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Process to Monitor and Manage Ungulate Browsing Pressure

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ABSTRACT

Plant communities are monitored to prevent ungulate browsing from having an adverse effect on habitat. The monitoring process described in this paper applies to plant species capable of growing through the browse zone, and uses two measurements (percent intensely browsed and LD Index) to determine if browsing will prevent the height growth of a young plant. To determine the potential effect of browsing on habitat structure, two variables are compared: 1) Existing browsing pressure is the percent of young plants that browsing is predicted to prevent from growing to full height. 2) Threshold browsing pressure is the percent of young plants that must grow to full height to attain a specified habitat structure. The process includes specifying target conditions, data collection and analysis, and refinement based on that analysis. The process requires a long-term commitment, but a minimal investment of time each year. By repeating the process over a period of years, the effects of browsing are documented and steps in the process are refined.

INTRODUCTION

It has long been recognized that ungulate browsing can have a major effect on communities of browse plants (Wright and Thompson 1935; Rasmussen 1941; Leopold 1943; Mussehl and Howell 1971; Hebblewhite and others 2005; Binkley and others 2006; Wagner 2006). To prevent ungulates from having an adverse effect on habitat, wild and domestic ungulate populations have been managed based on the monitoring of vegetation condition (Keigley and Frisina 1998; Mussehl and Howell 1971). This paper describes problems associated with a common method of monitoring (utilization rate), and describes a height-based approach that addresses those problems.

PROBLEMS WITH UTILIZATION-BASED MONITORING

Browse utilization by ungulates is measured in two ways: incidence of use (Cole 1959; Stickney 1966) and biomass consumed (Basile and Hutchings 1966; Schmutz 1983; Bilyeu and others 2007). Ungulate population objectives can be defined by specifying a maximum utilization rate such as 35 percent twigs browsed or biomass removed. Utilization values measured in the field are compared to target values to determine if the population objectives were attained.

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The utilization-based approach has the following problems. First, the biologic effect of 35 percent twigs browsed may differ from the biologic effect of 35 percent biomass removed. The relationship between utilization and biologic effect must be determined separately for both measurement protocols. Second, utilization measurements may not accurately reflect the actual effect of browsing. Protracted heavy browsing can stress plants, causing them to produce very short lengths of current-year-growth. If ungulates avoid consuming those short lengths, the measured utilization rate could be quite low. The measured rate could indicate an appropriate level of use, when in fact the plant is stressed by browsing and may be dying. Third, the potential effect of excessive utilization is seldom specified. Those effects include premature death, decreased production, reduced recruitment, and decreased height growth. If the effect is unspecified, there is no way to determine if utilization at some level actually had an adverse effect. Fourth, there is no direct relationship between utilization rate and structural habitat characteristics. For example, there is no obvious link between browsing at a rate of 35 percent and the species composition, stem height, and stem density that might result in the future. Because there is no prior expectation as to what browsing at 35 percent utilization will produce, a manager will likely accept whatever condition results. However, there is no guarantee that those conditions will be suitable for meeting land management objectives.

The height-based approach described below addresses the problems described above. However, the approach can only be applied to tall-growing trees and shrubs. In the case of short-growing species such as sagebrush, saltbush, and winterfat, monitoring by utilization may remain the best alternative.

A HEIGHT-BASED APPROACH

The height-based approach is a refinement of methods described in Keigley (1997), Keigley and Frisina (1998), Keigley and others (2002ab), Keigley and Fager (2006). The approach focuses on the effect that ungulates can have on plant height growth. It is best applied to species that, under light browsing, are capable of growing through the browse zone. Heavy browsing can prevent young plants of such species from growing taller than 30 to 50 cm (Keigley and Frisina 2008). If heavy browsing continues over a prolonged period of time, a meadow-like condition can be produced as the older, taller shrubs die, while browsing prevents the height growth of young plants.

