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In cooperation with the Murphy Wildland Fire Grazing and Fuel Assessment Team

Interactions Among Livestock Grazing, Vegetation Type, and Fire Behavior in the Murphy Wildland Fire Complex in Idaho and Nevada, July 2007

Open-File Report 2008–1214

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By Karen Launchbaugh, University of Idaho; Bob Brammer, Idaho Department of Lands; Matthew L. Brooks, U.S. Geological Survey; Stephen Bunting, University of Idaho; Patrick Clark, U.S. Department of Agriculture, Agricultural Research Service; Jay Davison, University of Nevada; Mark Fleming, Idaho Department of Fish and Game; Ron Kay, Idaho State Department of Agriculture; Mike Pellant, Bureau of Land Management; David A. Pyke, U.S. Geological Survey; and Bruce Wylie, ASRC Research and Technology Solutions contractor to U.S. Geological Survey

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U.S. Department of the Interior
U.S. Geological Survey

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Mark D. Myers, Director

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km^2)
	Density	
pound per acre	1.12	kilogram per hectare (kg/ha)
	Flow rate	
mile per hour (mph)	1.609	kilometer per hour (km/h)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8

Interactions Among Livestock Grazing, Vegetation Type, and Fire Behavior in the Murphy Wildland Fire Complex in Idaho and Nevada, July 2007[1]

By Karen Launchbaugh[2], University of Idaho; Bob Brammer, Idaho Department of Lands; Matthew L. Brooks, U.S. Geological Survey; Stephen Bunting, University of Idaho; Patrick Clark, U.S. Department of Agriculture, Agricultural Research Service; Jay Davison, University of Nevada; Mark Fleming, Idaho Department of Fish and Game; Ron Kay, Idaho State Department of Agriculture; Mike Pellant, Bureau of Land Management; David A. Pyke, U.S. Geological Survey; and Bruce Wylie, ASRC Research and Technology Solutions contractor to U.S. Geological Survey

Abstract

A series of wildland fires were ignited by lightning in sagebrush and grassland communities near the Idaho-Nevada border southwest of Twin Falls, Idaho in July 2007. The fires burned for over two weeks and encompassed more than 650,000 acres. A team of scientists, habitat specialists, and land managers was called together by Tom Dyer, Idaho BLM State Director, to examine initial information from the Murphy Wildland Fire Complex in relation to plant communities and patterns of livestock grazing. Three approaches were used to examine this topic: (1) identify potential for livestock grazing to modify fuel loads and affect fire behavior using fire models applied to various vegetation types, fuel loads, and fire conditions; (2) compare levels of fuel consumed within and among major vegetation types; and (3) examine several observed lines of difference and discontinuity in fuel consumed to determine what factors created these contrasts.

The team found that much of the Murphy Wildland Fire Complex burned under extreme fuel and weather conditions that likely overshadowed livestock grazing as a factor influencing fire extent and fuel consumption in many areas where these fires burned. Differences and abrupt contrast lines in the level of fuels consumed were affected mostly by the plant communities that existed on a site before fire. A few abrupt contrasts in burn severity coincided with apparent differences in grazing patterns of livestock, observed as fence-line contrasts. Fire modeling revealed that grazing in grassland vegetation can reduce surface rate of spread and fire-line intensity to a greater extent than in shrubland types. Under extreme fire conditions (low fuel moisture, high temperatures, and gusty winds), grazing applied at moderate utilization levels has limited or negligible effects on fire behavior. However, when weather and fuel-moisture conditions are less extreme, grazing may reduce the rate of spread and intensity of fires allowing for patchy burns with low levels of fuel consumption.

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[1] Report was prepared by a team and was peer reviewed following USGS standards.
[2] Launchbaugh is listed first as team leader. Other authors (team members) are listed in alphabetical order.

The team suggested that targeted grazing to accomplish fuel objectives holds promise but requires detailed planning that includes clearly defined goals for fuel modification and appropriate monitoring to assess effectiveness. It was recommended that a pilot plan be devised to strategically place grazed blocks across a landscape to create fuel-reduction bands capable of influencing fire behavior. Also suggested was the development of a general technical report that highlights information and examples of how livestock grazing influences fire extent, severity, and intensity. Finally, the team encouraged continued research and monitoring of the effects of the Murphy Wildland Fire Complex. Much more can be learned from the effects of this extensive fire complex that may offer insight for future management decisions.

Introduction and Background

The sagebrush steppe ecosystem dominates about 73 million acres of western North America, but this amount is only about 55 percent of its historical potential (Connelly and others, 2004). Fire has been a major factor contributing to this change. More frequent and larger fires are a growing reality in the management of western rangelands. In Idaho and Nevada, the last decade (1997 to 2007) has yielded 18 fires greater than 100,000 acres. However, the size of these very large fires appears to be increasing given that 6 of the 10 largest fires of the decade occurred in 2006 and 2007 (National Interagency Fire Center [NIFC] records; *http://www.nifc.gov*). Impacts on natural and fiscal resources are high during those years when large acreages burn. Annual weather conditions undoubtedly contribute to the acreage burned in any given year, but other factors also may contribute to the risk of wildfire in the sagebrush steppe ecosystems. These factors include (1) changes in livestock management, such as reductions in stocking rates and changes in grazing seasons; (2) increased abundance of invasive species, such as cheatgrass; and (3) increased wildland-urban interfaces where human-derived ignitions can occur (Miller and Narayanan, 2008).

Heavy livestock grazing is thought to have affected fire regimes by severely reducing fuel loads and thereby reducing the potential for fires to sustain ignition and spread. The introduction of cattle, sheep, and horses to the Great Basin in the 1860s quickly created large ranching operations and excessive grazing pressure. The severe overgrazing removed fine fuels and resulted in a substantial reduction in the number of fires and the acres burned. Only 44 fires, burning a total of 11,000 acres, were reported from 1880 to 1912 in Great Basin rangelands (Miller and Narayanan, 2008). Evidence for reduced numbers of fires during this period is also deduced from the near elimination of fire scars on trees adjacent to sagebrush ecosystems during the late 1800s and continuing through most of the 1900s (Miller and Rose, 1999; Miller and Tausch, 2001).

The number of livestock in Great Basin and sagebrush ecosystems has dropped rapidly since the passage of the Taylor Grazing Act of 1934 (43 USC 315; *http://www.blm.gov/wy/st/en/field_offices/Casper/range/taylor.1.html*, accessed July 23, 2008). Livestock numbers in Idaho decreased in the 1950s primarily from loss of large sheep operations (indicated by changes in authorized use for grazing; fig. 1). Livestock numbers have fluctuated at or below this initial decrease through the remainder of the 1900s, with a steady conversion from sheep to cattle. In the last decade, a substantial decrease in authorized use on Bureau of Land Management (BLM) lands in Idaho has been recorded (fig. 1).

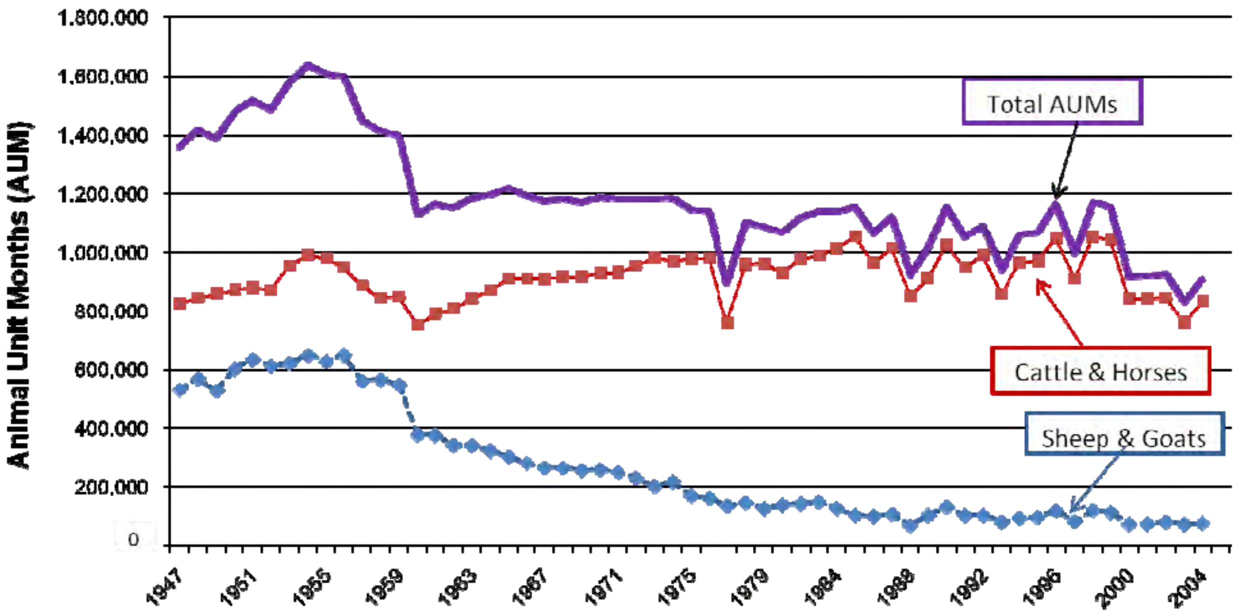

Figure 1. Trends in authorized use by grazing livestock on BLM lands in Idaho from 1947 through 2004.

An important factor contributing to an increase in wildfires includes the expansion of cheatgrass (D'Antonio and Vitousek, 1992). Of the nearly 98 million acres of BLM lands in Idaho, Nevada, Oregon, Utah, and Washington, 17.3 million acres are believed to have at least 10 percent of the plant biomass composed of annual grasses, including cheatgrass or medusahead (Pellant and Hall, 1994). These annual grasses create fine-fuel loads that increase the probability of fire starts and the rate of fire spread in areas they dominate (Brooks and Pyke, 2001).

Increased human activities in wildlands and expansion of the wildland-urban interface have also contributed to the recent increase in the number of wildfires (Connelly and others, 2004). Increases in human habitation and activity in the rangelands of southern Idaho have been at least partially responsible for the increase in wildfire starts in recent years. In the Jarbidge Field Office (FO) of the BLM, 43 percent of the wildfires since 1987 were human caused.

The Murphy Wildland Fire Complex

On July 16 and 17, 2007, a series of wildland fires were ignited by lightning in rangelands near the Idaho-Nevada border southwest of Twin Falls, Idaho. The Rowland Fire (initiated west of Murphy Hot Springs, Idaho) and Elk Mountain Fire (initiated southeast of Three Creeks, Idaho) grew together and became known as the Murphy Wildland Fire Complex (fig. 2). The Scott Creek Fire (west of Jackpot, Nevada) also was ignited by lightning on July 17 and was later designated as part of the Murphy Wildland Fire Complex. Some of the fires in this complex burned for more than two weeks, and the complex was fully contained by August 2, 2007. This complex of fires burned across portions of three BLM FOs (Jarbidge, Bruneau, and Elko), portions of the Humboldt-Toiyabe National Forest, about 48 sections of land managed by the State of Idaho, and extensive stretches of private lands. A total of 652,016 acres was encompassed by this fire complex (NIFC data: *http://www.nifc.gov*).

These wildfires had tremendous impacts on the sagebrush steppe ecosystems of south-central Idaho and a portion of north-central Nevada. Seasonal and year-long habitats were altered for sage-grouse, mule deer, elk, bighorn sheep, pronghorn, Brewer's sparrow, sage sparrow, other sagebrush-obligate birds, and many other wildlife species that use these rangelands. Severe impacts also were exacted on forage resources for livestock, cultural resource values, and watershed health and stability as a result of these fires. The ecological impacts of this fire will take several years to be fully realized and will vary depending on weather conditions in the coming years.

In the last three decades, several wildfires have occurred in the area that burned in the Murphy Wildland Fire Complex. Many of these burned areas were revegetated with perennial grasses, including both introduced and native species. Records from the Jarbidge Field Office (FO) of the BLM indicate that about 402,000 acres were seeded through the end of 2006. This number of acres represents 26 percent of the total public lands in the Jarbidge FO. Some land managers and livestock operators speculated that extensive seedings of perennial grasses following wildfires, without commensurate increases in livestock grazing, contributed to an increase in herbaceous production. The speculation in turn, considered the possibility that increased herbaceous production provided additional fuels for wildfire.

