliest in upper portions of the basin are considered spring run, while later spawners in lower elevation reaches are classified as summer run.

Project-Specific Results

1.) *Chinook salmon abundance & sport fishery*- Historical Chinook salmon runs were immense and Camas Creek formerly supported a substantial Chinook salmon sport fishery. An estimated 2-6 million adult Chinook salmon returned annually to the Snake River basin (NPPC 1986). By the early 1880s, these numbers had been reduced to ~1.5 million returning adults (Bevan et al. 1994). By the 1950s, the Chinook salmon harvest in the Columbia River was less than ¼ of the 1880's levels (Williams 2006). In 1952, Hauck (1953b) reported an estimated sport catch of 411 salmon in Camas Creek.

Salmon and steelhead populations plummeted as the Northwest was developed and by 1995, less than 1,200 wild Chinook salmon returned to the Snake River basin (US vs Oregon TAC, 2008). Federal fisheries management agencies identified "four H's" (habitat degradation, harvest, hatchery practices, and hydrosystem operation) as the primary causes of anadromous fish declines (NMFS 2000). By the early 1990s, all wild Snake River Chinook salmon and steelhead populations were federally listed under the ESA. Despite abundant, high quality natal habitat; absence of hatchery fish; and low ocean harvest rates verified by tag returns, Camas Creek and MFSR Chinook salmon and steelhead remain at risk of extirpation, primarily as a result of outside basin factors in the Columbia and Snake river migration corridors, estuary, and ocean. Today, all anadromous fish in the Salmon River basin must navigate eight dams (four in the Columbia River and four in the lower Snake River) to reach the ocean as smolts and then ascend those same eight dams as adults returning to spawn to MFSR natal habitats. Raymond (1979) documented the adverse effects of these dams and impoundments on salmon and steelhead survival. Salmon are a keystone species (Willson and Halupka, 1995) that provide ocean-derived nutrients to aquatic and terrestrial ecosystems. The severe declines in anadromous fish within the Columbia River basin (current wild populations are about 2% of historical numbers; Williams 2006) have reduced the productivity and adversely affected the functioning of the entire MFSR ecosystem. As a result of these severe salmon population declines, there has been no legal sport fishery or harvest of Chinook salmon in the MFSR or its tributaries since 1978; all salmon must be immediately released unharmed if accidentally hooked.

2.) Chinook s*almon population monitoring*- Early aerial redd surveys provided an index and began to assess trends in salmon abundances. Those counts did not represent a complete redd count for several reasons: a.) redds were counted in index reaches so some areas were not surveyed, b.) redds were counted during a "peak" spawning period so earlier redds may have been obscured and later redds would not have been observed, and c.) prior to the start ground-based surveys, counts were completed via fixed-wing aircraft; either a Cessna 182 or Piper 18, which often made redd observation challenging. As Richards and Gebhards (1959) observed, flights were at altitudes of 60-120 m at speeds of 31-57 knots. The authors noted that the 1958 Camas Creek survey was "made in the morning to take advantage of stable air conditions" and they reported, "light conditions in the canyon were poor at times because of dark shadows and some redds may have been missed." To enhance visibility, current RMRS aerial surveys are completed with a helicopter capable of flying much lower (20 m) and slower (10-15 knots) (Thurow 2000).

Despite the sometimes challenging survey methods, these early redd counts and the 58 year time trend they initiated are invaluable for estimating past salmon abundances and for assessing population trends. Within Camas Creek, the peak recorded count was 279 redds in the early 1960s (Hassemer 1993). Based on current continuous sampling and the ratio of redds in counted and uncounted areas, if all areas had been counted in the 1960's, there were likely more than 350 redds in the basin. During the 1950s and 1960s, harvest rates of salmon in the ocean fishery coupled with sport and commercial rates in the Columbia River and tributaries exceeded 50% (Schaller & Petrosky 2007). As a result, the potential number of Chinook salmon redds in

Camas Creek in the early 1960s would have exceeded 700 redds. During years of optimal smolt out-migration and ocean survival and growth, there could have been several times that abundance of redds. To place historical abundances in context, as described above, the annual number of redds in the 1880s may have been 4X the number in the early 1960s. Anecdotal accounts of the "salmon being so thick you could cross the river on their backs" or the salmon "so plentiful our horses would not cross the stream" were observed during those historical periods of immense abundances.

3.) *Westslope cutthroat ecology*- Mallet (1960) used tag recoveries to document the migratory nature of westslope cutthroat that spend about 2 years in tributaries before migrating (often more than 150 km) to overwintering habitats in the lower MFSR and Salmon River. Mallet's seminal work was followed by Ortmann (1971), Ball and Jeppson (1980) and a succession of other biologists who continue to assess the status of native westslope cutthroat trout. More recently, Zurstadt and Stephens (2004) used radio telemetry to track movements of 30 adult westslope cutthroat trout that were collected in Bear Valley Creek. The authors reported that by 22 February, tagged fished were distributed over more than 150 km of habitat, from Bear Valley Creek to the Salmon River. Return upstream movements began in March as water temperature and discharge increased and peaked in May. The longest total and downstream movements were 475 km and 194 km, respectively (Zurstadt and Stephens 2004). Their results illustrate that, when not constrained by barriers, westslope cutthroat trout migrate long distances and exhibit plasticity in seasonal habitat use.

4.) *Steelhead sport fishery*- Corley (1969) estimated that 102 steelhead were harvested in 110 angler days during the spring 1968 MFSR steelhead fishery. Surveys were incomplete and concentrated in just four areas: Dagger Falls, Middle Fork Lodge, the Flying B Ranch, and Big Creek. During this era, anglers also fished for steelhead in Camas Creek, other MFSR tributaries, and other portions of the MFSR. Corley observed high catch rates and low angler abundance as a result of limited road access. MFSR catch rates were nearly double catch rates observed in the main Salmon River. Corley also noted that the steelhead harvest should be expected to fluctuate by 2-3X as a result of run size, water and weather conditions, and anger effort. The 1968 fishery was described as having a small run, average water conditions, poor weather conditions, and light angler effort.

5.) *Steelhead abundance, native salmonid surveys, and special angling regulations*- Historically, the MFSR supported substantial steelhead runs which were estimated to annually exceed 10,000 adults (Thurow 1982). Steelhead returns diminished from ~5,000 in 1970-71 to 500 or less in 1975-76 (Jeppson and Ball 1979). The sport fishery was closed in 1974 and remains closed today. Thurow (1982; 1983) surveyed steelhead and other native fishes in Camas Creek and other MFSR drainages and observed adult steelhead and redds in Camas Creek between Hammer and White Goat creeks. He reported low spawner abundances and abundant, high quality habitat. Observations confirmed that steelhead spawned in Camas Creek from late March through the first week in June. Depending on elevation, flows, and temperatures, steelhead alevins might remain in the gravel into August.

In 1981 steelhead parr densities averaged $7.3/100m^2$, $5.2/100m^2$, and $0.6/100m^2$ in middle, lower, and upper Camas Creek reaches, respectively (Thurow 1982). Mountain whitefish were the next most abundant game fish followed by Chinook salmon parr, westslope cutthroat trout, and bull trout. In 1982 steelhead parr densities in middle Camas Creek averaged 9.5/100m^2 and Chinook salmon parr densities averaged 4.0/100m^2 (Thurow 1983). Also in 1982, Thurow (1983) assessed genetic characteristics of MFSR steelhead and reported local isolation of steelhead populations within the basin. In 1983, steelhead parr densities in middle Camas Creek averaged 7.5/100m^2 and Chinook salmon parr densities averaged 3.1/100m^2 (Thurow 1985). Steelhead parr densities in lower Yellowjacket Creek averaged 9.9/100m^2.

Thurow (1982; 1983; 1985) also surveyed anglers in the mainstem Salmon River. He estimated that a significant number of wild MFSR steelhead were being harvested and collected data on dorsal fin heights of wild and hatchery fish. His data suggested wild fish could be identified based on dorsal fin height and he recommended release of all wild steelhead and liberal harvest of hatchery steelhead. In the fall of 1983, a mandatory wild steelhead release regulation was initiated which continues today (Thurow 1985). Since 1984, the adipose fin of all hatchery steelhead has been removed to differentiate them from wild fish (Thurow 1985). Results of the 1980's IDFG steelhead research were also published in Howell et al. (1985).

6.) *Salmonid rearing densities*- During annual IDFG parr monitoring efforts, 27 extensive panel survey transects were sampled in Camas Creek in 2012 (Table 17, Kennedy et al. 2013). Six species of salmonids were identified (juvenile steelhead, Chinook salmon, westslope cutthroat trout, brook trout, bull trout, and mountain whitefish), and unidentified trout fry were observed. Juvenile steelhead were the most abundant species observed, with a mean density of 5.60 fish/100 m^2, and an occupancy rate of 74%. The highest observed density of juvenile steelhead was in Castle Creek with 20.18 fish/100 m^2. Bull trout were the second most abundant salmonid in the Camas Creek drainage, with a mean density of 1.27 fish/100 m^2. Bull trout were observed in 19 of the 27 (70%) transects surveyed. Mean densities of westslope cutthroat trout and mountain whitefish were 0.36 fish/100 m^2 and 0.41 fish/100 m^2, respectively. Chinook salmon parr were only observed in two transects, with an overall mean density of 0.01 fish/100 m^2 in the Camas Creek drainage. Declines in Chinook salmon parr densities (from 4.0 parr per 100m^2 in 1982) further illustrate salmon declines.

7.) *Structure and dynamics of Chinook salmon*- For the past 20 years (1995-2014), RMRS has conducted annual helicopter-supported surveys to census and georeference the distribution of Chinook salmon redds in 800 km of the mainstem MFSR and 12 major tributaries, including Camas Creek. This area supports populations within the MFSR Major Population Group (MPG), as defined by NOAA Fisheries. Prior to this research, redds were monitored by IDFG and tribal co-managers (Nez Perce and Shoshone-Bannock) in a small subset of MFSR index reaches only, usually employing a single pass survey approach. By conducting a long-term redd census, we have generated a data set that has tremendous analytical flexibility for: advancing our understanding of the dynamic nature of Chinook salmon populations, assessing population viability, and tracking population responses to outside-basin recovery efforts in the Columbia River basin. Our data are further strengthened by the ability to link 20 years of continuous surveys with longer time trends (since 1957, see #2 above) in index areas nested within our continuous surveys.

We counted redds in all portions of the Middle Fork Salmon River (MFSR) drainage with the potential to support spawning Chinook salmon. Since our objective was to georeference the locations of all Chinook salmon redds, we completed counts at the end of the spawning period while redds were still visible. Timing of Chinook salmon spawning in the MFSR is variable and influenced by elevation and water temperature (Thurow 2010). Redd construction typically begins the third week of July and most salmon have completed spawning by the second week of September. In late September, the onset of fall precipitation commonly increases water turbidity and obscures redds. During most years, we completed redd counts from September 5-12.

Following redd surveys, we differentially corrected GPS files with base station files. Corrected GPS files were exported into a GIS using Trimble Pathfinder Office software. We used Environmental Systems Research Institute, Inc. (ESRI) ArcInfo Workstation to create GIS layers and ESRI ArcView 3.2 to display annual redd locations on maps. Aerial redd counts were combined with supplemental ground surveys to create the comprehensive Chinook salmon redd map (Figure 2).

By censusing the distribution of a commonly measured demographic parameter (redds) through time, we have generated a data set that has tremendous analytical potential for advancing our understanding of the dynamic nature of Chinook salmon (Thurow 2000; Isaak and Thurow 2006). These data have and are being used in a host of studies to address key conservation issues for Chinook salmon, including: assessment of temporal changes in population synchrony (Isaak et al. 2003); examination of linkages between fine-scale genetic structure, demographic parameters, and environmental characteristics (Neville et al. 2006); evaluation of methods for monitoring salmon populations (Courbois et al. 2008); determination of dispersal ranges and environmental constraints using spatial autocorrelation analysis (Neville et al. 2007); assessment of environmental covariates that affect habitat occupancy (Isaak et al. 2007); validation of hydrologic models for predicting basin-wide distributions of spawning substrates (Lewicki et al. 2007); and evaluation of redd count methodologies (Thurow and McGrath 2010).

This research also provides the only status and trend data for monitoring four (Camas, Loon, Upper MFSR, and lower MFSR) of the nine MFSR Chinook salmon populations. Our redd counts are provided to IDFG to generate the Natural Origin Spawner Abundance and Productivity (recruits/spawner) estimates provided to NOAA Fisheries and stored in NOAA's Salmon Population Summary database (SPS) for the 5 year status reviews. Data generated by this project were used in the recent Life-Cycle Models of Salmonid Populations in the Interior Columbia River Basin and are currently used in NOAA's 5 year status review viability analysis, contributing to the determination of MFSR Chinook salmon ESA listing status and for recovery planning efforts.

Camas Creek Chinook salmon population trends from 1995 to 2014- Camas Creek cumulative redd counts from 1995-2013 have totaled 901 redds and averaged about 45 redds annually (Figure 2). Redd numbers have exhibited high temporal variation; from zero redds observed in 1995 to a high of 168 redds in 2003 (Figure 3; Thurow 2011). Improved stream flows and faster smolt travel times coupled with an increase in ocean productivity contributed to higher redd counts within individual stream segments from 2001 to 2003. From 2003 to 2006, there was a ten-fold decrease in the number of redds observed. Since 2004, the number of redds has remained small with the fewest observed in 2011 (Figure 3).

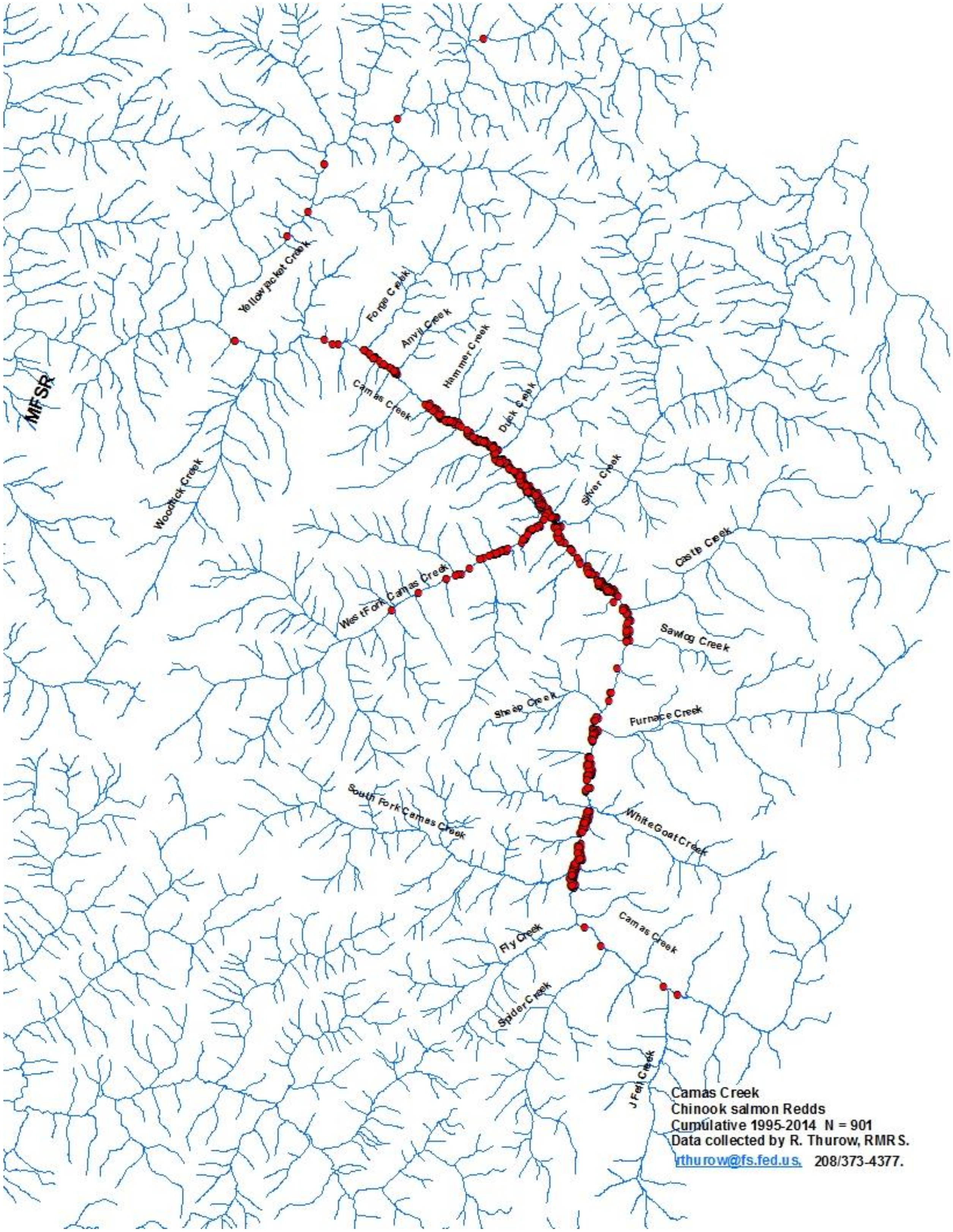

Figure 2. Cumulative distribution of Chinook salmon redds observed in the Camas Creek watershed, Idaho, September 1995-2014.

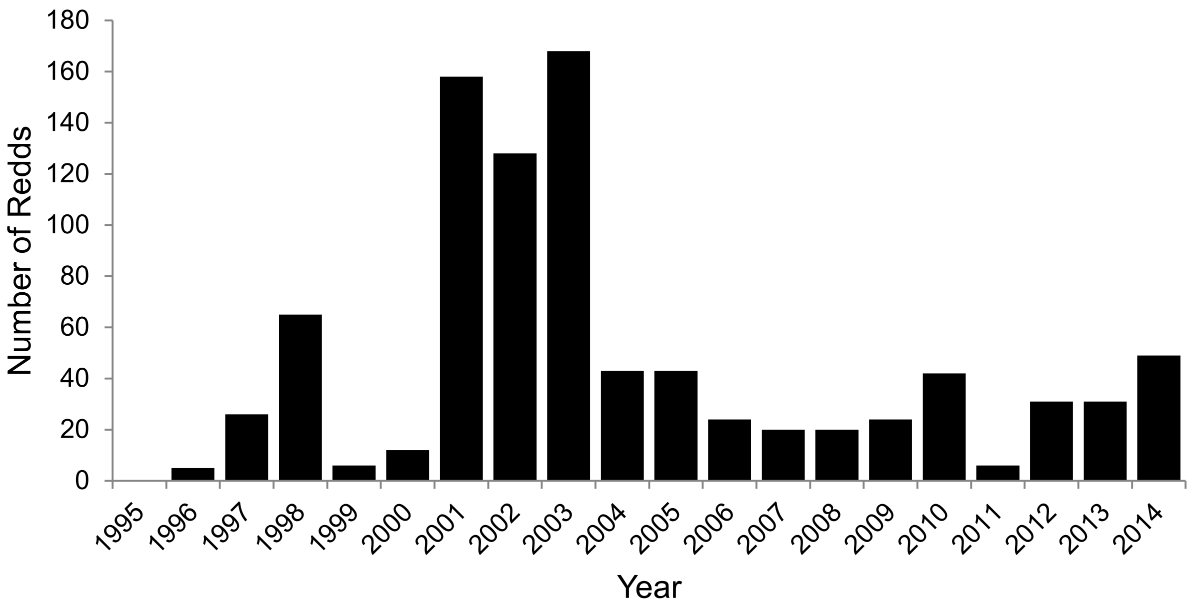

Figure 3. Total annual Chinook salmon redds observed in the Camas Creek watershed, Idaho, 1995-2014.

In addition to temporal variation, the distribution of redds has also been spatially variable across Camas Creek and the MFSR (Thurow 2013). In lower escapement years, redds have occurred sporadically through much of the network, while in years with larger escapements, redds have been more widely distributed, and fish appeared to be using a larger proportion of the available spawning habitat (Thurow 2013).

We have observed MFSR Chinook salmon redds at elevations between 1100 m and 2100 m and a majority were constructed between 1500 m and 2000 m (Thurow 2010). Although Chinook salmon spawn in both the mainstem MFSR and tributaries; about 99% of redds have been constructed in Camas Creek and seven other major tributaries (Thurow 2013).

MFSR Chinook salmon have diverse life history traits. They migrate one of the longest distances from salt water (up to ~1290 km) and segments of the population spawn at the highest elevations (>2,000 m) of any spring/summer Chinook salmon population in the World (Crozier et al. 2008). MFSR stocks may mature in freshwater as precocial males or migrate to the ocean after spending from less than a year to more than 2 years in fresh water. They return after spending from less than a year up to 5 years in salt water. This diverse combination of fresh and salt water ages results in the potential for up to 18 different age classes contributing to a single years' spawning.

MFSR and Camas Creek Chinook salmon stocks also exhibit high resiliency. Resiliency can be defined as the ability of a population to withstand detrimental conditions and to respond to favorable conditions. Our research illustrates that in response to favorable outmigration conditions (higher flows and faster smolt travel times) and increased ocean productivity from 2001-2003, the number of MFSR salmon recruits produced per adult spawner increased 4-5 fold and was among the highest ever reported in the scientific literature (Isaak and Thurow 2006). A factor contributing to this resiliency is their high fecundity (mean of 5,000 eggs per female) and their access to diverse, high quality, connected natal habitats in Camas Creek and other MFSR tributaries.

8.) *Bull trout redds and adults*- Also since 1995, we have georeferenced the location of all bull trout redds and adult bull trout staging areas incidentally observed in Camas Creek and other MFSR tributaries during salmon surveys. In contrast to the continuous Chinook salmon redd counts described above, bull trout redd counts were incidental and represent incomplete estimates of the distribution and abundance of bull trout spawning in Camas Creek. In order to estimate total bull trout redds, observers would need to survey bull trout from the onset of spawning in late August to the end of spawning in November. However, our incidental bull trout redd counts may be used to identify a portion of the potential bull trout spawning areas. Within upper Camas Creek, we georeferenced a total of 18 bull trout redds during aerial surveys since 1995 (Figure 4). All bull trout redds were observed upstream from White Goat Creek. During ground-based salmon redd counts from 2002-2004, we also georeferenced the location of 8 mature bull trout staging areas upstream from White Goat Creek (Figure 5) where schools of mature, fluvial bull trout staged prior to spawning.

9.) *Bias and precision of salmon redd counts*- From 2001-2005, we censused salmon redds with redd monitors who completed 552 individual ground based counts in 30 stream reaches across six major drainages; including one reach in the upper mainstem MFSR (Thurow and McGrath 2010). Expert redd counters completed 108 individual ground based counts and redd counters with a variety of experience conducted an additional 199 individual ground based counts. Sixty independent ground based observers completed more than 859 individual salmon redd counts from 2001-2005. Aerial redd counts were also completed in each of these study reaches annually. Both ground based and aerial salmon redd counts were similar to the census count with overestimates of redds less common than underestimates. Most ground based and aerial redd counts contained some errors and errors increased with increasing numbers of redds per reach. Most total errors were relatively small and errors of commission were less common than errors of omission. Net errors were also low in most reaches, although in many cases a low net error was a result of approximately equal numbers of omissions and commissions. Net redd counting errors varied by year as well as stream reach. Aerial redd counts tended to be negatively biased compared to ground based redd counts and aerial count commissions were relatively uncommon as compared to the ground based counts. Ground based counts tended to have more errors as compared to aerial counts. Results of our mark-resight analysis are inconclusive and will require additional analyses. We encountered problems meeting one of the critical mark-resight model assumptions, specifically we were unable to accurately map marked and resighted redds in close proximity. During both ground based and aerial redd counts, we measured a suite of redd and reach scale variables with the potential to influence redd sightability. Additional data analysis and modeling are in progress.

10.) *Salmon genetic structure*- Two important publications (Neville et al. 2006; Neville et al. 2007) summarize results of the genetic analyses of salmon in Camas Creek and other MFSR tributaries. Although Pacific salmon have been central to the development of management concepts associated with evolutionarily significant units (ESUs), there are still relatively few studies of genetic diversity within threatened and endangered ESUs for salmon or other species. Neville et al (2007) analyzed genetic variation at 10 microsatellite loci to evaluate spatial population structure and genetic variability in indigenous Chinook salmon across Camas Creek and the MFSR within a Snake River ESU. Despite dramatic 20th century declines in abundance, these populations retained robust levels of genetic variability. No significant genetic bottlenecks were found, although the bottleneck metric (M ratio) was significantly correlated with average population size and variability. Weak but significant genetic structure existed among tributaries despite evidence of high levels of gene flow, with the strongest genetic differentiation mirroring the physical segregation of fish from two sub-basins. Despite the more recent colonization of one sub-basin and differences between sub-basins in the natural level of fragmentation, gene diversity and genetic differentiation were similar between sub-basins. Various factors, such as the (unknown) genetic contribution of precocial males, genetic compensation, lack of hatchery influence, and high levels of current gene flow may have contributed to the persistence of genetic variability in this system in spite of historical declines. This unique study of indigenous Chinook salmon underscores the importance of maintaining natural populations in interconnected and complex habitats to minimize losses of genetic diversity within ESUs.