The approach is based on two premises. The first premise: The structural characteristics of the plant community are of primary importance. Those structural characteristics include species composition, stem density, and diversity of stem heights. The attainment of appropriate habitat structure is critical to attaining land management objectives. The second premise: Browsing should not be the dominant factor that influences the structure of the plant community.

In this paper we define our use of eight terms that are part of a systematic process. The aim of the process is to determine if browsing will affect the future structure of the plant community by preventing young plants from growing to full stature. The terms are described below. An example of the process is described in the final section.

DEFINITION OF TERMS

Indicator Species

A given plant community will likely contain several browse species, and likely it would not be feasible to measure the effect of browsing on each. Fortunately a single, or relatively few, species can be used to describe the approximate effect of browsing on all other browse species. Three criteria guide the selection of indicator species: height, presence of bud scars, and preference.

Because we focus on the effect of browsing as the plant grows within the browse zone, we restrict our attention to species in the community that are capable of growing to 2.5 m tall, or at least significantly into the browse zone. In addition, it must be possible to determine annual growth increments using bud scars; species with naked buds cannot be used.

Ungulates prefer some browse species more than others. For example, Bebb willow, Geyer willow, alder, and spruce form a preference gradient that runs from highly-preferred to least-preferred. When browsing increases, the more-highly-preferred species are heavily consumed before less-preferred species. If the increase occurred in a community that contained the above species, Bebb willow would be first to be heavily used. At this point, Geyer willow might be lightly used; alder and spruce might not be used at all. A continued increase in browsing would cause heavy use of Geyer willow, with alder and spruce lightly used. Alder would be next, and finally spruce. We infer the existence of this preference gradient because we can find examples of the combinations described above.

By selecting an appropriate indicator species, we can accomplish the following. First, if we select a highly preferred species such as Bebb willow, and find its condition to be acceptable with respect to browsing, we can assume that the condition of all other species is acceptable. We will have documented that current browsing has no effect on habitat structure. Second, we could use Bebb willow to document the earliest stage of habitat decline. Third, if habitat quality is in further decline, we can measure the magnitude of that decline by determining which species are heavily used and which are not. Are we at the point where Geyer willow, but not alder is heavily browsed? Finally, we can document changes in habitat condition that occur due to management action. Species at the beginning stages of heavy use will also be most sensitive to changes in browsing pressure. For example, if alder is heavily browsed (but not spruce), we can expect a reduction in browsing pressure to be reflected by the growth of alder before we see a response in Geyer willow.

Potential Stature

Potential stature is a concept used to distinguish the effect of browsing from other factors that may influence height growth. The concept allows us to deal with situations where, for reasons unrelated to browsing, plants do not grow to their expected height. In the absence of browsing, the mature individuals of a plant community grow to a stature that is determined by local conditions including climate, soil, slope, aspect, disease, and insect herbivory. We include in this list everything but browsing. We could refer to this height as the *potential stature in the absence of browsing at this local site*, or more simply as "potential stature."

Below we describe a criterion that marks the prevention of height growth by browsing. If that criterion is met, the plant is deemed unlikely to grow to potential stature. Otherwise, the plant is deemed likely to grow to potential stature. We do not need to know the actual potential height in m.

The concept of potential stature allows us to deal with situations where unfavorable environmental or physiologic conditions limit height growth. As long as the abovementioned criterion is not met, the plant is assumed to be growing to its potential stature even though unfavorable conditions prevent it from growing out of the browse zone. For example, an unbrowsed aspen sucker that dies from shading is presumed to have grown to its potential stature.

Browsing Level

Browsing level is the first of two attributes used to determine if browsing will prevent a given plant from growing to its potential stature; LD Index—described below—is the second. Browsing level is based on morphologic evidence, and provides a means of assigning a plant into one of two categories: 1) Light-to-moderate (browsing will probably not prevent growth to potential stature), and 2) Intense (browsing may prevent growth to potential stature). If the morphologic evidence suggests that browsing may prevent growth to potential stature, LD Index is used to determine if that is likely the case; this is the criterion mentioned in the preceding section.