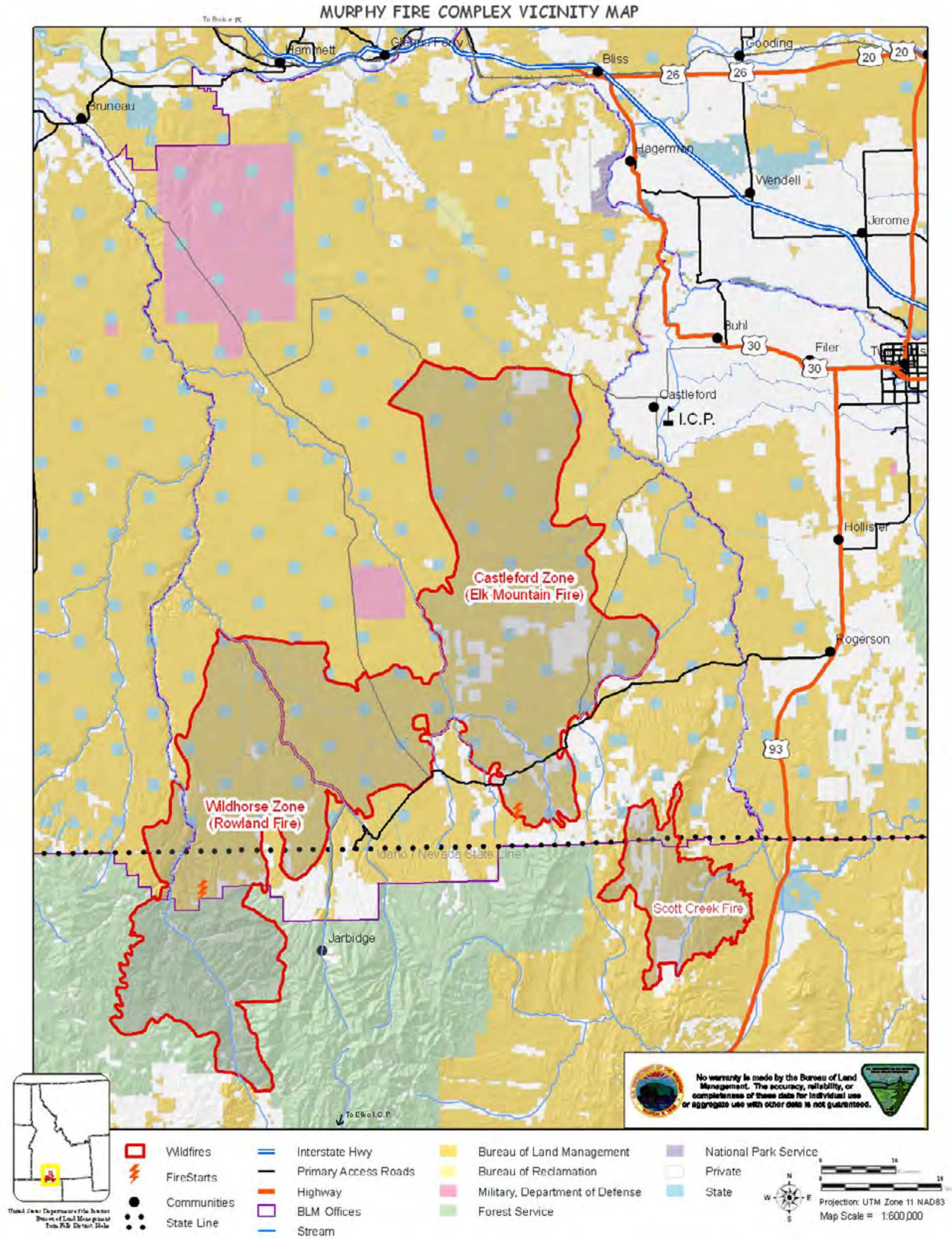

Figure 2. Map of area affected by Murphy Wildland Fire Complex, July 2007.

Purpose and Scope

In August 2007, a team[3] of scientists, habitat specialists, and land managers was called together by Tom Dyer, Idaho BLM State Director, to examine initial information from the Murphy Wildland Fire Complex in relation to plant communities and livestock grazing patterns. This report is the result, which is presented to meet the following objectives:

- Provide preliminary observations and recommendations regarding the effects, if any, of existing plant community composition (native rangeland and crested wheatgrass seedings) and current management of livestock grazing on fire behavior and rate of spread of the Murphy Complex Fires. Historical or potential vegetation composition, because it may have been influenced by historical livestock grazing levels or practices is, by necessity, background information and not the focus of this report.
- Provide recommendations for long-term research or studies needed to address issues or remaining questions surrounding the use of livestock to reduce fuels while maintaining post-fire resource values in the area encompassed by the Murphy Wildland Fire Complex.
- Discuss the potential application of the findings gleaned from the Murphy Wildland Fire Complex to other areas from a "lessons learned" perspective.

Description of Affected Area

The Murphy Wildland Fire Complex encompassed more than 1,000 square miles of rangelands. Most of this area was dominated by sagebrush steppe communities. Most of the areas (greater than 50 percent) that burned were sagebrush communities with an understory of native grass (based on figures for areas burned on BLM lands in Idaho). The most abundant vegetation type was Wyoming big sagebrush with an understory of native grass, including lesser coverages of low or black sage, and only small coverages of mountain big sagebrush or other combinations of sagebrush and non-native grasses.

About 20 percent of the area that burned was dominated by grasslands that included a few scattered shrubs. These grasslands included stands of native grasses (for example, bluebunch wheatgrass) and plantings of crested wheatgrass, intermediate wheatgrass, and other non-native grasses. Although fire in sagebrush steppe communities commonly is associated with an understory of annual grasses, only a small portion (less than 5 percent) of the area that burned in the Murphy Wildland Fire Complex was dominated by annual non-native grasses, including cheatgrass or medusahead. The plant communities dominated by annual plants were located in the northern reaches of the Murphy Wildland Fire Complex area (fig. 3). The remaining area that burned in the Murphy Complex Fires was a mix of rabbitbrush stands with an understory of grasses, a variety of other shrubland and woodland types, and sparsely vegetated areas.

[3] See appendix 1 for a full list of team members and their organizational affiliations.

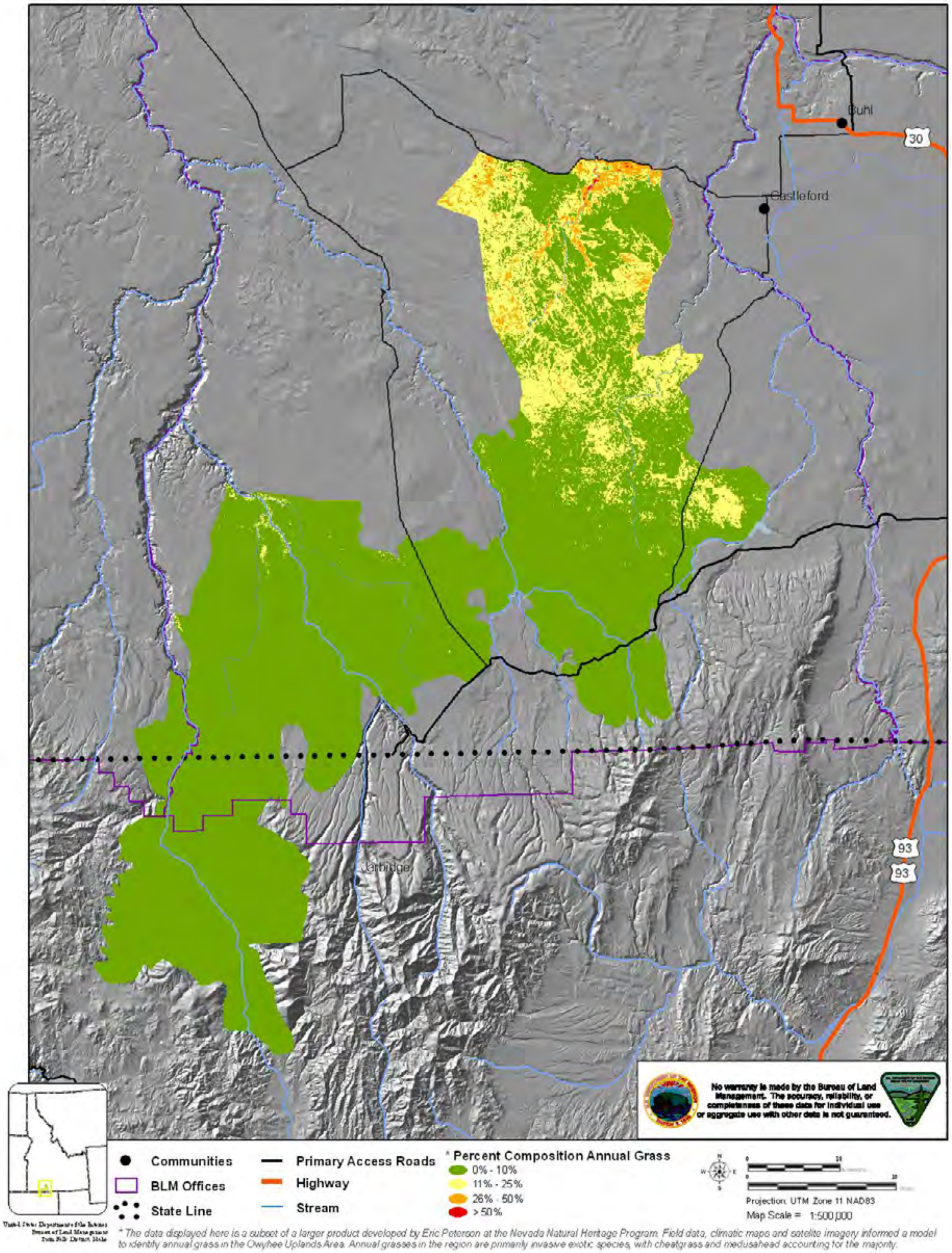

Figure 3. Cover of annual grasses and other annual plants in the area of the Murphy Wildland Fire Complex, July 2007.

Description of Fire Events

The wildfires that became the Murphy Wildland Fire Complex were started by lightning on July 16 and 17, 2007. Several environmental factors created conditions that favored the ignition and rapid spread of these fires. A low-pressure system produced windy conditions (from the south/southwest), and below-normal nighttime humidity supported the fires' rapid spread in the first few days after ignition.

A combination of weather and fuel conditions set the stage for the rapid growth and total extent observed in the Murphy Wildland Fire Complex. These conditions included a prolonged period of below-normal precipitation in the spring and early summer of 2007 (fig. 4). This dry period contributed to daily relative humidity (RH) values that were 12–25 percent below the long-term average (May–July 2007 compared to 1990–2006 average from four remote automated weather stations; RAWS). Temperatures also were high in south-central Idaho in the days preceding the fires, with daily temperatures the week before the fires exceeding 96°F and two days exceeding 100°F. These hot, dry conditions in the days before the fire resulted in conditions for fire fuels that were more extreme than any observed in the past decade. (The Energy Release Component [ERC] values in the week before the fire were higher than those reported in the last decade. The ERC value is an output of fire-modeling procedures and reflects fuel dryness and potential heat release per unit area in a fire event.)

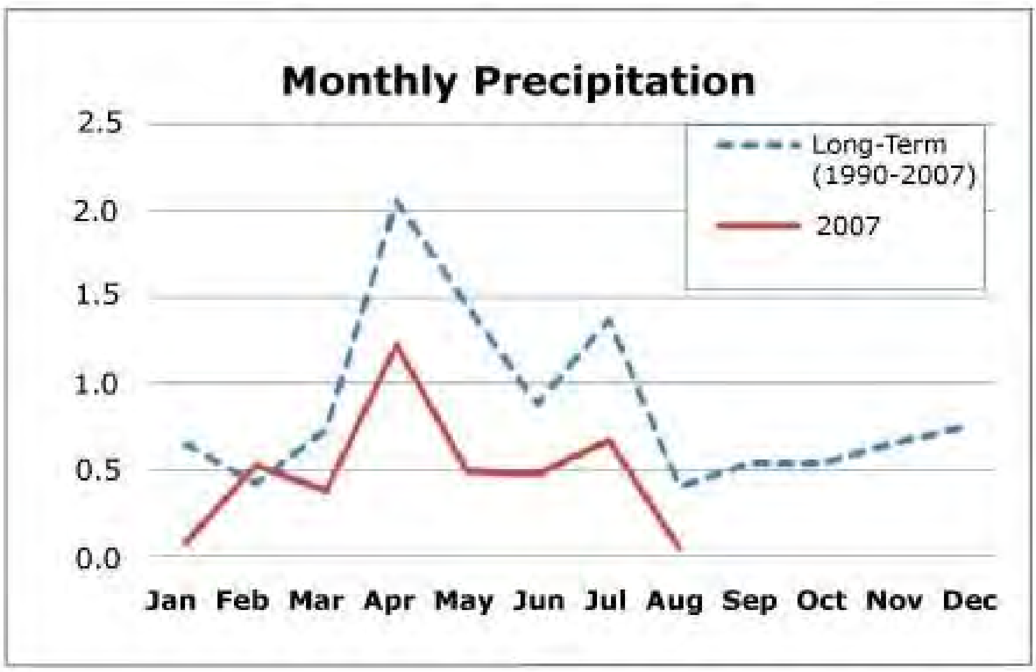

Figure 4. Precipitation records for Murphy Wildland Fire Complex Area, 1990–2007. Data are from RAWS: Horse Butte, Twin Butte, Pole Creek, and Bull Springs.

The Rowland and Elk Mountain fires were ignited by lightning and initially influenced by thunderstorms over the high country along the Idaho-Nevada State line (see lightning strike symbols in fig. 2). The passing of a weather front associated with the low-pressure system moved south across the area and was positioned south or southwest of the fires, creating winds that blew to the northeast and strongly pushed the fire during the initial stages. These fires showed rapid expansion in the three days after ignition, moving mostly in a northeasterly direction. The rapid expansion of these fires also was a result of sufficient fuel loads and low fuel moisture created by lack of precipitation in the weeks before the fires. Fire behavior in these first few days was reportedly extreme and erratic as a result of high daytime temperatures (87° to 99°F; based on four RAWS), low daytime RH (less than 10 percent on July 18 and 20), and gusty winds. Weather conditions on July 18 were particularly problematic with a daytime temperature greater than 95°F, RH of 8 percent, and winds gusting as high as 34 mph. These severe conditions resulted in rapid expansion of the Elk Mountain and Rowland fires from less than 10,000 acres each to near or greater than 100,000 acres in each fire within the first two days after ignition (fig. 5). By July 20, the Elk Mountain Fire had expanded to an estimated 160,000 acres and was only 10 percent contained (NIFC report; *http://www.nifc.gov*). The Rowland Fire had expanded to about 95,000 acres and was estimated to be only 15 percent contained by July 20 (*http://www.nifc.gov*). Fire suppression during these initial days of the Murphy Wildland Fire Complex was hindered by the scarcity of fire-suppression resources because of the large number of wildfires (more than 40 other fires) burning mostly in Idaho and Montana (NIFC reports, *http://www.nifc.gov*).