Natal homing is a hallmark of the life history of salmonid fishes, but the spatial scale of homing within local, naturally reproducing salmon populations is still poorly understood. Accurate homing (paired with restricted movement) should lead to the existence of finescale genetic structuring due to the spatial clustering of related individuals on spawning grounds. Thus, Neville et al. (2006) explored the spatial resolution of natal homing using genetic associations among individual Chinook salmon in the MFSR. We also investigated the relationship between genetic patterns and two factors hypothesized to influence natal homing and localized movements at finer scales in this species, localized patterns in the distribution of spawning gravels and sex. Spatial autocorrelation analyses showed that spawning locations in both sub-basins of our study site were spatially clumped, but the upper sub-basin generally had a larger spatial extent and continuity of redd locations than the lower sub-basin, where the distribution of redds and associated habitat conditions were more patchy. Male genotypes were not autocorrelated at any spatial scale in either sub-basin. Female genotypes showed significant spatial autocorrelation and genetic patterns for females varied in the direction predicted between the two sub-basins, with much stronger autocorrelation in the sub-basin with less continuity in spawning gravels. The patterns observed here support predictions about differential constraints and breeding tactics between the two sexes and the potential for fine-scale habitat structure to influence the precision of natal homing and localized movements of individual Chinook salmon on their breeding grounds.

11.) *Geomorphic controls on spawning substrates*- Results of the three approaches are reported by Lewicki et al. (2007): a.) Landscape features model: results of relating observed locations of Chinook salmon spawning to broad-scale geomorphic features in the MFSR indicate that spawning sites are correlated with channel slope (in particular, the control of channel slope on the occurrence of pool-riffle morphologies), stream width (as influenced by drainage area and discharge), and valley confinement (as controlled by glaciation and geomorphic history). We found that the highest densities of spawning sites occurred in broad alluvial valleys. These areas are typically low-gradient pool-riffle reaches that commonly contain suitable spawning substrates. However, median grain sizes tend to be on the smaller end of what is considered suitable (typically 10-20 mm). Marginal substrate size may be offset by favorable hyporheic flow through these alluvial valleys. Alternatively, extensive side-channels may increase offspring success, resulting in relatively larger densities of returning fish. b.) Hydraulic model: We applied field measurements to quantify the occurrence of textural patches and their grain-size characteristics in channel types used by spawning salmonids (pool-riffle, plane-bed, and step pool channels). Forty three channels were sampled throughout the MFSR basin in locations where reach-average characteristics were measured. These data are being used to refine predictions of spawning gravel availability by correcting reach average grain-size predictions for subreach variability of sediment size as a function of channel type. Presence/absence data suggest that MFSR Chinook salmon do not spawn in channels with bankfull widths less than about 8 m. We incorporated primary differences in geology (batholith vs. volcanics) in our bankfull depth predictions and determined that more detailed geologic classification (finer-scale lithological differentiation) of stream reaches does not improve model predictions of bankfull depth. c.) Sediment routing model: We are comparing predicted versus observed channel response to post-fire debris flows. The model performed well, providing reasonable predictions of debris-fan evolution, changes in streambed elevation, and sediment size over time. Predictions indicate that the sediment wave introduced by the debris flows will move rapidly through this steep, confined river, with the channel profile recovering within about 10 years. In contrast, the model indicates that it will require about 25 years for median grain sizes to recover to pre-disturbance conditions.

12.) *Natural disturbance processes*- During the last 20 years, a series of fires have burned large portions (> 52%) of the MFSR basin (Thurow 2015). Those fires, followed by intense thunderstorms over some burned areas, have resulted in large debris flows that have altered salmon habitats within both the mainstem MFSR and several major tributaries. Over this same 20 year period, as described in #7 above, we have annually surveyed and geo-referenced the location of all Chinook salmon redds across the entire MFSR basin. Thurow and Buffington (2015) described the mechanisms of debris flow creation and sediment routing, illustrated temporal and spatial responses of spawning Chinook salmon to natural patterns of habitat disturbance in the basin, assessed the importance of salmon dispersal and habitat connectivity, and addressed how a changing climate may alter natural landscape dynamics. In particular, warming temperatures are expected to increase fire frequency and subsequent debris flows in the basin, while increased rain-on-snow events may cause more frequent avalanches, both of which input wood and sediment to the stream network. Field observations are coupled with sediment routing models to explore the consequences of these dynamic processes on salmon habitat over space and time. Within portions of the Camas Creek watershed, we have observed post-fire debris flows depositing sediments in stream reaches where the substrate was formerly too coarse for salmon spawning. In several cases, Chinook salmon have colonized new spawning habitats relatively soon after the debris flows. Inspection of larger-scale stream and basin morphology shows that these processes have been acting on this landscape for millennia and have had long-term effects on channel gradient, stream width, and associated salmon habitats. Consequently, the disturbance processes are not new, geomorphically or biologically, but rather their frequency and spatial extent are being altered by climate change. Although salmon have evolved with these disturbance processes, a key question is whether adaptation of native species can keep pace with rates of climate change and associated disturbance regimes.

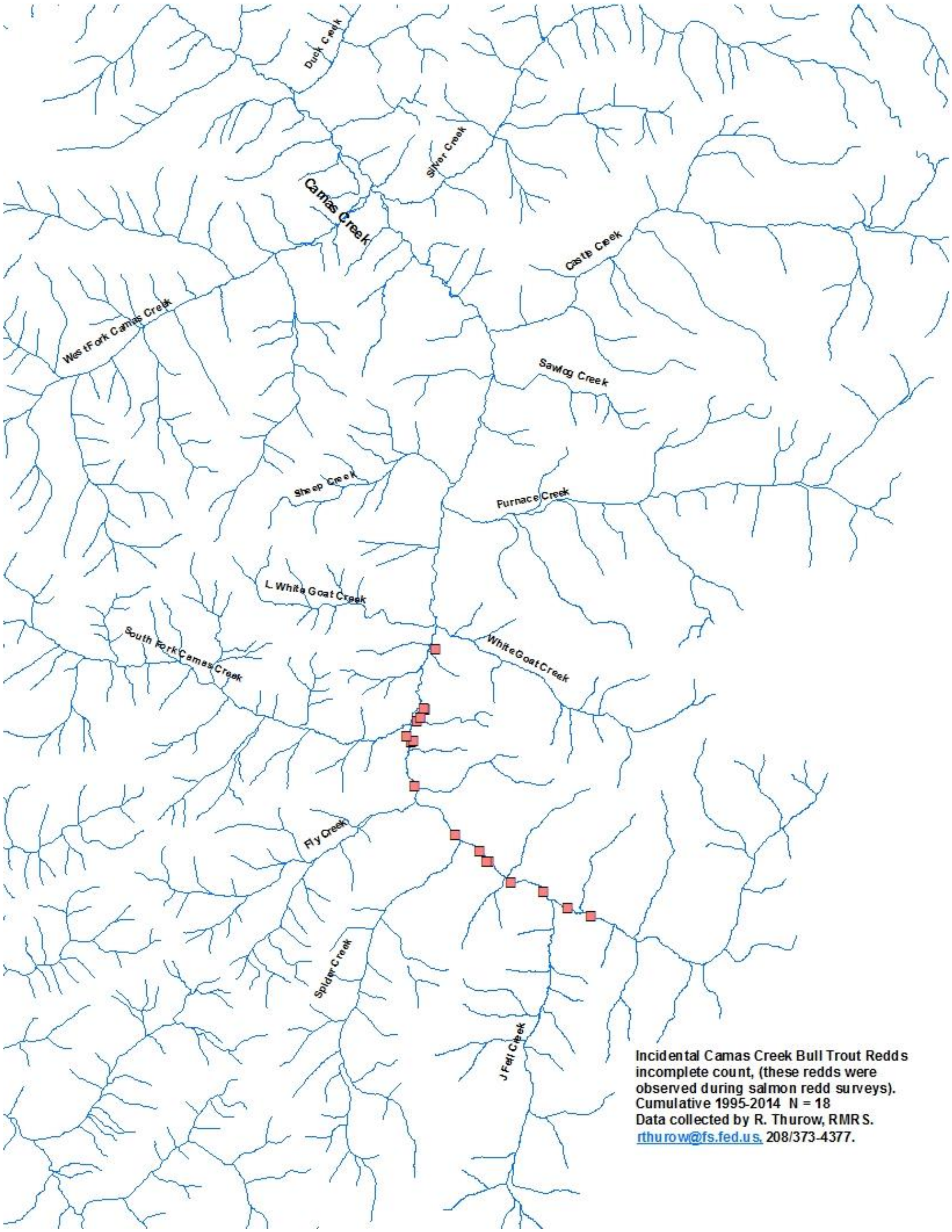

Figure 4. Bull trout redds incidentally observed in Camas Creek, Idaho during aerial salmon redd counts, 1995-2014.

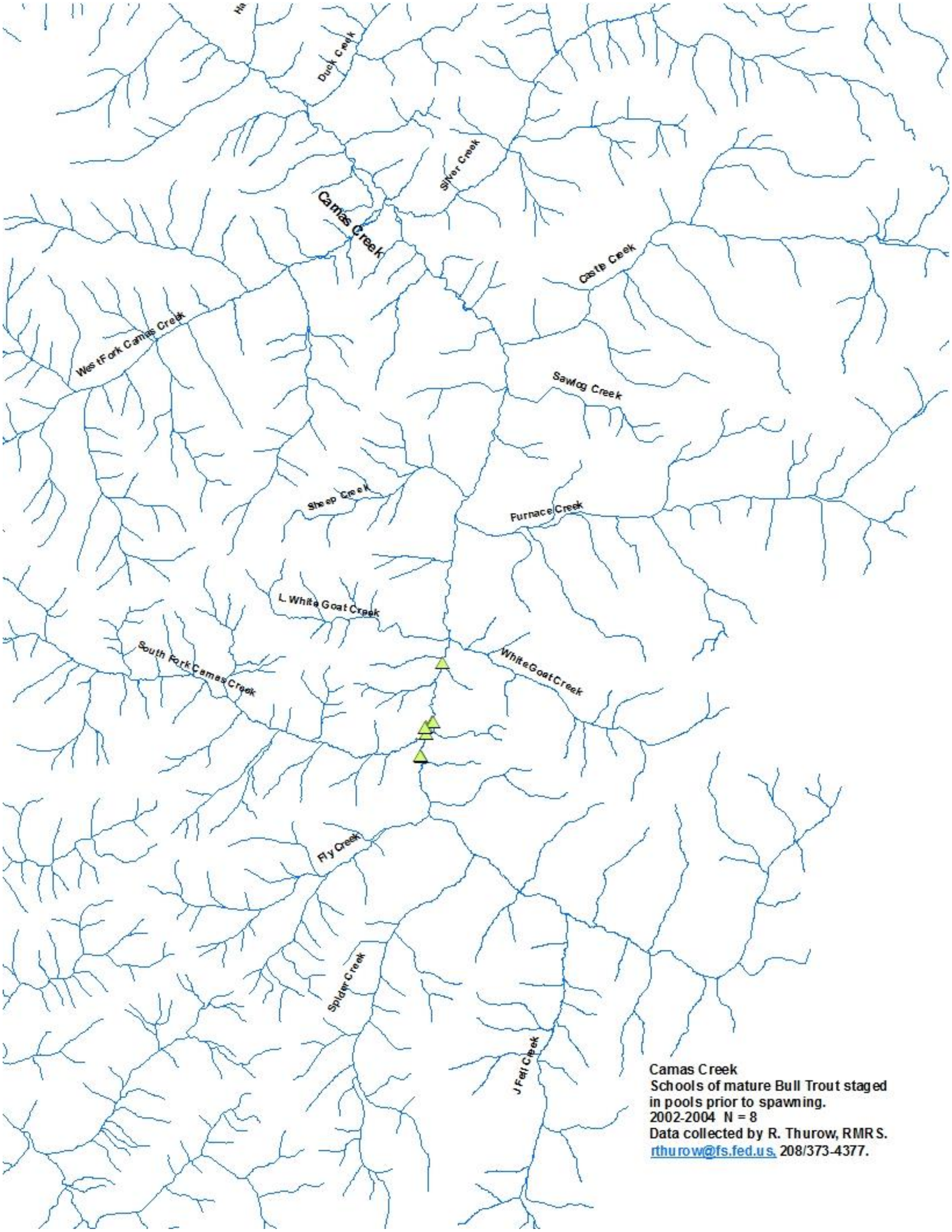

Figure 5. Mature bull trout staging areas incidentally observed in Camas Creek, Idaho during ground-based salmon redd counts, 2002-2004.

13.) *Aquatic ecosystem structure and function*- ISU researchers reported that floodplain and confined segments in Camas Creek do indeed differ in terms of aquatic ecosystem structure and function but not entirely as expected (Bellmore and Baxter 2014). Confined segments had greater allochthonous inputs but a lower capacity to retain those inputs, whereas floodplains had a high capacity to retain transported organic matter and also a more diverse community of invertebrates and higher overall community respiration to 'digest' retained organic matter. If these findings are generalizable, then they would indicate that confined segments are sources for organic matter within river networks, whereas floodplains act as filters, removing and processing organic matter transported from upstream confined segments.

14.) *Assessment of food-base production*- To evaluate if and how the productivity of the food-base that supports fish production was impaired in a dredge-mined flood plain, ISU utilized an ecosystem approach (Bellmore et al. 2012). They applied reference conditions in streams including Camas Creek and found the dredged segment had comparable terrestrial leaf and invertebrate inputs, aquatic primary producer biomass, and production of aquatic invertebrates relative to reference floodplains. Using a simple bioenergetics model, they estimated the invertebrate food-base was at least 4 times larger than present demand for food by fish in both dredged and reference segments. In the context of salmon recovery efforts, this observation questions whether additional food-base productivity provided by further habitat restoration would be warranted. Their findings highlight the importance of studies that assess the aquatic food-base, and emphasize the need for more robust ecosystem models that evaluate factors potentially limiting fish populations that are the target of restoration. Findings demonstrate a simple lesson: while it is usually possible to identify a form (or forms) of ''improvement'' that might result from restoration, the true potential for a project to restore a target population cannot be assessed without evaluating whether or not restoration will address a factor that is limiting population recovery (Bellmore et al. 2012).

CHINOOK SALMON MPG STATUS

The Chinook salmon Major Population Group status information summarized and *italicized* below is cited from the draft Chapter 5, Section 5.3, Status and Recovery of Middle Fork Salmon River MPG in the Snake River Spring/Summer Chinook Salmon ESU (NMFS 2014).

The Middle Fork Salmon River MPG consists of spring and summer Chinook salmon returning to the MFSR, in addition to spring Chinook salmon returning to Chamberlain Creek and other nearby tributaries on the main Salmon River. The MPG includes nine independent populations, including Camas Creek. Camas Creek is designated as a basic-sized population of spring and summer Chinook salmon with a desired threshold abundance of 500 adults and a productivity of 2.21 (Table 5.3-1) (ICTRT 2007). None of the populations in the MPG has received hatchery supplementation and there is no history of hatchery-origin Chinook salmon spawning in this group of populations. Minimum abundance and productivity values represent levels needed to achieve a 95% probability of existence over 100 years (ICTRT 2007). Currently, the MFSR MPG does not meet the MPG-level viability criteria. All nine populations are at high abundance and productivity risk (Table 5.3-2). Camas Creek has the lowest recent productivity estimate of the nine Middle Fork populations. Its desired status is "Maintained", with a moderate risk of extinction over 100 years. The recent 10-year (2000-2009) geometric mean *adult spawner abundance for the Camas Creek spring/summer Chinook salmon population is 30 fish. Based on recent adult spawner recruit series, the 10-year recruit per spawner productivity estimate for the same period is 0.74, which is less than the 2.21 productivity required at the minimum abundance threshold (Ford et al. 2011). Current abundance and productivity are also well below the minimums needed for a maintained status. The abundance/productivity risk for the population is therefore high.*

The recovery strategy for the MFSR MPG is to increase abundance and productivity for all populations. The VSP risk matrix (Table 5.3-3) shows that each population requires a decrease in abundance/productivity risk to reach its desired status of highly viable (very low risk), viable (low risk), or maintained (moderate risk). Increases in population abundance and productivity will result from the cumulative positive impacts of recovery actions targeting every life stage. NMFS noted that because all of the populations in this MPG are currently at high risk, *recovery actions will be needed at each life stage* to increase survival. The draft confirmed the results of prior research and concluded that *most natal habitat for Chinook salmon in the MFSR MPG is currently in good condition, protected from human impacts by the Frank Church River of No Return Wilderness, which encompasses much of the basin.* Consequently, NMFS observed that *the primary recovery goal is to protect the current high quality of existing habitat with limited opportunities to generate small increases in abundance and productivity through habitat restoration*. NMFS further concluded that *natal habitat actions in the MFSR basin will not produce the increases in survival needed for this MPG to achieve viability. Improvements in survival will need to come from additional "downstream" recovery actions.* NMFS also confirmed the scientific value of Camas Creek and the other Chinook salmon populations in this MPG, by stating they *used these populations, which are located primarily in designated wilderness and have nearly pristine habitat, to roughly estimate the magnitude of survival increases needed from "downstream" actions for all Salmon River populations. It will take a roughly 40 percent increase in survival for each MFSR population to reach viable status, so this recovery plan calls for a 40 percent increase in Snake River spring/summer Chinook salmon survival from downstream actions over the long term.* NMFS concluded *the combined improvements from the small number of natal habitat actions already funded and the prospective downstream survival improvement of 40 percent will likely achieve the desired status for the MFSR MPG.*

LIMITING FACTORS and THREATS to NATAL HABITAT

Text *italicized* below is also cited from NMFS (2014). As described above, the primary NOAA recovery goal for the Chinook salmon MPG in Camas Creek is to *protect the current, high quality habitat with limited opportunities to generate small increases in abundance and productivity through restoration of degraded habitats.* This will also benefit ESA listed steelhead and bull trout as well as cutthroat trout, redband trout, Pacific lamprey, and other native aquatic species. The recovery plan also describes limiting factors and threats and observes that this population *is also affected by limiting factors and threats in the mainstem Columbia/Snake River corridor, estuary and plume, and by climate change.* Threats specific to Camas Creek include: *roads, water diversions, mining, reduced beaver activity, potential nutrient deficiencies, invasive brook trout, and grazing* (NMFS 2014).

Roads

Overall road density in Camas Creek is about 0.25 miles per square mile (NMFS 2014). Most road crossings are improved (hardened-surface) stream fords or bridges (SNF 1994). Exceptions occur on three non-hardened stream fords accessing the White Goat Ranch upstream from Castle Creek. *No impassible road crossings have been identified in anadromous fish habitat (SNF 1994).* Despite low road densities, existing roads and improper road maintenance pose sedimentation risks to aquatic habitats and species (see Appendix A).

Natal Habitat Action: NOAA did not recommend any specific habitat actions related to roads and observed that *"Responsibility for implementation of habitat actions for this population lies within the jurisdiction of the U.S. Forest Service".* Existing U.S. Forest Service Land and Resource Management Plan may address transport of hazardous materials as well as road use and maintenance activities that threaten to add sediment to active stream channels.

Water Diversions

NMFS (2014) reviewed multiple data sources and consulted with local fisheries experts and watershed groups to evaluate the effect of water diversions on aquatic resources. They concluded that *diversions reduce streamflow in the Yellowjacket, Duck, Silver, and Castle Creek drainages. The maximum diversion rate of all water rights in the Yellowjacket Creek drainage is less than 10 percent of base streamflow and 70 percent of those water rights are associated with mines that are not currently in production. However, the one operating water diversion in Yellowjacket Creek is unscreened, so fish may be entrained and killed.*

The impact of water diversions on flow in the Silver, Duck, and Castle Creek drainages may reduce Chinook production in those drainages. Most of these diversions are on USFS lands and are undergoing ESA section 7 consultations, which should minimize impacts on Chinook salmon (and other aquatic species). The Silver, Duck, and Castle Creek drainages contain about 4.2 percent of rearing habitat (measured as smolt capacity) for the Camas Creek spring/summer Chinook population. NMFS further observed that *a dam blocks migration into Rams Creek (Silver Creek drainage), a dam and pond may raise water temperatures and impair migration in Silver Creek.*

NMFS (2014) observed that water use in (the above referenced) tributaries of Camas Creek *probably reduces flow in mainstem Camas Creek by less than 5 percent of base flow and likely has a minimal impact on spring/summer Chinook production. There is one small private hydropower diversion within the spawning and rearing areas that reduces flow in a 1.1-mile reach of Castle Creek.*

Natal Habitat Action: *Continue to improve irrigation and water withdrawal practices to minimize the impacts of water diversions* (NMFS 2014). Presumably, these actions would strive to maintain fish passage, eliminate entrainment, and reduce adverse effects of withdrawing water.

Mining

NMFS (2014) reported that *noticeable impacts of past mining are mostly confined to the Yellowjacket, Silver, and Duck creeks.* As described above, mining activity in the Camas Creek drainage began with the 1869 discovery of gold in Yellowjacket Creek. *There are 676 acres of* *patented mining lands in the watershed and test drilling and surface sampling with shovels still occurs on some of the private lands (SNF 1994). Recent commercial-scale mining activity is confined to one open pit gold mine that operated from 1992 to 2000 on 24 acres of private and USFS land in Yellowjacket Creek (SCNF 2004). Placer mining is prohibited in the MFSR (Public Law 96-312), but future open pit or subsurface mining on private land is a potential threat to anadromous fish and habitat in the Camas Creek watershed.*

Natal Habitat Action: NOAA did not recommend any specific habitat actions related to mines and observed that *"Responsibility for implementation of habitat actions for this population lies within the jurisdiction of the U.S. Forest Service".* Existing U.S. Forest Service Land and Resource Management Plan may address mine exploration activities, risks of hazardous materials, and restoration of mined areas.

Reduced Beaver Activity

NMFS (2014) reported that *the extent of beaver pond complexes in the Camas Creek drainage is not known. However, in the mid-1990s, private landowners apparently removed a substantial number of beaver from the Silver Creek drainage, resulting in adverse impacts to salmonid habitat (B. Smith, Salmon-Challis National Forest, personal communication, 2008). There is currently a considerable amount of beaver activity in lower Silver Creek (B. Rose, Salmon-Challis National Forest, personal communication, 2008), so the beaver population, and stream habitat, might be recovering.* NMFS concluded that *since the Camas Creek drainage is open to beaver trapping during the trapping season and beaver perceived to be a nuisance can be removed during any time of the year, salmonid habitat in the Camas Creek drainage is likely to continue to be adversely impacted by beaver removal.*

Natal Habitat Actions: *Encourage additional beaver activity in the Camas Creek watershed* (NMFS 2014).

Grazing

Camas Creek and its tributaries have likely been grazed by cattle and horses since settlement of the watershed in the late 1800s. Grazing continues on private lands in Silver Creek, upstream from Hammer Creek, and in Castle Creek. The USFS also permits grazing in Camas Creek and its tributaries between Hammer Creek and the headwaters of Camas Creek upstream from the South Fork Camas Creek.

Grazing allotments in Camas Creek overlap with critical natal habitat for three ESA listed fishes: Snake River spring/summer Chinook salmon, Snake River summer steelhead, and bull trout. As a result, the USFS is required to complete ESA Section 7 consultations on these grazing allotments in an effort to minimize adverse grazing effects (NMFS 2014). Existing Camas Creek grazing allotments also overlap with key habitat for three aquatic USFS Regions 1 and 4 Sensitive Species: Pacific lamprey, westslope cutthroat trout; and inland redband trout.

Documented Grazing Threats to ESA listed and sensitive fishes

As described above, from 2002 to 2005 we intensively monitored the construction of redds by ESA listed Chinook salmon in the Camas Creek drainage. Below we document our observations of the threats grazing poses to ESA listed and sensitive fishes in Camas Creek. Spring-spawning steelhead, summer-spawning Chinook salmon, and fall-spawning bull trout occur in grazed reaches of Camas Creek. As a result, there is no time window to graze Camas Creel allotments without affecting either spawning fish or incubating eggs or alevins. Camas Creek steelhead spawn from late Match to early June and depending on elevation, flow, and temperature, emerge from the gravel from June to August. Chinook salmon spawn from late July to early September and emerge from February to March. Bull trout spawn from late August to November and emerge from Match to April. Consequently, ESA listed fish are either spawning or incubating in Camas Creek gravels 12 months per year.