The classification of browsing level is based on whether or not browsing caused the death of a complete annual increment of any vertically oriented stem. If a relatively small length of stem is removed by browsing, current-year-growth the following year will likely develop from a lateral bud on the browsed segment that was current-year-growth the previous year. The development of current-year-growth on the previous-year-segment allows part of that segment to remain alive. If this condition occurred throughout the life of the stem, it is classified as light-to-moderately browsed (figure 1).

If a substantial length of a current-year-growth segment is consumed, the entire segment may die (figure 2). Death occurs because no current-year-growth develops from that segment the following year. To be classified as intensely browsed, two criteria must be met: 1) a complete vertically-oriented annual increment must be dead, and 2) the increment must have been browsed. The death of a complete vertically-oriented annual increment is an interruption in height growth. LD Index is used to determine if browsing will likely prevent further height growth.

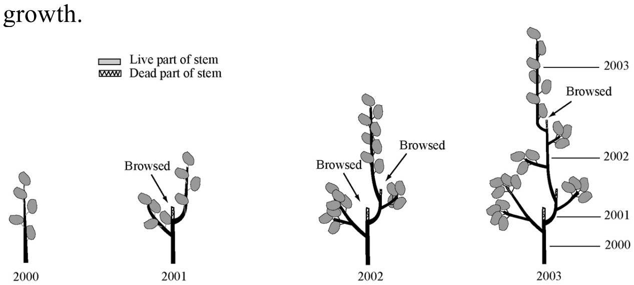

Figure 1—Light-to-moderately browsed stems. Browsing is classified by examining vertically oriented stems. These drawings show how the plant might appear from 2000 to 2003. Although the plant was browsed each year, part of each year's annual segment remained alive.

Once a stem is classified as intensely browsed, it retains that classification for the rest of its life. The browsing level of a plant is determined by examining its stems. Trees typically have a single stem. However browsing, as well as other influences, may cause the vertical growth of multiple stems. If any vertically oriented stem is intensely browsed, the tree is classified as intensely browsed. By definition, a shrub consists of multiple vertically oriented stems. If any of the shrub's vertically-oriented stems were intensely browsed (including stems that are completely dead), the shrub is classified as having been intensely browsed. Once a plant is classified as intensely browsed, it retains that classification for life.

LD Index

LD Index (Live-Dead Index) is a measure of height growth that occurred after a plant was intensely browsed (figure 3). It is based on two measurements, the first being the height to the base of the tallest current-year-growth (H_{BCYG}). (All measurements are made to the base of current-year-growth to minimize complications that arise if a stem is browsed after measurement.) The second measurement is the height to the tip of the tallest stem having a dead, vertically oriented, complete annual increment that was browsed (H_D; see figure 2).

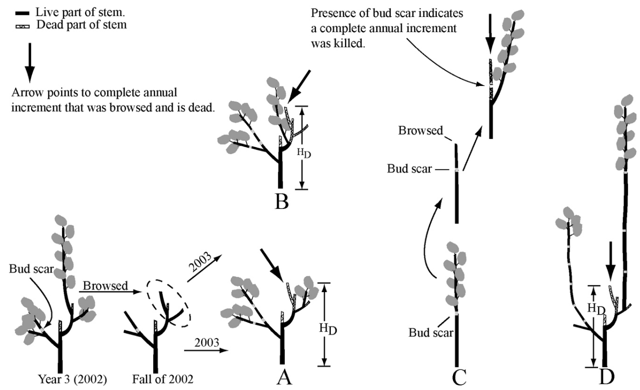

Figure 2—Intensely browsed stems. The left side of the figure depicts an aspen as it might appear during the 2002 growing season, and after browsing in the fall; we follow the fate of the browsed leaders (encircled by the ellipse) that developed from lateral buds. In Figure 2A, the upper leader died and the lower leader survived. In Figure 2B both the upper and lower leaders died. In Figure 2C the leader developed from a terminal bud; to identify complete annual increments we must inspect stems for the presence of terminal bud scars. In Figure 3D extensive growth occurred after the stem was intensely browsed. We continue to classify the stem as intensely browsed; LD Index is used to determine if browsing is likely to prevent height growth. The height to the tip of the tallest dead stem increment (H_D) is a measurement used to calculate the stem's LD Index.