These two fires continued to expand from July 21–23, aided by high daily temperatures (exceeding 95°F) and low daytime RH (10 to 13 percent). Nighttime recovery of RH was unusually low, with maximum reported RH less than 40 percent. These weather conditions resulted in large advances of the fire front with aggressive fire behavior occurring during nighttime hours. On July 22, four and five days after ignition, the Rowland and Elk Mountain fires burned together and, with inclusion of the Scott Creek Fire, covered about 442,000 acres with only 10 percent containment (NIFC reports, *http://www.nifc.gov*).

The fires of the Murphy Wildland Fire Complex continued to expand on several fronts to an estimated affected area exceeding 550,000 acres by July 23. Beginning late on July 23, moisture began to stream into the affected area from southern Nevada, and humidity increased dramatically by July 24. The days from July 24–27 signified a period when the fires began to slow and firefighters began to gain containment (fig. 5). Significant cloud cover, high daytime (29–32 percent) and nighttime (59–72 percent) RH, and much cooler temperatures (82–88°F) reduced the spread and intensity of the fires. Some light rain occurred on July 24, with thunderstorms over the fire area on July 25–26. By the morning of July 27, the Murphy Wildland Fire Complex was estimated to be 70 percent contained, and only small advancements were recorded in subsequent days. The fire was declared 100 percent contained on August 2, 2007 (NIFC reports, *http://www.nifc.gov*).

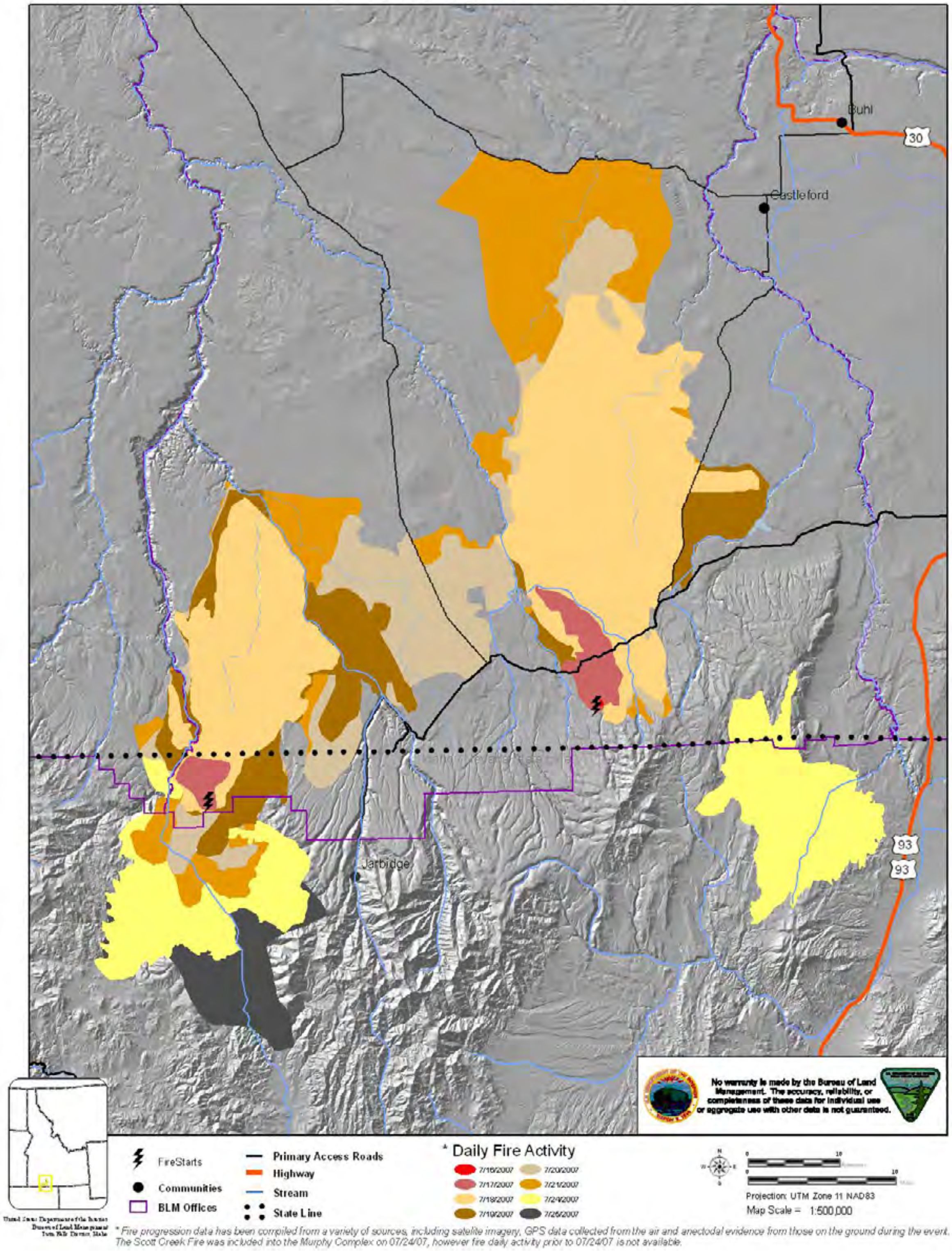

Figure 5. Fire progress and daily fire activity of the Murphy Complex Fires, July 16– 25, 2007.

Observations and Photographic Example of Fire Effects

The Murphy Wildland Fire Complex was recognized for its massive expanse and nearly complete consumption of vegetation on many of the burned areas (fig. 6). However, the fires of the Murphy Complex, like all wildland fires, burned in a mosaic over a portion of the area (fig. 7). Aerial views of the Murphy Wildland Fire Complex obtained by helicopter on August 3, 2007 illustrate several interesting examples of changes in fire behavior related to vegetation communities and are available at *http://www.uidaho.edu/range/MurphyFireComplex/* (provided by M. Pellant).

This report focuses on the potential role that livestock grazing played in altering fuel loads and fuel types that affected the pattern and severity of fires in the Murphy Wildland Fire Complex. Because fire behavior, fire extent, and level of vegetation consumed result from many interacting factors, the specific role that grazing had on the fires was difficult to ascertain. The team preparing this report toured the area of the Murphy Wildland Fire Complex on August 28, 2007 and saw first-hand examples of completely burned areas, patchily burned mosaics, and contrasts where fires stopped at a fence-line or only fingered into the adjacent pasture. A reasonable explanation for these contrasts was a difference in the grazing management between the areas on each side of the fence-line (fig. 8).

Livestock operators in the area shared their knowledge of the pre-burn vegetation conditions, levels of grazing use, and on-site observations of fire behavior with the report team. These observations supported the possibility that livestock grazing resulted in a mosaic burn or observable fence-line contrasts that could be attributed to differences in utilization levels created by livestock grazing.

Figure 6. Extensively burned area in the Murphy Wildland Fire Complex. Photograph taken west of Three Creek, Idaho on August 28, 2007, by K. Launchbaugh.

Figure 7. Mosaic of burned (in background) and unburned rangeland (in foreground) within the Murphy Wildland Fire Complex. Photograph taken west of Three Creek, Idaho on August 28, 2007 by K. Launchbaugh.

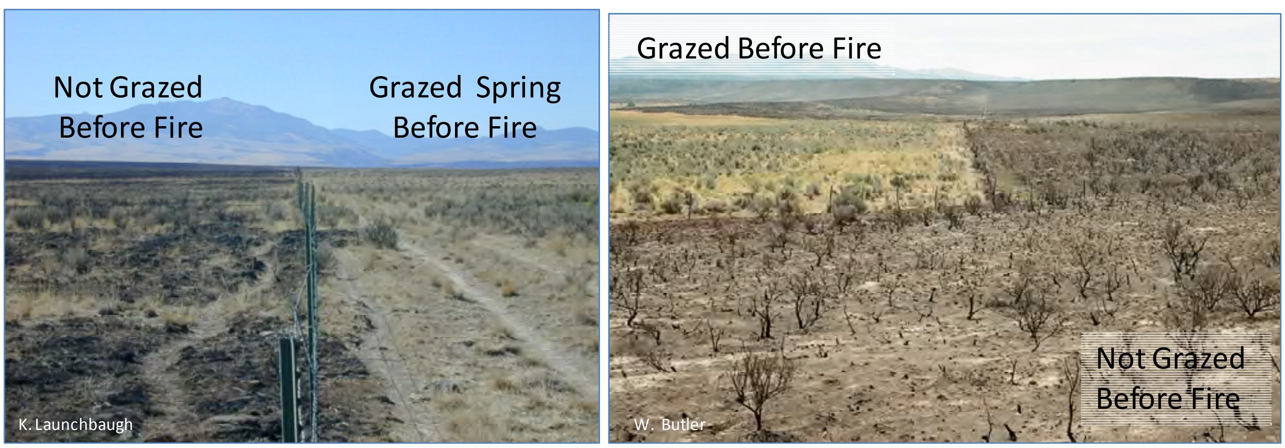

Figure 8. Two examples of fire-behavior contrasts at fence-lines separating pastures that had different grazing regimes before the fire. Photograph on left taken by K. Launchbaugh, Photograph on right by W. Butler.

In summary, the findings that follow provide a scientific analysis of the relationships among livestock use, wildfire characteristics, and fuels. However, the anecdotal information gathered by the team based on their observations, professional experience, and input by others involved in the suppression of this fire also contributed to the assessment.

Fire Behavior and Fuel-Consumption Analyses

The specific role of livestock grazing on fuel loads and fire behavior, and subsequent fuel consumed in the Murphy Wildland Fire Complex is of considerable importance to land managers, landowners, and the public interested in sagebrush steppe ecosystems. However, like most complex ecological questions, there are many ways to seek answers. Three approaches were used in our effort to understand the role that vegetation type and amount had on fire behavior and fuel consumption:

1. Identify potential for livestock grazing to modify fuel loads and affect fire behavior using fire models applied to various vegetation types, fuel loads, and fire conditions.
2. Compare level of fuel consumed within and among major vegetation types.
3. Examine several observed lines of difference and discontinuity in fuel consumed to determine what factors created these contrasts.

Examination Approach 1 – Potential for Livestock Grazing to Affect Fuel Loads and Subsequent Fire Behavior Using a Fire-Modeling Approach

It is well known that grazing, especially by cattle, late in the growing season or during dormant periods reduces herbaceous residual biomass. It also is accepted that the kind, amount, and distribution of herbaceous biomass are an important factor affecting behavior of wildland fires. Thus, grazing can potentially affect fire behavior. However, grazing effects on herbaceous fuels and fire behavior vary extensively by site and situation. The team used a fire-behavior modeling system (BEHAVE Plus; Andrews and others, 2003) to examine how varying the amounts of current-year and residual herbaceous biomass and fuel loads would affect fire behavior in sagebrush steppe and grasslands under various environmental and fuel-moisture conditions. The team's intent for this modeling exercise was to address two fundamental questions:

- What is the potential for livestock grazing in shrub and grassland communities of the sagebrush steppe to reduce fire intensity and facilitate effective fire containment and control?
- Under the environmental conditions observed during the Murphy Wildland Fire Complex, would livestock grazing have affected fire intensity, containment, and control?

Generally, the team's modeling approach was to simulate grazing effects on fire behavior by incrementally reducing herbaceous fuel-parameter values while holding parameters for other fuel and environmental conditions constant (for example, dead fuel loading, live shrub loading, live and dead fuel moisture, slope, and weather). The models used in this simulation were developed based on inputs from several sources, including BLM inventory data for vegetation, ecological site descriptions, published literature, and existing fuel models in the BEHAVE Plus software program.

Modeling Procedures

The team focused on four fuel models corresponding to cheatgrass, seeded grass, or one of two sagebrush steppe vegetation community types. Complete details on all model runs are available at: *http://www.uidaho.edu/range/MurphyFireComplex/*. The basic sagebrush steppe model (GS1) was derived from Scott and Burgan (2005), with some minor modifications to the fuel-loading values. The other sagebrush steppe model (SG06) was published by Ottmar and others (2007) and generally includes more sagebrush cover and higher herbaceous fuel loads than the GS1 model. The cheatgrass model was based primarily on BLM inventory data and findings reported by Whisenant (1990) and Keeley and McGinnis (2007). The seeded-grass model was a modification of the cheatgrass model and was the most difficult to develop because no published fuel models for this vegetation type existed.

There are several assumptions and caveats that should be kept in mind when interpreting the results presented below. The Rothermel equation (Rothermel 1972; 1983), on which BEHAVE Plus is based, assumes the following conditions exist: uniformity in fuel continuity, weather, wind, and slope; no fire spotting (that is, fire starting from embers landing in advance of the fire front); no extreme fire behavior; and surface fire only. These assumptions were not consistently met during the Murphy Wildland Fire Complex. For example, it was known that the fuels were not uniform throughout, relative humidity changed from day to night, and winds were gusty. However, these models provided a mechanism to compare the changes in fuels that grazing and vegetation composition would most likely impact. The results provide fire behavior predictions only for a free-running head fire at steady state. For simplicity, only results for surface rate of spread and fire line intensity are presented because these fire behavior variables are most easily understood and are indicative of overall fire behavior as they relate to controlling a fire.

