Graphed Relationships Between Herbaceous Retention and Wildlife & Habitat Parameters

Don DeLong, West Zone Wildlife Biologist – BTNF, April 9, 2018

Figure 1 contains all of the research results and published recommendations I know of that can be plotted on a graph; most lines are based on research results, although some cross-walking was needed. The series of curves gives a good representation of the range of effects across vertebrate and invertebrate wildlife species.

Figure 1 shows several things based on this information, including:

- **Suitable herbaceous habitat for a range of common, wide-spread wildlife species with general habitat requirements is retained with a key-forage use limit of 50%.**

  Other considerations:

  → These species have an abundance of habitat from the standpoint of habitat affected by grazing and many do well in altered plant communities (e.g., low plant species diversity and shorter), including on private lands.

  → Many of these wildlife species either increase in abundance with increasing grazing pressure or do not decline substantively with increasing grazing pressure.

  → These species typically are not experiencing population declines.

- **Most lines in Figure 1 show fairly rapid declines between 100% herb retention and 50-60% retention, at which time they begin leveling out at a low or very low level (relative to y axis). 50% use of key forage is situated at or near the bottom of most curves in Figure 1.A and two lines in Figure 1.B (including line 'G'); i.e., less-than-suitable habitat is provided.**
- **Retaining a min. 70% herb vegetation marginally provides for wildlife that directly or indirectly depend on herbaceous vegetation. There is moderate support for a threshold of 70%. It retains an average of about 50% of vegetation attributes important to wildlife** (thick gray lines, Fig. 1.A), although attributes of some groups of species (e.g., microtine voles and their predators) average lower.

  Other considerations:

  → Habitat for these species in the West Zone area has declined and is underrepresented due to (1) loss of herb and shrub-herb habitat to conifer forestland, roads, reservoirs, developments, and agriculture; (2) reductions in herb species diversity and vegetation density due to historic livestock grazing, altered hydrology, and noxious weeds; and (3) reductions in vegetation height, density, and availability of specific plant parts due to livestock grazing.

  → The max. 30-40% use of key forage (recommended by WAFWA 2009 in mule deer habitat) aligns very closely with a minimum 70% herb retention. It was authored by 14 biologists from 7 state game and fish agencies in the West (including WGFD).

  → Some of these species are also impacted by corvids (nest predators), which are increasing in abundance; brown-headed cowbirds (nest parasitism), which are increasing abundance in western Wyoming and continue to expand into higher elevations; and motorized use (reduced nest success).

  → Many species are experiencing downward trends at larger geographic scales (e.g., Wyoming).

- **The ideal for wildlife as a whole appears to be approximately ≥85-90% herbaceous retention.**

This has been spelled out in detail in several reports for the West Zone, Upper Green allotments, Sherman allotment, and for the BTNF (for sensitive amphibians, and for microtine voles and great gray owls, and for MIS in USFS 2009).