An LD Index of about zero (figure 3a) indicates that current-year-growth is being browsed to the level of mechanical protection provided by stems and twigs that were killed by browsing. An LD Index of about zero indicates that browsing is preventing height growth.

If the LD Index is substantially less than zero (figure 3b), the plant is dying back to ground level. In the case of trees, the death of the stem at ground level means the death of the plant. Because shrubs can produce additional stems from belowground, the plant will persist as long as additional stems can be produced. The plant diagramed in figure 3b illustrates a succession of such stems. An LD Index of substantially greater than zero (figure 3c) indicates the plant is growing taller after having been intensely browsed.

How Browsing Level and LD Index are Used

We make the assumption that browsing will not prevent the height growth of a light-to-moderately browsed plant. This assumption can be tested as part of the systematic process described below. To determine if browsing will prevent the height growth of an intensely browsed plant, we compare its measured LD Index value to a threshold LD Index that, initially, is estimated. If the plant's measured LD Index value is greater than or equal to the threshold value, we assume that browsing will not prevent height growth. If the LD Index is less than the threshold value, we assume that browsing will likely prevent height growth. This is the criterion that marks a failure to grow to potential stature due to browsing. An initial threshold LD Index value of 50 cm is a reasonable starting point. As monitoring at a site continues over a period of years, data are collected to adjust the threshold LD Index upward or downward. The process for evaluating threshold LD Index is described in Step 5 of the last section of this paper.

Browsing–related Architectures

The degree to which a plant is browsed affects its shape. We refer to those shapes as browsing-related architectures. Four browsing-related plant architectures document the effect of browsing as plants grow through the browse zone (Keigley 1997; Keigley and Frisina 1998; Keigley and others 2002a). The uninterrupted-growth-type architecture is produced by light-to-moderate browsing; the retrogressed-type architecture is produced by an increase from light-to-moderate browsing to intense browsing; the arrested-type architecture is produced by intense browsing; the released-type is produced by a change from intense browsing to light-to-moderate browsing. The architectures apply to both trees and shrubs. Figure 4 illustrates the architectures as expressed by aspen. The browsing related architectures are used to conduct a rapid survey of large areas to select indicator species and identify sites where monitoring should be a priority.

Replacement Percentage

Replacement percentage is the first of three concepts used to relate ungulate browsing to its effect on plant community structure—the other two are existing browsing pressure and threshold browsing pressure. For a stand of plants to be sustained, young plants must grow through the browse zone to replace those that die. Replacement percentage is the percent of young plants that must grow through the browse zone to produce the stem density of the parent stand.

Replacement percentage varies by site and is influenced by the lifespan of the species and the age structure of the stand. Where young plants replace plants that die of old age, replacement can be largely incremental. On an annual basis, the incremental replacement rate could be very low. The highest replacement rate occurs when all stems must be simultaneously replaced due to an event such as fire.

For two reasons, we use simultaneous replacement as the basis for assessing the potential effect of browsing on habitat structure. First, the determination of simultaneous replacement percentage is much less complicated than the determination of incremental replacement percentage, and for that reason more appropriate for general monitoring. Second, all sites are potentially exposed to wildfire or prescribed fire. We base the determination of replacement percentage on the hypothetical occurrence of fire.

Replacement percentage is calculated using two estimates of stem density. The first is the stem density that we desire to grow through the browse zone after a hypothetical fire. This is the target stem density. The second is the density of stems that will be available after that hypothetical fire to grow through the browse zone and establish the target stem density. This is the propagation stem density. Depending on the species, post-fire propagation could be from seed, root suckers, rhizomes, or root crown. Each of these sources is a propagule. The propagation density is determined by estimating the density of propagules that would be present after a hypothetical fire.