2002- In 2002, we encountered cattle grazing within the riparian area of Camas Creek between Furnace Creek and the South Fork Camas Creek within a critical spawning reach for ESA listed salmon. We observed cattle trampling riparian areas, caving in stream banks, adding fine sediment to the active channel, and saw evidence (tracks and disturbed gravel) that cattle walked through and trampled newly constructed redds. We notified Salmon-Challis National Forest (SC-NF) staff via phone and a detailed email on August 8, 2002 (see Appendix B) Staff initially responded that the cattle were allowed in the allotment until August 15 and thereafter were to be only in upland areas. When I informed S-C NF staff that ESA listed Chinook salmon were already spawning prior to July 30, staff responded that they would consult with the District Ranger and Range personnel and work with the grazing permit holder to resolve the problem. We were asked to report all further sightings of cattle. Thereafter we reported numerous cattle sightings within salmon spawning areas. I also spoke with the District Ranger and explained the critical need to remove cattle from ESA listed salmon spawning areas.

Nearly two weeks after our initial reports, cattle were still grazing areas within spawning salmon. A NOAA enforcement officer contacted me for a report and later visited upper Camas Creek. Cattle remained in the area with spawning salmon until the end of our surveys in late August.

2003- In February 2003, S-C NF staff sent me an email stating that the S-C NF Forest Plan specifically stated there will be “no grazing along Camas Cr above Furnace Cr.” On July 25 and 26, 2003 I walked two reaches of Camas Creek while training an RMRS crew member. In reach #1 (Hammer Creek to Silver Creek) the entire reach had been heavily grazed by livestock as evidenced by extremely closely cropped perennial grasses, exposed topsoil, degraded riparian vegetation, and trampled stream banks. In reach #2 (upstream from Furnace Creek), we observed 35-40 grazing cattle and evidence (tracks, droppings, trampling) that cattle had been grazing along mainstem Camas Creek upstream to the South Fork Camas Creek. We also observed spawning Chinook salmon and staging bull trout in the grazed reach. Upon returning to the office on July 28, I called and left a message for S-C NF staff in an attempt to report my observations and alert them that what we observed may have resulted in past “take” or could result in future “take” of listed species. Section 3 of the Endangered Species Act states that “take” means “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct”. On July 31 I emailed a report to S-C NF staff (see Appendix C). On August 4, S-C NF staff shared my report with Level 1 team members from NOAA Fisheries, the US Fish and Wildlife Service, and the Bureau of Land Management.

Despite our reports, in 2003 we again observed cattle trampling riparian areas, caving in stream banks, adding fine sediment to the active channel, and saw evidence (tracks and disturbed gravel) that cattle walked through and trampled newly constructed redds. Cattle remained in the allotment throughout the spawning period for ESA listed salmon in 2003 (2nd year). We again notified S-C NF of ESA listed species concerns and were again asked to reported specific observations of cattle to S-C NF personnel. From 7/29 to 8/22 we reported nine separate detailed observations of cattle grazing reaches of Camas Creek where salmon were spawning. Cattle remained in the allotment from July to September.

2004- In 2004 the pattern from the previous two years was repeated. We again observed cattle trampling riparian areas, caving in stream banks, adding fine sediment to the active channel, and saw evidence (tracks and disturbed gravel) that cattle walked through and trampled newly constructed redds. Cattle remained in the allotment throughout the spawning period for ESA listed salmon in 2004 (3^{rd} year). We again notified S-C NF staff of ESA listed species concerns and were again asked to reported specific observations of cattle to S-C NF personnel. In 2004 the S-C NF attempted to reduce grazing conflicts by constructing new gates and fences and through the use of a range rider to move cattle out of sensitive areas. Despite their efforts and our repeated reporting of cattle in sensitive salmon spawning areas, cattle were observed in the allotment every 4 days from July to late August. On September 10, during my aerial redd surveys, I observed cattle still grazing Camas Creek near the South Fork Camas Creek as well as inside the Meyers Cove livestock exclosure and also reported these violations to the S-C NF. In late September I was notified by S-C NF staff that a NOAA enforcement officer was investigating possible ESA violations in Camas Creek during the 2004. In October I further corresponded with S-C NF staff to again remind them that their assumed August 15 date for the start of Chinook salmon spawning was inaccurate. I also clarified that, as a result of spring-spawning steelhead, summer-spawning Chinook salmon, and fall-spawning bull trout, there was no time window to graze Camas Creel allotments without affecting either spawning fish or incubating eggs or alevins.

2005- Prior to the start of our redd surveys in July 2005, S-C NF staff informed me that no cattle would be grazing the Camas Creek allotment upstream from Furnace Creek; those cattle were being moved to upland areas. We began monitoring that reach of Camas Cr on July 21 and on July 22 our RMRS redd monitor called me to report cattle grazing restricted reach of Camas Cr for the 4^{th} consecutive year (2002-2005). I immediately called S-C NF staff and reported cattle again grazing the restricted reach of Camas Creek. For the 4^{th} consecutive year I was again asked to document sightings of cattle. I agreed to do so but reminded them that we had already clearly documented the problem for three years (2002-2004) and that this was the 4^{th} year of the problem. I stated that in 2005 it was particularly critical to remove the cattle immediately because returns of wild salmon were projected to be extremely low. I also reminded staff that cattle grazing and trampling of redds could constitute “take” and a violation of ESA. S-C NF staff thanked me and said they would address the problem.

On August 6, 2005 our RMRS redd monitor in Camas Creek called me to report that Chinook salmon were still actively constructing redds in Camas Cr. He stated that the cattle he initially observed on July 22 had remained in the allotment and said he had been regularly reporting the locations, cattle numbers, and dates to S-C NF staff as requested. On August 6 at about 1400, he and a companion had observed approximately 20 cattle cross Camas Creek directly over and trample a newly constructed Chinook salmon redd. He took pictures to document the activity (Figure 6). I reminded him to report the observation to S-C NF staff and contacted my RMRS supervisor the following morning. I reported the redd trampling observation and the fact that no action had been taken to remove the cattle despite our reports since July 22. From July 22 to August 6 we had made seven separate reports to S-C NF personnel of cattle violating closures. I reported to my Supervisor that documented the trampling of a Chinook salmon redd constituted “take” and therefore was a violation of ESA which I was obligated to report to NOAA. On August 11, I notified NOAA fisheries of our documentation of cattle trampling a redd. Subsequently, NOAA enforcement asked the RMRS observer and me to prepare statements for an investigation.

On August 19, the S-C NF District Ranger reported in a memo that despite the best efforts by Forest staff and the grazing permit holder, factors such as “an exclosure needing constant maintenance”, “new riders”, “gates left open”, and “livestock that are “missed during gathering in the rugged, forested terrain that characterizes the allotment”, had limited success in keeping livestock out of unauthorized reaches along Camas Creek. He concluded that long-term management solutions were being considered.

2006- Funding for additional field crews was not maintained so in 2006 we had no crews in Camas Creek so were unable to intensively monitor salmon spawning and livestock. I continued to annually, aerially survey the entire Camas Creek drainage and georeference the location of all salmon redds. During my one day, September aerial survey in 2006, I did not observe livestock in salmon or bull trout spawning areas within Camas Creek. I submitted data to the S-C NF summarizing the distribution of Chinook salmon redds, the distribution of incidentally observed bull trout redds and staging areas, Chinook salmon and steelhead redd construction dates, and a reminder that ESA listed species were spawning or incubating 12 months each year.

2007- We had no crews in Camas Creek so were unable to intensively monitor salmon spawning and livestock. During my one day, September aerial survey in 2007, I did not observe livestock in salmon or bull trout spawning areas within Camas Creek.

2008- We had no crews in Camas Creek so were unable to intensively monitor salmon spawning and livestock. During my one-day aerial survey of Camas Creek on September 8, 2008, I observed cattle trespassing within the Meyers Cover exclosure designed to protect salmon spawning habitat and reported that observation to S-C NF staff.

FOIA-On July 25, 2008 I received a letter from Advocates for the West requesting information on behalf of the Western Watersheds Project. The FOIA requested "all documents describing, depicting, or relating to impacts from livestock to any fish species or their habitat, including redds, in Camas Creek from January 1, 1999 until present." I was directed by the RMRS Program Manager to respond as soon as possible. I compiled and attached copies of all pertinent documents including reports, data tables, maps, memoranda, emails, letters, and other correspondence and submitted the materials on August 20, 2008. On January 6, 2009 I received additional questions from the plaintiff, sought and followed RMRS protocols, and responded via email on January 15, 2009. I had no further correspondence regarding the FOIA until May 28, 2009 when RMRS Information Specialist D. Tippets sent an article from the Challis Messenger (see Appendix D)

2012- On May 17, 2012 I received an email from K. Dunlop of the S-C NF stating the Forest was in litigation regarding the Camas Creek grazing allotment and asking me to fill out a Forest Service Witness form. I completed and emailed the form but was not called as a witness.

Figure 6. Cattle crossing Camas Creek directly over and near newly constructed Chinook salmon redds. Picture A. (top) group of cattle crossing near three redds. Picture B. (bottom) last of three cattle observed crossing directly over and trampling a Chinook salmon redd. Both photographs were taken on August 6, 2005.

2013- In November 2013, S-C NF staff requested information to assist their preparation of a draft Camas Creek Grazing Allotment BA. I updated and re-submitted data to the S-C NF that summarized the distribution of Chinook salmon redds, the distribution of incidentally observed bull trout redds and staging areas, Chinook salmon and steelhead redd construction dates, and a reminder that ESA listed species were spawning or incubating 12 months each year. I also explained my concern that someone may inappropriately attempt to use the bull trout shapefiles to represent the extent of bull trout spawning in Camas Creek and reiterated that the bull trout redd locations simply represented "incidental" observation of bull trout during salmon redd surveys.

2014- In May S-C NF staff sent me a Draft of the Camas Creek Grazing Allotment BA and I submitted comments (see Appendix E). Also in 2014, I received a request for additional information describing the timing of Chinook salmon spawning in Camas Creek and responded on June 3 (see Appendix F).

Summary of Key Grazing Issues

1.) The Camas Creek spring/summer Chinook population does not currently meet viability criteria because abundance/productivity risk is high. Recovery actions will be needed at each life stage.

2.) In addition to Snake River spring/summer Chinook salmon, Camas Creek provides critical natal habitat for two other ESA listed fishes: Snake River summer steelhead and bull trout as well as habitat for three aquatic USFS Regions 1 and 4 Sensitive Species: Pacific lamprey, westslope cutthroat trout; and inland redband trout.

3.) The primary recovery goal for the Chinook salmon MPG in Camas Creek is to protect the current, high quality habitat with limited opportunities to generate small increases in abundance and productivity through restoration of degraded habitats. This goal will similarly benefit the other two ESA listed species, three sensitive species, and other native aquatic species.

4.) Although specific spawning and incubation dates may vary with annual stream temperatures and discharge, in general, steelhead spawn from late March to mid-June and their alevins incubate until emergence in July or early August. Chinook salmon spawn from late July to early September and their alevins incubate until February or March. Bull trout spawn from late August to November and their alevins incubate until March or April. As a result, one of these three ESA listed salmonids is either spawning or incubating in the Camas Creek basin the entire year.

5.) From 2002-2005, during intensive (every four day) redd surveys, cattle in Camas Creek allotments were regularly observed trampling riparian areas, caving in stream banks, and adding fine sediments to the active channel. Cattle were also documented trampling newly constructed Chinook salmon redds. Four years of detailed and documented observations illustrate that if cattle are allowed to graze areas adjacent to Camas Creek or its tributaries, they will degrade critical natal habitat and will very likely trample redds of three ESA listed species, resulting in "take". Section 3 of the Endangered Species Act states that "take" means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct".

6.) Experienced S-C NF staff stated in a 2005 memo that, despite the best efforts by Forest staff and the grazing permit holder, factors such as "an exclosure needing constant maintenance”, “new riders”, “gates left open”, and “livestock that are “missed during gathering in the rugged, forested terrain that characterizes the allotment”, limited success in keeping livestock out of unauthorized reaches along Camas Creek.

7.) Conservation groups have threatened legal actions to reduce Camas Creek grazing impacts.

8.) The preponderance of evidence suggests that livestock grazing in Camas Creek is not compatible with efforts to conserve high quality natal fish habitat nor is it compatible with efforts to recover ESA listed Chinook salmon, steelhead, or bull trout.

Natal Habitat Action: *Improve grazing management to minimize the impacts of redd trampling and riparian vegetation impacts* (NMFS 2014).

ACKNOWLEDGEMENTS

Since the 1950s, a host of dedicated aquatic biologists and seasonal employees with IDFG and the USFS, and more recently with RMRS, ISU, NOAA Fisheries, and the Shoshone-Bannock Tribe have collected critical data in the Camas Creek watershed. Many, but not all, of their resulting publications are cited in this report. We continue to benefit from and build upon their important work.

Author Credentials

Experience- Professional Fisheries Biologist for 38 years. Certified as a Fisheries Scientist by the American Fisheries Society. Began working in Camas Creek in 1981 as an Idaho Department of Fish and Game Senior Fisheries Research Biologist and continues to investigate fish populations and aquatic habitats in the drainage as a USFS-RMRS Fisheries Research Scientist.

Expertise- Native trout and salmon life history, ecology, and population dynamics; aquatic habitat requirements of native fishes; landscape processes and aquatic habitats; and the effects of anthropogenic activites on fish and aquatic habitats. Very familiar with the Camas Creek drainage; having hiked all of Camas Creek and its major tributaries multiple times, snorkeled juvenile rearing areas throughout the drainage, and has aerially surveyed Chinook salmon and (incidentally) bull trout spawning areas annually for the past 20 years.

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APPENDICES

Appendix A: September 14, 2010 Statement on sediment side casting into Camas Creek; R. Thurow, Fisheries Research Scientist, USFS Rocky Mountain Research Station, Boise.

On Wednesday afternoon September 8, I was counting newly constructed Chinook salmon redds along a reach of Camas Creek, tributary to the Middle Fork Salmon River in Central Idaho. The pilot and I were flying at a low level (<15 meters) and slow speed (~10 knots) in a Bell Soloy helicopter with tail #7887S. We began our survey upstream from the South Fork of Camas Creek and were proceeding downstream toward Meyers Cove.

At approximately 1425 hours Mountain Time, we passed the White Goat Ranch at the confluence of Camas Creek. Soon thereafter, I observed fresh bulldozer cleat tracks on the road downstream from the ranch as well as sand and other fine materials that had been bladed on the road surface. These tracks and the fine material were visible along the entire road downstream to the stream crossing just upstream from Castle Creek.

At approximately 1430 hours, I observed where the bulldozer operator had side cast sand and silt directly into Camas Creek. I became very concerned because Camas Creek provides critical spawning and rearing habitat for ESA listed spring/summer Chinook salmon. During our flight, I was observing and mapping the locations of Chinook salmon redds that had recently spawned in this reach in 2010. There was a fresh Chinook salmon redd within 10 meters downstream from the location where road material had been sidecast into the active stream channel. Between this location and Castle Creek, I observed two more locations (total of three locations) where the bulldozer operator had side cast fine materials directly into Camas Creek.

The side casting of sand and fine material can severely impact Chinook salmon redds. Sand and silt will fill the intersticial areas in the gravel and smother the eggs and developing alevins. Consequently, the side casting I observed is very likely to adversely affect the survival of the ESA Chinook salmon population in Camas Creek. This reach of Camas Creek also supports critical spawning and rearing habitat for ESA listed summer steelhead and bull trout.

On September 9 I called Dane Cook, IDFG enforcement officer and reported my observations in Camas Creek. I asked Dane to pass my report on to the NOAA enforcement officer and request a visit to the site.

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Appendix B: August 8, 2002 email outlining concerns about livestock adversely affecting spawning ESA listed Chinook salmon; sent to S-C NF staff by R. Thurow, RMRS.

T.A. and I surveyed reaches of Camas Creek on July 30-31 searching for Chinook salmon redds. On July 30 we surveyed the area upstream from Furnace Creek to the end of the meadow reach upstream from the South Fork Camas Creek. We observed many adult chinook, 1 completed redd, and 10 redds in progress. As we have seen in the other tributaries this year, a large % of the fish appeared to be 3-salt. We also observed a few concentrations (perhaps 20-25 fish total) of large (>45 cm) fluvial bull trout staging in pools. That is the good news.

The bad news is that many cows were camped in the riparian zone on top of the spawning fish. Cattle were crossing areas that had redds in progress, breaking down banks near redds, and fine sediment was being added to the stream. From the appearance of the banks, condition of trails, and the smell, in my opinion the cattle have been camped in the riparian area for several weeks I came out to Challis the evening of 7/31 after the FS office was closed so could not contact S-C NF staff. I did see IDFG staff at the gas station and informed him of the situation He said he thought there was supposed to be a timing restriction so the cattle are removed before the chinook spawn.

Thurs 8/1 AM I called S-C NF staff and relayed my observations. Staff said the removal date is 8/15 but that the cattle are supposed to be in the tributaries only, NOT on mainstem Camas. Staff was very responsive and was going to speak with the Ranger and then contact the grazing permittee. He said he would contact me Friday with an update.

As promised, staff called and left a message Friday (8/2) to say other staff was contacting the permittee and asking them to move the cattle. This AM 8/5 I called back for an update and since both staff were out, I spoke with the Ranger. The ranger said staff was headed to Camas Cr to determine if the cattle had been moved. He suggested I send this email describing my observations and concerns. I told the Ranger I also wanted to alert the Level I team so I spoke with and ccd other S-C NF staff.

Thanks to field staff, hopefully the first priority of immediately moving the cattle out of the spawning area has already been accomplished. As a follow up, I think it might be useful to share some data with each of you that may influence future mgt decisions in Camas Creek:

1. The primary spawning area in Camas Cr has historically been in Meyers Cove (Hammer to Silver Creek). This area has a grazing exclosure (although I told staff we observed trespass cattle inside the exclosure as well) and receives a lot of emphasis. Fish in Meyers Cove typically begin spawning fairly late (after Aug 10). The area upstream from Meyers Cove, however, has actually supported more redds than the Meyers Cove area in a few recent years.

2. The fish spawning upstream from Furnace may represent a distinct population since they enter and spawn much earlier than the Meyers Cove fish. As such, they may represent a genetically distinct group. We at RMRS and IDFG have some analysis of carcass fin clips planned that will shed light on this question.

*(Note for the reader, our later genetic analysis (Neville et al. 2007) did reveal genetic differentiation between Chinook salmon populations that spawn in lower and upper Camas Creek).

3. Timing to avoid Chinook spawning does not really protect all of the critical resources in upper Camas Cr. The area that is currently grazed above Furnace Cr supports spawning and rearing by three listed species (chinook, steelhead, and fluvial and resident bull trout). I have personally observed redds of all three species in the reach currently being grazed. As a result, the only time window that fish would not be spawning or eggs would not be incubating in the gravel would be the time after steelhead emerge and before Chinook salmon begin spawning. Based on my experience trapping steelhead redds in the South Fk Salmon R in the mid 1980s, in many years, the steelhead might not all be emerged until about the same time chinook begin spawning.

4. Restricting grazing to the tributaries may sound like a solution but I question how feasible it would be to enforce. Except for the South Fork Camas Creek (which should not be grazed since it also supports spawning by bull trout and steelhead and perhaps by chinook in higher flow years), the tributaries are steep and have very limited meadows. As a result, unless fenced or constantly watched by a rider, the cattle will likely move back to and camp on the mainstem.

If it would be useful, after the end of the field season, I would be glad to meet with Forest personnel and or the Level I Team to review this information.

FYI –we also saw a fresh wolf track in the area just upstream from the South Fork Camas.

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Appendix C: **July 31, 2003 email outlining concerns about livestock adversely affecting ESA listed Chinook salmon and steelhead; sent to S-C NF staff by R. Thurow, RMRS.**

Reach #1: July 25 survey; downstream from Hammer Creek trailhead to confluence of Silver Creek.
The entire reach had been heavily grazed by livestock as evidenced by: extremely closely cropped perennial grasses, exposed topsoil, degraded riparian vegetation, and trampling of stream banks. If the grazing occurred this spring, it likely occurred after Chinook salmon fry emerged from 2002 redds. However, ESA listed summer steelhead also spawn in this reach of Camas Creek. Our observations in the 1980s confirm that steelhead spawn in Camas Creek from late March through the first week in June. Depending on flows and temperatures, steelhead alevins might remain in the gravel into August. As a result, incubating steelhead eggs and alevins would have been susceptible to increased mortality as a result of trampling and intrusion of fine sediments. In the 22 years (since 1981) I worked in Camas Creek, this is the most degraded I have seen the Meyers Cove area.

Reach #2: July 26 survey, 1 km upstream from Furnace Creek to upstream edge of the meadow above the confluence of the South Fork Camas Creek.
One completed redd, 14 live adult salmon, and one male chinook post-spawning mortality, two concentrations of adult bull trout staging in pools. Based on our observations in 2001 and 2002, additional chinook salmon redd construction will begin in this reach very soon. While hiking to this reach, we observed 20-25 head of livestock (cows and calves) grazing and resting in the riparian area along mainstem Camas Creek. At Furnace Creek, we encountered a new drift fence with the gate open. From Furnace Creek upstream to the first ford upstream from the Hidden Valley Ranch buildings, we observed about 15 head of livestock grazing and resting in the riparian area along mainstem Camas Creek. Upstream from the ford to the end of the reach upstream from the South Fork Camas Creek, we saw no additional livestock but observed evidence (tracks, droppings, trampling) that cattle have been along mainstem Camas Creek. It is my understanding that the S-C NF Plan states that there will be no grazing along mainstem Camas Creek upstream from Furnace Creek. Many Chinook salmon in Camas Creek will be spawning during the next couple weeks within the areas currently being grazed by livestock.

Thanks,

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Appendix D: Copy of 2009 Challis Messenger article.

Commissioners work with feds to head off grazing lawsuits

BY TODD ADAMS

The Custer County commissioners have told local Forest Service and BLM officials they want to work together to head off lawsuits that could restrict livestock grazing on federal allotments that are home to fish species listed under the Endangered Species Act (ESA).

Commissioner Wayne Butts noted last week that Western Watersheds Project (WWP) has filed several 60-day notices of intent to sue the Forest Service and BLM over outdated endangered species consultations with federal fish management agencies on local grazing allotments.

The action won't affect turnout on the range for 2009, said Butts, but might in 2010 if consultations on the effects of grazing on fish aren't updated by next season.

The commissioners want to keep cows on the range and local ranchers in business, said Butts, so "we're looking for help and partnerships." To that end, the commissioners have already talked with officials of the Idaho Governor's Office of Species Conservation (OSC) and are demanding to have representatives on a Salmon-Challis National Forest interdisciplinary team to update consultations.

The University of Idaho has volunteered Custer County Extension Agent Sarah Baker to serve on a team, led by Diane Weaver, the Salmon-Challis National Forest's lead range specialist. Butts would like to see two more people on the team, including former County Agent Jim Hawkins and another rancher.

Middle Fork District Ranger Chris Grove said they've found funding to update the forest's biological assessments of the grazing allotments.

BLM feels good about its administrative record documenting ESA consultations, said Dave Rosenkrance, Challis Area BLM manager.

WWP has filed notices of intent to sue on the Smiley and Fisher creek allotments of the Sawtooth National Recreation Area; Camas and Pass creek allotments on the Salmon-Challis National Forest; the Upper Salmon River watershed between the East Fork and the Pahsimeroi River, which includes Morgan, Challis and Garden creeks; the Pahsimeroi River and its tributaries and the Lemhi River watershed and tributaries.

The Hailey-based environmental group notified officials of the Forest Service and Bureau of Land Management that livestock grazing mismanagement on the allotments has negatively affected streams that provide habitat for ESA-listed bull trout, Chinook salmon, steelhead and sockeye salmon, on the SNRA only. Letters also went out to the fish regulatory agencies, — Fish and Wildlife Service and NOAA Fisheries — and to some ranchers with grazing permits on the affected allotments. WWP notices were filed from January through April. No actual lawsuits have been filed yet, Brian Ertz, media director for WWP told The Challis Messenger this week. The notices are a way to open a conversation with federal agency officials on what they need to do to better manage livestock grazing to protect fish habitat to avoid lawsuits, he said.

ESA consultations are out of date and, among other things, never addressed how the agencies would manage livestock to avoid trampling on fish redds during and after spawning season, Ertz said. The federal agencies have failed to implement some of the livestock management practices to protect fish habitat that they developed under the stale consultations, he added.

WWP is insisting that the agencies update the consultations and change grazing management to protect fish, said Ertz.

Weaver told The Messenger that prior to WWP filing the notices, she'd already started updating consultations on about 50 grazing allotments forest-wide that have ESA listed fish species. The goal is to have all updated by the 2010 grazing season, she said. The 2009 turnout of cattle onto the range won't be affected, she confirmed.

The Forest Service has new data showing changes in fish spawning, Weaver said. For example, bull trout are spawning earlier in some areas than previously thought, in August rather than September, which means the Forest Service will probably have to change some grazing times so cattle or sheep aren't present when fish start spawning. Earlier on and off dates may result, said Weaver.

Also, the agency initially thought steelhead probably were in some streams on grazing allotments, but they have not actually been found there, she said.