In fire models such as BEHAVE Plus, the green grass and forbs consumed by grazing animals are termed “live herbaceous fuel loading” or LHFL. Because it is LHFL that is altered by grazing, LHFL is always presented in this report on the horizontal X-axis. Values range from 0 to 1,200 lb/acre. In some runs, the residual fine fuel loads were reduced to simulate several years of consecutive grazing that could lower the carryover of residual fine fuel loads from one year to the next. The fuels created by dead grass and small twigs are called “1-hour time lag” (1-htl) fuels in fire models. These 1-htl fuels were modified to simulate the effect of grazing to reduce carryover of residual dormant grass and forbs from one year to the next.

Several considerations apply when interpreting the results presented. First, direct fire attack is not recommended when fire line intensity is greater than 100 British Thermal Units per foot per second (BTU/ft/sec) or when flame length exceeds 4 feet. Under these conditions, fire professionals generally retreat and find a better place to stop the fire or to wait for the weather to change. Additionally, to keep this report concise, only selected graphical results from the GS1 sagebrush steppe model are presented as figures; however, other models are discussed in relation to these graphs. The other output graphics from each model can be viewed at *http://www.uidaho.edu/range/MurphyFireComplex/*.

Interpretation of Fire Modeling Results

The sagebrush steppe and grassland models were run at varying dead fuel moisture (DFM) levels, including 6, 8, 10, 12, and 14 percent. The results of the two sagebrush models (GS1 and SG06) were similar with respect to how decreasing LHFL affected fire behavior. When live herbaceous fuel was decreased to simulate grazing, both sagebrush models predicted a reduction in all fire behavior variables, although specific effects varied depending on wind speed.

Under relatively dry conditions of 10 percent DFM, extreme fire behavior (that is, fire line intensity greater than 100 BTU/ft/sec) was predicted until LHFL was reduced to less than 200 lb/acre (fig. 9). The effect of reduced herbaceous biomass on fire behavior was more pronounced under less-intense fire conditions (that is, greater than or equal to 12 percent DFM; fig. 10). The potential role of grazing to reduce fuel loads and modify fire behavior is more feasible and effective under cooler and more humid conditions (compare figs. 9 and 10). There appeared to be a threshold in the herbaceous biomass effect at 400 to 600 lb/acre of LHFL under the 12 percent DFM condition (fig. 10). Within this LHFL range, there was a rapid change in fire behavior indicating a condition under which fire behavior was particularly responsive to changes in biomass of live herbaceous biomass. Model runs at 14 percent DFM were nearly at the moisture level where the fire would have been extinguished; consequently, the predicted fire barely burned. (Results available at: *http://www.uidaho.edu/range/MurphyFireComplex/*).

To simulate effects of several consecutive years of grazing, the team considered a situation in which the carryover of fine fuels was reduced by 50 percent to 300 lb/acre. Under these fuel conditions, measures of fire behavior were further reduced and apparent thresholds became more obvious as the LHFL changed from 700 to 1,000 lb/acre (fig. 11). Thus, the rate of spread and fire line intensity of a wildfire may be reduced if grazing or lower-than-normal precipitation occurred in the years preceding a fire, reducing the carryover of fine fuels from one year to the next.

Effect of slope was tested using the GS1 model, and no interaction between slope and simulated grazing-use levels was detected. This indicates that effects of removing biomass by grazing would have a similar effect on level or sloped land. (Results available at: *http://www.uidaho.edu/range/MurphyFireComplex/*).

The cheatgrass and seeded grass models were run at 6, 8, 10, and 12 percent DFM. Simulated grazing reduced measures of fire behavior at all fuel moisture levels, but was more pronounced under more moist conditions (that is, higher DFM values). Although the cheatgrass and seeded grass models were nearly identical, all fire behavior variables were reduced by the lower grass volumes (that is, the ratio of surface area to volume; SAV) in the seeded grass model. This effect of grass volume was evident even at 6 percent DFM, but it was more pronounced at higher DFM values. (Results available at *http://www.uidaho.edu/range/MurphyFireComplex/*).

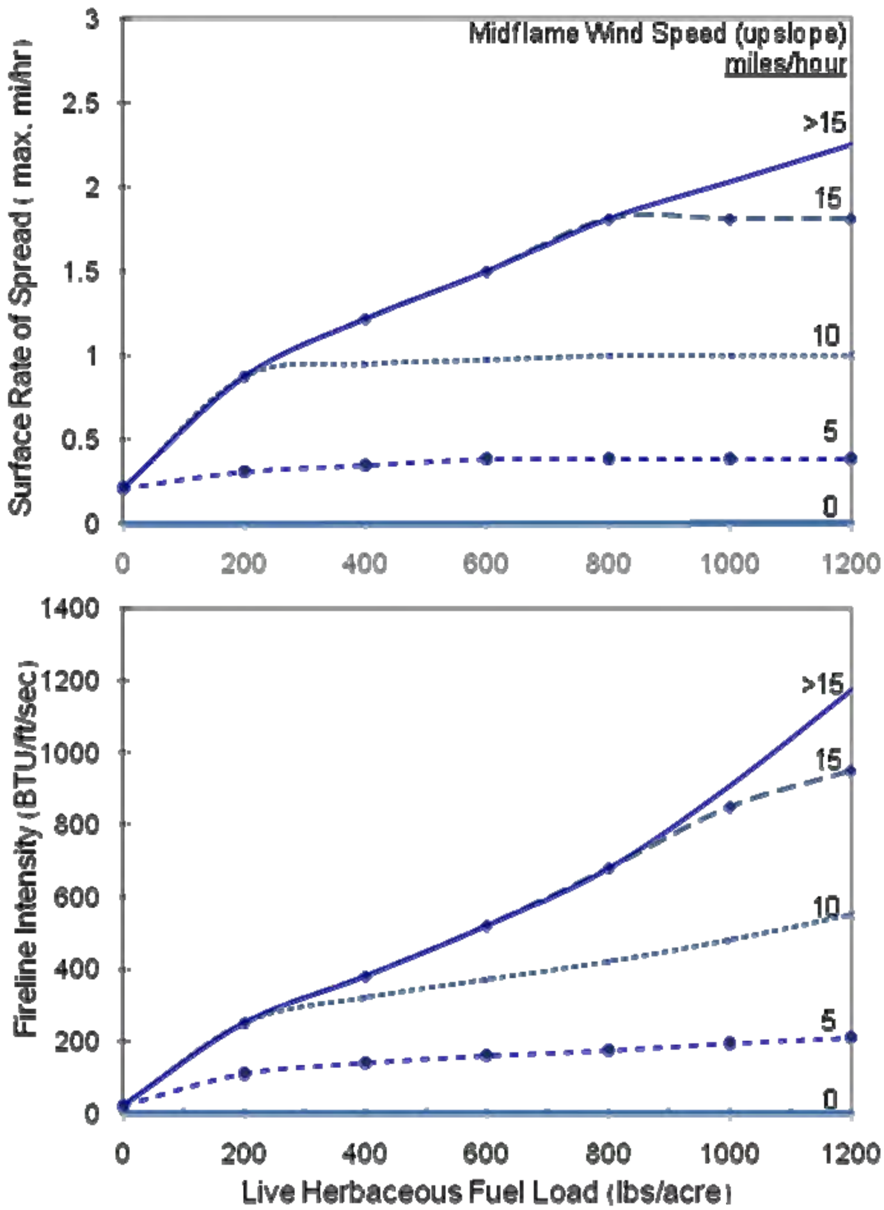

Figure 9. Fire behavior estimates based on modeling of a sagebrush steppe situation (GS1 model) with herbaceous fuel (1-htl) and 10 percent dead fuel moisture (DFM).

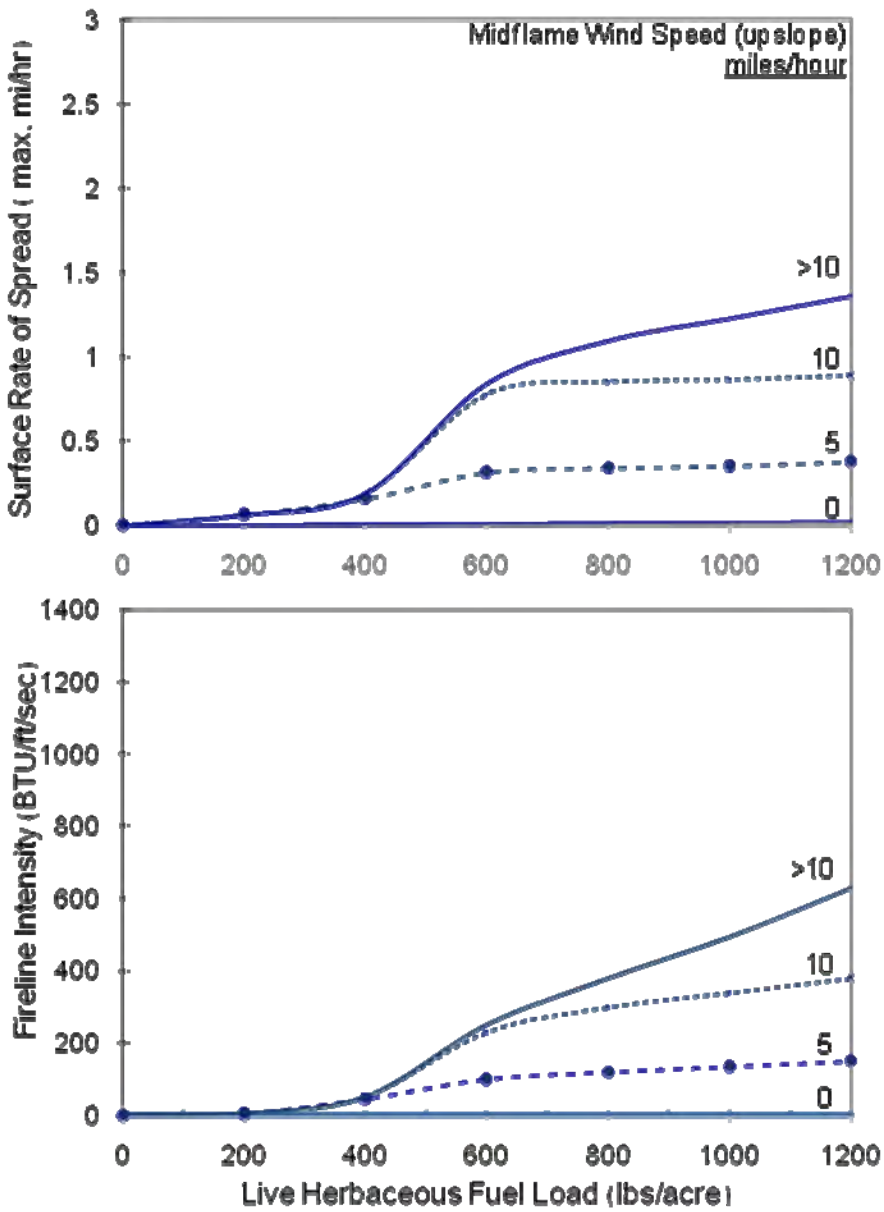

Figure 10. Fire behavior estimates based on modeling of a sagebrush steppe situation (GS1 model) with herbaceous fuel (1-htl) and 12 percent dead fuel moisture (DFM).

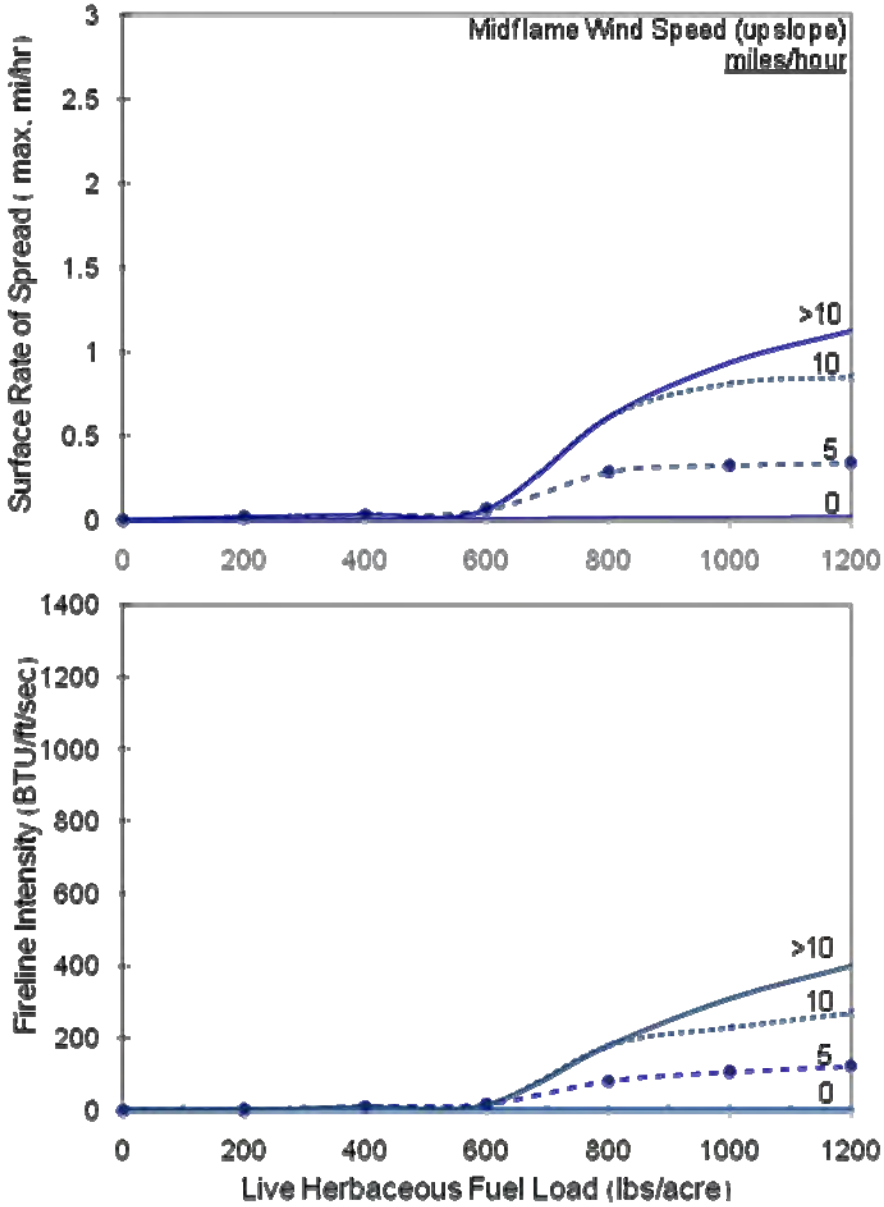

Figure 11. Fire behavior estimates based on modeling of a sagebrush steppe situation (GS1 model) with carry over fuels from previous years reduced by 50 percent (to 200 lb/acre) and 12 percent dead fuel moisture (DFM).