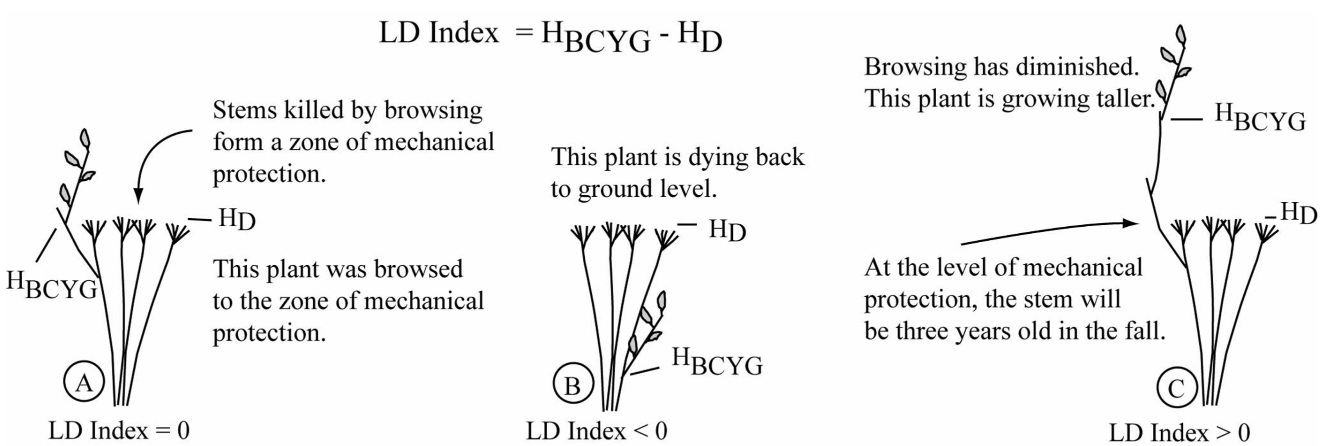

Figure 3—Measurement of LD Index. LD Index is calculated by subtracting the height of the tallest stem having a complete dead annual increment (H_D) from the height of the tallest live leader as measured to the base of current-year-growth (H_{BCYG}).