Weaver said she's working with both OSC and the University of Idaho Extension Service to update consultations and will put information together for Custer County. The Forest Service will be monitoring fish habitat and populations this season, gathering new data on spawning times and locations, she said.

Baker said her role is one of education and outreach. She'll help get the word out to ranchers on possible grazing management changes and keep them in the loop as agency officials update their ESA consultations.

Cows vs. fish

WWP contends livestock grazing, under current management, is a threat to cherished Idaho fisheries because it reduces streamside vegetation that cools water, shades fish and hosts insects that fish eat, Ertz said. Grazing degrades stream banks, polluting fish spawning habitat with sediment, cattle defecate in stream water and livestock can directly trample fish nests or redds.

Water diversions and water developments built for livestock production reduce the flow of water in streams that salmon, steelhead, and bull trout recovery relies upon.

"A single trampling event impacting even one fish redd can kill thousands of these protected fish's developing eggs and baby fish." said Ertz. "Current management unlawfully ignores the impacts of livestock grazing to the recovery and habitat needs of these fish."

Appendix E: **May 28, 2014 Comments on the Camas Creek Grazing Allotment BA; submitted upon request to S-C NF staff by R. Thurow, RMRS.**

I briefly skimmed the Camas Cr BA and have a few suggestions:
1. The Aug 15 timing for the start of Chinook salmon spawning is erroneous and needs to be weeks early. As noted in the BA, we have observed salmon constructing redds in Camas Cr near Castle Cr as early as July 24. The West Fork and Meyers Cover stream reaches are just a few km downstream. Also, in higher adult return years, the spawning period broadens. The potential Chinook salmon spawning window is ~July 24 to Sept 6.

2. The page 41 discussion suggestions that cattle will not disturb spawning or staging adults. In fact, Chinook salmon and steelhead often spawn in gravels within stream trail crossings. Cattle crossing these locations have the potential to repetitively disturb spawning fish that are attempting to construct redds. Data collected on the upper Salmon River by the Sawtooth NF may be relevant to cite; ask Mark Moulton for the 1995 data. They observed that when float craft passed within 20 feet of spawning salmon it caused the fish abandoned the redd and stay off the redd for 25 minutes. Cattle obviously may also trample incubating embryos in redds.

3. Since 1995, RMRS has surveyed all potential salmon spawning areas in the Camas Cr drainage; including lower Castle Cr when flows are adequate. The cumulative redd maps I sent you last week provide our best estimate of the extent of Chinook salmon spawning in the drainage.

4. Abundant literature demonstrates that livestock grazing in or passing through riparian areas or crossing streams have the potential to adversely affect fish populations by degrading riparian and in stream habitat. Although this disturbance is especially critical to avoid during the staging, spawning, and incubation periods, it is also important to critical to degradation of juvenile rearing and overwintering habitats.

5. While working for IDFG, I mapped observed steelhead redds and the extent of some major steelhead spawning areas in Camas Creek. I also snorkeled sites throughout the drainage and recorded all salmonids observed. These data may be found in:
Thurow, R. 1982. Middle Fork Salmon River fisheries investigations. Job Performance Report. Federal Aid in Fish Restoration Project F-73-R-4. Idaho Department of Fish and Game, Boise. 80 pp.
Thurow, R. 1983. Middle Fork Salmon River fisheries investigations. Job Performance Report. Federal in Fish Restoration Project F-73-R-5. Idaho Department of Fish and Game, Boise. 103 pp.
Thurow, R. 1985. Middle Fork Salmon River fisheries investigations. Job Completion Report. Federal Aid in Fish Restoration Project F-73-R-6. Idaho Department of Fish and Game, Boise. 100 pp.

6. More recent Camas Creek genetic data may be found in:
Neville, H.M., D.J. Isaak, J.B. Dunham, R.F. Thurow, and B.E. Rieman. 2006. Fine-scale natal homing and localized movement as shaped by sex and spawning habitat in Chinook

salmon: insights from spatial autocorrelation analysis of individual genotypes. Molecular Ecology 15: 4589–4602.
Neville, H., D. Isaak, R. Thurow, J. Dunham, and B. Rieman. 2007. Microsatellite variation reveals weak genetic structure and retention of genetic variability in threatened Chinook salmon Oncorhynchus tshawytscha) within a Snake River watershed Conservation Genetics DOI 10.1007/s10592-006-9155-4. Conservation Genetics 8:133-147.

Thanks for the opportunity, sorry the turnaround was so short, hope this helps.

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Appendix F: June 3, 2014 email describing the timing of Chinook salmon spawning in Camas Creek; submitted upon request to S-C NF staff by R. Thurow, RMR.

On May 29 you sent me the following email:
"Russ, I talked to XY this morning and it was his understanding in discussions with you in 2009 or 2010, while he was working on the 2010 Camas Creek Allotment BA, that Chinook salmon start spawning upstream in Camas Creek near the White Goat Creek area on July 24th. In 2010 and until your recent email, it was not our understanding there were Chinook salmon spawning in Camas Creek near Castle Creek and Furnace as early as July 24th. We were of the understanding that the initiation of Chinook salmon spawning on July 24th was in the White Goat Creek area. That is why we considered a spawning initiation date of August 15th for Chinook salmon in Camas Creek near Furnace Creek and Castle Creek. If there is documentation of Chinook salmon spawning in Camas Creek from Castle Creek upstream before August 15th that would be new information to us and we probably will need the data that can show the location of the observed Chinook salmon redds with the year, date and who were the observers. If you don't have this data compiled in some type of summary or report then copies of the raw data sheets would be helpful. The reason I am asking for us to have a copy of the data that shows Chinook salmon spawning in Camas Creek near Castle Creek as early as July 24th is this could possibly require a change in our proposed action. Right now we only have livestock grazing in the Upper Silver Creek Unit after August 15th. We did that because livestock presence would have been well away from Camas Creek on August 15th, what we thought was the initiation of Chinook salmon spawning near Castle Creek and Furnace Creek. If the August 15th date changes to July 24th we may need to revisit our proposed action and revisit with the permittee. I'll need to talk to the Ranger when he comes back from the field today but the data and documentation will be important for us to have for our files. Thanks for catching this misunderstanding and thanks for all your help."

In response, yes, we have data that were collected in Camas Creek from 2002 to 2005 to document Chinook salmon spawn timing downstream of White Goat Creek. These data are summarized below from Reaches 1 and 3. I also recall sharing our data from Reach 2 upstream from White Goat Creek with XY in the late 2000s. The reason we focused on Reach 2 is because our redd surveyors and myself consistently encountered cattle when completing redd surveys above White Goat Creek from 2002 to 2005. We were concerned about the potential take of ESA listed Chinook salmon so brought this issue to the attention of the Forest. However, we were also simultaneously collecting data to document Chinook salmon spawn timing in areas downstream from White Goat Creek (Reaches 1, 3).

INTRODUCTION
Before I share the additional data, it might be useful to address the origin of your August 15 onset of spawning date and why it is not accurate. Since 1957, the Idaho Department of Fish and Game (IDFG) has conducted annual one-pass redd surveys in reaches of Camas Creek. These counts were completed during the "peak" spawning period at about the same date each year. It is likely that IDFG determined that mid-August was about the peak timing for salmon spawning in the Meyers Cove index reach. Over time, the August 15 date may have been misinterpreted as the date for initiation of spawning rather than as the average peak spawning date.

In 1995 I began a continuous survey of all potential spawning areas within Camas Creek as well as in other Middle Fork Salmon River basin spawning areas, including the mainstem. In order to conduct a complete redd count, I waited until the end (not peak) of spawning in Sept to do the *surveys. The redd maps and shape files I just sent you summarize those counts and can be used to illustrate all of the known, recent (since 1995) spawning sites used by salmon in Camas Creek.*

METHODS
In 2002, we began a new project to estimate the accuracy and precision of my aerial redd counts. In the process, we also collected very accurate information to document the start and end of Chinook salmon spawning in Camas Creek. We placed experienced redd surveyors (monitors) on the ground who surveyed select spawning reaches. We attempted to begin surveys prior to the first redd and continue until the last redd was built. We applied those data to compare my aerial estimates to their unbiased estimates of the actual number of redds. These data are summarized below.

Reach boundaries are summarized in Table 1. For example, Camas Creek Reach 1 extended from the second tributary downstream from Hammer Creek upstream to the confluence of Silver Creek. We flagged those boundaries and the redd monitors surveyed the same reach every 4-5 days from prior to spawning until the last redd was completed.

Table 1. Camas Creek redd monitor Reach boundaries, UTMs, and Reach Length.

STREAM	*REACH #*	*START-utm*	*START-utm*	*END-utm*	*END-utm*	*LENGTH (KM)*
Camas Cr	*1.*	*693343*	*4970703*	*697611*	*4966863*	*6.5*
		2nd trib below Hammer Cr to.		*Silver Creek*		
Camas Cr	*2.*	*698813*	*4958725*	*698161*	*4954085*	*6.3*
		1.2 Km above Furnace Cr to		*1.3 km above SFk*		
Camas Cr.	*3.*	*698782*	*4965253*	*700087*	*4963024*	*4.1*
		1.7 km above West Fork to		*Sawlog Creek*		

The number of surveys by year and observer are summarized in Table 2. For example, in 2002 T.A. surveyed Reach 1 nine different times. In 2003, J.M. surveyed Reach 1 eleven different times, etc. During each survey, the redd monitors recorded adult salmon staging near spawning sites and redds under construction or completed.

Table 2. Number of redd surveys by Reach, Year, and Redd monitor.

STREAM	*REACH #*	*2002 Monitor # surveys*	*2003 Monitor # surveys*	*2004 Monitor # surveys*	*2005 Monitor # surveys*
Camas Cr	*1.*	*T.A. n= 9*	*J.M. n=11*	*D.A. n=9*	*T.A. n=12*
Camas Cr	*2.*	*T.A. n= 7*	*J.M. n=11*	*D.A. n=9*	*T.A. n=11*
Camas Cr	*3.*	*T.A. n= 8*	*No survey*	*D.A. n=8*	*No survey*

RESULTS

The data we collected in Reaches 1 and 3 are summarized below in Tables 3 and 4. The Tables report: the date of the first survey, the date when adults staging near spawning sites were first observed, the date completed redds were first seen, the date the first redds were likely initiated, the date the last redds were initiated, and the date of the last survey.

It is very important to view these data as "conservative" estimates of the timing of Chinook salmon spawning in Camas Creek. In other years, the date of first redd construction could be earlier and the date of last redd construction could be later than we report here. During larger adult return years, we have observed that the dates of spawning broaden. That means more phenotypic diversity in spawn timing seems to be expressed with larger adult returns. During years of extremely low returns, the timing of spawning tends to narrow. Although these data are very useful, they are limited to four years in two reaches (1, 2) and for two years in one reach (3). The adult returns during those years were variable and still far below the historical adult returns. Current adult returns are an estimated 5-10% of historical returns. The evidence strongly suggests that with larger adult returns, the window of spawning will broaden; the first fish would spawn earlier and the last fish later.

First Observations of Staging Adults

Adult Chinook salmon migrate into the Middle Fork Salmon River weeks to months before spawning and hold in large, deep pools in the mainstem as well as the lower reaches of spawning tributaries. Just prior to the onset of redd construction, adults migrate to the vicinity of spawning sites and stage near those sites. The 3rd column of Tables 3 and 4 documents the dates when adult salmon were first observed staging near spawning sites. Adult salmon staging near spawning sites are typically visible and vulnerable as they hold in small pools or beneath undercut banks. Salmon began constructing redds and spawning shortly thereafter.

In Reach 1 (Below Hammer Creek to Silver Creek), redd monitors observed adult Chinook salmon staging in close proximity to spawning areas as early as July 23 in 2004 (Table 3). Staging adults were first observed in Reach 3 (downstream from Castle creek) on August 6 in 2002 and no early data were collected in 2004 (Table 4).

Table 3. Reach 1 date of first survey, first staging adults, first redds, last redds, and last survey.

Year	*Date of First survey*	*First Staging Adults Observed*	*Date First Redd Initiated*	*Date First Redd Completed*	*Date Last Redd Initiated*	*Date Of Last Survey*
2002	*July 31*	*July 31*	*Aug 12*	*Aug 14*	*Sept 5*	*Sept 5*
2003	*July 25*	*July 25*	*Aug 9*	*Aug 11*	*Sept 3*	*Sept 16*
2004	*July 23*	*July 23*	*July 27*	*July 29*	*Aug 30*	*Aug 30*
2005	*July 20*	*Aug 11*	*Aug 17*	*Aug 19*	*Sept 4*	*Sept 4*

Table 4. Reach 3 dates of first survey, first staging adults, first redds, last redds, and last survey.

Year	*Date of First survey*	*First Staging Adults Observed*	*Date First Redd Initiated*	*Date First Redd Completed*	*Date Last Redd Initiated*	*Date Of Last Survey*
2002	*July 31*	*Aug 6*	*Aug 4*	*Aug 6*	*Aug 30*	*Aug 30*
2003	*No survey*					
2004	*July 31*	*No early data*	*July 29*	*July 31*	*Aug 31*	*Aug 31*
2005	*No survey*					

<u>Completed Redds</u>
Completed redds were initially observed in Reach 1 on July 29, 2004; August 11, 2003; August 14, 2002; and August 19, 2005 (Table 3). Completed redds were first observed in Reach 3 on July 31, 2004 and August 6, 2002 (Table 4).

<u>Onset of Spawning</u>
We observed female salmon remaining on redds for 2 to 5 days from the onset of redd construction to redd completion. As a result, the most conservative estimate of the onset of spawning would be at least two days prior to the date the first redd was completed. Consequently, our best estimates of the onset of spawning in Reach 1 are July 27, 2004; August 9, 2003; August 12, 2002; and August 17, 2005 (Table 3). In Reach 3, salmon began redd construction on July 29, 2004 and August 4, 2002 (Table 4).

<u>End of Spawning</u>
We estimated the end of the spawning period using the date when the last redds were observed under construction. In Reach 1, final redds were observed on August 30, 2004, Sept 3, 2003, Sept 4, 2005, and Sept 5, 2003 (Table 3). Final redds were observed in Reach 3 on August 30, 2002 and August 31, 2004 (Table 4).

DISCUSSION
The data collected in Reaches 1 and 3 document adult salmon staging near spawning sites as early as July 23 and the onset of spawning as early as July 27. These dates are more than two weeks earlier than the former estimated August 15 initiation of spawning date for these reaches. As noted in your email referenced in this letter, you may want to revisit your proposed action in Camas Creek.

As you are aware, three ESA listed salmonids spawn and rear in the Camas Creek basin. In addition to spring/summer Chinook salmon, summer steelhead and bull trout are present. Although specific spawning and incubation dates will vary with stream temperatures and discharge, in general, steelhead spawn from late March to mid June and their alevins incubate until emergence in July or early August. Chinook salmon spawn from late July to early September and their alevins incubate until February or March. Bull trout spawn from late August to November and their alevins incubate until March or April. As a result, one of these *three salmonids is either spawning or incubating in the Camas Creek basin nearly the entire year.*

I hope the data are useful. Please let me know if any of this information needs clarification. These data will ultimately be published; we are working on a manuscript to illustrate the broad diversity in Chinook salmon spawning ecology across the Middle Fork Salmon River basin.]

Thanks,

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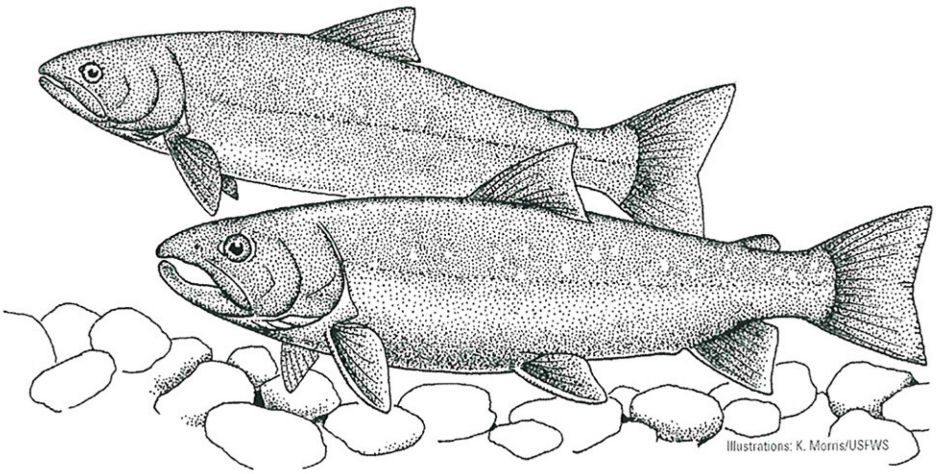
ASSESSING THE EFFECTS OF GRAZING ON BULL TROUT AND THEIR HABITAT

An alternative approach – the effects and the variables influencing those effects



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1.0 INTRODUCTION

This paper is one of the products resulting from a collaborative effort between Theresa Doumitt with ATW Consulting and Doug Laye with the U.S. Fish and Wildlife Service. Our intention was to create a tool for individuals who use and manage public lands to increase the efficiency and thoroughness of their assessments of impact. This document is targeted specifically at the effects of grazing on bull trout (*Salvelinus confluentus*) and their habitat, but the overall concept has a wide range of possible applications.

By researching and organizing some of the available literature; we identified (based on current understanding) the effects created when livestock and fish share part of the same ecosystem. This document is considered a work in progress to be revised and updated as new information comes available through ongoing research.

The primary goals of this paper are to:

- clearly identify and validate the ways, proven and suspected, in which grazing affects bull trout and their habitat (thereby establishing the effect pathways in section 2.0); and
- describe and confirm with research, where support is available, the variables which influence the degree of expression of these effects (in section 3.0).

Since research is limited on the effects of grazing on bull trout, studies performed with other members of the trout family (*Salmonidae)* are utilized. Members of this family of fish include salmon, trout, char, grayling, and freshwater whitefish.

2.0 IDENTIFICATION AND VALIDATION OF THE PATHWAYS BY WHICH GRAZING AFFECTS BULL TROUT AND THEIR HABITAT

Discussion of the effects begins with the individual activities of grazing in order to clearly establish the causes of each effect. The discussion is divided into two sections based on timing: activities which create immediate changes in habitat or conditions for bull trout and activities which result in delayed changes in habitat or conditions. 'Immediate changes' occur at the same time as the activity and are the result of activities in the stream or on the streambank. 'Delayed changes' occur at a later time than the activity and are the result of activities in the **uplands*** or within the **riparian area** (excluding the stream and its bank).

Activities which create immediate changes:

- Grazing on streamside vegetation
- Walking on the streambank
- Walking or loafing in the stream
- Urinating or defecating in the stream
- Using or creating trails to the stream

Activities which lead to delayed changes:

- Bedding in riparian areas and uplands
- Using or creating trails in riparian area/uplands
- Using salt or mineral supplement
- Using corrals, loading chutes, or weaning areas
- Using, maintaining, or constructing/developing alternative watering structures
- Maintaining or installing fences
- Using roads to transport cattle to/from allotment
- Implementing monitoring plan – determining range-readiness, utilization, bank alteration,...
- Urinating or defecating in riparian areas/uplands
- Grazing on riparian and upland vegetation

***NOTE** – all words in bold, sage-colored font (**that look like this**) are defined in the Glossary.

In our review of the above activities and the subsequent changes in the environment that are triggered, three facts became clear: one activity can create several different changes in the environment, different activities can have common consequences, and the relationships between the activities and the resulting changes are complex and non-linear. In an attempt to simplify the effects of grazing in a manner that can be clearly discussed and evaluated, each of the above activities and its resulting changes were dissected individually to reveal somewhat of a linear pathway. This method resulted in nine unique pathways that will be referred to as Effect Pathways. These nine Effect Pathways (summarized in Figure 1 and described in detail in Section 2.1 and 2.2) are concise explanations of the chain of events triggered by the activities of grazing.

Figure 1. Summary of Effect Pathways 1-9 that may be triggered by grazing activities and the possible environmental results and consequences to bull trout/aquatic habitat as established and validated in Sections 2.1 and 2.2.

Effect Pathway	Grazing Activity	Environmental Change	Consequences to Bull Trout
Pathway 1	Grazing on streamside vegetation	Less shade	Increased stream temperatures
Pathway 2	Grazing on streamside vegetation	Less overhanging vegetation thereby less food/habitat for prey	Less aquatic and terrestrial food for bull trout
Pathway 3	Livestock use of streambank (section 2.1.2)	Decreased bank stability leading to	Lower number of undercut banks and pools Increased width to depth ratio Increased sediment in water and substrate
Pathway 4	Walking or loafing in stream	Trampling of redds	Decrease bull trout population
Pathway 5	Walking or loafing in stream	Displacement of juveniles from cover increasing predation risk	Decrease juvenile survival
Pathway 6	Urinating or defecating in stream	Lowered water quality	Decrease prey populations
Pathway 7	Activities causing compaction (section 2.2.1)	Increased runoff and erosion	Causes stream incision and and triggers pathways 3, 6, 8
Pathway 8	Activities causing compaction (section 2.2.1)	Decreased infiltration	Decreases stream flow, lowers water table and triggers pathways 1 and 3
Pathway 9	Grazing on riparian and upland vegetation	Shifts in plant community	Reduces woody debris and triggers pathways 3 and 7

Even though these pathways are depicted as linear and independent, as discussed previously we acknowledge that they are quite interconnected and complex, and have been reduced into simplistic pathways for ease of discussion and presentation. For example, the activity of 'grazing on streamside vegetation' can be a trigger for Pathways 1-6, but for simplicity sake it is discussed where it is thought to be the primary cause for effect (in Pathways 1-3). This interrelatedness is depicted below in Table 1 and also becomes more apparent in Section 3 when some of the variables (affecting degree of effect) are shown to be the same.

Table 1. Grazing activities, the location of the discussion of the activity's effects, and the different pathways that can, in actuality, be triggered by that activity.

ACTIVITY	DISCUSSED IN PATHWAY	CAN TRIGGER PATHWAY
Grazing on streamside vegetation	1, 2, 3	1-6
Walking on the streambank	3	3-6
Walking or loafing in the stream	4, 5	4-6
Urinating or defecating in the stream	6	4-6
Using or creating trails to the stream	3	3,6,7,8
Using, maintaining, or constructing watering structures	8	1,3,8
Urinating or defecating in riparian areas/uplands	7	6,7
Grazing on riparian and upland vegetation	9	3,7,9
Other 7 activities (listed in Section 2.2.1)	7, 8	1,3,6,7,8

In Section 2.1 and 2.2 (that follows) there are simplified summary tables depicting each of the individual Effect Pathways. Below each summary table is a discussion section that offers further support and explanation. A more detailed explanation of the variables influencing degree of activation of the pathways can be found in Section 3.

2.1 ACTIVITIES WITH IMMEDIATE CHANGES

2.1.1 Grazing on streamside vegetation (Effects of reduction of plant matter)

Grazing along streams, by reducing the amount of **overhanging vegetation** (Platts 1991, pg 393), can act through two different pathways to cause potential effects to bull trout or their habitat. Pathway 1 and Pathway 2 are displayed in a simple table below (Table 2). More detailed discussion of the pathways is offered below the table in a narrative format.

Table 2. Simple display of Effect Pathway 1 and Effect Pathway 2 – effects of reduced plant matter.

	Immediate Change	Resulting Change	Effects on Bull Trout or their Habitat
PATHWAY 1 Changes to temperature	decreases stream shading and exposes more water surface to solar radiation	increases stream temperature in the summer (VanVelson 1978, pg 53; Platts and Raleigh 1984, pg 1107; Li et al. 1994, pg 633; Tait et al. 1994, pg 48; Zoellick 2004, pg 24)	increased stream temperature can decrease trout occurrence (Barton et al. 1985, pg 377); decrease trout densities (Tait et al. 1994, pg 51); decrease productivity/**biomass** production (Bisson and Davis 1976, pg 767-768; Platts and Nelson 1989a, pg 455-456); decrease growth rate by inhibiting appetite (Wurtsbaugh and Davis 1977, pg 87) and increasing metabolic rate (Li et al. 1994, pg 637), and increase the risk of invasion of other fish species (Bayley and Li 2008, pg 143)
PATHWAY 2 Reduction of prey	reduces plant matter available (Gunderson 1968, pg 513; Van Velson 1978, pg 54; Clary and Kinney 2002, pg 139) as habitat and food for terrestrial insects and as leaf litter for food for aquatic insects (Chapman and Demory 1963, pg 144; Minshall 1967, pg 147)	decreases terrestrial **prey** available to **salmonids** (Baxter et al. 2005, pg 201; Saunders and Fausch 2007, pg 1223) and affects the type and quantity of aquatic insects present.	less prey results in reduced fish biomass (Saunders and Fausch 2007, pg 1225).