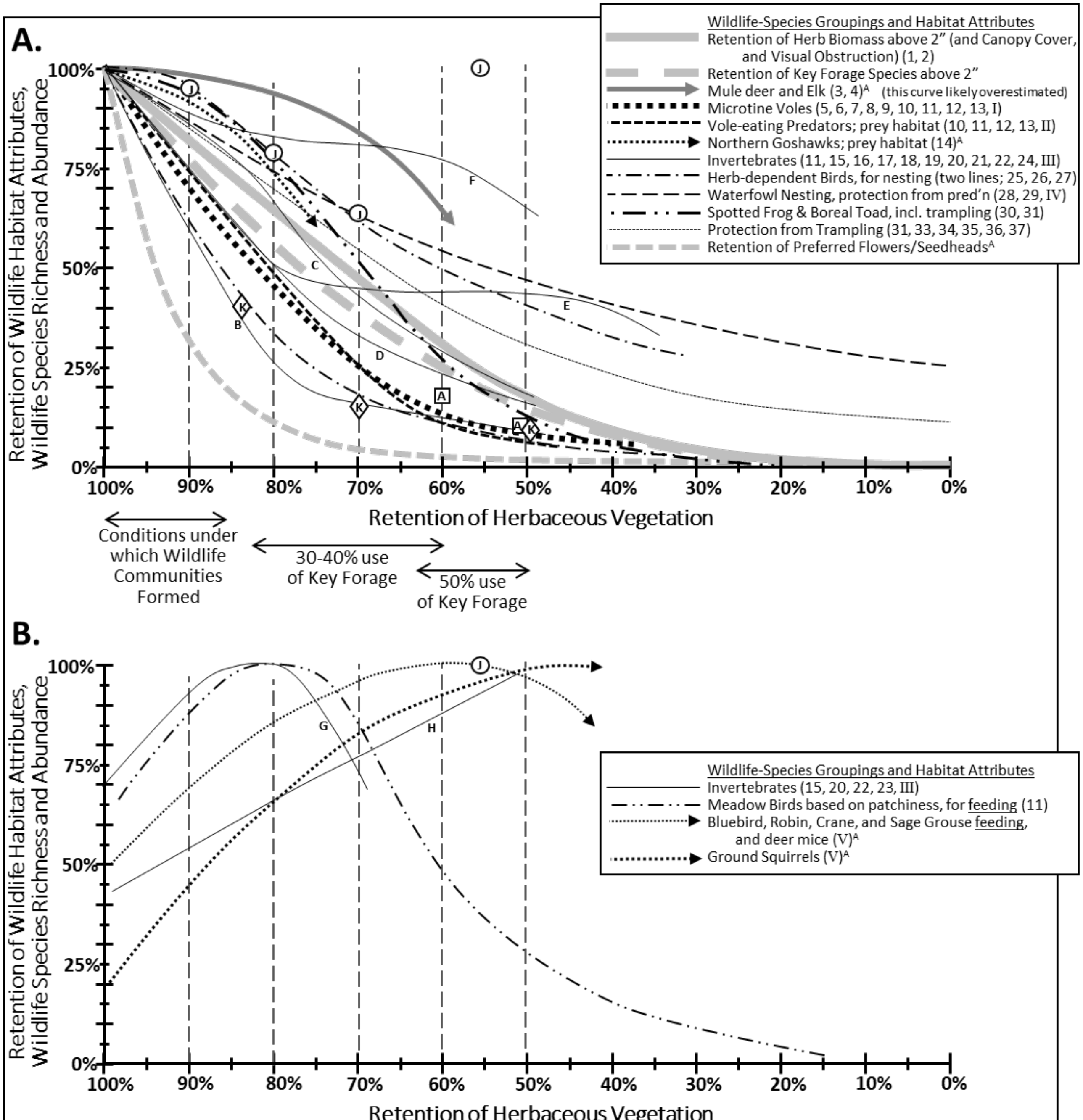

Figure 1. Generalized estimated proportion of various wildlife attributes (e.g., number of species, abundance, reproductive success, percent of ponds occupied, protection from trampling) that are retained relative to retention of herbaceous vegetation, by wildlife-species grouping, as represented by different lines. Groupings with attributes that generally decline with declining retention levels are shown in Graph A, and groupings with attributes that initially increase and then generally decline or that generally increase with declining retention levels are shown in Graph B. In all cases, the uppermost measure for each attribute was re-scaled to 100%. Numbers in the legend refer to specific scientific papers or other references (see "Basis of Graphed Lines" section). Letters A, J, and K (in square, circles, and diamonds) refer to specific data points for microtine voles, herb-dependent birds, and spotted frogs, respectively. Letters B-H (associated with thin solid lines) refer to different groups of invertebrates (see Table 1 in the "Basis of Graphed Lines" section).

[A] These lines were hand-drawn (i.e., roughly estimated). Attempts were made to do this in a way that reflects the cited studies or recommendations.

Basis of Graphed Lines

The following headings correspond to each of the "wildlife-species groupings and habitat attributes" listed in the legend of Figure 1. The numbers in the legend refer to literature cited.

For studies that presented changes in wildlife parameters (e.g., number of species, abundance, reproductive success) in relation to percent utilization or percent retention, results were directly transcribed into the graph. For studies that presented changes in wildlife parameters in relation to changes in herbaceous vegetation height, changes in height were converted to percent herbaceous retention, using published vegetation height-weight curves, for presentation in the graph (see Appendix A). Because the multipliers used in this process were estimates, the graphed lines are not exact. Also, some lines represent the results of more than one study or more than one species or taxa, which makes the lines approximations.

Retention of Herb Biomass above 2" (Canopy Cover and Visual Obstruction)

Height–weight curves in the following papers were recalibrated to eliminate or ignore plant material within 2 inches of the ground since this contributes little if anything to habitat (e.g., to forage, hiding and nesting cover, living space, retention of humidity), and consumption of this plant material as forage compromises the health of individual plants (i.e., it can be considered unavailable as forage in order to protect plant vigor and health). Retention of herbaceous biomass above 2 inches is a good indicator of the following:

- Availability of forage
- Hiding cover. Visual obstruction readings (Robel pole) at different herbaceous retention levels correspond closely with herbaceous biomass above 2 inches, and Robel pole readings go to 0 by the time stubble heights decline to 2 inches.
- Herbaceous canopy cover tracks closely with herbaceous biomass above 2 inches.
- Humidity retention near ground level declines more sharply than herbaceous biomass above 2 inches, based on available science.

1. Bureau of Land Management (BLM), U.S. Forest Service, USDA Natural Resources Conservation Service, Cooperative Extension Service. 1999 (revised from 1996). Utilization studies and residual measurements. U.S. Department of the Interior, Bureau of Land Management, Technical Reference 1734-3. National Business Center, Denver, Colorado.
2. Kinney, J. W. and W. P. Clary. 1994. A photographic utilization guide for key riparian graminoids. U.S. Dept. of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-GTR-308.

Dr. James Peek, University of Idaho, Moscow, also assessed that a max. 50% use of key forage is not sufficient to maintain suitable forage for big game (pers. comm., 2008). Dr. Peek has conducted many studies on the effects of livestock grazing on big game species.

Mule Deer and Elk (3, 4)

This curve was hand drawn in an attempt to reflect recommendations by the following report and paper; i.e., for deer, a maximum of 30-40% use of key forage species (3), and for elk, a maximum 40% use of key forage species (4), with the assumption that beyond 30-40% use of key forage species, the amount of available, preferred forage or rate of intake would be too low. The line assumes that 75% of the amount and quality of forage resources is retained at 40% use (60% retention) of key forage species. However, the curve likely greatly overestimates the availability and quality of forage for deer and elk because, at 60% retention of key forage species, only an estimated 25% (± 25%) of the weight of key forage is retained and only an estimated 30-50% (± 25%) of the weight of total herbaceous vegetation is retained.