Summary of Modeling Results

Reducing levels of fine fuels, as might be accomplished with livestock grazing, reduced the modeled surface rate of spread and fire line intensity in the simulated shrub and grassland communities. This might be expected given the basic assumptions incorporated into the BEHAVE Plus modeling system. The BEHAVE Plus system simplifies the combustion process, and the fire characteristics the team chose were primarily determined by 1-htl fuels, LHFL, fuel moisture, and wind speed. The effects of reduced fuel load on fire behavior were more pronounced at low wind speeds and high fuel moisture values. When burning conditions became extreme (less than 12 percent DFM and greater than 15 mph wind speed), changes in live herbaceous fuel load and amount of dead herbaceous fuels (1-htl fuel classes) had little effect on fire behavior variables. Consequently, under the extreme conditions that characterized most of the Murphy Wildland Fire Complex, grazing levels probably had little effect on fire behavior over much of the area. Within the larger fire area, however, there were certainly sites where less-extreme conditions occurred and grazing-induced reductions in herbaceous biomass were likely an important determinant of fire behavior. Under less-extreme fire weather conditions (DFM greater than12 percent and wind speeds less than 10 mph), reductions in herbaceous fuels resulting from livestock grazing may influence fire behavior, making a fire in these shrub and grassland plant communities easier to contain.

Examination Approach 2 – Relation between Vegetation Type and Fuel Consumption

Comparing satellite images and data collected before and after a fire is a technique widely used to assess the effects of fire across a landscape (Key and Benson, 2006). This differencing technique has been used extensively to assess the level of fuel consumed and vegetation changes caused by fire (Miller and Thode, 2006). For the Murphy Wildland Fire Complex, the team used a recently developed technique to examine fire-induced changes to vegetation amount and structure by creating a variable called delta Normalized Burn Ratio (dNBR). Values for dNBR were calculated based on ratios of the difference between the pre-burn and post-burn reflectance in two spectral bands of Landsat Thematic Mapper satellite data (30 m-per-pixel resolution). The difference in the spectral reflectance before and after a fire for a specific piece of land (or, more specifically, a pixel in the image) indicated how much the fire changed vegetation and soil on that unit of land.

In fire ecology research, dNBR is one approach to quantify changes caused by fire on a landscape. Burn severity is the term used to describe the changes to vegetation and soils caused by a fire (Key and Benson, 2006). Thus, dNBR is often used to quantify burn severity such that areas that have high dNBR values are described as having high burn severity. In the team's analyses, the term burn severity was used to infer the amount of fuel (live vegetation, dead standing vegetation, or litter) consumed by the fire, with recognition that burn severity does not necessarily indicate levels of ecological damage caused by fire. Nonetheless, "burn severity" is synonymous with "fuel consumption" in this report.

Defining Burn Severity and Fuel Consumption

Burn severity describes the degree of environmental change caused by fire. It refers to the composite degree of physical and chemical changes to the soils, degree of change in living and dead vegetation, changes to inorganic carbon and ash, and degree of change in plant structure and composition (that is, proportions of species). The concept of burn severity also can be applied to specific environmental responses, most frequently focusing on soils or vegetation. Burn severity is affected primarily by fire line intensity, how long the fire burns on a specific area (that is, fire residency time), and moisture conditions at the time of burning (Sugihara and others, 2006).

Fire intensity, burn severity, and level of fuels consumed are inherently related because the more fuel that is consumed, the more intense the fire, and the more heat created that could impact plant vigor and survival. As well, with more intense fires and greater heat transfer, there is a greater likelihood of increased soil fire effects such as loss of organic matter, exposed mineral soil, and soil erosion. Although the relation between level of fuel consumed and burn severity are not completely correlated, they are so closely associated in this context that we use these as interchangeable terms for the purposes of this report.

High levels of fuel consumed (or high burn severity) generally are recorded in areas where trees, with their concomitant high biomass, existed before a fire but no longer exist after a fire. Moderate burn severity is most characteristic of shrublands. Low burn severity is typical of areas dominated by grasslands. Thus, burn severity or fuel consumption should be evaluated relative to the pre-fire community. It is always best to compare fuel consumption within a particular vegetation type (for example, among shrubland stands), rather than among plant communities that differ in structure (for example, among grasslands, shrublands, and forests), because burn severity values derived in different structural communities may not represent equal ecological change.

Within shrub-dominated areas, a high burn severity likely reflects higher consumption of shrubs by fire compared to a low burn severity value for a similar shrubland area. However, even low and moderate amounts of fuel consumed can have significant ecological effects. For example, Wyoming big sagebrush is killed when fire removes the above ground foliage because this species of sagebrush does not sprout from buds in the root crown after fire (Howard, 1999). Therefore, Wyoming big sagebrush is largely dependent on establishment from seeds for stands to recover after fire. LANDFIRE fire regime modeling indicates that 86 percent of fires in Wyoming big sagebrush are stand-replacing events (LANDFIRE Rapid Assessment, 2007).

Within a grassland community the amount of fuel removed by the fire may or may not be a good indicator of burn severity. Grasses are well adapted to fire because they have basal buds that can sprout after fire and create new tillers for continued growth and survival (Briske, 1991). Because grasslands generally have less total biomass available as fuel compared to adjacent shrublands or woodlands, low values for burn severity may result from satellite image comparisons. However, the fire effects can be severe if heat damages the root crown or soil and promotes soil erosion. A careful field assessment may be necessary to determine fire effects to grassland communities.

A dNBR map was created for the Murphy Wildland Fire Complex based on remotely sensed data. To accomplish a comparison of images before and after the fires, the team used a post-burn image taken on August 10, 2007 (with minor cloud patching corrected using an image acquired on August 17, 2007). This image was compared to a pre-fire image acquired on July 29, 2006 (with minor cloud patching corrected using an image acquired on July 9, 2007), about one year prior to the fire. The initial dNBR image was further examined and calibrated with ground-reference data collected with field observations by several technicians and professionals in mid-September. The calculation of dNBR from remotely sensed data created a continuous attribute that was then thresholded into classes (for example, low, moderate, and high). In this analysis, the thresholds used generally agreed with other rangeland fire mapping thresholds, and only minor adjustments were made based on field examinations. The dNBR values were used to create a burn severity map (fig. 12).

Landscape Comparison of Fuel Consumption Among Vegetation Types

Landscape patterns of grassland and shrubland communities and their influence on the level of fuel consumption in the Murphy Wildland Fire Complex were examined by calculating the proportions of burn severity classes within each major vegetation type. This descriptive analysis provided an overview of the range of burn severity that occurred within each vegetation type and allowed qualitative comparisons among types. This analysis described how vegetation type influenced fuel consumption and set a foundation to interpret grazing effects that modify fuel loads potentially observed as differences in burn severity. The team did not conduct an analysis of the relationship between grazing and dNBR because a complete data set characterizing the level of grazing was not available within the time frame of the project. The vegetation classification used for this evaluation was derived from remotely sensed images that were verified and adjusted by field data and input from experienced local observers[4].

A comparison of fuel consumption (that is, dNBR) across vegetation types supported a general premise that the plant community occurring on a site before a fire influences the amount of fuel consumed and changes in plant structure caused by the fire. These data confirmed well-known relations between vegetation type and level of fuel consumed, for example, grasslands yielding lower fuel consumed and therefore lower burn severity values than shrublands (fig. 13).

A closer examination of burn severity classes observed in specific vegetation types revealed that each plant community can experience a range of fuel consumption levels from unburned to fully consumed vegetation. The burn severity categories in our analysis reflected the level of vegetation consumed and the patchiness of burning within and among 30-m pixels in the image used for this analysis (table 1). Therefore, acreages in the low burn severity category can be assumed to include mixes of burned and unburned areas. These data indicated that a significant portion of each vegetation community experienced fire in the low burn severity category. This indicated low initial biomass, and therefore low levels of fuel consumed, patchy burning patterns, or removal of fuels in a way that was less than complete.

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[4] Vegetation community classification was based on field data collected by resource staff at the Jarbidge Field Office from 2002 to 2006 and 2004 National Agricultural Image Program (NAIP) imagery. This effort was conducted by resource personnel that are familiar with the landscape. The data have been verified in the field by Jarbidge Field Office resource management staff.

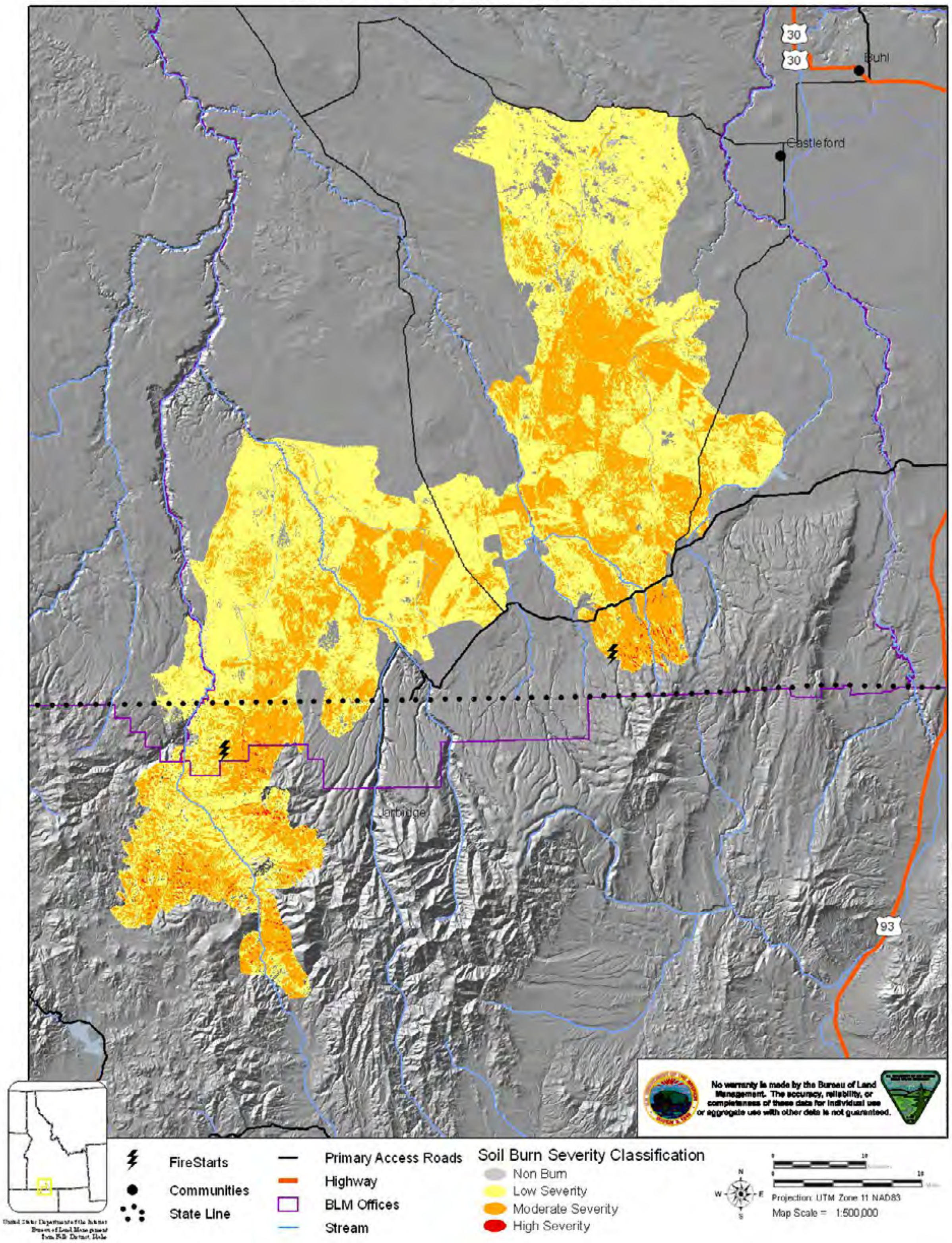

Figure 12. Burn severity based on delta Normalized Burn Ratio for the Murphy Wildland Fire Complex, Idaho, July 2007.

Table 1. Burn severity (dNBR) observed and classified after Murphy Wildland Fire Complex expressed as a percentage of area within pre-fire vegetation types. These figures reflect the Idaho BLM lands that were affected by the Murphy Wildland Fire Complex (450,535 acres) and account for about 75 percent of the total Murphy Wildland Fire Complex area.