Discussion

How do plants affect water temperature? Stream temperatures are determined by a complex relationship between stream shading, width and depth of the stream, water source temperature, water flow volume, and air temperature. "Rooted streamside plants…provide shade, food, and nutrients for aquatic and riparian species" (Winegar 1977, pg 12; Thomas et al. 1979, pg 7; Kauffman and Krueger 1984, pg 431; Belsky et al. 1999, pg 3). By simply reducing the overhanging vegetation, grazing can decrease the insulative effects that overstory provides to the stream. Bull trout are believed to be one of the most thermally sensitive species of trout (Rieman and McIntyre 1993, pg 7; Selong et al. 2001, pg 1026), and water temperature has been proven to be the primary factor determining whether bull trout occur in a stream (Barton et al. 1985, pg 364; Dunham et al. 2003, pg 894). Because of this sensitivity, warmer summer stream temperatures can trigger a variety of effects for bull trout depending on the severity of thermal change. Studies also found that an increase in stream temperature caused trout to fed less (Wurtsbaugh and Davis 1977, pg 87). Reduced cover provided by overhanging vegetation, roots, and **undercut banks** has been linked to lower fish production (Bisson and Davis 1976, pg 767-768; Platts and Nelson 1989a, pg 455-456;). However by decreasing livestock access to the streamside vegetation (through fencing); VanVelson (1978, pg 53-54) showed that overhanging vegetation can recover and lead to reduced stream temperatures and increased trout production. See the discussion in Section 3.1 for variables that influence the degree of effect that grazing can have on overhanging vegetation.

How do plants affect bull trout prey? Grazing streamside vegetation also reduces the amount of plant matter which can affect the food chain that supports fish growth and survival in two ways:

- By decreasing the habitat for terrestrial insects (a food item for bull trout). Shaw and Clary (1996, pg 148) found that willow (*Salix* sp.) height and density (which provide cover for trout prey) were greater in ungrazed or moderately grazed pastures than those pastures grazed season long. Bayley and Li (2008, pg 25) found that the increased cover and potential food supply within grazing exclosures resulted in increased trout densities as compared to grazed reaches.
- By decreasing the **detritus** that gets deposited into the stream**.** Detritus from streamside plants is a primary food source for aquatic insects that become food for fish (Minshall 1967, pg 144) and is the source of about 50% of the nutrients that are the basis for the stream food chain (Chapman and Demory 1963, pg 145; Cummins 1974, pg 639). Cummins and Spengler (1978, pg 3) found that riparian vegetation is the largest source of detritus providing up to 60% of the organic matter that enters the stream. This organic matter is necessary to support headwater stream communities (Kauffman and Krueger 1984, pg 430)**.**

Chapman and Demory (1963, pg 145) showed that reducing overhanging vegetation can decrease both aquatic and terrestrial insect populations. When comparing high-intensity, short duration grazing to season-long grazing; Saunders and Fausch (2007, pg 1222) actually found three times more vegetative biomass and twice as many terrestrial **invertebrates** falling into the streams in less grazed sites. These reductions in plant and prey availability resulted in half the trout biomass production. This study and overall evidence reviewed by Platts (1991, pg 400) both showed that grazing can have substantial effects on the productivity of the fish within a stream.

2.1.2 Grazing on streamside vegetation (Effects on bank stability), Walking on the streambank, and Using/creating trails to the stream

In addition to triggering Effect Pathways 1 and 2, 'Grazing on streamside vegetation' can also damage individual plants or change the vegetative community (Schultz and Leininger 1990, pg 297; Greene and Kauffman 1995, pg 307; Clary 1999, pg 218) leading to decreased bank stability. The two other activities in this category 'walking along the stream's edge' and '**active or passive trailing** to or through the stream' can create immediate changes that initiate the same chain of events affecting the streambank. Therefore these three activities are combined into a single pathway, Pathway 3 (Table 3), because of their primary and immediate effect on bank stability.

Table 3. Simple display of Effect Pathway 3 – effects of streamside use on bank stability/sediment.

	Immediate Change	Resulting Change	Effects on Bull Trout or their Habitat
PATHWAY 3 Changes in stream characteristics and sedimentation levels	Reduces vegetative root mats and causes shearing of the bank into the stream which decreases streambank stability.	Decreases the number of undercut banks (Gunderson 1968, pg 510-511; Overton et al. 1994, pg 13) and leads to the creation of wider and shallower streams (increase **width to depth ratio**) (Overton et al. 1994, pg 13). Wider, shallower streams are more susceptible to subsurface ice formation and freezing throughout the water column (Platts 1991, pg 398; Cunjak 1996, pg 277).	Reduced numbers of **pools** and undercut banks that provide protective cover from predators (Beschta and Platts 1986, pg 371; Belsky et al. 1999, pg 25), decreased overall fish production (Boussu 1954, pg 239; Gunderson 1968, pg 512; Lanka et al. 1987, pg 27; Scarnecchia and Bergersen 1987, pg 315; Wesche et al. 1987, pg 152; Kozel et al. 1989, pg 180; Li et al. 1994, pg 627; Bayley and Li 2008, pg 143-144), and decreased winter survival (Platts 1991, pg 398; Cunjak and Randall 1993, pg 50).
		Increases sediment (Platts 1991, pg 404) that settles out of the water and covers the surface of the stream bed and fills in the spaces between gravel (Megahan et al. 1980, pg 380; Lisle 1982, pg 1650; Beschta and Platts 1986, pg 374-375; Bjornn and Reiser 1991, pg 98).	Reduced survival of eggs and emerging fry (Phillips et al. 1975, pg 461; Chapman 1988, pg 13; Reiser and White 1988, pg 434; Bjornn and Reiser 1991, pg 98) and interferes with the development of eggs and fry (Cordone and Kelley 1961, pg 199; Sorensen et al. 1977, pg36; Alabaster and Lloyd 1982, pg 2; Reiser and White 1988, pg 435).
		Increases sediment in water column.	Depending on concentration and duration of suspended sediment, effects on bull trout can include: decrease in abundance (Watson and Hillman 1997, pg 245), abandonment of cover (Gradall and Swenson 1982, pg 394), sediment avoidance (seeking refugia) (Lawrence and Scherer 1974, pg 25), short-term reduction in feeding success (Sorensen et al. 1977, pg36; Alabaster and Lloyd 1982, pg 2), elevated physiological stress that increases susceptibility to disease (Sorensen et al. 1977, pg 36; Alabaster and Lloyd 1982, pg 1), reduction of growth rate (Alabaster and Lloyd 1982, pg 1), modification of natural movements (Bjorn and Reiser 1991, pg 85), and reduction in the abundance of food organisms available to the fish (Cordone and Kelley 1961, pg 205; Sorensen et al. 1977, pg 36; Langer 1980, pg 5; Alabaster and Lloyd 1982, pg 2).

Discussion

Walking on streambanks, accessing the stream by trails, or creating trails can cause shearing of the bank into the stream simply from the sharpness and pressure of livestock hooves (Behnke and Zarn 1976, pg 5; Platts 1978, pg 501; Dahlem 1979, pg 32; Clary and Webster 1990, pg 209; Trimble 1993, pg 451; Trimble and Mendel 1995, pg 224). Shearing of the bank increased sediment being deposited into the stream and changes the stream width, bank angle, **bank retreat**, and root biomass (Clary and Kinney 2002, pg 139).

How can changes in vegetation create bank instability? When vegetation is grazed too long or consistently too late into the growing season (not allowing recovery time before winter):

- **plant vigor** and **productivity** is diminished (Vallentine 1990, pg 331; Archer and Smeins 1991, pg 109; Thurow 1991, pg 150; Ehrhart and Hansen 1998, pg 9),
- roots can die back (Vallentine 1990, pg 331; Ehrhart and Hansen 1998, pg 9),
- seed development can cease (Ehrhart and Hansen 1998, pg 9), and
- individual plants can be damaged or destroyed (Vallentine 1990, pg 331).

This damage can alter species composition of streamside vegetation leading to the reduction or elimination of **woody and hydric herbaceous vegetation** (with deeper, more vast roots) (Platts 1991, pg 393). This riparian vegetation is subsequently replaced by **upland or nonnative vegetation** (with shallower roots and less ability to bind the soil) (Stebbins 1981, pg 75-85; Archer and Smeins 1991, pg 109-115, 119-130; Thurow 1991, pg 150; Fleischner 1994, pg 631). This process reduces the complex root masses and above-ground structures (Dunaway et al 1994, pg 47; Clary 1999, pg 218; Clary and Kinney 2002, pg 144) that serve to retard streambank erosion by filtering sediments out of the water and maintaining/building streambanks (Meehan et al. 1977, pg 138; Winegar 1977, pg 11; Platts 1991, pg 396). Kleinfelder et al. (1992, pg 1920) and Dunaway et al. (1994, pg 47) showed that the density of herbaceous plant roots is responsible for most of the soil stability found in streambanks. "During floods these vegetative root mats reduce water velocity along stream edge, causing sediment to settle out and become part of the bank. Where streamside vegetation is insufficient and protective mats are absent, the banks erodes (Platts 1981a, pg 5) and the stream usually responds by adjusting its channel width" (Platts 1991, pg 397). Severity of effect is a function of soil type, plant community, and interactions between these factors (Dunaway et al. 1994, pg 47).

How do unstable banks affect bull trout? Regardless if decreased plant vigor or trampling is the cause of unstable banks, the results are the same: wider, shallower streams; less pools and undercut banks; and increased sediment in the **water column** and **substrate**. These changes in the stream channel affects the fish **production**, survival, and reproduction. "Stream width normally decreases when domestic livestock is eliminated from the surrounding area" (Gunderson 1968, pg 513; Platts 1981a, pg 6; Platts and Nelson 1985a, pg 377) and water depth increased slightly (10%) to markedly (500%) (Gunderson 1968, pg 513; Platts 1981a, pg 6).

Wider, shallower streams results in elevated water temperature in the summer and decreased number of pools and undercut banks that offer protection to bull trout from predators (Beschta and Platts 1986, pg 371; Vallen ine 1990, pg 51). Research has also found that wider, shallower channels are less likely to drift-over with snow in the winter, therefore increasing the possibility of surface and subsurface ice formation (Chisholm et al. 1987, pg 182). Snow cover can provide insulation against low air temperatures (Needham 1969, pg 54); and prevent the loss of stream-bed heat, prevent sub-surface ice formation, provide for stable water temperatures, and enable a free-flowing channel under the snow (Chisholm et al. 1987, pg 181). There are two types of subsurface ice, frazil and anchor ice, which form within the water column. Frazil is extremely soft and composed of fine crystals that undulate in the current, clump at the surface of the water, or present itself as stationary, slushy mass occupying the entire depth of the water. Anchor ice coats unmovable objects in the stream bed and is composed of larger, more granular, rigid crystals than frazil ice (Maciolek and Needham 1952, pg 206). Sub-surface ice formation could affect stream life through the mortality of

juvenile and adult fish (Tack 1938, pg 26; Maciolek and Needham 1952, pg 202; Cunjak 1996, pg 273) and mortality of eggs (Reiser and Wesche 1979, pg 58).

Grazed watersheds typically have higher stream sediment levels than ungrazed watersheds (Lusby 1970, pg 256; Platts 1991, pg 8). Increased sedimentation is the result of grazing effects on soils (compaction), vegetation (elimination), hydrology (channel incision, overland flow), and bank erosion (sloughing) (Platts 1981a, pg 6; Platts 1981b, pg 17; Kauffman et al. 1983a, pg 683; Lee et al. 1997, pg 9-28).

What does sediment do? Sediment can profoundly affect the productivity and complexity of a stream (Cordone and Kelly 1961, pg 208; McNeil and Ahnell 1964, pg 1). Negative effects extend from interference with spawning, egg and **alevin** survival, rearing habitat to adult holding habitat. Sediment settling out of the water onto trout **redds** can reduce the survival of salmonids eggs and alevins (Phillips et al. 1975, pg 461; Chapman 1988, pg 13; Reiser and White 1988, pg 434) by smothering and trapping them. In a healthy stream, young trout hide in the **interstitial spaces** between cobbles and boulders to avoid predation and to avoid the extreme cold of winter surface flows (Heggenes 1990, pg 341). Deposition of silt on spawning beds can fill these interstitial spaces in stream bed material impeding water flow, reducing dissolved oxygen levels, restricting waste removal, reducing survival of emerging fry, and blocking juvenile use of the area (Chapman 1988, pg 16; Bjornn and Reiser 1991, pg 98).

Increased sediment can also cause a loss of pool depth (where both adults and juveniles may reside), can decrease aquatic invertebrate production (by decreases the amount of substrate suitable for invertebrates), and can cause channels to **braid** (Megahan et al. 1980, pg 380; Lisle 1982, pg 1650; Beschta and Platts 1986, pg 371). Sediment has also been shown to affect trout occurrence (Watson and Hillman 1997, pg 245; Zoellick and Cade 2006, pg 269), decrease channel stabilization, and modify channel shape and complexity (Meehan 1991, pg 2 and 9; Lee et al. 1997, pg 9-28).

Sediment in the water column (suspended sediment) can reduce light penetration to plants and reduce oxygen carrying capacity of the water. The effect of suspended sediment on juvenile and adult fish has been well documented (Newcombe and MacDonald 1991, pg 74-77). Depending on concentration and duration of exposure to sediment; different effects can be expressed:

- Behavorial effects – abandonment of cover, sediment avoidance (seeking refuge from sediment),
- Sublethal effects – short-term reduction in feeding success, increase in physiological stress and stress-related disease, and
- Lethal effects – reduced growth rate and fish densities, abrades gills, increased predation, and death (with long enough exposure to high levels).

2.1.3 Walking or loafing in the stream

Livestock walking or loafing in the stream may result in effect to bull trout through two different pathways (see Table 4).

Table 4. Simple display of Effect Pathway 4 and Effect Pathway 5 – changes caused by in-stream use.

	Immediate Change	Resulting Change	Effects on Bull Trout or their Habitat
PATHWAY 4 Changes in reproduction	stepping on redds and pre-emergent fry (Roberts and White 1992, pg 454; Ballard and Krueger 2005, pg 276; Gregory and Gamett 2009, pg 364)	-	increases mortality rates of embryos and alevins (Roberts and White 1992, pg 454)
PATHWAY 5 Changes in survival	relocating juvenile bull trout from protective cover into open water	-	increases their susceptibility to predation

Discussion

What are alevin and fry? There are four life stages of the bull trout: egg, alevin, fry and adult. The first two stages are not mobile. Eggs are laid by the female and fertilized by the male. The eggs are deposited in redds (nests that adult trout build in the gravel). The timing of development of embryos inside the eggs depends on water temperature. Bull trout eggs require a long incubation period (100-145 days) compared to other salmon and trout, and hatch in late winter or early spring (USFWS 1998, pg 1). When the eggs hatch, tiny fish called alevins emerge. Alevins stay within the gravel of the redd while continuing to develop feeding only on their yolk sacs. The stage when trout begin to swim and start eating is called 'fry'. Fry remain in the stream bed for up to three weeks before emerging (USFWS 1998, pg 1). The word 'juvenile' is the general term used to refer to young trout from the fry stage up until sexual maturity. Bull trout reach sexual maturity between four and seven years of age.

How does wading affect trout? Grazing livestock with access to streams where bull trout are spawning and depositing eggs can disturb spawning fish and trample redds. During the spawning period for bull trout, livestock presence in the stream can disturb adults that are initiating or tending redds by displacing them and affecting their breeding behavior. It is suspected that this disturbance only temporarily impairs their reproductive behavior. During the incubation period for bull trout, livestock presence in stream can have huge effects on the survival of the eggs and pre-emergent fry, since there is a large number concentrated into a small area and they have no ability to move. Trampling can destroy eggs and pre-emergent fry dislodging them or directly killing them. Gregory and Gamett (2009, pg 361) found that during the 14–21-day grazing period, 12–78% of the simulated redds were affected by trampling and as stocking intensity increased, impacts increased. Roberts and White (1992, pg 450) showed that a single wading event was responsible for 43% mortality and twice-daily wading events caused mortality of 96% of pre-hatching embryos in a simulated bed. Ballard and Krueger (2005, pg 274) showed that the time cattle spent in close proximity to salmon redds was small (<0.01%) in relation to the total time spent grazing the allotment. Even though the contact time was minimal, two out of 14 redds observed over the two-year project were trampled by cattle.

Trout use rooted and free-floating vegetation as cover (Boussu 1954, pg 239). Livestock wading into streams or occupying streamside habitat are likely to displace juvenile bull trout from protective streamside cover and other preferred habitat increasing their predation risks. Frid and Dill (2002, pg 11) argue that disturbance can indirectly affect both fitness and population dynamics by the costs caused by lost energy and lost opportunity. They stated that on an individual basis disturbances can affect prey behavior in regards to vigilance, fleeing, and habitat selection.

2.1.4 Urinating or defecating in the stream

When livestock urinate or defecate directly into the stream, these contaminants can affect bull trout through the **mechanism** explained in Pathway 6 (see Table 5).

Table 5. Simple display of Effect Pathway 6 – changes caused by increased nutrients.

	Immediate Change	Resulting Change	Effects on Bull Trout or their Habitat
PATHWAY 6 Changes in prey	increase phosphorus and nitrogen concentrations in the water column (Brooks et al. 1997, pg 227; Lemly 1998, pg 232)	increases bacteria growth on the gills and bodies of aquatic insects and can cause significantly lower density of insects occurring downstream (up to 66 percent less) (Lemly 1998, pg 234-235; Lemly and King 2000, pg 91).	decreases densities of aquatic insects reducing the food available for bull trout thereby lowering the growth rate and potentially displacing trout to other stream reaches

Discussion

How does livestock urine and feces affect bull trout? "When grazing animals become concentrated near water bodies or when they have unrestricted long-term access to streams for watering; sediment and nutrient loading can be high and bacteriological quality of surface water can be affected adversely (Brooks et al. 1997, pg 230). Feces and urine deposited in the stream increased nutrient levels in the water column, specifically phosphorous and nitrogen. These increased levels were demonstrated to cause extensive growth of bacteria on aquatic insects which resulted in high mortality levels in insect populations. In some cases entire hatches were lost (Lemly 1998, pg 237).

Nutrients from animal wastes can also stimulate aquatic algae and plant growth, however moderate levels of growth provide food as a basis for the aquatic food chain. Bauer and Burton (1993, pg 8-9) found that "the risk of nutrient enhancement is low in arid rangelands where animal wastes are distributed and runoff is comparatively light". In contrast, Alderfer and Robinson (1947, pg 948) observed high runoff rates in heavily grazed pastures and very little runoff in ungrazed areas. Nutrient impacts vary based on specific site conditions that include: precipitation, runoff, vegetation cover, grazing density, proximity to stream, and length of grazing use.

Livestock grazing can also cause increases in bacteria/protozoa levels (due to urination and defecation in the water) in areas where cattle are concentrated near water (Doran et al. 1981, pg 166; Gary et al. 1983, pg 123; Tiedeman 1987, pg 328-329; Taylor et al. 1989, pg 491; Hall and Amy 1990, pg 293). Bacteria can also enter the stream through runoff events via overland flow (Doran and Linn 1979, pg 985; Miner et al. 1992, pg 35). However in arid rangelands **coliform** contamination may be low (Bauer and Burton 1993, pg 10), because bacteria was found to stay within a few feet of the manure on dry rangelands at grazing intensity of 2 **ha/AUM** (Buckhouse and Gifford 1976, pg 109). No research was found on effects of coliforms on fish, so this action has not been identified to a pathway.

2.2 ACTIVITIES WITH DELAYED CHANGES

2.2.1 Bedding in riparian areas and uplands; Using or creating trails in riparian area and uplands; Using salt or mineral supplement; Using corrals, loading chutes, or weaning areas; Using, maintaining, or constructing/developing alternative watering structures; Maintaining or installing fences; Using roads to transport cattle to/from allotment; and Implementing monitoring plan

The first six activities (listed above) can cause compaction of the soil in areas where cattle congregate or frequent (Trimble and Mendel 1995, pg 234). Using Roads to Transport Cattle to/from Allotment and Implementing Monitoring Plan also results in compaction of roads and trails. Compaction can affect bull trout through two different pathways (see Table 6).

Table 6. Simple display of Effect Pathway 7 and Effect Pathway 8 – changes in the input of sediment, pollutants, and flood energy that gets channeled into the stream; and changes in water storage and stream base flows – all caused by compaction.

	Delayed Change	Resulting Change	Effects on Bull Trout or their Habitat
PATHWAY 7 Changes in input to stream channel	increased surface runoff and soil erosion (Alderfer and Robinson 1947, pg 948; Warren et al. 1986b, pg 1340; Valentine 1990, pg 47; Trimble and Mendel 1995, pg 236; Krueger et al. 2002, pg 5,7,8)	elevates the amount of sediment and pollutants getting channeled into the stream and increases the flood energy causing channel incision (downcutting) with narrowing of riparian zone (Clary and Webster 1989, pg 7; Buckhouse and Elmore 1993, pg 49; Simon and Rinaldi 2006, pg 361)	causing the same 'Effects on Bull Trout' as discussed in Pathway 3 and 6, and channel downcutting can result in lowering of the **water table** as detailed in the 'Resulting Effects' and 'Effects on Bull Trout' in Pathway 8
PATHWAY 8 Changes in water storage	reduced infiltration of precipitation into the soil (Alderfer and Robinson 1947, pg 948; Warren et al. 1986b, pg 1340; Wentz and Wood 1986 pg 365; Usman 1994, pg 69; Trimble and Mendel 1995, pg 235)	decreases water table (Platts and Raleigh 1984, pg 1108) and **groundwater** recharge resulting in warmer stream temperatures and overall shallower streams and pools	causing the same 'Effects on Bull Trout' as discussed in Pathway 1 and 3

Discussion

What is soil compaction and how does it lead to erosion? Soil compaction is the packing together of soil particles by forces exerted at the soil surface. This compression of the soil particles results in an increase in bulk density by decreasing pore space. Grazing, trailing, and repetitive use of the same site by livestock decreases the porosity of the soil through the pressure of their hooves (Heady and Child 1994, pg 63-67). Orodho et al. (1990, pg 11) found that "heavy" grazing in New Mexico caused an 8% increase in soil bulk density. Other studies that describe increases in soil bulk density associate with grazing included Kauffman and Krueger (1984, pg 434), Naeth et al. (1990, pg 157), Tollner et al. (1990, pg 75), and Vallentine (1990, pg 48).

"Soil erosion is the detachment and movement of soil or rock by wind, water, ice, or gravity" (Krueger et al. 2002, pg 7). Instead of absorbing rainfall, compacted soil resists penetration of water droplets. This resistance increases the impacts that raindrops have on the soil by increasing **sheet erosion** and increasing runoff created by a rain event (Krueger et al. 2002, pg 7). High rates of runoff have been observed in heavily grazed sites compared to ungrazed areas (Alderfer and Robinson 1947, pg 948). This enhanced run-off from the uplands increases the erosive force that rainfall events have on the stream bank through the elevated sediment load and surface flow that gets funneled directly into the stream channel (Trimble and Mendel 1995, pg 246). Simon and Rinaldi (2006, pg 361) found that channel incision can result from disturbances (such as compaction) that affect "available force, stream power or flow energy, or change erosional resistance".

What is infiltration and how does it affect streams? Infiltration is the downward movement of water through soil. Since compacted soil does not allow rain droplets to penetrate through the soil surface as does non-compacted soil, the following effects are possible.

- Significantly decreased infiltration rate and increased sediment production that is caused by bare soil produced from intense grazing (Alderfer and Robinson 1947, pg 948; Warren et al. 1986a, pg 491).
- Greater water loss and lower water tables – Water losses are high from heavily grazed pastures, whereas ungrazed areas lose little water due to runoff (Alderfer and Robinson 1947, pg 948). Therefore less precipitation penetrates the soil resulting in lower water table levels and reduced stream flows. Li et al. (1994, pg 638) found that "grazing can cause streams to become intermittent through lowering of the water table due to diminished interaction of the stream channel with the riparian vegetation and lowered water permeability of riparian soils due to compaction."
- Groundwater supplies are not replenished at the same levels (Thurow 1991, pg 144-145, 151) which can also reduce stream flows.
- Warmer, summer water temperatures and overall shallower streams and pools caused by lower stream base flow.
- Soil supports less vegetation growth because of the lower moisture (Krueger et al. 2002, pg 6).

Management considerations can be implemented to decrease the degree of compaction created by grazing. See section 3.1.4 for discussion of these variables.

2.2.2 Using, Maintaining, or Constructing/developing alternative watering structures

Constructing/Developing Alternative Watering Structures can have additional effects other than compaction. Developing watering structures from the same water sources that feed bull trout streams can decrease water tables and stream base flows (Li et al. 1994, pg 638). This **dewatering** works through a similar mechanism as discussed in Deacon et al. (2007, pg 693-694) and creates the same 'Resulting Effects' and 'Effects on Bull Trout' as discussed in Effect Pathway 8.