3. Western Association of Fish and Wildlife Agencies (WAFWA). 2009. Habitat guidelines for mule deer: intermountain west ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.
4. Wisdom, M. J. and J. W. Thomas. 1996. Chapter 10: elk. Pages 157-182 *in* Krausman, P. R. (ed.). Rangeland wildlife. Society for Range Management, Denver, Colorado. 440pp.

Microtine Voles (5, 6, 7, 8, 9, 10, 11, 12, 13, I)

The following papers provided data points on the relationship between either percent utilization of vegetation or change in height and vole densities, and the line reflects this data. The two squares in the graph (labeled as "A") are actual data points from Birney et al. (1976) in which utilization was directly measured.

5. Batzli, G. O., S. J. Harper, Y. K. Lin, and E. A. Desy. 1985. Experimental analysis of population dynamics: scaling up to the landscape. Pgs. 107-127 *in* Barrett, G. W. and J. D. Peles (eds.). Landscape ecology of small mammals. Springer, New York, New York.
6. Birney, E. C., W. E. Grant, and D. D. Baird. 1976. Importance of vegetative cover to cycles of Microtus populations. Ecology 57:1043-1051.
7. Edge, W. D., J. O. Wolff, and R. L. Carey. 1995. Density-dependent responses of gray-tailed voles to mowing. Journal of Wildlife Management 59:245-251.
8. McAninch, J. 1978. An ecological framework for vole management. Paper 100 *in* Eastern pine and meadow vole symposium. Univ. Nebraska, Lincoln, Internet Center for Wildlife Damage Management, http://digitalcommons.unl/voles/100.
9. Johnson, M. D. and C. M. Horn. 2008. Effects of rotational grazing on rodents and raptors in a coastal grassland. Western North American Naturalist 68:444-452.
10. Wheeler, P. 2008. Effects of sheep grazing on abundance and predators of field vole (*Microtus agrestis*) in upland Britain. Agriculture, Ecosystems, and Environment 123:49-55.
11. Evans, D. M., N. Villar, N. A. Littlewood, R. J. Pakeman, S. A. Evans, P. Dennis, J. Skartveit, and S. M. Redpath. 2015. The cascading impacts of livestock grazing in upland ecosystems: a 10-year experiment.
12. Villar, N., X. Lambin, D. Evans, R. Pakeman, and S. Redpath. 2013. Experimental evidence that livestock grazing intensity affects the activity of a generalist predator. Acta Oecologica 49:12-16.
13. Beemster, N. and J. T. Vulink. 2013. The long-term influence of grazing by livestock on common vole and raptors in man-made wetlands in the Netherlands. Lutra 56:5-21.

I. The line in the graph is also generally supported by a large volume of scientific literature demonstrating that microtine voles require relatively-tall, dense herbaceous vegetation and that increasing levels of grazing pressure incrementally reduce habitat quality for them; more than 15 papers supporting this are cited in DeLong (2012) and DeLong (2016).

Vole-eating Predators (10, 11, 12, 13, II)

A small number of studies assessed the effects of changes microtine vole densities (caused by livestock grazing) and the effects this had on several species of raptors and on red foxes. The scientists found that reductions in vole densities caused by grazing resulted in reduced densities of both specialist predators (vole-eating raptors) and generalist predators (red foxes). See 10, 11, 12, 13, above.

II. The line in the graph is also generally supported by a large volume of scientific literature demonstrating that reductions in prey density typically causes raptor densities to decline or for reproductive success to decline. Ten or more papers supporting this are cited in DeLong (2012) and DeLong (2016).

Northern Goshawk (14)

To provide habitat needs of goshawk prey, Reynolds et al. (1992) recommended that utilization of grasses and forbs average no higher than 20% and not exceed 40% in any given area.

14. Reynolds, R. T., R. T. Graham, M. H. Reiser, R. L. Basset, P. L. Kennedy, D. A. Boyce, Jr., G. Goodwin, R. Smith, E. L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report GTR-RM-217. 90pp.

Invertebrates (11, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 III)

Seven lines are based on generalized response types (i.e., patterns) in East and Pottinger (1983) and data points on the relationship between vegetation response variable (either percent utilization of vegetation or change in height) and invertebrate response variables (e.g., species richness, abundance) for particular groups of invertebrate species (from references 14-23). An intent was to identify as few lines as possible while still representing the range of possible patterns. See Appendix A.

Each of the seven lines for invertebrates in Figure 1 capture effects of reductions in herbaceous height on different groups of invertebrates as outlined in Table 1.

East and Pottinger (1983) estimated that approximately 15% of invertebrate taxa are represented by the pattern denoted by "G" in Figure 1.B and approximately 10% of invertebrate taxa are represented by the pattern denoted by "H," leaving approximately 75% to be represented by "B" through "F" in Figure 1.A.

Table 1. Invertebrate taxa comprising lines B-H in Figure 1. Numbers refer to literature cited.