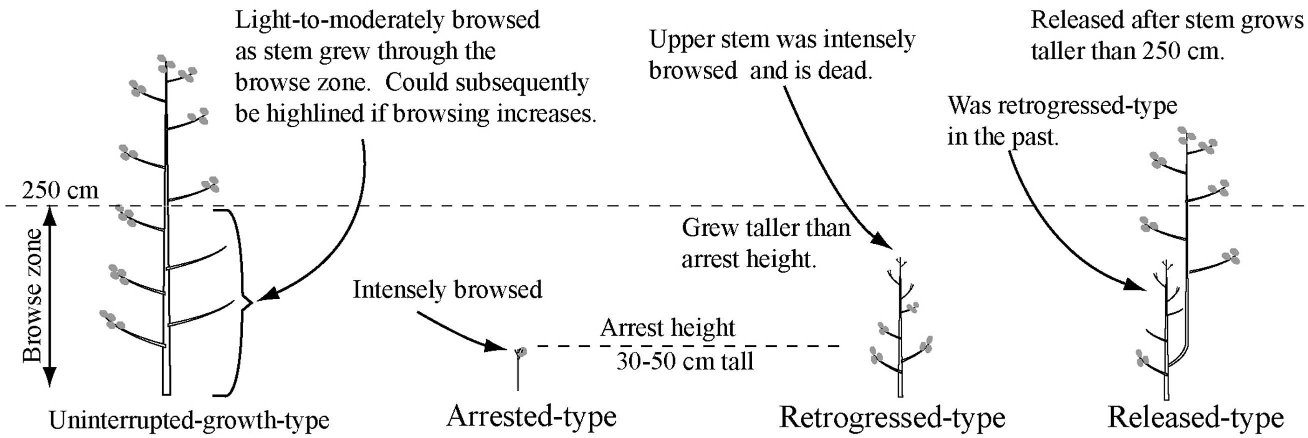

Figure 4—Browsing-related architectures as expressed by trees. The uninterrupted-growth-type architecture is produced by light-to-moderate browsing as the trunk grows through the browse zone. Arrested-type architecture is produced by the chronic intense browsing of young plants. Retrogressed-type architecture is produced by a change from light-to-moderate browsing (that allowed the plant to grow taller than arrest height) to intense browsing (that prevented further height growth). Released-type architecture is produced by a change from intense browsing to light-to-moderate browsing.

Replacement percentage is calculated by dividing the target stem density by the propagation stem density. In the case of aspen, the number of suckers present after a fire may be substantially greater than the number required to produce the desired future stem density; the replacement percentage could be much less than 100 percent. To re-establish a mature stand of willow after fire, it may be necessary for stems from each root crown to grow through the browse zone; the replacement percentage could be 100 percent. In the following section, replacement percentage is used to determine the point at which ungulate browsing will be a dominant factor in shaping the structure of the plant community.

Browsing Pressure: Existing and Threshold

We define browsing pressure to be the percent of plants that are prevented by browsing from attaining their potential stature. A browsing pressure of 100 percent means that browsing prevents all plants from attaining potential stature. There are two types of browsing pressure: the existing browsing pressure (which is measured), and the threshold browsing pressure (which is calculated).

In a previous section we described how browsing level and LD Index could be used to determine if browsing will prevent an individual plant from growing to potential stature. To determine the effect of browsing on the future structure of the plant community, we examine a sample of 20 plants that are between 50 and 150 cm tall. Plants in this size range are attempting to grow through the browse zone to replace plants that die of old age or for other reasons. Such plants are tall enough to have been exposed to browsing, and are short enough to be available to all ungulate species.

Based on the sample of 20 plants, we estimate the percent that browsing will prevent from growing through the browse zone. This is the percentage of plants having a measured LD Index that is less than the threshold value. We refer to that percentage as the existing browsing pressure.

Threshold browsing pressure describes the point at which browsing will affect stand structure. It is calculated by subtracting the replacement percentage from 100 percent. For example, if the estimated replacement percentage of a stand of willow was 100 percent, the threshold browsing pressure would be 0 percent.

To determine the effect of browsing, we compare the existing browsing pressure to the threshold browsing pressure. If the existing browsing pressure is less than (or equal to) the threshold value, then browsing will not have a dominant effect on the structure of the plant community. If the existing browsing pressure is greater than the threshold value, then browsing is predicted to have a dominant effect on stand structure.

MONITORING PROGRAM: AN EXAMPLE

Using the browsing-related architectures an indicator species is selected, and one or more sites are identified as permanent monitoring sites. At each monitoring site, the systematic process described in figure 5 is conducted. To be successful, a commitment should be made to monitor each site for a period of decades. This will allow a succession of managers to compare predicted results with actual results, and make corrections as appropriate. Establishing a site and collecting the first year's data should require about four hours. Once a site is established, the time required for monitoring should require one to two hours; annual monitoring may not be required. Data analysis can be automated in a spreadsheet.

Step 1: Describe the desired target density of stems that are taller than 2.5 m.
The target density is the density of stems we would like to grow through the browse zone after a hypothetical fire. It is a rough approximation that could be based on measurements taken at an existing stand, or could be based on past experience. In this example we used aspen data collected at the Mt. Fleecer Wildlife Management Area in southwest Montana. Using a belt transect we determined that the density of stems taller than 2.5 m was 0.2 stems / m^2. A desired density could also have been estimated based on an approximate spacing of stems. Stems spaced 2.2 m apart result in a density of 0.2 stems / m^2.