2.2.3 Urinating or defecating in riparian area and uplands

If density and distribution of grazing is not well-managed; then urinating and defecating in riparian and upland areas can increase nutrient concentrations that gets channeled into the stream and results in the same effects detailed in Effect Pathway 6. Even though the activity is similar and the subsequent effects are the same as in Effect Pathway 6, this activity is listed separately because of the location of the activity and its requirement of a precipitation event to trigger the mechanism.

Manure and urine deposited on land near surface waters can transport contaminants to streams through leeching and surface runoff (Krueger et al. 2002, pg 9). As much as 75 to 95% of the nutrients that grazing animal eats may be returned to the pasture in feces and urine (which has more nitrogen and is susceptible to leeching) in highly concentrated patches (Whitehead 1995 cited in Krueger et al. 2002). Nutrient concentration also depends on how skewed the distribution of urine patches and dung pats are relative to natural water courses or groundwater tables (West et al. 1989, pg 788-789).

2.2.4 Grazing on riparian and upland vegetation

If timing, density, and distribution of livestock are not well managed; then grazing can impact plant communities by causing decreased plant vigor and/or changes in soil characteristics that lead to effects on bull trout through Pathway 9 (see Table 7).

Table 7. Simple display of Effect Pathway 9 – changes in plant community.

	Delayed Change	Resulting Change	Effects on Bull Trout or their Habitat
PATHWAY 9 Changes in plant community	changes in the plant community (to include shallower rooted and non-native species) (Leopold 1924, pg 1; Schultz and Leininger 1990, pg 297)	decreases vegetative cover that protects and binds the soil and conserves soil moisture and nutrients (Krueger et al. 2002, pg 4-5)	causing the same 'Effects on Bull Trout' as discussed in Pathway 3 and 7.
		impedes plant **succession** which decreases large woody debris contribution to stream (Fleischner 1994, pg 633; Belsky et al. 1999, pg 32)	less large woody debris in the stream channel creates simpler stream structure with less protective cover increasing the possibility of trout predation and decreasing the quality of habitat (Kozel et al 1989, pg 180).

Discussion

How can grazing affect plant communities? Grazing can create significant differences in vegetative communities (Schultz and Leininger 1990, pg 297). "For plants to remain vigorous they must have time for growth, seed development, and storage of carbohydrates. Continual grazing during the plant's growth period eventually causes the roots to die back, reduces its vigor, and ceases seed development; which, in turn, can change the plant community to less productive and less palatable species" (Vallentine 1990, pg 331; Ehrhart and Hansen 1998, pg 9). Routine grazing too late in the growing season can change plant communities by the elimination of individual plants that are not able to recover from grazing. Myers (1989, pg 118) observed that nine grazing operations that had healthy riparian zones allowed for 36 days vegetation regrowth versus 21 days of regrowth for operations with unhealthy riparian zones. Marlow et al. (1991, pg 261-262) found that failure to allow for regrowth after grazing, over time, will not only impact vegetation in the riparian area, but will also reduce the vigor of the upland plants and may change plant communities. This shift in vegetation happens through selection of preferred forage. For example, when grasses (*Gramineae* family) are preferred, shrubs may be more competitive and eventually may dominate (Krueger et al. 2002, pg 5). In this way grazing can affect succession as well as plant communities within the ecosystem (Fleischner 1994, pg 633; Collins and Glenn 1995, pg 114-118,137).

How can changes in plant communities cause erosion and affect water storage? When hydric, deeply rooted herbaceous vegetation dies out and is replaced by upland or non-native species with shallower roots (less ability to bind the soil), erosion can increase. Alterations in plant communities are also assisted by the changes in soil characteristics and erosion caused by grazing. These changes and improper grazing management can reduce preferred forages and promote their replacement by invasive species (Archer and Smeins 1991, pg 123-124).

Another part of the plant community that can be affected by grazing is ground cover (leaf cover plus plant litter). Ground cover is important for many reasons. In regards to stream health; ground cover intercepts, absorbs, and retains moisture. These actions allow for greater infiltration of water and greater disbursement of surface water flow (Osborn 1955, pg 133-135). Ground cover is also the primary protection against both impact of raindrops and sheet erosion (Osborn 1955, pg 129, 133-135; Blackburn et al. 1986, pg 34; Farmer et al. 1999, pg 299). When ground cover is at or near its successional potential, it can ensure any additional sediment contributed to streams (from upland and riparian areas due to livestock grazing) is minimized. When vegetative cover is compromised by heavy grazing high water loss can occur as was found by Alderfer and Robinson (1947, pg 948). They attributed the high rates of runoff from the heavily grazed area to the lack of soil cover and compaction of the surface layer of the soil. Reduction in vegetative cover makes the soil more susceptible to erosive factors, increases runoff, and decreases soil moisture and nutrients (Krueger et al. 2002, pg 7). Less vegetative cover also reduces leaf litter which decreases organic matter and moisture in the soil (Belsky et al. 1999, pg 30). For soil and watershed protection the most important elements seem to be total ground cover, dispersion of ground cover, and quality of ground cover (Osborn 1955, pg 133-135; Blackburn et al. 1986, pg 32-34; Simanton et al. 1991, pg 281; Watters et al. 1996, pg 282-283; Goodrich and Reid 1999, pg 317).

How can changes in plant community affect the structure of the stream channel? In addition to increasing erosive factors when riparian vegetation is replaced with more **xeric** plants, stream channels may begin to braid or trench (depending on soil and substrate composition) (Platts and Raleigh 1984, pg 1108). Also when succession of riparian vegetation is hindered by grazing, input of large woody debris into the stream channel is decreased (Fleischner 1994, pg 633; Belsky et al. 1999, pg 32). When input of large woody debris is decreased and its influences on stream channel are diminished, then the channel structure becomes more simple (Gregory et al. 1991, pg 548-549).

NOTE – A simplistic review of the Effect Pathways can be found in Figure 1. This synopsis is offered to summarize the previous discussion and serve as a reference for the reader as they move into the degree of effects discussion in section 3.0.

3.0 DISCUSSION OF THE VARIABLES WHICH INFLUENCE THE DEGREE OF THESE EFFECTS

The purpose of this section is to clarify the factors influencing the degree that each pathway (discussed earlier) is activated. By doing this, we create a means of individualizing the discussion of effects for the unique qualities of the area being assessed.

The activities which immediately trigger Effect Pathways 1-6 all occur in the stream or on the streambank. If livestock cannot access the stream and its bank, then these activities cannot occur, and the only effects that need to be analyzed are those initiated by the activities that trigger Effect Pathways 7-9 (which indirectly included Effect Pathways 1, 3, and 6 (see Figure 1).

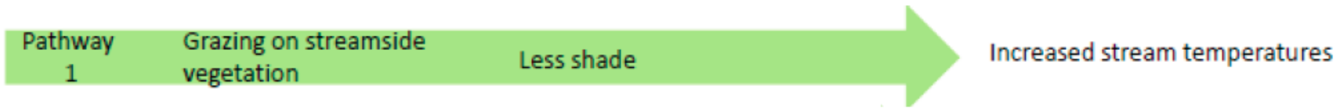
If livestock can only access part of the stream, then immediate effects of these streamside activities need to be evaluated on those sections (and in some cases downstream of those sections). Therefore accessibility of the stream is the first variable evaluated within each of the first six pathways and is an essential variable in analysis.

In the following discussion, the variables influencing severity of each effect are identified. Through this identification, it is found that some variables affect multiple pathways. These commonalties represent the complexity and interconnectedness of the pathways and are summarized in Table 8.

Table 8. Variables which influence the degree of impact that grazing can have on bull trout or their habitat separated by Effect Pathways (pathways are summarized in Figure 1 and described fully in Section 2.0). For example, the 'amount of stream access' can influence the degree of effect that grazing has on streamside vegetation and, in turn, on 'stream temperature'. For a detailed explanation of how these variables influence degree of effect, see Section 3.0.

Effect pathway # and element that may be affected by grazing	Variables that influence the degree of impact that grazing can have on bull trout or their habitat							
	Amount of stream access	Vegetation type	Slope and aspect	Elevation	Soil condition, type, and moisture content	Habitat suitability for spawning	Habitat suitability for juveniles	Management considerations
1 Stream temperature	✓	✓	✓					✓
2 Prey abundance	✓	✓			✓			✓
3 Bank condition and sediment load	✓	✓	✓	✓	✓			✓
4 Redd Trampling	✓	✓				✓		✓
5 Juvenile displacement	✓	✓					✓	✓
6 Stream nutrient levels	✓	✓						✓
7 Runoff and erosion		✓	✓		✓			✓
8 Infiltration Rate		✓	✓		✓			✓
9 Plant community		✓			✓			✓

3.1 VARIABLES FOR EFFECT PATHWAY 1



Decreased shading is triggered by grazing on over-hanging vegetation and the variables that affect the degree of activation of this pathway are:

- Accessibility of the streambank
- Vegetation type – desirability, height, and amount/diversity
- Slope and aspect
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; and adaptive management based on monitoring

See sections below for a more detailed discussion of each of the above variable.

3.1.1 Accessibility of the streambank

There are natural and man-made conditions that exist which exclude or minimize livestock access to the stream and its banks. These barriers include:

a) Steep terrain adjacent to the stream that provides less access than low gradient terrain,
b) Larger **boulders** lining the stream armour the banks and provide less access than smaller **cobble**.
c) Dense vegetation that allows less access than sparse vegetation,
d) Large amounts of large woody debris in the riparian area which provides less accessibility to streams and their banks than those with clear understory,
e) High stream flows in the spring that limit access as opposed to low summer flows that allow access,
f) Man-made barriers (well-placed trees, shrubs, boulders,…) that discourage livestock from accessing the stream, and
g) Properly located and well-maintained fences that prevent access by excluding livestock from the stream and protecting the riparian area, the fish, and their habitat (Platts and Rinne 1985, pg 118).

In 20 studies reviewed by Platts (1991, pg 400), he found that areas previously degraded by grazing were improved when livestock were restricted from the habitat. In an Oregon study Storch (1979, pg 56) revealed that trout comprised 77% of the total fish population in a section of stream within a fenced area that excluded grazing, but only 24% of the population outside the exclosure.

3.1.2 Vegetation type

Each vegetation type plays an important role in forming and protecting the aquatic habitat (Platts 1983, pg 184 and 187) and is susceptible to damage by improper grazing (Platts 1991, pg 396). The quantity and type of riparian vegetation affects the riparian area's ability to perform its natural functions of storing water, recharging aquifers, filtering chemicals and organic wastes, trapping sediment, building and maintaining banks, and reducing stream flow energy (Ehrhart and Hansen 1998, pg 3). Different vegetation offers various amounts of shading for streams, and the categories below are one way of evaluating degree of effect on vegetation.

a) **Desirability –** If the streamside vegetation is undesirable, then livestock will feed on it less and therefore the overhanging vegetation will be less impacted. Food preference may differ depending on the season of use. In the spring cattle prefer the succulent herbaceous species and are naturally more dispersed across the uplands (Platts and Nelson 1985b, pg 554; Ehrhart and Hansen 1998, pg 10). In the late summer and fall, woody species are preferred by cattle because of the greater palatability and higher protein content compared to surrounding herbaceous species (Kovalchik and Elmore 1992, pg 114).

b) **Height –** Grasses offer less shading and are more easily affected by grazing, whereas mature trees are beyond the grazers reach and thereby less impacted by grazing. The effects of grazing are therefore more evident where herbaceous vegetation provides the only shade to stream. However in riparian areas where woody vegetation of accessible height (like shrubs, young trees, and woody vines) make up the majority of stream cover, grazing can impact overhanging cover. Vegetation needed for shading also depends on stream size. Grasses are sufficient for cover only on very small streams (1st and 2nd-**order streams**), but brush (such as willow) is required for larger streams (3rd through 5th-order streams) (Platts 1991, pg 399).

   Cattle often begin to browse woody species when stubble height of palatable herbaceous species falls below approximately 4 inches (Hall and Bryant 1995, pg 6) or when herbaceous forage quality has diminished due to curing. Others suggest that approximately 6-8 inches of herbaceous residual stubble height may be needed to protect woody plants, especially during late season grazing (Clary and Leininger 2000, pg 569)." For further discussion of stubble height, see section 3.1.4f.

c) **Amount and diversity of vegetation –** If streamside vegetation is dense (depending on the move triggers and intensity, season, and length of grazing); the possible negative effects of reduced vegetation can be negated by the sheer abundance of vegetation. In addition to density of vegetation, diversity of vegetation can absorb effects created by grazing. Riparian communities comprised of one primary vegetation (**monoculture**) are suspected to provide less insulative effects and be more easily impacted than riparian areas comprised of more diverse, multi-canopied vegetation.

3.1.3 Slope and Aspect

The direction in which the surface of the stream faces can be a variable influencing the degree of effect that grazing on streamside vegetation can have on stream temperature. Streams on southerly-facing slopes are more vulnerable to temperature shift caused by removal of overhanging plant matter because of their increased exposure to the sun as well as the overall lower amount of vegetation supported on southerly slopes (Renner 1936, pg 29).

3.1.4 Management considerations/Grazing strategy

As Kauffman (1995, pg 29) stated effective management of salmonid habitats begins at the ridgeline (watershed boundary) and not at the streambank. Any grazing strategy, if it is to work, must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, the particular ranching operation, streambank, stream channels, water quality, and streamside vegetation (Platts 1991, pg 403). In reviewing the influence that management considerations and grazing strategy have on degree of effect, the following variables were identified.

a) Timing of grazing – The season of use of an area can have substantial influence on the degree of effect that grazing has on stream temperature. In the spring it is easier to keep livestock out of the stream when they naturally prefer herbaceous vegetation in the floodplains and uplands (Siekert et al. 1985, pg 278; Marlow and Pogacnik 1986, pg 212; Clary and Booth 1993, pg 493; Del Curto et al. 2000, pg 42) and when the cooler temperatures prevent loitering in the riparian (Ehrhart and Hansen 1998, pg 10). Also because livestock is attracted to the uplands, there is less browsing on willows and other woody plants (Kovalchik and Elmore 1992, pg 114; Clary 1999, pg 218). Shaw and Clary (1996, pg 148) found that willow height and density were greatest in pastures grazed in spring as compared to pastures grazed season long or grazed in the fall, and Lucas et al (2004, pg 466) found that herbaceous species richness and diversity were significantly greater during the cool season grazing at light to moderate levels. Therefore when spring grazing occurs in areas where riparian vegetation is comprised mostly of shrubs, then the effects on overhanging vegetation is minimized.

Mid-season (summer) grazing is considered the most injurious to the plant community unless management considerations are implemented to minimize riparian use and livestock congregation. Woody species browse is more likely (Buckhouse and Elmore 1993, pg 50; Krueger 1996, pg 161) and reduction in plant vigor is most possible, because of repeated and intense use caused by congregation (Ehrhart and Hansen 1998, pg 16). This is the period of greatest stress in the plant community, because plants are completing the carbohydrate storage process that maintains them during the dormant cycle (Leonard et al. 1997, pg 30). However effects on overhanging vegetation can be minimized; if conditions are monitored closely, alternative watering sources exist, the use is short-term, the use is rotated across years, and enough soil moisture remains for regrowth of plants (before the end of the growing season) (Ehrhart and Hansen 1998, pg 15 and 17). Myers (1989, pg 118) documented nine grazing operations with healthy riparian zones allowed for 36 days of vegetation regrowth versus 21 days for unsuccessful operations.

Late season (fall) grazing is also a time when woody species browse is more like because of the reduced palatability of herbaceous species and inclement weather can cause congregation in bottoms (Buckhouse and Elmore 1993, pg 50; Green and Kauffman 1995, pg 312; Krueger 1996, pg 161). Regrowth of overhanging vegetation is least likely to occur with fall grazing decreasing the vegetation's ability to fulfill its riparian role (sediment trapping, bank building and maintenance, flow energy dissipation (Ehrhart and Hansen 1998, pg 3). The impacts of fall grazing are lessened in riparian systems that are comprised mainly of herbaceous plants (Ehrhart and Hansen 1998, pg 12), since woody species are typically more palatable at this time of year. Plus if herbaceous species are grazed on, the herbaceous seeds have already set, so grazing has less impact than earlier in development (Gillen et al. 1985, pg 208).

b) Distribution of grazing – Livestock will spend a greater amount of time in riparian areas (even though it typically represent 20% of the forage) unless measure are taken to influence their distribution (Bryant 1982, pg 781-783; Roa h and Krueger 1982, pg 101-103; Platts and Nelson 1985c, pg 8-10). Management considerations implemented simultaneously can spread the distribution of livestock across the rangelands reducing the time they spend in the riparian and the impacts of grazing on streamside vegetation (Leonard et al 1997, pg 42; Ehrhart and Hansen 1998, pg 20). These practices also insure proper forage **utilization** and include:

- b1) The use of alternate water sources that are monitored and maintained throughout the grazing period (Riparian Habitat Committee 1982, pg 6; Miner et al 1992, pg 37 and 38; Clawson 1993, pg 63),
- b2) The placement of mineral supplement at least ¼ mile and preferably ½ mile away from heavily used trails, roads, water, and concentration areas (Riparian Habitat Committee 1982, pg 6; Ehrhart and Hansen 1998, pg 23),
- b3) The use of active trailing techniques to herd livestock into unutilized areas while preventing overutilization of riparian areas (Riparian Habitat Committee 1982, pg 6), and
- b4) The use of drift fences in mountainous terrain to deflect movement patterns in areas where livestock tend to use riparian areas as travel corridors (Ehrhart and Hansen 1998, pg 26).

Miner et al. (1992, pg 38) found that under winter conditions, the amount of time livestock spent drinking or loafing in the stream was reduced by more than 90% in the presence of a watering tank. McInnis and McIver (2001, pg 651) "found that off-stream water and salt attracted cows to the uplands enough to significantly reduce uncovered and unstable streambanks from 9% in non-supplemented pastures to 3% in supplemented pastures." Platts and Nelson (1985b, pg 553) also saw evidence that placing salt away from streams decreased grazing use of the riparian area. Several studies showed that frequent herding of livestock was a successful technique in lessening the time grazers spent in the riparian area (Storch 1979, pg 57; Masters et al. 1996a, pg 193; Masters et al. 1996b, pg 197), but Ehrhart and Hansen (1998, pg 25) warned that "poorly conducted trailing can be more detrimental than leaving livestock in riparian areas." Ehrhart and Hansen (1998, pg 23) provide anecdotal evidence that salt, when used in conjunction with alternate water sources, can help distribute livestock over open range and can reduce the impacts of grazing on trout habitat.

c) **Intensity of grazing** – The length of time grazing is allowed and number of livestock present are variables affecting the reduction of streamside vegetation. Marlow et al. (1991, pg 263) found "the most critical aspect in any grazing plan for the protection of the riparian areas is the length of time cattle have access to a particular stream reach." After reviewing 34 allotments in SW Montana, Myers (1989, pg 119) concluded that the duration of livestock is a key factor in determining the impact on riparian health.

There is an abundance of research showing the detrimental effects of heavy grazing on plant health, and other research that documents that light to moderate use maintains overall plant health. Holechek et al. (2006, pg 8) defined light grazing as 0-30% use of forage by weight, conservative grazing as 31-40% use, moderate grazing as 41-50% use, and heavy grazing as 51-60% use. In their review of 20 studies in the western North America that had some degree of replication, it was concluded that grazing can have a positive impact on forage plants compared to exclusion, if average long-term use did not exceed 40%. In central Idaho when light (20–25% use) or medium (35–50% use) grazing was applied to historically heavier grazed rangeland; Clary (1999, pg 218) observed narrowing and deepening of the streams, substrate **embeddedness** decreased, streambank stability increased, and streamside willow communities increased in both height and cover. Biondini et al (1998, pg 469) designed an eight-year study of moderate (residual vegetation of 50%) and heavy grazing treatments (residual vegetation of 10%) and found that heavy grazing lead to decline in standing dead biomass, litter biomass, and peak root biomass. They also concluded that moderate grazing seemed to be sustainable and compatible with the maintenance of range conditions.

When comparing foothills streams in west central Wyoming; Saunders and Fausch (2007, pg 1216) found that areas with high-intensity, short-duration grazing had much greater vegetative biomass than areas that were grazed season-long. Vegetation biomass was up to three times greater. No single management approach was best in all situations, but the light to moderate grazing treatments appears to be successful at maintaining riparian communities (Lucas et al. 2004, pg 466).

d) **Annual pasture use –** Rest or deferred use of pastures at different annual intervals can be an effective tool to minimize the reduction of over-hanging vegetation and ensure riparian plant communities remain vigorous. "For plants to remain vigorous they must have time for growth, seed development, and storage of carbohydrates. Continual grazing during the plant's growth period eventually can change the plant community to less productive and less palatable species" (Vallentine 1990, pg 331; Ehrhart and Hansen 1998, pg 9). Leonard et al. (1997, pg 33) gave examples of the success of the rest or deferred use system in protecting riparian areas, but stress that livestock must be moved from pasture to pasture quickly for this system to be effective. Platts (1991, pg 411) rates this system as fair for stream and riparian rehabilitation potential and recommends that utilization of riparian grasses and woody species must be carefully monitored in pastures grazed during summer and fall, as shifts in palatability may lead to increased use of these plants. A study in Nevada by Myers and Swanson (1995, pg 428) found that a switch to deferred grazing strategy resulted in improved riparian and stream condition. Leonard et al. (1997, pg 34-35) described the benefits of different deferred grazing techniques, which included improved willow reproduction, increased bank stability, improved plant vigor, and stabilized streambanks.

e) **Location of concentrated use areas** – Placing bedding grounds, corrals, livestock turnout points, loading chutes, weaning area,… away from riparian areas not only reduces congregational grazing on vegetation (Riparian Habitat Committee 1982, pg 6; Gillen et al. 1985, pg 209), it also allows sediment from these areas to get captured by vegetation (if ground cover is healthy) before reaching the stream channel.

f) **Adaptive management based on monitoring** – Individualized grazing plans that prescribe use based on the unique conditions of the given area can enable the improvement and rehabilitation of the riparian areas "as long as techniques are accompanied by clear objectives and an adequate monitoring system" (Krueger 1996, pg 160-161,164; Ehrhart and Hansen 1998, pg 5). Efficient movement between pastures and at end-of-year removal is also an essential element to protect properly functioning riparian systems and allow for recovery of degraded riparian habitats (Leonard et al. 1997, pg 33-34).

Selection of sound forage utilization standards (woody browse, stubble height, and bank alteration) that determines the amount of vegetation cover that is left after grazing is an important factor to riparian health. "It is important to remember that vegetation which exists on site at the end of the growing season or at the end of a grazing period, whichever comes last, is what matters since this is essentially what will be available for its protective effect during the next runoff period" (Ehrhart and Hansen 1998, pg 8). Basing these utilization standards on the current status of the riparian community can allow maintenance of existing vegetative conditions or more conservative standards can allow seral stages to progress (Holechek et al. 2004). Clary et al. (1996, pg 139) concluded that different stubble heights are needed to fulfill the two processes of sedimentation: deposition (trapping sediment requires <6 inches) and sediment retention (bank building requires 8-12 inches. Clary (1999, pg 218) found when using a 6" stubble height virtually all measurements of streamside variables move "closer to those beneficial for salmonid fisheries". Clary and Leininger (2000, pg 562) reported that maintaining a minimum stubble height can help preserve forage plant vigor, retain herbaceous forage to reduce browsing on willows, limit bank trampling, stabilize sediment, and maintain cattle gains. However the stubble height that is required to achieve these benefits ranges from 4" to 8" depending on the riparian conditions and responses (Clary and Webster 1990, pg 210; Clary and Booth 1993, pg 493; Clary 1999, pg 218). Bengeyfield (2006, pg 6) concluded that stream-bank alteration is the most powerful of the triggers, and that only streams that met stream-bank alteration levels showed significant improvement in the stream channel.

Diligent monitoring and efficient movement of livestock when standards are approached are as important to minimizing impact on streamside vegetation as the standards themselves. As Bengeyfield (2006, pg 6) found in his work with riparian improvement in southwestern Montana, "the key to successfully improving stream conditions in the presence of livestock is having the commitment of the agencies, the permittees, and the riders."

NOTE – From this point forward within section 3, if a variable is the same as the one defined previously (in Effect Pathway 1, section 3.1), then the reader will be referred back to the above discussion. For example, 'Accessibility of the streambank' is a variable in Pathways 1-6 and it is only discussed in detail in section 3.1.1.

3.2 VARIABLES FOR EFFECT PATHWAY 2

Pathway 2 → Grazing on streamside vegetation → Less overhanging vegetation thereby less food/habitat for prey → Less aquatic and terrestrial food for bull trout

Decrease in vegetative biomass that serves as habitat and food for prey species can be caused by grazing on overhanging vegetation. The variables affecting degree of activation of this pathway are:

- Accessibility of the streambank
- Vegetation type – desirability, height, and amount/diversity
- Soil condition, type, and moisture content
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; and adaptive management based on monitoring

3.2.1 Accessibility of the streambank

See variable discussion in section 3.1.1.