B. Butterflies and Moths, Bees, and Beetles	**C. Insects in General, Butterflies and Moths, Bees, and Beetles**	**D. Insect in General, and Bees**	**E. Odonates**
16, 22	15, 16, 17, 20, 21, 22, 24	15, 16, 17, 22	18
F. Butterflies and Moths	**G. Bees**	**H. Andrena Bees**	
19, 20, 24	15, 20, 23	22	

15. East, R. and R. P. Pottinger. 1983. Use of grazing animals to control insect-pests of pasture. New Zealand Entemologist 7:352-359.
16. Kruess, A. and T. Tscharntke. 2002a. Grazing intensity and the diversity of grasshoppers, butterflies, and trap-nesting bees and wasps. Conservation Biology 16:1570-1580.
17. Kruess, A. and T. Tscharntke. 2002b. Contrasting responses of plant and insect diversity to variation in grazing intensity. Biological Conservation: 293-302.
18. Foote, A. L. and C. L. Rice Hornung. 2005. Odonates as biological indicators of grazing effects on Canadian prairie wetlands. Ecological Entomology 30:273-283.
19. Pöyry, J., Luoto, M., Paukkunen, J., Pykälä, J., Raatikainen, K. & Kuussaari, M. (2006) Different responses of plants and herbivore insects to a gradient of vegetation height: an indicator of the grazing intensity and successional age. Oikos 115:401–412.
20. Sjödin, N. E., J. Bengtsson, and B. Ekbom. 2008. The influence of grazing intensity and landscape composition on the diversity and abundance of flower-visiting insects. Journal of Applied Ecology 45:763-772.
21. Pöyry, J., J. Paukkunen, J. Heliölä, and M. Kuussaari. 2009. Relative contributions of local and regional factors to species richness and total density of butterflies and moths in semi-natural grasslands. Oecologia 160:577-587.
22. Kimoto, C., S. J. DeBano, R. W. Thorp, R. V. Taylor, H. Schmalz, T. DelCurto, T. Johnson, P. L. Kennedy, and S. Rao. 2012. Short-term responses of native bees to livestock and implications for managing ecosystem services in grasslands. Ecosphere 3:1-19.
23. Zhu, H., D. Wang, L. Wang, Y. Bai, J. Fang, and J. Liu. 2012. The effects of large herbivore grazing on meadow steppe plant and insect diversity. Journal of Applied Ecology 49:1075-1083.

24. Dennis, P., J. Skartveit, A. Kunaver, D. I. McCracken. 2015. The response of spider (Araneae) assemblages to structural heterogeneity and prey abundance in sub-montane vegetation modified by conservation grazing. Global Ecology and Conservation 3:715-728.

III. The lines in the graph are also generally supported by a large volume of scientific literature demonstrating that most species and taxa of invertebrates decline with increasing levels of livestock grazing; more than 20 papers supporting this are cited in DeLong (2016) and a few literature reviews cited in this report cite many other supporting papers.

Herb-dependent Birds (25, 26, 27)

Two representative curves from Fig. 6 of reference no. 24 (Beintema and Müskens 1987) were incorporated into Figure 2. In the study by Johnson (2011) in which utilization was directly measured, nest success declined with declining retention, except that the lowest retention level had the highest nest success; averages are shown with small circle in the graph (labeled as "J"). Three of the data points following along one of the lines of Beintema and Müskens (1987) and the fourth falls outside the pattern (it sits at the top of the graph).

25. Beintema, A. J. and G. J. D. M. Müskens. 1987. Nesting success of birds breeding in Dutch agricultural grasslands. Journal of Applied Ecology 24:743-758.
26. Johnson, T. N. 2011. Direct and indirect effects of livestock grazing intensity on processes regulating grassland bird populations. PhD Dissertation, Oregon State University, Corvallis, Oregon.
27. Johnson, T. N., P. L. Kennedy, and M. A. Etterson. 2012. Nest success and cause-specific nest failure of grassland passerines breeding in prairie grazed by livestock. The Journal of Wildlife Management 76:1607-1616.

Meadow Birds Needing Vegetation Cover and Small Open Patches (11)

This grouping includes birds that require or favor herbaceous cover but some also need or favor open patches for feeding, whether they are feeding on invertebrates or seeds that have fallen to the ground. Species include savannah sparrows and white-crowned sparrows (see also "Waterfowl Nesting," below; and northern harriers also require relatively-tall, dense herbaceous cover for nesting).

In reference no. 11 (Evans et al. 2015), meadow pipit breeding abundance was highest at intermediate grazing intensity (which appears to have equated to an estimated 70-80% herbaceous retention), and was next lowest in more heavily grazed areas (an estimated 70% or lower herbaceous retention) and lowest in ungrazed areas (100% retention). Because pipit breeding abundance (number of territories) was so variable year to year, it was not possible to obtain numbers from Figure 3.a of Evans et al. (2015), so the line was drawn in an attempt to capture this.

Several bird species that feed on the ground in riparian areas (for both invertebrates and seeds) and that favor or need vegetation cover, such as white-crowned sparrows, many times favor open patches within a matrix of taller, denser vegetation cover for feeding (Chilton et al. 1995). Another example is savannah sparrows. They nest in dense herbaceous vegetation but feed in small openings or patches where shorter vegetation occurs.

For meadow birds that require herbaceous cover and that also benefit from open patches, 80% herbaceous may represent optimum conditions, with 70% herbaceous retention (i.e., 50% ±20% retained canopy cover) providing considerably less cover and invertebrate diversity, and considerably more open patches.

Also:

Chilton, G., M. C. Baker, C. D. Barrentine, and M. A. Cunningham. 1995. White-crowned sparrow. *In* The birds of North America, No. 183 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philidelphia, Pennsylvania, and The American Ornithologist's Union, Washington, D.C.