Step 2: Measure the existing density of stems that are greater than 2.5 m tall and the density of stems that are less than 2.5 m tall.
As described in Step 1, the density of stems taller than 2.5 m was 0.2 stems / m^2. The density of stems shorter than 2.5 m was 1.0 stems / m^2. We use this density as an estimate of the propagation density (suckers that would be present after fire) recognizing that an actual fire could affect the production of suckers. When the process is repeated in subsequent years, the measurements taken in Step 2 provide the basis for comparing the predicted result to the actual result, and for making adjustments accordingly.

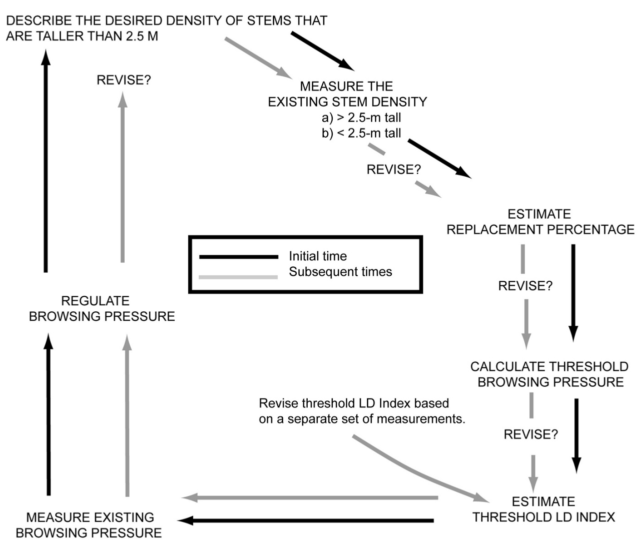

Figure 5—Flowchart of the process. The process consists of a series of steps aimed at regulating browsing to attain specific habitat characteristics.

Step 3: Estimate the replacement percentage.
To calculate replacement percentage we divide the target density by the propagation density: 0.2 stems per m^2 / 1.0 stems per m^2 = 20 percent. Based on our current information, if all of the tall stems were to simultaneously die, the existing stand density would be attained if 20 percent of the short stems were to grow through the browse zone.

When calculating replacement percentage, the propagation density is based on how the species propagates after fire. In the case of aspen, stems are classified into the two categories based on their actual measurements. If a tall aspen is burned, that stem dies; recruitment only occurs due to the growth of suckers. Above, the density of those short stems was used as the propagation density. In the case of sprouting species, new stems could originate from plants of any height. In those cases, the propagation density would be based on the presence of plants of any height.

Step 4: Calculate the threshold browsing pressure.
We calculate the threshold browsing pressure by subtracting the replacement percentage from 100 percent: 100 percent - 20 percent = 80 percent. If browsing prevented 80 percent of the short stems from growing through the browse zone (which are present at 1 stem per m^2), 20 percent would do so, theoretically resulting in a stand density of 0.2 stems per m^2. Other factors such as disease might influence the establishment of the stand, but as long as the existing browsing pressure is less than 80 percent, browsing will not be the dominant influence.

Step 5: Estimate a threshold LD Index.
In this example the initial estimated threshold LD Index was set at 50 cm, meaning that plants having an LD Index greater than (or equal to) 50 cm are predicted to grow through the browse zone. Data are collected to evaluate this estimate. A transect is established in which LD Index of 20 plants is periodically re-measured. (This is one of the two kinds of transects that would be established at each site.) It will likely be found that plants having small LD Indexes fail to grow taller over the measurement period, while plants initially having larger LD Indexes did grow taller. The smallest LD Index in the latter category would suggest a threshold LD Index.

Step 6: Measure the existing browsing pressure.
Existing browsing pressure is measured by sampling 20 individuals at equal intervals along a paced transect (this is the second type of transect established at each site). At each point the nearest plant 50 to 150 cm tall is measured. If plants in this range are absent (or some distance away), intensely browsed plants that are less than 50 cm tall can be included. Short light-to-moderately browsed plants are avoided because the absence of browsing may be due to their short stature. Plants are not necessarily re-sampled from one year to the next. The existing browsing pressure at a site is equal to the percent of plants that have an LD Index that is less than the threshold LD Index value.