3.2.2 Vegetation type

Different vegetation offers various amounts of habitat for terrestrial prey and detritus for food for aquatic prey. The categories below are one way of evaluating the influence that vegetation type has on degree of effect of this pathway.

a) **Desirability** – See variable discussion in section 3.1.2a.
b) **Height** – Vegetation; such as grasses, forbs, and shrubs; offer more cover and food for prey species for fish than do mature trees, but are more easily affected by grazing because of their accessibility. Mature trees offer less cover for terrestrial insects that become food for bull trout, but still provide detritus for food for aquatic insects. Also mature trees are, for the most part, beyond the grazers reach and thereby less susceptible to the impacts of grazing.
c) **Amount and diversity of vegetation** – If streamside vegetation is dense (depending on the move triggers and intensity, season, and length of grazing); then the possible negative effects of reduced vegetation can be absorbed by the shear abundance of vegetation. Plus riparian communities comprised of one primary vegetation (monoculture) can be expected to provide less diversity of species (in this instance, insect species); than riparian areas comprised of more diverse, multi-canopied vegetation. In streams with fine substrate, woody debris and organic matter can provide necessary food and hiding places for stream insects (Reice 1974, pg 1271-1272; Reice 1980, pg 589; Dudley and Anderson 1982, pg 10).

3.2.3 Soil condition, type, and moisture content

The type of soil is a factor in determining the level of effect that grazing has on the food chain of the stream. In areas dominated by granite (which provides little nutrients to streams); streamside vegetation provides habitat for terrestrial insects and leaf litter, a principal food source, for aquatic invertebrate (Minshall 1967, pg 147). More nutrient-rich soils provide an additional source of nutrient input to support the aquatic food chain.

3.2.4 Management considerations/Grazing strategy

See variable discussion in section 3.1.4.

3.3 VARIABLES FOR EFFECT PATHWAY 3

Pathway 3	Livestock use of streambank (section 2.1.2)	Decreased bank stability leading to	Lower number of undercut banks and pools Increased width to depth ratio Increased sediment in water and substrate

Decreased bank stability along with the physical shearing of the bank into the stream is reduced by minimizing the time livestock spend in the riparian area. The variables that affect the degree of effect of Pathway 3 include:

- Accessibility of the streambank
- Vegetation type – desirability, height, and amount/diversity
- Slope and aspect
- Elevation
- Soil condition, type, and moisture content
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; adaptive management based on monitoring; and condition of stream crossings/access points

3.3.1 Accessibility of the streambank

See variable discussion in section 3.1.1.

3.3.2 Vegetation type

Severity of effect of bank stability is a function of soil type, plant community, and interactions between these two factors (Dunaway et al. 1994, pg 47). Different vegetation offers various amounts of stability to the streambank soil through their root structure. The categories below are one way of evaluating the influence that vegetation type has on degree of effect of this pathway.

a) **Desirability** – See variable discussion in section 3.1.2a.

b) **Height** – Because of the accessibility of the plant; grasses, **forbs**, shrubs, and young trees are more prone to the impact of grazing than mature trees. Each vegetation type plays an important role in forming and protecting the aquatic habitat (Platts 1983, pg 184 and 187) and is susceptible to damage by improper grazing (Platts 1991, pg 396). Trees provide shade (through canopy), streambank stability (through size and mass of root system), high quality pools and riffles (when mature and fall into stream), control slope and stability of channel (through large mass), prevents channel degradation thereby protecting spawning gravel (through depositing large amounts of organic debris into stream). Brush provides cover (through low overhang), protects from erosion, provides stream stability (through root system and litter fall); and grasses reduces erosion and increase stream bank stability (through forming vegetative mats), help create undercut banks (through gradual erosion of well-sodded banks), and help rebuild damaged banks (through trapping sediment in root systems of grasses and other plants) (Platts 1991, pg 396). However Daniels and Gilliam (1996, pg 246) determined that riparian areas comprised of grass removed 50%–60% of the sediment that entered the buffer and were more effective filters than mixed hardwood and pine buffers.

c) **Amount and diversity of vegetation –** The greater the amount and diversity of plant life, then the more complex the root system is that is maintaining and rebuilding the streambank. Leonard et al (1997, pg 7) stated that a "mix of vegetation increases channel roughness and dissipates stream energy. Willows and other large woody vegetation filter larger water-borne organic material, and their root systems provide bank stabilization." Sedges and rushes are species known to be strongly-rooted (Manning et al. 1989, pg 311; Platts and Nelson 1989b, pg 73; Kleinfelder et al. 1992, pg 1920; Dunaway et al. 1994, pg 47). "Sedges (*Cyperaceae* family), rushes (*Juncaceae* family), grasses, and forbs capture and filter out finer sediment, while their root masses help stabilize banks and colonize filtered sediments. On sites with potential for both woody and herbaceous vegetation, combined plant diversity greatly enhances stream function" (Leonard et al 1997, pg 7). Dunaway et al. (1994, pg 47) also found that sedges and rushes had the lowest erosion rates followed by mixed herbaceous species, but that soil texture also factored in to the degree of erosion effect. Sovell et al. (2000, pg 637) found that riparian sites dominated by mature trees (characterized by steep slopes, bare banks, little understory vegetation) had fine sediment-dominated streambeds. They suspect that lack of vegetative ground cover, due to almost complete canopy cover, may have reduced filtering of upland sediment and promoted erosion of streambank soils causing increased sediment to be deposited in the stream channel.

3.3.3 Slope and Aspect

The steepness of the terrain surrounding the stream affects the amount of erosion that can be caused by grazing and thereby the amount of sediment that gets channeled into the stream. Renner (1936, pg 28) found that erosion increased as gradient increased for all slopes that were accessible to livestock. The direction in which the slope of the terrain faces can be a variable influencing the degree of effect that grazing has on sediment that gets channeled into the stream. In northern latitudes southerly-facing slopes are exposed to more sunlight for longer periods of time than are other slopes. In a study in the Boise River Watershed in Idaho, Renner (1936, pg 13) revealed that the order of solar exposure from greatest to less exposure is as follows: south, southeast, east, southwest, west, northwest, northeast, and north. He also found that south-facing slopes are more vulnerable to erosion; because of their inherently shallower soil, lower litter cover, and overall lower amount of vegetation supported on these slopes (Renner 1936, pg 29). The areas of greater plant density had less erosion, because of the protection provided by both the vegetation and the litter cover. Since south-facing slopes have less litter and vegetation, the erosive impacts of grazing (sediment created during runoff events) can be more pronounced on these slopes.

3.3.4 Elevation

Elevation can be a variable of bank stability especially with a late season grazing strategy that doesn't allow enough time for the streamside vegetation to recover before winter begins. "Chisholm et al. (1987, pg 176) showed that middle-elevation streams (8366' to 9514') in Wyoming experience harsher winter conditions than high-elevation streams because of a lack of snow-bridge formation. Jakober et al. (1998, pg 223) also documented harsher winter conditions in mid-elevation stream where frequent freezing and thawing led to variable surface ice cover and frequent super-cooling. The insulating effects of a healthy overstory during winter as well as summer are important, because of the potential for summer stream heating and winter freezing (Platts and Nelson 1989a, pg 450)." Without the insulative effects of overstory, subsurface ice is more prone to form. See explanation of subsurface ice in section 2.1.2. Subsurface ice and ice flow is suspected to have an erosive effect that degrades streambank conditions.

3.3.5 Soil condition, type, and moisture

Severity of effect of bank stability is a function of soil type, plant community, and interactions between these two factors (Dunaway et al. 1994, pg 47). Silt has a negative effect on erosion in communities of sedges, rushes, or grasses; but has no effect on mixed sedge communities (Dunaway et al. 1994, pg 47). They also found that as percent clay in the soil increased, so did erosion. With sections of stream that are classified as **Rosgen A and B type channels**, with large cobble and well armored streambanks, streamside vegetation does not play as an important role in streambank stability. Clarifying the site specific nature of this variable, Buckhouse (1995, pg 36) warned that in areas with poorly-drained soil in seasons when soil moisture is high, the risk of compaction is greater than in areas of well-drained soils.

Soil moisture is a primary variable determining the streambanks susceptibility to erosion (Wolman 1959, pg 204; Hooke 1979, pg 60). The effects of trampling on streambanks have been found to be significantly correlated with soil moisture content (Marlow and Pogacnik 1985, pg 279; Marlow et al. 1987, pg 291). These researchers discovered that the greatest amount of bank damage occurs when soil moisture exceeds 10% and suggested that a primary guideline for grazing riparian areas would be to limit livestock use to periods where soil moisture was <10%. Trimble and Mendel (1995, pg 246) found that "most studies recommend that cattle be excluded from the riparian zone until the banks are allowed to dry. Cooke and Reeves (1976, pg 6-8,188-189) discussed the effect of formation of trails along floodplains. "Although formed by compression and displacement, their form and alignment would conceivably allow them to transport a greater depth and velocity of water during overbank flows so that such trails might be expected to be eroded (Trimble and Mendel 1995, pg 246)."

3.3.6 Management considerations/Grazing strategy

As Kauffman (1995, pg 29) stated effective management of salmonid habitats begins at the ridgeline (watershed boundary) and not at the streambank. Any grazing strategy, if it is to work, must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, the particular ranching operation, streambank, stream channels, water quality, and streamside vegetation (Platts 1991, pg 403). In addition, "grazing management strategies must also consider the sensitivity of different riparian areas to disturbance, and their resiliency, or ability to recover, once degraded. Sensitive riparian areas experience a high degree of natural stress (or any natural attribute that makes them more sensitive to disturbance, such as non-cohesive granitic soils), and therefore can tolerate little management-induced stress without degradation" (Leonard et al. 1997, pg 9). In reviewing the influence that management considerations and grazing strategy have on degree of effect, the following variables were identified.

a) **Timing of grazing** – In addition to the variable discussion found in section 3.1.4a, the season of use can have further effect on bank stability. An additional advantage to early use is that in the spring, plants have time to recover growth if grazers are removed while there are still sufficient moisture and appropriate temperatures (Clary and Webster 1990, pg 210; Kovalchik and Elmore 1992, pg 116; Buckhouse and Elmore 1993, pg 48; Elmore and Kauffman 1994, pg 222-223; Buckhouse 1995, pg 36). Therefore plants can recover in time to grow and provide stability for runoff events. However, a disadvantage to spring use for bank stability, is that soil moisture is high and depending on the soil type, the time that livestock spends in the riparian area can have elevated negative consequences. Another disadvantage to spring use is that this is a critical period for plant growth and development, so the possibility of increased impact on plant vigor or plant communties exist (Ehrhart and Hansen 1998, pg 11).

   In the summer, dry months livestock tend to utilize riparian vegetation more, but the soil moisture is typically less, so if managed closely and grazing periods are short, then the risk of compaction and bank trampling is decreased (Ehrhart and Hansen 1998, pg 17).

b) **Distribution of grazing –** See variable discussion in section 3.1.4b.

c) **Intensity of grazing –** In addition to the variable discussion in section 3.1.4c, streambank stability can be further impacted by the intensity of grazing chosen. Clary and Kinney (2002, pg 141 and 144) found that plant root biomass changed depending on the type of grazing strategy. Light and moderate grazing treatments show slightly less root biomass than ungrazed sites and had similar bank retreat as ungrazed sites (averaging 1.4"). Heavy, season-long grazed sites showed a 32% decrease in root biomass than the other grazing treatments and averaged 4.7" of bank retreat. They also observed that the streambanks in their study area were well-vegetated with a variety of plant species, but even in the presence of strong root systems; bank alteration and channel widening were significant with season-long, heavy grazing.

   Kauffman et al. (1983a, pg 685) found that grazing intensity of 25-30 **MAS/AUM** created significantly greater streambank erosion and disturbance than in ungrazed areas. Similar moderate grazing (3.2 ha/AUM) was found in another study area to have minimal streambank disturbance (Buckhouse et al. 1981, pg 340). This information shows that each riparian site has a unique response to disturbance, so this is why tailoring the management plan is so crucial.

d) **Annual pasture use –** Rest or deferred use of pastures at different annual intervals can be an effective tool to minimize the reduction of streambank stability and ensure riparian plant communities remain vigorous. Sovell et al. (2000, pg 634) found higher turbidity levels in streams on continuously grazed sites than on rotationally grazed sites. They concluded that rotational grazing may reduce sediment abundance by effectively decreasing grazing intensity along streams. See further discussion of this variable in section 3.1.4d.

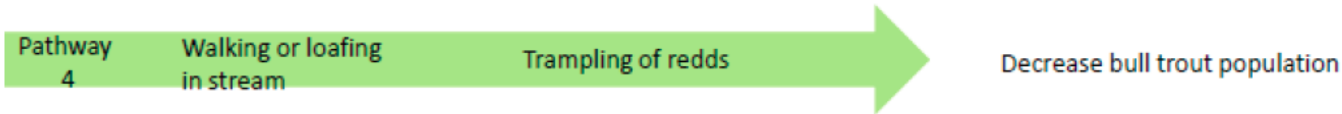
e) **Location of concentrated use areas –** See variable discussion in section 3.1.4e.

f) **Adaptive management based on monitoring –** In addition to the information provided regarding this variable in section 3.1.4f, a further discussion of bank alteration is offered. Bank alteration is discussed here as it is used as a utilization standard. Bank alteration is the procedure for estimating the percent of the linear length of streambank that has been altered by herbivores walking along or crossing the stream during the current grazing season (Burton et al. 2008, pg 18). Bank alteration can occur when large herbivores walk along streambanks or across streams causing shearing that results in a breakdown of the streambank and subsequent widening of the stream channel. It also exposes bare soil, increasing the risk of erosion of the streambank. In this way bank alteration can affect streambank stability, and therefore is a strong indicator of disturbance within the riparian area (Burton et al. 2008, pg 4). Bengeyfield (2006, pg 5-6) observed narrower channel width and deeper depths over a seven-year period when streambank alterations was 20% or less.

   Adaptive management can lessen the potential impacts that grazing can have on bull trout and their habitat. For example, adjusting the date that livestock are brought onto pastures based on range readiness will allow soil moistures to lessen and thereby decrease the susceptibility of streambanks to alterations and shearing.

g) **Condition of stream crossings and water access points –** Stabilizing or hardened access and crossing points on the stream can minimize streambank trampling (Ehrhart and Hansen 1998, pg 22). Kellogg (1995 cited in Ehrhart and Hansen 1998) reported evidence that cattle prefer stable footing and clean water, and will travel considerable distances for such access sites. Leonard et al. (1997, pg 43) reported that locating narrow watering gaps in rocky areas (natural or man-made) can minimize trampling of banks and streambeds and discourage loafing in the stream.

3.4 VARIABLES FOR EFFECT PATHWAY 4



The effects of Pathway 4 are completely eliminated if livestock do not have access to the stream during the spawning and incubation periods for bull trout or if they are removed before this period. If livestock are grazing during this timeframe, then the following variables affect the degree of effect that grazing will have on the reproductive efforts of bull trout:

- Accessibility of the streambank
- Vegetation type
- Suitability of habitat for spawning – gradient, flow, gravel size,…
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; adaptive management based on monitoring; and condition of stream crossings/access points

3.4.1 Accessibility of the streambank

See variable discussion in section 3.1.1.

3.4.2 Vegetation type

The type of vegetation present on the streambank is a variable that affects redd trampling via the desirability and accessibility of the plant to grazers. If the streamside vegetation is undesirable, then livestock will feed on it less and therefore the amount of time they spend in the riparian area impacting redds will also lessen. See discussion in section 3.1.2 for further details on this variable.

3.4.3 Suitability of habitat for spawning – gradient, flow, gravel size,…

There are natural conditions that exist that make segments of the stream unsuitable spawning habitat. “Substrate composition, cover, water quality, and water quantity are important habitat elements for salmonids before and during spawning” (Bjornn and Reiser 1991, pg 89). If a section of the stream is known to not support bull trout spawning, then this section is not susceptible to spawning impact from grazers’ presence. Also there is general consensus among fisheries biologist that **resident** bull trout spawning does not occur in stream segments with gradients greater than 10%. Bonneau et al. (1995, pg 564-565) actually stated that 8% gradient was the uppermost extent of bull trout migration. Therefore to be on the conservative side, sections of stream with gradients >10% are not susceptible to spawning impact from grazers because spawning is not thought to occur in stream reaches with this degree of slope.

The **migratory** forms of bull trout are much larger than the resident form and have different preferences for spawning habitat. Sanborn et al. (1998, pg i) reported that migratory bull trout spawn in low gradient areas (<2%) that have gravel/cobble substrate, water depths between 0.1 and 0.6m, and water velocities from 0.1 to 0.6 meters/second. Migratory bull trout are extremely particular regarding spawning habitat and prefer 2% gradient, but will tolerate up to 4% gradient (T. Weaver, personal communication).

3.4.4 Management considerations/Grazing strategy

As Kauffman (1995, pg 29) stated effective management of salmonid habitats begins at the ridgeline (watershed boundary) and not at the streambank. Any grazing strategy, if it is to work, must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, the particular ranching operation, streambank, stream channels, water quality, and streamside vegetation (Platts 1991, pg 403). In reviewing the influence that management considerations and grazing strategy have on degree of effect, the following variables were identified.

a) **Timing of grazing** – In addition to the variable discussion found in section 3.1.4a, the timing of grazing can have further effects on redd trampling. Elimination of redd trampling can be achieve by changing the scheduled grazing period to end before known bull trout spawning in the area begins. Also Roberts and White (1992, pg 450) found that the effects of wading on trout eggs and pre-emergent fry depended on stage of egg or fry development. "Wading killed fewest eggs between fertilization and the start of chorion softening (except for a short period during blastopore closure when mortality increased slightly). Wading killed the most eggs or fry from the time of chorion softening to the start of emergence from the gravel."

b) **Distribution of grazing –** See variable discussion in section 3.1.4b, but basically if efforts are made to insure that livestock is well-distributed across the rangelands and thereby minimizing the time they spend in the riparian; then the risk to trout redds are also minimized.

c) **Intensity of grazing –** The greater the number of livestock and the longer their duration of presence on pastures during bull trout spawning, the greater the likelihood of trampling effect (Gregory and Gamett 2009, pg 364). Roberts and White (1992, pg 450) found that the frequency of wading increases the fatal effects on trout redds. Twice-daily wading killed up to 96% of eggs and pre-emergent fry, whereas daily wading killed up to 43%.

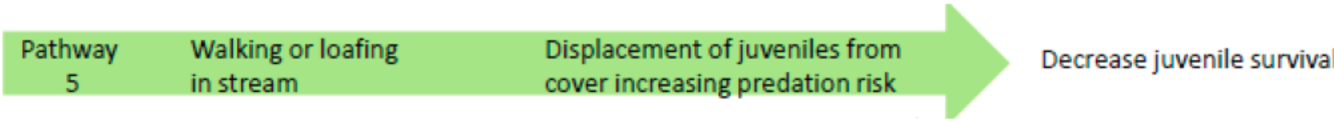
d) **Annual pasture use –** See variable discussion in section 3.1.4d, but more specifically if a pasture is being rested/deferred from grazing during the spawning season of bull trout, then the threat of redd impact is eliminated when rested or limited to the time period that the pasture is in deferred use.

e) **Location of concentrated use areas –** See variable discussion in section 3.1.4e.

f) **Adaptive management based on monitoring –** In addition to the information provided in section 3.1.4f, management practices can have further effects on the degree of redd trampling. Reduction of impacts on redds can be achieved by excluding known spawning areas from livestock access.

g) **Condition of stream crossings and water access points –** See variable discussion in section 3.3.6g, but basically in the presence of hardened, well established crossings; livestock may utilize these points more often and lessen their random access of the stream. Less random access will lessen the probability of redd impact.

3.5 VARIABLES FOR EFFECT PATHWAY 5



As with Pathway 4 the effects of Pathway 5 are completely eliminated if livestock do not have access to the stream. For the segment of the stream where livestock do have access, then the following variables affect the degree of relocation and subsequent elevated exposure to predation:

- Accessibility of the streambank
- Vegetation type – desirability, height, and amount/diversity
- Suitability of habitat for juveniles
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; adaptive management based on monitoring; and condition of stream crossings/access points

3.5.1 Accessibility of the streambank

See variable discussion in section 3.1.1.

3.5.2 Vegetation type

The type of vegetation present on the streambank is a variable that affects juvenile displacement. The categories below are one way of evaluating the influence that vegetation type has on degree of effect of this pathway.

a) **Desirability** – If the streamside vegetation is undesirable, then livestock will feed on it less and therefore the amount of time they spend in the riparian area impacting juvenile will also lessen. See discussion in section 3.1.2a for further details on the seasonal effects of this variable.

b) **Height** – Overhanging grasses offer more protective cover for bull trout than mature trees, but less than dense streamside shrubs. See discussion in section 3.1.2b for further details of this variable.

c) **Amount and diversity of vegetation** – If streamside vegetative cover is dense; then this affords more protective cover than sparse vegetation. Plus riparian communities comprised of one primary vegetation (monoculture, like mature pines) can be expected to provide overall less cover than riparian areas comprised of more diverse, multi-canopied vegetation.

3.5.3 Suitability of habitat for juveniles

There are natural conditions that exist that make segments of the stream unsuitable habitat for juvenile bull trout. If a section of the stream is known to not support juvenile bull trout, then this section cannot receive harassment impact from grazers' presence. Rearing habitat factors for juvenile bull trout include cold summer water temperatures (15 °C), an abundance and complexity of protective cover, unembedded cobble substrate, steady streamflow, and overall channel stability (Sanborn et al. 1998, pg i-ii).

3.5.4 Management considerations/Grazing strategy

As Kauffman (1995, pg 29) stated effective management of salmonid habitats begins at the ridgeline (watershed boundary) and not at the streambank. Any grazing strategy, if it is to work, must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, the particular ranching operation, streambank, stream channels, water quality, and streamside vegetation (Platts 1991, pg 403). Management efforts that improve riparian and in-channel conditions (high bank stability, more undercut banks, deeper pools, high amounts of large woody debris,…) and minimize use of the stream can decrease the level of harassment that young trout experience. In reviewing the influence that management considerations and grazing strategy have on degree of effect, the following variables were identified.

a) **Timing of grazing** – The season of use of an area can have a substantial influence on the degree of effect that grazing could have on displacement of juveniles from cover. For details on how season of use can affect the time that livestock spend in the riparian environment, see variable discussion in section 3.1.4a.

b) **Distribution of grazing** – See variable discussion in section 3.1.4b, but basically if efforts are made to insure that livestock is well-distributed across the rangelands and thereby minimizing the time they spend in the riparian; then the risk to juvenile trout are also minimized.

c) **Intensity of grazing** – The greater the number of livestock and the longer their duration of presence on pastures, the greater the likelihood of their effects on juvenile trout. See further variable discussion in section 3.1.4c.

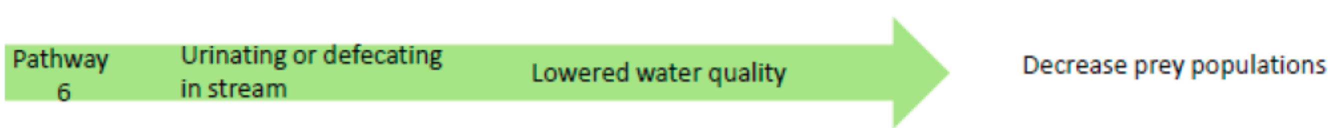
d) **Annual pasture use** – See variable discussion in section 3.1.4d, but more specifically if a pasture is being rested/deferred from grazing, then the threat of harassing juveniles is eliminated when rested or limited to the time period that the pasture is in deferred use.

e) **Location of concentrated use areas** – See variable discussion in section 3.1.4e.

f) **Adaptive management based on monitoring** – See variable discussion in section 3.3.6f.

g) **Condition of stream crossings and water access points** – See variable discussion in section 3.3.6g; but basically in the presence of hardened, well established crossings, livestock may utilize these points more often and lessen their random access of the stream. Less random access will lessen the probability of displacement of juveniles.

3.6 VARIABLES FOR EFFECT PATHWAY 6



By decreasing livestock presence in the stream and properly managing the intensity and distribution of grazing in the riparian, the effects of this pathway can be reduced. The variables affecting the amount of contaminants that are contributed to the stream are:

- Accessibility of the streambank
- Vegetation type – desirability, height, and amount/diversity
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; adaptive management based on monitoring; and condition of stream crossings/access points

3.6.1 Accessibility of the streambank

See variable discussion in section 3.1.1.

3.6.2 Vegetation type

The type of vegetation present on the streambank is a variable that affects the amount of nutrient that get directly deposited into the stream via the desirability and accessibility of the plants to grazers. If the streamside vegetation is undesirable, then livestock will feed on it less and spend less time in the riparian area. See discussion in section 3.1.2 for further details on the seasonal variations within this variable.