Waterfowl Nesting (28, 29, IV)

This line was derived directly from a graph presented in Bloom et al. (2013) (nest success x vegetation density), and it closely corresponds to a bar graph of nest density in Kirsch et al. (1978) for each of five vegetation density divisions and a bar graph of percent nest success presented in Kirsch et al. (1978) for each of three vegetation density divisions. There were 2,554 nests in Bloom et al. (2013) and 573 nests in Kirsch et al. (1978).

28. Bloom, P. M., D. W. Howerter, R. B. Emery, and L. M. Armstrong. 2013. Relationship between grazing and waterfowl production in the Canadian prairies. The Journal of Wildlife Management 77:534-544.
29. Kirsch, L. M., H. F. Duebbert, and A. D. Kruse. 1978. Grazing and haying effects on habitats of upland nesting birds. Pages 486-497 *in* Sabol, K. (ed.). Transactions of the 43rd North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, D.C.

IV. Kirsch et al. (1978) and Braun et al. (1978) reviewed several dozen studies on the effects of livestock grazing on waterfowl nesting, and found that all of these studies, except for a one or two, demonstrated that livestock grazing reduces nest densities and nest success, with negative effects beginning at relatively low levels of grazing.

Spotted Frog & Boreal Toad, incl. trampling (30, 31)

The upper part of the line (near the upper left part of the graph) was defined both by DeLong (2015) and data in Munger et al. (1994:7). Munger et al. (1994) found that occupancy of 172 wetlands by spotted frogs declined substantively before utilization reached about 80% or in the vicinity of 80% (see DeLong 2015:Appendix A for crosswalk) and that it dropped by a major amount when grazing intensity reached an estimated 21-40% (see DeLong 2015:Appendix A, page A-101 for crosswalk).

> Three “data points” from Munger (1994:7) are presented in the graph with the letter “K” in diamonds. Half of the wetlands that were ungrazed in their study were occupied by spotted frogs, so 50% occupancy was converted to 100% in Figure 1. Of the wetlands with a grazing rating of 1 (an estimated 6-20% use of herbaceous vegetation; as described in Munger 1994 and Bull and Hayes 2000, compared to BLM et al. 2008; see DeLong 2015:Appendix A), only 20% were occupied, which resulted in an estimated 40% “retention” of occupancy after factoring 50% occupancy in ungrazed wetlands. Similarly, of the wetlands with a grazing rating of 2 (an estimated 21-40% use of herbaceous vegetation), an estimated 8% were occupied, which resulted in an estimated 16% retention of occupancy. Of the wetlands with a grazing rating of 3 (an estimated 41-60% use of herbaceous vegetation), a roughly estimated 5% were occupied, which resulted in an estimated 10% retention of occupancy.

Information from DeLong (2015) was used in the following way. The relative amount of scientific information supporting each retention level (at 10% increments) was given a percent value (large = 90%, moderately large = 75%, moderate = 75%, moderately small = 25%, small = 10-15%, very small = 5%). At the upper part of the line, this followed the same pattern as Munger et al. (1994).

30. DeLong, D. 2015. Literature review and analysis of scientific information for the conservation assessment for Columbia spotted frogs and boreal toads on the Bridger-Teton National Forest: a reference document. Unpublished report, Bridger-Teton National Forest, Jackson, Wyoming.
31. Munger, J. C., L. Heberger, D. Logan, W. Peterson, L. Mealy, and M. Cauglin. 1994. A survey of the herpetofauna of Bruneau Resource Area, Boise District, with focus on the spotted frog, Rana pretiosa. Idaho Bureau of Land Management Technical Bulletin No. 94-7.

Bluebird, Robin, Crane, and Sage Grouse feeding; and Deer Mice & Ground Squirrels (V)

The line was hand drawn to reflect less-than-suitable habitat at 100% herbaceous retention for these species in relatively-tall, dense herbaceous vegetation, with increasing suitability as herbaceous retention declines until just after the point at which short-stubble begins to dominate and relatively-intact vegetation shifts to the minority.

For most species in this group, available habitat for feeding is not limiting, especially where range condition is at mid-seral, which is fairly common on the West Zone (and other parts of the BTNF).

- For foraging, mountain bluebirds and American robins favor areas of short herbaceous vegetation and, where vegetation is relatively tall, they favor microsites between plants (Wetmore 1964, Power and Lomardo 1996, Wiggins 2006).
- Grazing of graminoids by cattle in meadows in any given year has been shown to increase the availability of forbs to adult and young sage grouse (Oakleaf 1971, Klebenow and Burkhardt 1982, Evans 1986). Relatively high utilization levels (e.g., moderate, heavy, and severe) in a patchy mosaic with lighter utilization levels appear to favor use of meadows by foraging sage grouse, with patches of vegetation of 2-6 inches tall apparently being preferred in one study (Oakleaf 1971, Klebenow and Burkhardt 1982, Evans 1986).
- Sandhill cranes have also been found to selectively feed in parts of wet and moist meadows that have been grazed by cattle, likely because it increases the availability of their preferred food.
- Deer mice inhabit a wide range of herbaceous conditions, from ungrazed pastures to moderately or heavily grazed pastures, so long as some amount of hiding cover remains, even in the form of shrubs (Grant et al. 1982, Medin and Clary 1990, Fagerstone and Ramey 1996).

No species native to this part of the Rocky Mountains / Intermountain West were identified that depend on grazing to produce required habitat conditions.