Vegetation Community	Acreage in analysis	Percentage of area			
		Non-burned	Low	Moderate	High
Herbaceous Types:					
Annual Grasses and Forbs	5,469	7	73	20	0
Native Grasslands	85,071	5	76	19	0
Seeding (Crested and Intermediate Wheatgrass)	38,773	2	85	13	0
Recent Burn (2006 Fires) - Herbaceous Plants	24,373	13	84	3	0
Sagebrush Types:					
Mountain Big Sagebrush	10,620	2	28	68	2
Low-Black Sage/Native Grass understory	35,683	2	48	50	0
Wyoming Sagebrush /Native Grass understory	200,694	3	55	43	0
Wyoming Sagebrush/Understory Introduced Grasses (for example, Crested and Intermediate Wheatgrass)	6,062	6	70	24	0
Non-Sage Shrublands and Woodland Types:					
Rabbitbrush/Native Grass	23,509	2	56	41	0
Rabbitbrush/Non-Native Grass	2,643	1	87	12	0
Shadscale Saltbush	1,522	1	99	0	0
Other types:					
Semi-Wet Meadow	302	21	21	52	5
Sparse Vegetation	12,941	10	71	18	0
Other shrub/woodlands types (including: aspen, juniper, curl-leaf mountain mahogany, bitterbrush, etc.)	2,865	2	18	73	7

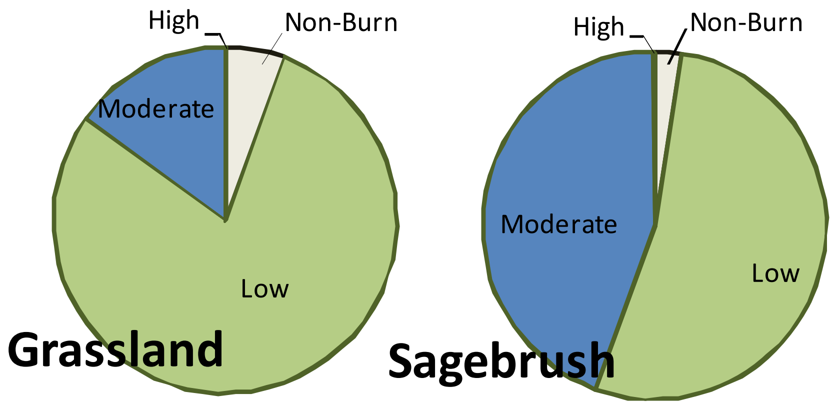

Figure 13. Variation in burn severity averaged in grassland and sagebrush vegetation types.

Variation of fuel consumption within a vegetation type indicates variation in the biomass, cover, and relative abundance of plants among sites classified as a single vegetation type. The effects of grazing would reflect reduced herbaceous biomass, and therefore could contribute to variation within a vegetation type. This variation in fuel consumed within a vegetation type reflects biotic and abiotic factors that influence fire behavior including topography, weather conditions, and fuel characteristics. Managing fuel characteristics offers land managers the potential to influence biomass of herbaceous species, and therefore reduce the amount of fuel consumed (that is, burn severity) within a vegetation type.

Examination Approach 3 – Major Drivers That Created Distinct Lines of Difference and Discontinuity in Burn Severity

Examination of the burn severity map created for the Murphy Wildland Fire Complex (fig. 12) revealed several linear contrasts that apparently reflected distinct differences in conditions on either side of the contrast. The team carefully examined these contrasts, to understand the attributes and conditions that influenced fire behavior and effects in the Murphy Wildland Fire Complex. The goal was to determine the major drivers of discontinuities in burn severity. Were these differences primarily driven by vegetation type or by levels of residual herbage affected by livestock grazing? Discontinuities where the vegetation community type was the same on both sides of the contrast (either shrubland or grassland) also were examined to determine if discontinuities in burn severity were driven by differences in residual herbage potentially created by different levels or seasons of grazing. One limitation of this analysis was the absence of complete knowledge of weather during the fire and other conditions that affected fire behavior at the specific locations involved.

Examination Procedures

Fourteen focus areas with lines of contrasting burn severity were selected within the perimeter of the Murphy Wildland Fire Complex (fig. 14). These focus areas were selected arbitrarily with some intentional selection for contrasts where burn severity occurred along a fence-line with similar vegetation type on both sides of the fence. Field verification of contrast lines was not conducted. Several landscape features and fire attributes were gathered and examined along these contrast segments to explain the source of the distinct change in burn severity. These landscape and fire characteristics or factors included:

- Vegetation type obtained from the BLM Jarbidge FO (described above).
- A map of seedings, usually post-fire revegetation efforts, provided by the BLM Jarbidge FO.
- An annual grass cover class map (2006 Annual Grass Cover Index) based on work by Eric Peterson, Nevada Natural Heritage Program (fig. 3).
- Shrub cover estimated by image interpretation of pre-fire Landsat images (combination of bands 7, 4, and 3).
- Actual grazing use from BLM and rancher records of livestock numbers and dates in and out of selected pastures.
- Distance from nearest water source in the pasture calculated for each contrast segment with interest in how this might influence utilization levels on either side of pasture boundaries.
- Fire behavior and suppression derived from a fire progression map provided by the BLM Jarbidge FO.
- Fire history provided by maps of historical fire perimeters labeled with the year they burned (BLM Jarbidge FO). Digital color maps for the factors consisted of both regional maps and maps zoomed in on each focus area.
- Anomaly performance, used to highlight areas that were greener or browner than expected based on difference between a pixel’s actual growing season Normalized Difference Vegetation Index (NDVI) and its climatically predicted growing season NDVI[5] (Wylie and others, 2008).
- Pre-fire Biomass in 2007 derived from a regression relationship ($R^2 = 0.70$) developed from the 2006 current year’s growth in mid-summer (ecological site inventory data collected by the BLM Jarbidge FO) and the early-to-mid summer 2006 MODIS NDVI. The regression tree was then applied to the 2007 pre-fire MODIS NDVI to estimate and map the 2007 pre-fire current year’s growth.

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[5] The normalized difference vegetation index (NDVI) is a measure of vegetation photosynthetic potential and correlated to biomass, net primary productivity, and leaf area index. The pixel anomaly was derived from a regression model that predicted the pre-fire growing season integral of NDVI from climate data (*http://www.prism.oregonstate.edu/products/*, accessed September 2007) and 1997 through 2006 average growing season NDVI. Two separate regression tree models were produced correlating climate and NDVI data one for grasslands ($R^2 = 0.86$) and one for shrublands ($R^2 = 0.95$). Preliminary analysis indicated that the pixel “anomaly” was related to pasture actual grazing pressures in grassland areas ($R^2 = 0.7$ overall).

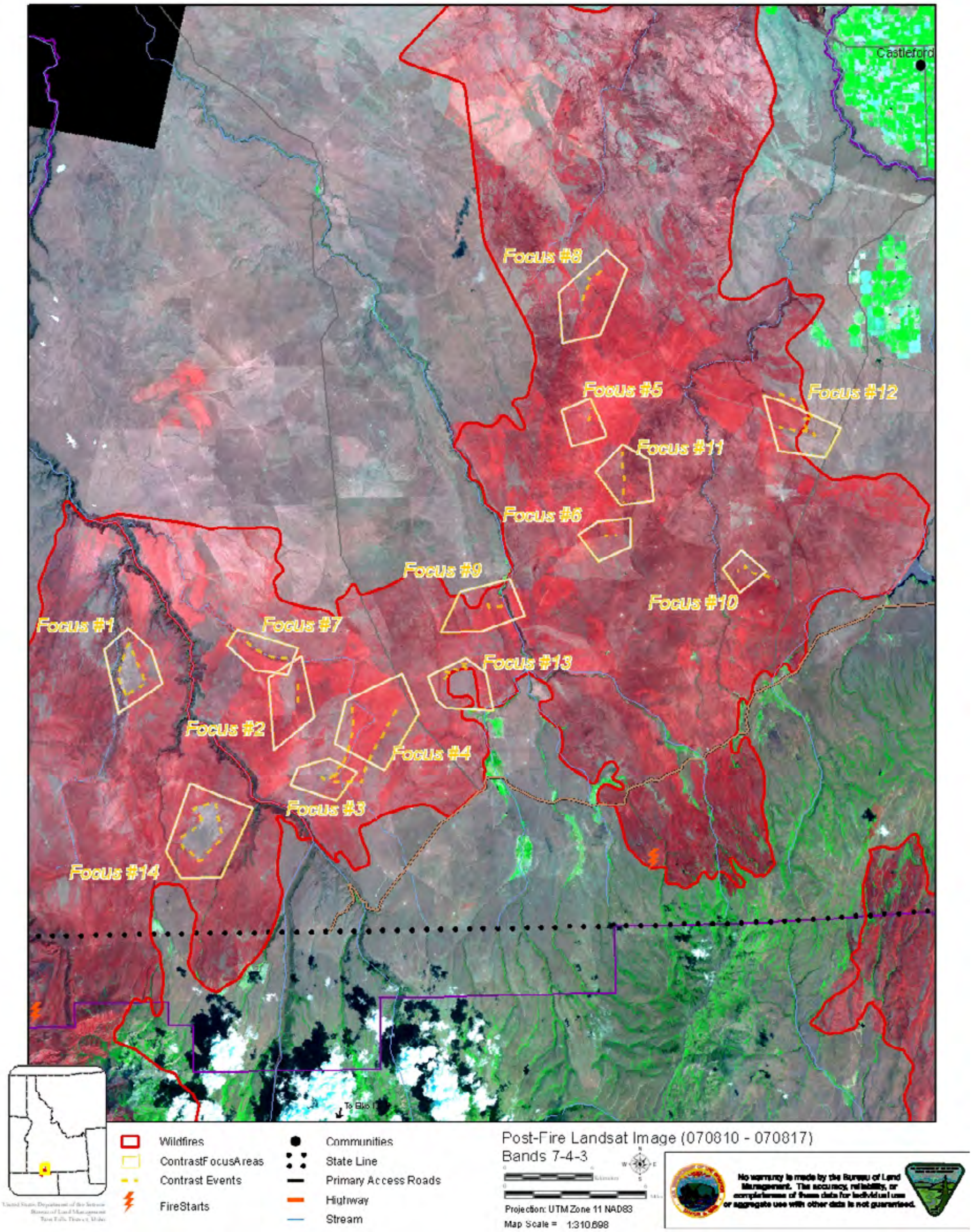

Figure 14. Fourteen focus areas of distinct contrasts in burn severity based on delta Normalized Burn Ratio (dNBR) for the Murphy Wildland Fire Complex that were examined to determine possible explanation for these contrasts.

Color maps and images of each factor in each focus area were created with GIS allowing observers to visually assess the importance of the selected factors in determining the observed contrasts in burn severity. (These maps and images can be viewed at: *http://www.uidaho.edu/range/MurphyFireComplex/*). Four observers[6] examined the maps and data for each focus area and ranked the importance of each factor in explaining each burn severity contrast segment. The median importance value from the four observers was determined for each factor and each burn severity contrast segment. The burn severity contrast segments were grouped into segments dominated on both sides of a fence by one particular vegetation type: grass, shrub, or a mixture of grass and shrub. Separate analyses were conducted for the grass- and shrub-dominated fence-line related burn severity contrast segments. Summarization of the drivers of the burn severity contrasts were (1) across the fire, (2) within grasslands fence-line contrasts, and (3) within sagebrush fence-line contrasts.

Major Drivers of Discontinuities in Burn Severity

Shrub cover, visually estimated from a pre-fire Landsat scene, was the most important determinant of burn severity contrast across the 16 burn severity contrast segments examined (table 2). (Note: there were 14 focus areas examined, but two of these areas had two distinct contrast segments). Shrub cover reflected variations not only in woody biomass and potential fuel BTUs but also in flammability related to volatile oils of sagebrush. Factors other than shrub cover contributing to contrasts in burn severity were biomass, vegetation type, and fire history (table 2).

The first three factors generally were related to actual fuel loads. Importance values for explaining contrasts were low for factors related to grazing pressures (actual use, anomaly performance, and distance from water). Cheatgrass did not appear to be an important factor because most of the burn severity contrast segments were not in areas where cheatgrass was a dominant vegetation type (fig. 2).

By holding the vegetation type relatively constant (that is, situations where both sides of burn severity or fence-line contrasts were grass or shrub), the team anticipated grazing effects would be more clearly illustrated because they would be less confounded by differences in major vegetation type. In this examination, shrub cover and biomass were still the primary factors responsible for grassland burn severity contrasts associated with fence-lines (table 3). Current year's growth or annual production in grassland systems represented a large proportion of the total grass fuel loads. Factors related to grazing (actual use, anomaly performance, and distance from water) were ranked higher relative to the overall analysis (table 2) and possibly indicated that grazing in grassland systems reduced fuel levels more significantly than in a shrubland ecosystem. Seedings were similarly ranked in the overall analysis (table 2) and the grass analysis (table 3). Vegetation type and fire history were ranked substantially lower from table 2 to table 3, reflecting the grass-dominated systems on both sides of the burn severity contrast with similar fire histories.

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[6] Observers included Bruce Wylie, ASRC Research and Technology Solutions, contractor to the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center. Work performed under USGS contract 08HQCN0007; Jay Davison, Cooperative Extension, University of Nevada; Stephen Howard, SAIC contractor to the USGS EROS; and Eva Strand, Rangeland Ecology and Management Department, University of Idaho.

Table 2. Burn severity contrast importance values (10 is high, 1 is low) from four observers summarized across all burn severity contrast segments having the highest mean. The number of times the inter-observer median value was greater than 6 also was recorded.