3.6.3 Management considerations/Grazing strategy

As Kauffman (1995, pg 29) stated effective management of salmonid habitats begins at the ridgeline (watershed boundary) and not at the streambank. Any grazing strategy, if it is to work, must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, the particular ranching operation, streambank, stream channels, water quality, and streamside vegetation (Platts 1991, pg 403). Management efforts that minimize use of the stream can decrease the level of nutrients that get deposited into the stream. In reviewing the influence that management considerations and grazing strategy have on degree of effect, the following variables were identified.

a) **Timing of grazing –** The season of use of an area can have a substantial influence on the degree of effect that grazing could have on nutrient input. See variable discussion in section 3.1.4a.

b) **Distribution of grazing –** See variable discussion in section 3.1.4b, but basically if efforts are made to insure that livestock are well-distributed across the rangelands and time spent in the riparian area is minimized; then the nutrient input into the stream is also minimized.

c) **Intensity of grazing –** The greater the number of livestock and the longer their duration of presence on pastures, the greater the likelihood of effects on nutrient levels in the stream. See further variable discussion in section 3.1.4c.

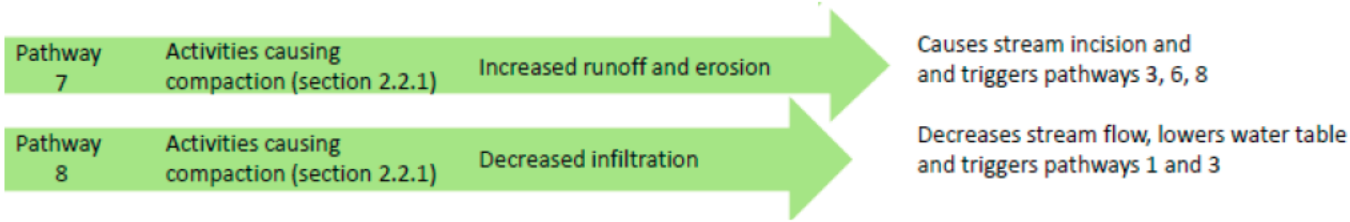
d) **Annual pasture use –** See variable discussion in section 3.1.4d, but more specifically if a pasture is being rested/deferred from grazing, then the threat of nutrient input is eliminated when rested or limited to the time period that the pasture is in deferred use. Also when a pasture is being grazed the grazing strategy chosen can affect nutrient input into the stream. Sovell et al. (2000, pg 636) found higher fecal coliform in streams on continuously grazed sites than on rotationally grazed sites. They concluded that rotational grazing may reduce fecal coliform abundance by effectively decreasing grazing intensity along streams.

e) **Location of concentrated use areas –** See variable discussion in section 3.1.4e.

f) **Adaptive management based on monitoring –** See variable discussion in section 3.1.4f.

g) **Condition of stream crossings and water access points –** See variable discussion in section 3.3.6g.

3.7 VARIABLES FOR EFFECT PATHWAY 7 AND 8



Compaction of the soil is the trigger for both Effect Pathway 7 and 8. Therefore the variables that influence degree of effect are the same for both pathways, and include:

- Slope and aspect
- Vegetation type – desirability, height, and amount/diversity
- Soil condition, type, and moisture content
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; adaptive management based on monitoring; and condition of stream crossings/access points

3.7.1 Slope and aspect

The degree of soil erosion associated with compaction caused by livestock grazing is related to slope gradient and aspects of the site being grazed (Meehan and Platts 1978, pg 275). Southerly slopes show a higher degree of erosion than other slopes due to the overall shallower soil, lower litter and humus levels, and plant types and densities (Renner 1936, pg 29). Gradient is of minor importance to erosion, in and of itself, but when other factors, such as grazing come into play, the amount of erosion increases as the gradient increases (Renner 1936, pg 28).

3.7.2 Vegetation type

In addition to the discussion in section 3.1.2, if the vegetation is desirable, then livestock will feed on it more and this preference can increase the level of compaction of the soil around it. In the summer months compaction can be increased around vegetation that provides shade, especially in areas where livestock congregate.

The degree of soil erosion associated with livestock grazing is related to type and density of the vegetation, and as the vegetation deteriorates the susceptibility of the soil to erosion increases (Heede 1977, pg 15; Meehan and Platts 1978, pg 275). Packer (1953, pg 29-30) and Alderfer and Robinson (1947, pg 948) found that livestock reduced ground cover density and increased bare soil openings, which in turn caused increased runoff and erosion levels. Warren et al. (1986a, pg 491) found that lack of vegetation caused by intense grazing lead to significantly increased sediment production and significantly decreased infiltration. If vegetative cover is healthy and abundant; then it can perform its natural function of protecting soil moisture and trapping sediment. If vegetation is diverse and one type of vegetation is impacted by grazing, then other vegetation types can absorb some of the effects of erosion. In a pasture comprised of one, primary vegetation; if this vegetation is preferred by grazers, then there is no fail-safe to protect the soil as in a more diverse, vegetative community.

3.7.3 Soil condition, type, and moisture content

Meehan and Platts (1978, pg 275) found that the degree of soil erosion associated with livestock grazing is related to the condition of the soil and the accessibility of the soil to livestock. Well-drained soils reduce the possibility of compaction (Clary and Webster 1989, pg 2-3). Wet soil is more susceptible to compaction, because wet particles disintegrate more easily (Proffitt et al. 1993, pg 317, 329). Bare soil is more susceptible to erosion than well-vegetated soil. Clary and Webster (1989, pg 2) found that the greatest grazing effects occurred in Rosgen B type channels (with medium to fine-textured, easily eroded soil materials) and most type C channels (typically associated with meadow complexes that are attractive to livestock). Warren et al. (1986a, pg 491) found that intense grazing lead to significantly decreased infiltration rate and significantly increased sediment production on a site with a silty clay surface soil devoid of vegetation. They also found that the damage caused by grazing was increased if the soil was moist. For further details regarding the soil moisture component of this variable, see discussion in section 3.3.5.

3.7.4 Management considerations/Grazing strategy

As Kauffman (1995, pg 29) stated effective management of salmonid habitats begins at the ridgeline (watershed boundary) and not at the streambank. Any grazing strategy, if it is to work, must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, the particular ranching operation, streambank, stream channels, water quality, and streamside vegetation (Platts 1991, pg 403). When making management decisions regarding livestock density, distribution, and duration; soil condition and type should also be considered to reduce potential compaction and erosion effects. In reviewing the influence that management considerations and grazing strategy have on degree of effect, the following variables were identified.

a) **Timing of grazing –** In addition to the variable discussion found in section 3.1.4a, the season of use can have further effect on compaction. One disadvantage to spring use in regards to compaction and subsequent erosion/runoff is that the soil moisture is high. Depending on the soil type, the time that livestock spends on the pasture can have elevated negative consequences. Another disadvantage to spring use is decreased plant vigor and plant communities, because this is a critical period for plant growth and development (Ehrhart and Hansen 1998, pg 11). If plants are lost, bare soil or less desirable species (species with less soil-holding capacity) occurrence can result in increased runoff and erosion. However an advantage of spring grazing is that plants have time to recover growth if grazers are removed while there are still sufficient moisture and appropriate temperatures (Clary and Webster 1990, pg 210; Kovalchik and Elmore 1992, pg 116; Buckhouse and Elmore 1993, pg 48; Elmore and Kauffman 1994, pg 222-223; Buckhouse 1995, pg 36). This time for growth enables vegetation an opportunity to recover in order to perform its natural function of dissipating energy of flowing water and thereby reducing erosive effects (Ehrhart and Hansen 1998, pg 3).

   In the summer the soil moisture is typically less, so if managed closely and grazing periods are short, then the risk of compaction and bank trampling is decreased (Ehrhart and Hansen 1998, pg 17).

b) **Distribution of grazing –** See variable discussion in section 3.1.4b, but basically if efforts are made to insure that livestock is well-distributed; then risk of compaction and the subsequent effects are minimized.

c) **Intensity of grazing –** The greater the number of livestock and the longer their duration of presence on pastures, increases the likelihood of compaction and subsequent effects. Warren et al. (1986a, pg 491) found that the deleterious impact of compaction due to grazing generally increased as stocking rate increased. See further variable discussion in section 3.1.4c.

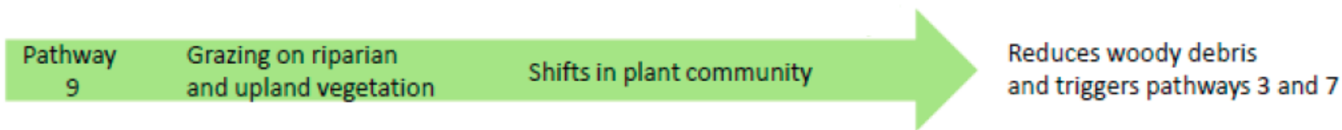
d) **Annual pasture use** – See variable discussion in section 3.1.4d, but more specifically if a pasture is being rested/deferred from grazing, then the threat of compaction is eliminated when rested or limited to the time period that the pasture is in deferred use. Furthermore, natural processes, such as soil wetting and drying cycles and grazing recovery periods can restore the physical condition of the soil (Weltz and Wood 1986, pg 368; Heady and Child 1994, pg 68-69; Greenwood and McKenzie 2001, pg 1232; Wheeler et al. 2002, pg 49). However Warren et al. (1986a, pg 491) found that on heavily grazed sites, thirty days of rest were insufficient to allow hydrologic recovery.

e) **Location of concentrated use areas** – See variable discussion in section 3.1.4e.

f) **Adaptive management based on monitoring** – See variable discussion in section 3.3.6f.

g) **Condition of stream crossings and water access points** – See variable discussion in section 3.3.6g.

3.8 VARIABLES FOR EFFECT PATHWAY 9



Variables affecting the expression of effects of this pathway include:

- Vegetation type – desirability, height, and amount/diversity
- Soil condition, type, and moisture content
- Management considerations/Grazing strategy – timing, distribution, and intensity of grazing; annual pasture use; location of concentrated use areas; and adaptive management based on monitoring

3.8.1 Vegetation type

The categories below are one way of evaluating the influence that vegetation type has on degree of effect of this pathway.

a) **Desirability** – If the vegetation is desirable, then livestock will feed on it more increasing the potential effect on plant vigor. See variable discussion in section 3.1.2a.

b) **Height** – Because of the accessibility of the plant; grasses, forbs, shrubs, and young trees are more prone to impact on plant vigor caused by grazing than mature trees. Kauffman et al. (1983b, pg 685) described shrub use as generally light, except on willow-dominated gravel bars, where they concluded that succession was retarded by grazing. Of the 10 plant communities that were sampled, four showed significant differences in species composition and productivity. Green and Kauffman (1995, pg 307) analyzed 10 year of data from the same area that included fall grazing at a rate of 1.3 to 1.8 ha/AUM. They reported extreme variability between a plant communities response to grazing pressure, but found that in heavily grazed communities, conditions favored early successional stage and exotic plants. In exclosures in the same plant communities, they observed that competitive and competitive, stress-tolerant species were favored and exotics decreased. They also reported that the woody species height was significantly reduced in grazed area versus ungrazed counterparts (pg 312) as did Shaw and Clary (1996, pg 148).

c) **Amount and diversity of vegetation –** Depending on the grazing strategy selected; if vegetation is abundant and diverse, then the possible negative effects on plant vigor and changes to the soil can be negated by the sheer quantity and variety of vegetation. In a pasture comprised of one, primary vegetation; if this vegetation is preferred by grazers, then there is no fail-safe to protect the soil as in a more diverse, vegetative community.

Kauffman et al. (1983b, pg 890) explained that in areas with vegetation levels high enough to produce litter layer accumulation, the increased soil moisture also increased the abundance of hydric plants and decreased the abundance of xyric plants. Shaw and Clary (1996, pg 148) and Green and Kauffman (1995, pg 312) concluded that density and growth of woody species was decreased as well as reproduction was less vigorous on grazed site than ungrazed. Glinski (1977, pg 120-122) and Crouch (1979, pg 1) also observed that grazing on woody vegetation prevented the regeneration and produced even-aged non-reproducing vegetation community. Fleischner (1994, pg 633) also found that regeneration of some woody vegetation (such as willow, cottonwood (*Populus* sp.), and aspen (*Populus sp.*)) is inhibited by grazing on seedlings.

Sovell et al. (2000, pg 637) found that riparian sites dominated by mature trees (characterized by steep slopes, bare banks, little understory vegetation) had fine sediment-dominated streambeds. They suspect that lack of vegetative ground cover, due to almost complete canopy cover, may have reduced filtering of upland sediment and promoted erosion of streambank soils causing increased sediment to be deposited in the stream channel.

3.8.2 Soil condition, type, and moisture content

In addition to the effects that grazing can have on the amount of vegetative cover and compaction of soil (discussed in section 3.7.3), grazing can also change the moisture content of the soil. For further details regarding the soil moisture component of this variable, see discussion in section 3.3.5. Decreased plant and liter cover caused by grazing results in more bare ground and a decrease in nutrients and moisture that enter the soil through infiltration (Krueger et al. 2002, pg 7). Changes in moisture and nutrient content of the soil affect the type and amount of vegetation that can be supported. Therefore shifts in plant communities and plant densities can occur as a result of decreased soil moisture and nutrient content.

3.8.3 Management considerations/Grazing strategy

As Kauffman (1995, pg 29) stated effective management of salmonid habitats begins at the ridgeline (watershed boundary) and not at the streambank. Any grazing strategy, if it is to work, must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, the particular ranching operation, streambank, stream channels, water quality, and streamside vegetation (Platts 1991, pg 403). Also "understanding the physiological and ecological requirements of key woody species is essential in designing a proper management program (Thomas et al. 1979, pg 13). This includes determining the effects of grazing on the particular growth characteristics of the species involved and the probable outcomes in community change (Leonard et al. 1997, pg 7)." In reviewing the influence that management considerations and grazing strategy have on degree of effect, the following variables were identified.

a) **Timing of grazing –** In addition to the variable discussion found in section 3.1.4a, the season of use can have further effect on plant communities. In the spring plants have time to recover growth if grazers are removed while there are still sufficient moisture and appropriate temperatures (Clary and Webster 1990, pg 210; Kovalchik and Elmore 1992, pg 116; Buckhouse and Elmore 1993, pg 48; Elmore and Kauffman 1994, pg 222-223; Buckhouse 1995, pg 36). This time for grow enables vegetative cover an opportunity to recover and progress in successional stage. Another disadvantage to spring use is decreased plant vigor and plant communities, because this is a critical period for plant growth and development (Ehrhart and Hansen 1998, pg 11). If plants are lost, bare soil or less desirable species (species with less soil-holding capacity) occurrence can result in increased runoff and erosion.

b) **Distribution of grazing –** See variable discussion in section 3.1.4b, but basically if efforts are made to insure that livestock is well-distributed; then the risk of community change can be minimized.

c) **Intensity of grazing –** The greater the number of livestock and the longer their duration of presence on pastures, the greater the likelihood of affecting soil condition or plant vigor and prompting community change. See further variable discussion in section 3.1.4c.

d) **Annual pasture use –** See variable discussion in section 3.1.4d, but more specifically if a pasture is being rested/deferred from grazing, then the threat of reduced plant vigor is eliminated when rested or limited to the time period that the pasture is in deferred use. Kauffman et al. (1983b, pg 690) noted that species recovery was observed after three years of cessation of grazing on rangelands that were heavily grazed.

e) **Location of concentrated use areas –** See discussion in section 3.1.4e that explains how this variable can serve to reduce impacts on the riparian plant community. This variable can actually represent increased effects on plant vigor and soils in the uplands, because it brings concentrated use activities into the uplands.

f) **Adaptive management based on monitoring –** In addition to variable discussion in section 3.1.4f, Clary and Webster (1990, pg 210) concluded that regardless of current seral stage, 4 to 6" of residual stubble or regrowth is recommended to meet the requirements of plant vigor maintenance. As with all these variables the specific of the site must be taken into consideration. For example, growing season may vary between sites, and as reported in the Blue Mountains of Oregon, regrowth of herbaceous vegetation does not normally occur after July (Gillen et al. 1985, pg 208), so any livestock use of riparian vegetation in the summer and fall would need to be closely managed.

4.0 GLOSSARY

AUM – an abbreviation for Animal Unit Month. An animal Unit Month is the minimum area of land necessary to sustain grazing by one cow for one month.

Ha – an abbreviation for a hectare. A hectare is a unit of area equal to 10,000 square meters (107,639 sq ft), and is commonly used for measuring land area.

MAS – an abbreviation for Meters of Accessible Streambank. Meters of Accessible Streambank is a measurement used to quantify the intensity of grazing use with the numbers of animals per length of streambank (MAS/AUM) rather than density of animals per unit area (ha/AUM).

Alevin – larval fish that have hatched from the eggs, but have not yet emerged from the nesting area. Alevins eat the contents of their yolk sac while their digestive systems are developing. At this stage, the fish are not prepared to hunt live prey, and are completely dependent on the yolk sacs. Alevins stay within the gravel of the redd while continuing to develop.

Bank retreat – when the streambank face at the water's edge erodes away causing widening of the stream channel.

Biomass – the mass (weight) of living biological organisms in a given area at a given time. Biomass can refer to species biomass, which is the mass of one or more species, or to community biomass, which is the mass of all species in the community. It can include microorganisms, plants or animals. The mass can be expressed as the average mass per unit area or as the total mass in the community. It might be measured in grams per square meter or tonnes per square kilometre, or it might be measured as the total mass present in a system such as a lake. How biomass is measured depends on why it is being measured. An example of measurement of fish biomass is the mass in kilogram of fish per hectare. An example of invertebrate biomass is grams per fish, and an example of aboveground vegetation biomass is grams of vegetation per square meters.

Boulder – a rock greater than 10 inches in diameter.

Braided – a condition when the channel of a stream divides into a network of smaller channels separated by small and often temporary islands. Braided channels can result from deposition of sediments. Braided rivers, in contrast to meandering rivers, occur when a threshold level of sediment load or slope is reached. An increase in sediment load will over time increase the slope of the river, so these two conditions can be considered synonymous and consequently a variation of slope.

Cobble – gravel that ranges in size from 2.5 to 10 inches in diameter.

Coliform (fecal) – bacteria derived from feces, the most common being Escherichia coli (E. coli).

Detritus – non-living organic material that typically includes fragments of dead organisms, fecal material, leaf litter,... Detritus is typically colonized by communities of microorganisms which act to decompose or remineralize the material. In terrestrial systems detritus refers to leaf litter and other organic matter intermixed with soil and is also known as humus. In aquatic systems detritus refers to organic material suspended in water.

Dewatering – removal or draining of the groundwater or surface water from a stream by pumping or redirection.

Embeddedness – The degree to which cobble are surrounded or covered by fine sediment, usually expressed as a percentage.

Forb – an herbaceous flowering plants that is not a grass, sedge, or rush. They are native, nongrass, broadleaf, herbaceous range plants eaten by livestock, and are responsible for a great deal of animal production in arid and semiarid regions. Includes saltbush (*Atriplex* sp.), sage (*Artemisia* sp.), shinoak (*Quercus* sp.), clover (*Trifolium* sp.), milkweed (*Asclepias* sp.), etc.

Fry – the stage when trout have fully absorbed their yolk sac, begin to swim, and start eating. Bull trout fry may remain in the stream bed for up to three weeks before emerging.

Green line – the first perennial vegetation above the stable low water line of a stream or body of water.

Groundwater – water located beneath the surface in spaces in the soil. An unconsolidated water deposit is called an aquifer if the quantity of water is useable. The depth at which soil pore spaces and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form wetlands.

Herbaceous vegetation – plants that have leaves and stems that die down at the end of the growing season to the soil level. They have no persistent woody stem above ground. Herbaceous vegetation can include annual, biennial, or perennial plants.

Hydric herbaceous vegetation – herbaceous vegetation (see above definition) that is relates to or requires an abundance of moisture.

Interstitial spaces – the small openings or spaces between the gravel of the stream bed.

Invertebrates – animals without a backbone some of which include insect, worms, snails,…

Juvenile – general term used to refer to young trout from the 'fry' life stage up until sexual maturity.

Mechanism – the processes involved in or responsible for an action, reaction, or effect. In this case the process triggered by the action of the cattle that creates an effect on bull trout or their habitat.

Migratory form of bull trout – bull trout that leave their natal tributaries to mature elsewhere. The fluvial form of bull trout mature in large rivers. The adfluvial form of bull trout mature in lakes. The anadromous form of bull trout mature in the ocean.

Monoculture – refers to an area where only one primary species of plant occurs. Single species stands of trees that occur naturally show a diversity in tree sizes with dead trees mixed with mature and young trees.

Nonnative vegetation – non-indigenous plants that adversely affect the habitat they invade economically, environmentally, or ecologically. They disrupt by dominating an area from loss of natural processes.

Order (stream) – a system of ranking a stream and its tributaries from the headwaters to its mouth that describes its general characteristics. Stream order is expressed as a ranking from 1 to 7.

Overhanging vegetation – live plants that extend over the stream to create shade and/or protective cover for fish.

Pool – an area in the stream that has deeper water and reduced water velocity.

Prey – an organism taken by a predator as food.

Pre-emergent fry – the stage when trout begin to swim and start eating is called 'fry'. Fry remain in the stream bed for up to three weeks before emerging, this stage is called pre-emergent fry.

Production or productivity – refers to the rate of creation of biomass in an ecosystem. It is usually expressed in units of mass per unit surface per unit time, for instance grams per square meter per day. Productivity of plants is called primary productivity, while that of animals is called secondary productivity.

Reach (stream) – A designated segment of stream often identifying where monitoring is conducted.

Redds – nests that bull trout build in the gravel where they lay their eggs.

Resident form of bull trout – bull trout that are restricted to headwater streams for their entire lives.

Riparian area – the plant community along stream margins which are characterized by plants that require an abundance of water. In this paper when the phrase riparian area is used it is speaking of the plant community along the streams margin that does not include the immediate streamside vegetation.

Rosgen A and B type channels – Rosgen channel typing is a method used to classify stream channels through consideration of water surface slope, entrenchment, width/depth ratio, and sinuosity. Using these characteristics streams can be placed in categories A-G. For example, streams with channel type A have 4-10% slope, are well entrenched, have low width/depth ratios, and are totally confined (laterally). The streamflows at the bankfull stage are typically described as step/pools with attendant plunge or scour pools.

Salmonids – Members of a family of fish that include salmon, trout, char, grayling, and freshwater whitefish.

Seral – stages of progression found in ecological succession where a system moves toward its climax community. An example of seral communities in succession is a recently logged coniferous forest. At first grasses, heaths and herbaceous plants will be abundant. A few years later shrubs will start to appear; and several years later, the area is likely to be crowded with young tree. Each of these stages can be referred to as a seral community.

Sheet erosion – the detachment of soil particles by raindrop impact and their removal downslope by water flowing over land as a sheet instead of in definite channels. The impact of the raindrop breaks apart the soil. After the surface pores are filled with sand, silt, or clay; overland surface flow of water begins due to the lowering of infiltration rates. Once the rate of falling rain is faster than infiltration, runoff takes place.

Stocking rates – the quantity of livestock grazed on a given area of land. Stocking rates are expressed in terms of number of stock per hectare or acre.

Streambank stability – the capacity of a stream channel to transport water and sediment that is inputted into the stream without changing its dimensions (width, depth, slope,…). Bank stability is measured by the percentage of any stream reach that has >90% stability.

Substrate – the material (sand, cobble, boulders,…) which makes up streambed.

Succession – the series of changes in an ecological community that occur over time after a disturbance.

Trailing (active) – the movement of livestock on rangelands through the use of horse and rider.

Trailing (passive) – the movement of livestock on rangelands on their own accord.

Undercut bank – a part of the stream bank that has been carved away by the water so that a protusion of the upper portion of the bank overhangs the water's surface.

Upland vegetation – in mountainous terrain the upland vegetation is the vegetation that occurs on the higher land outside of the riparian area.

Utilization – the amount of vegetation removed by grazing animals.

Uplands – in mountainous terrain the uplands refer to the area of higher land outside the riparian zone.

Vigor (plant vigor) – the ability of a plant to survive, grow, and reproduce.

Water column – a conceptual column of water from the stream surface to stream bed.

Water table – see explanation under 'groundwater'.

Width to depth ratio – a measurement of channel condition where the width of the stream is compared to the depth of the stream. For bull trout a width to depth ratio of <10 is considered functioning appropriately (Lee et al. 1999).

Woody debris (large woody debris) – debris contributed from trees of a certain size that occur within the riparian area. Woody debris adds structure and habitat to the stream channel for the short and long-term benefit for fish and fish habitat.

Woody vegetation – a plant that has its structure made up of wood. Woody vegetation is typically perennial and has the main stem, larger branches, and roots covered by a layer of thickened bark. Woody plants are trees, shrubs, or lianas. Lianas include various long-stemmed, woody vines that are rooted in the soil at ground level and use trees as well as other means of vertical support to climb up to the canopy.

Xeric plants – plants that require little water to survive and grow and that typically occupy areas of low moisture.

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