V. The following citations generally apply:

Evans, C. C. 1986. The relationship of cattle grazing to sage grouse use of meadow habitat on the Sheldon National Wildlife Refuge. M.S. Thesis, University of Nevada, Reno.

Fagerstone, K. A. and C. A. Ramey. 1996. Chapter 8: rodents and lagomorphs. Pages 83-132 *in* Krausman, P. R. (ed.). Rangeland wildlife. Society for Range Management, Denver, Colorado.

Grant, W.E., E. C. Birney, N. R. French, and D. M. Swift. 1982. Structure and productivity of grassland small mammal communities related to grazing-induced changes in vegetative cover. Journal of Mammalogy 63:248-260.

Klebenow, D. A. and J. W. Burkhardt. 1982. Sage grouse on the Sheldon National Wildlife Refuge. University of Nevada, Reno, Nevada.

Medin, D. E. and W. P. Clary. 1990. Bird and small mammal populations in a grazed and ungrazed riparian habitat in Idaho. USDA Forest Service. Research Paper INT-425, Ogden, Utah. 4pp.

Oakleaf, R. J. 1971. Relationship of sage grouse to upland meadows in Nevada. M.S. Thesis, University of Nevada, Reno, Nevada. 73pp.

Power, H. W. and M. P. Lombardo. 1996. Mountain bluebird. *In* The birds of North America, No. 222 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philidelphia, Pennsylvania, and The American Ornithologist's Union, Washington, D.C. 24pp.

Wetmore, A., and 13 other ornithologist. 1964. Song and garden birds of North America. National Geographic Society, Washington, D.C.

Wiggins, D. 2006. Mountain bluebird (*Sialia currucoides*): a technical conservation assessment. Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project. 35pp.

Protection from Trampling (32, 33, 34, 35, 36 and see 29)

Detailed information on trampling rates at different livestock grazing intensities was converted to estimated trampling rates for herbaceous retention at each 10% increment, as outlined in DeLong (2015:A-53 through A-62). The potential for trampling derived from this conversion was reversed (100% – x) to come up with an index of protection from trampling.

32. Guthery, F. and Ralph L. Bingham 1996. a theoretical basis for study and management of trampling by cattle. journal of range management. pages 264-269.
33. Jensen, Holger P.1990. effects of cattle stock density on trampling loss of simulated ground nests. wildlife Society Bulletin. pages 71-74.
34. Koerth, H. B. 1983. cattle trampling of simulated ground nests under short duration and continuous grazing. journal of range management. pages 385-386.
35. Mandema, S. F. 2013. Livestock grazing and trampling of birds' nests: an experiment using artificial nests. journal coastal conservation. pages 409-416
36. Paine, L. 1996. Cattle trampling of simulated ground nests in rotationally grazed pastures. Journal od range management. pages 294-300.

Retention of Key Forage Species above 2"

The same height–weight curves were used as in the subsection "Retention of Herb Biomass above 2" (1, 2)," except only for key forage species, which are grazed more heavily than non-key forage species; i.e., they are grazed more heavily than the remainder of the plant community and the plant community as a whole.

Retention of Favored Flowers/Seedheads

This curves was hand drawn to reflect — at the extreme — the selective grazing of preferred flowers by sheep and grass seedheads by cattle. As an example in plant communities dominated by single-flowered sunflowers, it is common for >95% of flowers of this species to be grazed by sheep when they consume ≤5-10% of the rest of the plant. It is not uncommon for high percentages of other flowers and seedstalks to be selectively grazed or skimmed, as discussed in BLM et al. (2008).

BLM, U.S. Forest Service, Natural Resources Conservation Service, University of Wyoming Dept. of Renewable Resources, University of Wyoming Extension Service, Wyoming Dept. of Agriculture, Wyoming Section of the Society for Range Management. 2008. Wyoming rangeland monitoring guide: a cooperative and voluntary approach to monitoring rangelands (version 2). U.S Department of Interior, Bureau of Land Management, Cheyenne, Wyoming.

Appendix A — Calculations of Herbaceous Retention; Studies Involving Microtine Voles, Invertebrates, and their Predators

Don DeLong, West Zone – BTNF (April 5, 2018)

Effects of Livestock Grazing and Clipping on Voles

For studies on the effects of mowing and livestock grazing on microtine voles, height is the most common metric that has been used to measure changes in herbaceous vegetation. Height – weight curves (Kinney and Clary 1994, BLM et al. 1999:118) were used to convert these changes in vegetation height to percent herbaceous retention (see table, below). Because measurements appeared to focus on height of the predominant plant material (i.e., leafy material, or sward height), height–weight curves were recalibrated to remove the uppermost 10% of the weight, which effectively removed seed stalks (see pictures in Kinney and Clary 1994). Figure A-1 shows the recalibrated curves. The curve for sedges in Figure A-1 was not considered in most cases; it was only used when studies specifically identified sedge or rushes as the dominant plant taxa. If seed stalks were included in measurements of height in some studies, the elimination of the uppermost 10% of the weight will underestimate herbaceous retention ("Estimated % Ret'n of Weight"); i.e., in the absence of recalibration, herbaceous retention estimates would be higher. Birney et al. (1976) has the most direct comparison between herbaceous retention based on weight (since they measured changes in vegetation weight) and vole densities.