In 2003 all aspen at the Fleecer site were intensely browsed; the maximum measured LD Index was 17 cm. Because all 20 plants had an LD Index that was less than the threshold LD Index of 50, the existing browsing pressure at this site in 2003 was 100 percent.

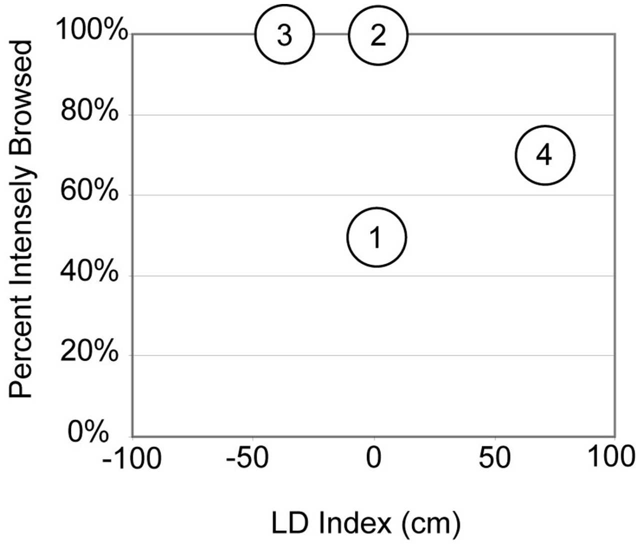

Figure 6—Graph of percent intensely browsed and LD Index. This graph provides a means of describing changes in a stand that may occur over time, or to describe differences between separate stands. Two circumstances could cause a stand to have the characteristics shown at point 1. First, an increase in browsing has prevented the height growth of some plants while others remain light-to-moderately browsed. Second, a decrease in browsing has allowed some young plants to grow into the browse zone; plants that were previously intensely browsed remain alive but fail to grow. The characteristics at Point 2 depict a heavily browsed community that is on the verge of entering decline. Point 3 depicts the characteristics of a community that is in decline. The characteristics depicted at Point 4 could be produced by a decrease in browsing that permitted plants that were previously intensely browsed to grow taller. A community of light-to-moderately browsed plants would not be plotted on this graph.

A graph of mean percent intensely browsed and mean LD Index can be used to describe changes over time or differences between sites (figure 6). The data collected in 2003 would be plotted slightly to the left of point 2. As described above, aspen was heavily browsed in 2003. We collected data at this site again in 2008. Those data would be plotted somewhat below point 1. A graph such as that shown in figure 6 could provide a focus for describing the potential reasons why the existing browsing pressure of aspen at this site was reduced from 100 percent in 2003 to 35 percent in 2008. Such a graph could also be used to describe how browsing might vary spatially.

Step 7: Regulate browsing pressure.
To attain or maintain the desired habitat, browsing pressure must be regulated so that existing browsing pressure is less than the threshold browsing pressure. A detailed discussion of the regulation of browsing pressure is beyond the scope of this paper. In part, ungulate population size is a factor. Climate can indirectly cause decreases or increases in browsing pressure by respectively making available more or less of the browse resource. Declines in the abundance or vigor of a preferred browse species could lead to an apparent increase in browsing pressure on that species.

Repeat the process in subsequent years.
Using a set of approximations, the height based approach directly relates browsing to community structure. The data collected in the initial year provide a starting point. There will likely be a discrepancy between the anticipated result and actual result. This discrepancy can be reconciled by periodic adjustments based on periodic measurements. For example, in subsequent years the initial estimates of densities should be examined; it should be possible to improve the accuracy of threshold LD Index as a predictor of height growth. The long-term application of this systematic process should make it possible to determine if the relationship between ungulates and habitat is consistent with meeting land management objectives.

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