Factor related to contrast	Rank	Mean importance value	Standard deviation	Number of times ranked greater than 6
Shrub cover (Landsat)	1	6.5	0.7	42
Biomass	2	4.8	0.3	23
Vegetation type	3	3.9	0.6	20
Fire history	4	3.8	0.4	21
Seedings	5	3.0	0.8	16
Actual use (ac/AUM)	6	2.9	0.5	9
Anomaly performance	7	2.6	0.5	5
Distance from water	8	2.3	1.0	4
Cheatgrass	9	2.1	0.6	1
Fire behavior/suppression	10	1.4	1.0	4

Only one of the burn severity contrast segments was concurrent with a fence-line that had shrub-dominated systems on both sides of the contrast segment; therefore, no statistics (that is, standard deviation) were generated among contrast segments and no table of data is presented in the report. In this segment, shrub cover, an indicator of woody fuel loads, was the strongest factor explaining this contrast segment (Mean Importance Value of 9 among four observers where 10 was the highest possible importance value assigned). Current year's biomass was the third most important factor (Mean Importance Value of 5.5). Grazing effects and utilization levels, represented by actual use and distance to water, increased in their importance ranking relative to the overall analysis in table 2. Vegetation type decreased in importance ranking compared to the overall analysis as a result of efforts to hold this factor relatively constant. Seedings and fire history also dropped in importance ranking compared to the overall analysis because shrub-dominated areas have low occurrence of seedings, which are a common management intervention for intensely burned areas where shrub mortality is high.

Table 3. Importance values (10 is high, 1 is low) from four observers for three burn severity contrast segments within grass-dominated areas. The number of times the inter-observer median value was greater than 6 also was recorded.

Factor related to contrast	Rank	Mean importance value	Standard deviation	Number of times ranked greater than 6
Biomass	1	6.1	0.9	6
Shrub cover (Landsat)	2	5.9	1.7	6
Actual use (ac/AUM)	3	4.2	1.2	2
Seedings	4	3.9	1.4	4
Anomaly performance	5	2.8	1.0	2
Distance from water	6	2.4	0.9	1
Cheatgrass	7	1.8	1.6	0
Fire history	8	1.8	1.9	2
Vegetation type	9	1.7	1.5	1
Fire behavior/suppression	10	0.6	0.3	0

Though the primary goal of this analytic approach was to determine if differences in burn severity along selected contrast lines were related to grazing pressure, several factors made that interpretation difficult. Actual data for livestock use were available only on a pasture scale. Levels of grazing use are rarely uniform across a pasture, and therefore are unreliable as an indicator of actual forage utilization along the burn severity contrast lines. Distance from water was evaluated, but this analysis was limited by the assumption that utilization levels generally were linear in nature radiating out from the water sources. In fact, while forage use is undoubtedly highest adjacent to the water source, utilization levels rapidly become less uniform as distance from water increases. Utilization levels as reported by BLM personnel are not useful in estimating fuel removed by livestock and other herbivore utilization. Utilization levels were determined only for key forage species, which did not represent fuel loads for a pasture. Furthermore, a focus on estimates of utilization (proportion of forage removed) is not as relevant to fire behavior as is the amount of forage remaining, which was not measured.

Report Summary and Conclusions

The Murphy Wildland Fire Complex was essentially “a perfect storm” for sagebrush-grassland wildfires. Several factors influenced the extreme fire behavior documented in the fire, including favorable growing conditions for vegetation in previous years and early summer weather conditions that resulted in dry fuels for dead and living biomass. These factors combined with strong winds and high temperatures to make this fire extremely difficult to control, particularly in the first four to five days after ignition when the vast majority of the area of the fires burned. Evidence of the aggressive nature of the Murphy Wildlife Fire Complex was demonstrated by the fires jumping the Jarbidge and Bruneau river canyons.

Major Findings and Lessons Learned

- Much of the Murphy Fire Complex burned under extreme fuel and weather conditions. Weather conditions in the first four to five days of the fire were particularly dry, hot, and windy. It was during this period that between 75 and 90 percent of the total area burned. As confirmed by fire modeling, these extreme conditions likely overshadowed (or swamped) livestock grazing as a factor influencing fire extent and fuel consumption in many areas where these fires burned.
- Level of fuels consumed (or burn severity) was affected mostly by the plant communities that existed on a site before fire (that is, shrubland communities can potentially experience a greater loss of biomass and vegetative structure than grasslands yielding higher burn severity values). Our study of fuel consumption and our field examination confirm that all vegetation types experienced a range of fuel consumption, including many acres in the low burn severity class, indicating patchy burning patterns or incomplete consumption of fuels. Greater proportions of plant communities characterized as grasslands were categorized in the low burn severity class than shrublands. This observation confirms that fuel consumption (or burn severity) is largely influenced by the kind of plant biomass and structure that exists before the fire.
- There were many abrupt contrasts in fuel consumption (or, burn severity) primarily attributed to abrupt changes in vegetation type, such as a transition from seeded grasslands to shrubland communities. Burn severity contrasts throughout the Murphy Wildland Fire Complex were most strongly aligned with amount of shrub cover, current year’s biomass, and vegetation type. A few abrupt contrasts in burn severity coincided with apparent differences in actual use by livestock and other grazing factors, as illustrated by fence-line contrasts.
- Potential effects for livestock grazing to reduce fuel and affect fire behavior were dependent on the vegetation type. Fire behavior in sagebrush vegetation types is driven by sagebrush cover and height, with the herbaceous component on which livestock focus their grazing, playing a lesser role. Consequently, opportunities to influence fire behavior through livestock grazing are greatest in grassland vegetation types. Fire modeling suggests grazing in grassland vegetation can reduce surface rate of spread and fire line intensity to a greater extent than in shrubland types where woody fuels generally are not reduced by cattle or sheep grazing.
- Herbaceous biomass produced during one year and persisting into the next growing season contributes to the dead fine fuel load (that is, 1-htl fuels) in subsequent years. Livestock grazing that reduces the carryover of dead fuels from one year to the next can influence fire behavior, particularly under less intense fire conditions.

- The potential effects of grazing on fire behavior are highly dependent on weather, fuel load, and fuel-moisture conditions. Extensive fires, such as those of the Murphy Wildland Fire Complex, generally result from a combination of many factors but are largely weather driven. Under such extreme conditions, grazing applied at sustainable utilization levels would have limited or negligible effects on the fire behavior. When weather and fuel moisture conditions are less extreme, grazing may reduce the rate of spread and intensity of fires allowing for more patchy burns with lower fuel consumption levels.

Future Opportunities

Fire behavior results from factors related to topography, weather, and fuels. Land managers cannot change weather or topography, so they are compelled to focus on manipulating fuels. Fuel manipulations can change the potential for fires to sustain ignition, rates at which fires spread, and their final size. Reducing fuel loads could enhance fire suppression activities when weather conditions are not extreme by increasing opportunities for safely applying back burns and increasing available time to strategically fight fires.

The differences in fuel consumption observed among areas with apparently different grazing histories in the Murphy Wildland Fire Complex, published research on the relationship between fuel loads and fire behavior, and the professional opinions of several team members suggest potential for managed grazing to reduce fine fuels and affect wildfire behavior. Grazing targeted to reach fuel objectives could ameliorate the spread, intensity, and extent of wildfires, particularly in grasslands. However, our review of fire effects in the Murphy Wildland Fire Complex offers only cursory evidence that grazing influenced fire behavior under some conditions. We are not able to give conclusive evidence on the extent to which grazing influenced the Murphy Complex Fires. Such an endeavor would take more time and resources than our team was able to commit to this review.

Whereas livestock grazing can affect fire behavior through the reduction of fine fuels on semi-arid rangelands, it is important to distinguish between landscape-scale grazing programs designed to protect numerous natural resource values and targeted grazing programs aimed at reducing fine fuel loads on specific areas. It is also essential to make a clear distinction between standard grazing management prescriptions and fuels reduction endeavors. Reducing herbaceous biomass to levels that would strongly influence fire behavior, particularly under extreme fire conditions, would require reductions to levels that would potentially compromise sustained livestock production and ecosystem goals. However, a targeted grazing program to accomplish fuel management could be both feasible and achievable on selected sites. These grazed fuel-reduction sites or pastures could be most easily established in areas dominated by grazing tolerant grasses with little or no shrub cover. This may require connecting these target sites to provide areas of continuous fuel reduction zones. In the region of the Murphy Wildland Fire Complex, introduced forage grasses (for example, crested wheatgrass) are recognized as being quite grazing tolerant during all phases of the growing season. Grazing as a fuels management technique would be most effective on uniform grasslands and becomes less effective as the amount and size of the shrub component in the plant community increases. Grazing also may be more difficult to sustain in communities dominated by native grasses compared to introduced grasses. It would be important to weigh these inputs against the potential environmental and economic damage that occurs when massive wildfires burn across native rangelands.

Recommendations

- Changes in grazing management aimed at managing fuel loads are not appropriate for homogeneous application across large landscapes and multiple management units. Such application of grazing across entire landscapes at rates necessary to reduce fuel loads and affect fire behavior, especially under extreme conditions, could have negative effects on livestock production and habitat goals. Rather, the team recommends carefully planned, targeted application, and monitoring of fuel management strategies strategically placed across defined areas. The idea of targeted grazing to accomplish fuel objectives holds promise but requires a detailed planning effort that includes target goals for fuel loads and accounts for prevailing winds, fire behavior, and fire control strategies. Furthermore, targeted grazing projects could be strategically applied with clearly defined ecosystem criteria and be piloted in sufficiently large areas to monitor the effects on fuels, plant community composition, and wildlife habitat. Large-scale projects aimed at evaluating the potential of livestock grazing to reduce fuel loads under several grazing scenarios are largely non-existent (that is, comparing a landscape-scale grazing program that conforms to BLM standards to a high-intensity targeted grazing program aimed at reducing fuel loads).
- The team recommends creating a task group of grazing, fire, wildlife, and landscape specialists and scientists to develop a pilot project for a landscape-sized area. The task group's goal would be to devise a plan for strategically placing grazed blocks or pastures across a landscape to create fuel-reduction bands to influence fire behavior and facilitate fire management. These grazed bands would need to consider protection of native plant communities and wildlife habitat. The team envisions specific opportunities to apply grazing aimed at fuel management in grasslands composed of introduced grasses and to consider targeted grazing opportunities in concert with post-fire revegetation efforts. Detailed and spatially explicit plans for implementation and monitoring would be developed by this team. Such integrated and strategic plans are not easily created and will require spatial decision processes. An approach similar to that outlined in Meinke and others (in press) using probabilities of success for each objective could be used to identify potential locations for these fuel-reduction bands. Partnering with state and private landowners within the proposed project area is encouraged where such opportunities could enhance success of projects.
- The team supports the publication of a general technical report that focuses on published research and existing field examples of how livestock grazing influences fire extent, severity, and intensity. A carefully drafted technical report of this nature would provide a platform to create targeted grazing strategies, consider possible changes to existing grazing plans, and evaluate livestock grazing effects on recent and future wildfires. This report could focus on existing research and identify information gaps for specific ecosystems, grazing practices, or fire conditions. The potential effect of invasive grasses on fire and grazing management plans could also be presented. Though there are significant knowledge gaps, much information exists on these topics in published research and experiences of land managers. However, the information has not been synthesized into a single document that is readily accessible to land managers.

- The team encourages continued research and monitoring of the ecosystem effects of the Murphy Wildland Fire Complex. The fires occurred in a region that holds significant ecological information and importance. In addition, revegetation efforts in the area of the Murphy Wildland Fire Complex have been documented and should be monitored. The team's investigation has gathered many sources of pre-fire information. With careful data storage and cataloguing, much more can be learned from the effects of this extensive fire that may offer insight for future management decisions.

Research Gaps and Limitations

- There is sufficient evidence to support a pilot project of targeted grazing on grasslands for fuel reduction, but effects of grazing aimed at fuel management in mixed shrub and grass vegetation types are more difficult to predict. If targeted grazing was applied on sites that varied in the amount of shrub and grass cover, the results would help define use levels and percentage shrub cover where livestock grazing is effective and where it is ineffective as a fuels management tool. Of particular interest is research aimed at: (1) the potential role of livestock grazing to reduce fuel loads in mixed shrub and grass vegetation types in the short- and long-term; (2) the ecological impact of heavy utilization to accomplish fuel reduction on the wildlife, plant, and soil microbial communities, especially those related to or dependent upon native plants; (3) the rate, frequency, and timing of grazing events necessary to maintain target fuel levels; and (4) management strategies to accomplish high herbaceous biomass utilization without extensive fencing or new water developments.
- The use of the delta Normalized Burn Ratio (dNBR) has value for quantifying fuel consumption, soil impacts (that is, soil burn severity), identifying unburned areas within fire perimeters, and refining fire perimeters, especially for large fires, in sagebrush steppe systems. However, there were several instances within the Murphy Wildland Fire Complex where variation in dNBR was not related to vegetative conditions that were anticipated to lead to changes in burn severity. The concept of burn severity, quantified as dNBR, has been studied extensively in forests and less in rangelands. Additional research into the relationship of dNBR to post-fire soil burn severity and vegetation mortality in shrubland and grassland systems should be pursued.
- The application of fire behavior models to develop fuel management strategies for sagebrush steppe ecosystems requires better methods to assess and quantify the amount and continuity of fine fuels at landscape scales. The development of remote sensing technology is needed to rapidly and accurately assess fine fuels and detect the influence of grazing at broad scales. This information would allow better use of fire models that examine the spread of fire across a landscape (such as FARSITE) rather than the one-dimensional view provided by BEHAVE models (as used in this report). A promising approach for improving biomass estimation, including senescent and green vegetation, is a spectral index called the soil adjusted total vegetation index (SATVI; Huete, 1988; Qi and others, 1994). The SATVI was related to total herbaceous vegetation cover in the southwestern United States (Marsett and others, 2006). SATVI could be used in combination with indices related to green biomass (modified soil adjusted vegetation index and the NDVI) to quantify total and green biomass.