Study	Ungrazed/ Unmowed Height or Weight	Grazed/ Mowed Height or Weight	% Ret'n of Height or Weight	Estimated % Ret'n of Weight	Reduction in Voles	Species of Microtine Vole	Predator Species That Declined
McAninch et al. (1978)	12 – 24"	4-5" (est.)	20-40%	40-70%[B]	40%, 60%, and 90%[A,B]	Meadow, montane, and pine voles	nm[C]
Edge et al. (1975)	12"	3.15"	25%	40-65%[B]	50%[B]	Gray-tailed voles	nm
Birney et al. (1976)	20 – 40"	4-8"	20-60%	50-75%	70% 90%	Prairie voles Meadow voles	nm
Johnson & Horn (2008)	24.8 – 29.9"	5.9-15.7"	30-70%	50-80%	50-85%	California voles	White-tailed kites Short-eared owls
Birney et al. (1976)	408 g/m^2	235 g/m^2	—	60%	90-95%	Prairie voles	nm
(*during pop. increase*)	460 g/m^2	235 g/m^2	—	50%	75-90%[D]		
Wheeler (2008)	9.1 – 12.2"	7.1 – 10.6"	—	70-85%[E]	30-60%	Field voles	Several modeled[F]
Villar et al. (2013) and Evans et al. (2015)	Veg. Density = 34 cm	Veg. Density = 24-27 cm	Veg. Density 71-79%	70-90%[G]	35-60%	Field voles	Red fox
	Veg. Density = 34 cm	Veg. Density = 18 cm	Veg. Density 53%	60-80%[G]	50-90%	Field voles	Red fox

[A] Depending on timing of mowing and type of mowing.

[B] Mowed vegetation was left on the ground after mowing in this study or in some treatments, which likely lessened the degree of vole density reductions.

[C] nm = not measured.

[D] This reflects vole numbers during a population increase in the ungrazed area and does not reflect the full effects of grazing at the specified level.

[E] Assuming that percent changes in cover depth (using the drop-disc method) generally equates to percent change in weight, which is supported by Vartha and Matches (1977) and Douglas and Crawford (1994).

[F] Authors modeled response of vole-eating predators and estimated increases in species such as red foxes, weasels, kestrels, tawny owls, long-eared owls, and short-eared owls.

[G] Herbaceous retention was based on changes in vegetation density; see text for further discussion.