- The development of a new generation of fire behavior models is needed to better reflect fire behavior in shrub-dominated communities. BEHAVE and FARSITE (the most widely used models for wildland fire on rangelands) assume that sagebrush steppe fuels are composed of a single layer. Field experiences suggest that fire in sagebrush steppe is driven by the live and dead herbaceous understory fuels under some conditions and by sagebrush overstory characteristics (for example, height, cover, continuity, and biomass) in more extreme environmental conditions. Fire research and models are needed to reflect fire behavior in sagebrush steppe that likely burns in at least two layers of vegetation.

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Appendix 1. Murphy Wildland Fire Grazing and Fuel Assessment Team

Core Team

Bob Brammer— Assistant Director; Lands, Minerals and Range Division; Idaho Department of Lands in Boise, Idaho. Twenty-three years with the Department in various positions, including Area Supervisor, Range Resource Supervisor, Lands and Range Specialist, and Range Resource Manger. Bachelor of Science degrees in Range Resources and Wildlife Resources from University of Idaho. Specific experience with use and management of state-endowment rangelands and forestlands to maximize financial returns and long-term sustainability. Contributed to report as member of Grazing Subgroup.

Stephen Bunting— Professor of Rangeland Ecology and Management, University of Idaho, Moscow, Idaho. At the University since 1978, following completion of doctoral degree in fire ecology at Texas Tech University. Teaches rangeland ecology and landscape ecology. Research interests include effects of fire in several types of ecosystems, including canyon grasslands, sagebrush steppe, and juniper woodlands in Pacific Northwest and northern Great Basin. Contributed to report as member of Fire Behavior Subgroup.

Matthew L. Brooks— Research Botanist, U.S. Geological Survey, Western Ecological Research Center, Yosemite Field Station, El Portal, California. Research topics include effects of climate change, altered ecosystem processes, and biological invasions. Major research focus is ecology and management of invasive plants and fire. Contributed to report as member of Vegetation Assessment Team.

Patrick Clark— Rangeland Scientist, U.S. Department of Agriculture - Agricultural Research Service, Northwest Watershed Research Center, Boise, Idaho. Research experience evaluating effects of landscape-scale disturbance, such as wildfire, prescribed fire, invasive plants, and predator reintroductions on rangeland animals, vegetation, and hydrologic processes. Considerable experience with modeling of animal behavior, remote sensing, geographic information systems, and other systems for spatial analysis. Contributed to report as member of Fire Modeling Team.

Jay Davison— Area Specialist, University of Nevada, Reno Cooperative Extension, Fallon, Nevada. Teaches and conducts research in the areas of rangeland restoration following wildfire, loss of irrigation water on farmlands, use of livestock as an environmental management tool, and forage management and production in the Great Basin. Contributed to report as chair of the group evaluating fire-severity contrast lines and as member of Vegetation Assessment Team.

Mark Fleming— Regional Wildlife Habitat Manager, Idaho Department of Fish and Game, Magic Valley Region. Sixteen years with the Department, focusing on wildlife habitat management and ecology. Work experience in four Regional Offices throughout Idaho. Bachelor of Science degree in Fisheries and Wildlife Biology from Iowa State University and Master of Education degree from Boston University. Contributed to report as member of Vegetation Assessment Team.

Ron Kay— Range Program Manager, Idaho State Department of Agriculture, Boise, Idaho. Has worked for the department for the last two years on grazing issues throughout Idaho. Retired from Bureau of Land Management, with over 30 years experience working in six states in the Bureau's range program and as a field manager in two offices. Experience with grazing systems, rehabilitation, monitoring, inventory, rangeland assessments, range ecology, range improvements, and agency procedural policy. Bachelor of Science degree in Range Management. Certified Professional in Rangeland Management with Society for Range Management. Contributed to report as member of Grazing Subgroup.

Karen Launchbaugh— Associate Professor and Chair, Rangeland Ecology and Management Department, University of Idaho, Moscow, Idaho. Research focuses on ecological implications of grazing, and targeted grazing to accomplish vegetation management. Contributed to report by working with the Vegetation Assessment Team. Also served as team leader, which included preparing drafts of the report and managing the revision process.

Mike Pellant— Coordinator, Bureau of Land Management's Great Basin Restoration Initiative, stationed in Boise, Idaho. Initiative is a five-state effort to maintain intact ecosystems and strategically restore degraded ones. Expertise includes rangeland restoration, fire rehabilitation, and monitoring and assessment of rangelands. Contributed to report as member of Vegetation Assessment Team and as Bureau of Land Management's liaison to the workgroup.

David A. Pyke— Supervisory Research Rangeland Ecologist, U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon. Research focus is restoration and rehabilitation of sagebrush grasslands in the Intermountain West, and development of monitoring and assessment tools for rangeland managers. Contributed to report as member of Vegetation Assessment Team.

Support Team

Matthew Bobo— Senior Remote-Sensing Specialist, Bureau of Land Management, National Operations Center, Denver, Colorado. Assists with coordination of remote-sensing activities for national, state, and field offices within the bureau. Master of Science degree in Environmental Monitoring from University of Wisconsin-Madison. Experience with a broad spectrum of geospatial technologies gained over 14 years by supporting a variety of applications in private and public sectors. Contributed to report as member of Science Support Team, focusing on applications of remote sensing.

Jesse German— Geographic Information System Coordinator, Bureau of Land Management, Twin Falls District, Idaho. Bachelors degree in Cartography and Geographic Information Systems, University of Wisconsin, Madison, 2001. With Bureau of Land Management in south central Idaho for last 5 years, providing support and coordination with geographic information. Contributed to report as member of Science Support Team, providing general data, maps and analysis.

Ken Crane— Rangeland Management Specialist, Bureau of Land Management, Jarbidge Field Office, Twin Falls, Idaho. Bachelor of Science and Master of Science degrees in Rangeland Ecology. Eighteen years of experience in rangeland resource management. Contributed to report as member of Fire Team.

Don J. Major— Fire and Landscape Ecologist, The Nature Conservancy - Idaho and the Bureau of Land Management's, Great Basin Restoration Initiative. Research focuses on applied aspects of rangeland restoration, and development and evaluation of monitoring and assessment strategies for multi-scale management of semi-arid ecosystems. Contributed to report by providing technical expertise in applications of remote sensing, and in fire and fuel characterization and modeling.

Danelle Nance— Natural Resource Specialist, Bureau of Land Management, Jarbidge Field Office, Twin Falls, Idaho. Bachelor degree in Agricultural Science and Technology, University of Idaho. Six years working for Bureau of Land Management for six years, providing assistance to monitoring and range resources. Contributed to report as support member for the Vegetation Assessment Team.

Randy A. McKinley— Scientist, ASRC Research and Technology Solutions. Formerly an employee of the Science Applications International Corporation at the USGS Center for Earth Resources Observation and Science (EROS), Sioux Falls, South Dakota. Member of Fire Science team at USGS EROS. Research focuses on mapping areas burned by wildfire using satellite remote sensing. Contributed to report as member of Fire Team.

Arnie Pike— Supervisory Rangeland Management Specialist, Bureau of Land Management, Jarbidge Field Office, Twin Falls, Idaho. Bachelor of Science degree in Agricultural Production-Range Management, Montana State University, 1976. Thirty-one years with the bureau, working in Montana and Idaho. Experience in range management, fire suppression, and fire rehabilitation in South Central Idaho since 1991. Supported Fire Team by providing information about vegetation, livestock grazing, and the Murphy Wildland Fire Complex Emergency Stabilization and Rehabilitation Plan.

Bruce K. Wylie— Scientist, ASRC Research and Technology Solutions. Formerly an employee of the Science Applications International Corporation at the USGS Center for Earth Resources Observation and Science (EROS), Sioux Falls, South Dakota. Research focuses on ecosystem performance anomalies. Experience mapping rangeland carbon fluxes from flux towers using remote sensing and ancillary spatial data in rangelands. Contributed to report as member of the Burn Severity Contrast Team.

Appendix 2. Common and Scientific Names of Plants Referred to in Text. Scientific names follow the USDA PLANTS Database[7]

Common Name	Scientific Name (and Authority)
Grasses:	
Bluebunch Wheatgrass	*Pseudoroegneria spicata* (Pursh) A. Löve
Cheatgrass	*Bromus tectorum* L.
Crested Wheatgrass	*Agropyron cristatum* (L.) Gaertn.
Intermediate Wheatgrass	*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey
Medusahead	*Taeniatherum caput-medusae* (L.) Nevski
Shrubs and Trees:	
Aspen or Quaking Aspen	*Populus tremuloides* Michx.
Bitterbrush or Antelope Bitterbrush	*Purshia tridentata* (Pursh) DC.
Black Sagebrush	*Artemisia nova* A. Nelson
Curl-leaf Mountain Mahogany	*Cercocarpus ledifolius* Nutt.
Low Sagebrush	*Artemisia arbuscula* Nutt.
Mountain Big Sagebrush	*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle
Rabbitbrush includes both:	
gray or rubber rabbitbrush	*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird
green or yellow rabbitbrush	*Chrysothamnus viscidiflorus* (Hook.) Nutt.
Shadscale Saltbrush	*Atriplex confertifolia* (Torr. & Frém.) S. Watson
Wyoming Big Sagebrush	*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young

[7] USDA, NRCS. 2008. The PLANTS Database (http://plants.usda.gov, June 12, 2008). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Appendix 3. Glossary of Terms and Unit Abbreviations

1-htl – See One-hour time lag

British Thermal Unit (BTU) – A unit of energy used to describe the heat value or energy content of fuels

BTU/ft/sec – British Thermal Unit per foot per second – a unit commonly used to describe fire line intensity

Burn Severity – the degree of environmental change caused by fire. Burn severity refers to the composite degree of physical and chemical changes to the soils, degree of change in living and dead vegetation to inorganic carbon and ash, and degree of change in plant structure and composition. Assessing and mapping burn severity is important for monitoring fire effects.

Dead Fuel Moisture (DFM) – level of moisture found in dead fuels (fuels with no living tissue in which moisture content is governed almost entirely by absorption or evaporation of atmospheric moisture) that is critical in determining fire potential. Dead fuels are classified by time lag (e.g., 1-hr vs. 10-hr).

delta Normalized Burn Ratio (dNBR) – a measure that examines the difference between the pre-burn and post-burn reflectance in two spectral bands (expressed as a ratio) of Landsat Thematic Mapper satellite data (30 m-per-pixel resolution) that is used to describe burn severity.

DFM – See Dead Fuel Moisture

dNBR – See delta Normalized Burn Ratio

Energy Release Component (ERC) – an output of fire modeling procedures that reflects fuel dryness and potential heat release per unit area in a fire event

ERC – See Energy Release Component

Fire Intensity – measure of the rate of heat released by a fire. Fire intensity is influenced by fuels, weather, and topography

Fire line Intensity – rate of heat energy released per unit length per unit time of fire front

lbs/acre – pounds (lbs) per acre – a unit of air dry forage production

LHFL – See live herbaceous fuel loading

Live Herbaceous Fuel Loading (LHFL) – a model parameter that describes the green grass and forbs consumed by grazing animals

National Interagency Fire Center (NIFC) – A leading support center for wildland firefighting that is lead cooperatively by several agencies and organizations. Learn more at *http://www.nifc.gov/*.

NDVI – See Normalized difference vegetation index

NIFC – See National Interagency Fire Center

Normalized Difference Vegetation Index (NDVI) – a satellite observation-derived value that is sensitive to vegetative growth used to remotely assess whether the target being observed contains live green vegetation or not.

One-hour Time Lag (1-htl) – fuels consisting of dead herbaceous plants and roundwood less than about one-fourth inch (6.4 mm) in diameter (*e.g.*, dead grass and small twigs)

Potential Vegetation Composition – refers to the "climax" vegetation that would occupy a site in the absence of disturbance or climactic variation

RAWS – See Remote Automated Weather Station

Relative Humidity (RH): ratio of moisture (%) in a volume of air to the total amount which that volume can hold at the given temperature and atmospheric pressure. Conditions of unsaturation promote fire danger as evaporation from fuels increases.

Remote Automated Weather Station (RAWS) – there are nearly 2,200 interagency Remote Automated Weather Stations (RAWS) strategically located throughout the United States. These stations monitor the weather and provide weather data that assists land management agencies with a variety of projects such as monitoring air quality, rating fire danger, and providing information for research applications (*http://www.raws.dri.edu*).

RH – See Relative Humidity

SATVI – See Soil Adjusted Total Vegetation Index

SAV – See Surface Area to Volume Ratio

Soil Adjusted Total Vegetation Index (SATVI) – a spectral vegetation index that accounts for and minimizes the effect of soil background conditions

Surface Area to Volume Ratio (SAV) – the ratio between the surface area of an object to its volume. The smaller the particle, the more quickly it can become wet, dry out, or become heated to combustion temperature during a fire.

Targeted Grazing – application of livestock grazing at a specified season, duration and intensity to accomplish specific vegetation management goals. For more information visit: http://www.cnr.uidaho.edu/rx-grazing/.
Utilization – proportion (%) of available forage removed by grazing animals.

Launchbaugh and others— **Murphy Wildland Fire Complex in Idaho and Nevada, July 2007**—Open-File Report 2008–1214