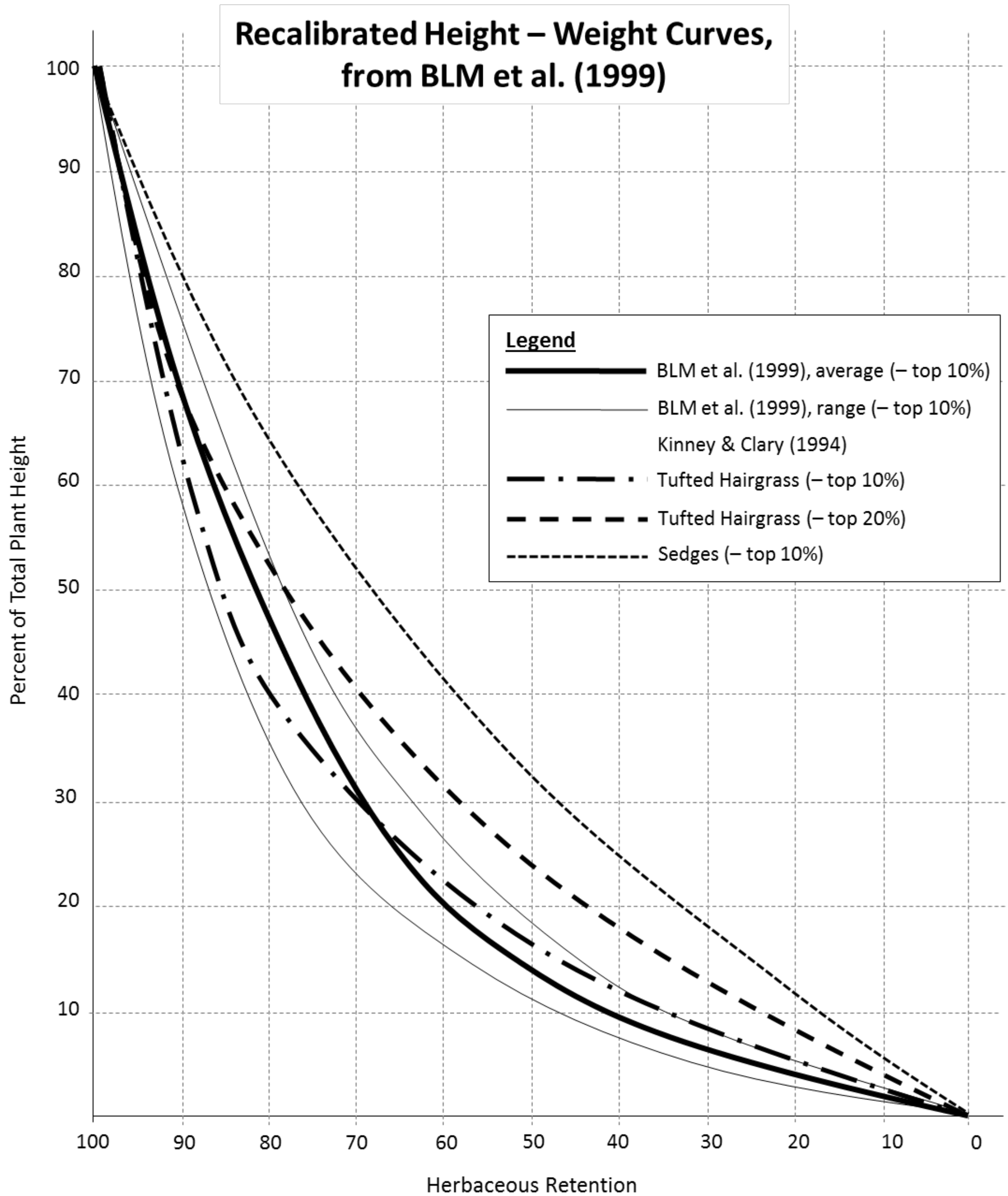

Figure A-1. Recalibrated height-weight curves from BLM et al. (1999). The upper 10% of the height was "removed" from the curves in BLM et al. (1999) as a closer approximation of vegetation height minus seedheads.

Herbaceous retention was estimated three different ways for Villar et al. (2013) and Evans et al. (2015), including the way it was estimated in Table 1, above, for several reasons. Estimates based on changes in their vegetation biomass index do not correspond to estimates based on changes in height (they are considerably different; note the differences in the tables on the next page). Evans et al. (2015) only directly measured two vegetation variables: height and density, and density is a more accurate reflection of biomass than height. They only "approximated" vegetation biomass and this approximation appears to have compounded height as an influencing factor by "double-dipping" on vegetation height. In their methods, they stated that "Vegetation biomass was approximated as the product of vegetation height and density," and height is an major component of the way density was measured by Evans et al. (2015); they used a density pole for which they essentially measured the height at which dense vegetation cover transitioned to sparse vegetation cover.

As a way of illustrating the problem, the average height for treatment I (the most intensively grazed area) was about 67% of the average height of the ungrazed area (treatment IV), while the average vegetation biomass index of treatment I was about 35% of that of treatment IV (information was obtained from Fig. 1 of Evans et al. 2015). Retaining 35% of the biomass normally equates to retention of <15% of the height (Kinney and Clary 1994, BLM et al. 1999). Fluctuations in vole densities over time under treatment I (Fig. 4 of Evans et al. 2015) would likely have not occurred to the extent they did if only about 35% of the biomass was retained, based on other studies (e.g., see Birney et al. 1976 for discussion).

As such, I decided to incorporate into Table 1 the estimates of herbaceous retention based on changes in vegetation density since vegetation density was measured and the biomass index was only estimated, the biomass index compounded height (explained above), and the estimate based on vegetation density falls between the other two estimates.

The three methods are outlined below.

Based on Changes in Vegetation Density — Evans et al. (2015:3) measured density as followings: "visibility of white marks at 5-cm intervals on the vertically held stick was recorded to measure vegetation density." Although Evans et al. (2015) measured vegetation density, they did not present results of density measurements. However, because their vegetation biomass index "…was approximated as the product of vegetation height and density" and vegetation height was presented, vegetation density can be back-calculated:

$$\frac{\text{Vegetation Biomass Index from Fig. 1}}{\text{Vegetation Height}} = \text{Vegetation Density}$$

Vegetation densities of the treatments was as follows: I = 18 cm, II = 27 cm, III = 24 cm, and IV = 34 cm. After vegetation density was ascertained, then percent retention of vegetation density was calculated: I = 53%, II = 79, III = 71%, and IV = 100% (treatment IV is the ungrazed treatment). Then percent retention of vegetation density was treated as percent retention of Robel pole readings (see Fig. 4 of the main report), which provided the estimates that were incorporated into Table 1.

Based on Changes in Vegetation Height — Herbaceous retention based on changes in vegetation height were estimated using methods described at the top of the first page, and the results are presented in the table below. It is unclear how they measured vegetation height, but the estimated herbaceous retention levels using height-weight curves of Kinney and Clary (1994) and BLM et al. (1999:118), factoring out the uppermost 10% of the heights in these curves, appear to be overestimated. If the uppermost 10% were not removed, overestimates would be even higher.

Study	**Ungrazed/ Unmowed Height or Weight**	**Grazed/ Mowed Height or Weight**	**% Ret'n of Height or Weight**	**% Ret'n of Weight**	**Reduction in Voles**	**Species of Microtine Vole**	**Predator Species That Declined**
Villar et al. (2013) and	27"	24-25"	90-95%	>95%	35-60%	Field voles	Red fox
Evans et al. (2015)	27"	18"	65-70%	80-90%	50-90%	Field voles	Red fox

Based on Changes in Vegetation Biomass Index — Under this approach, percent herbaceous retention was based on the inverse of the vegetation biomass index presented in Fig. 1.d of Evans et al. (2015:6).

Study	Ungrazed/ Unmowed Height or Weight	Grazed/ Mowed Height or Weight	% Ret'n of Height or Weight	% Ret'n of Weight	Reduction in Voles	Species of Microtine Vole	Predator Species That Declined
Villar et al. (2013) and Evans et al. (2015)	Biomass index = 910	Biomass index =610-655	n/a	67-72%	35-60%[G]	Field voles	Red fox
	Biomass index = 910	Biomass index = 325	n/a	35%	50-90%[G]	Field voles	Red fox

[G] During periods of peak vole densities, percent reductions were at the high end of these ranges.

Invertebrate-based Studies

The same methods were used as described above for vole-based studies. Where utilization was estimated or measured, this information was incorporated directly into the "Estim'd % Ret'n of Wt," by subtracting the percentages from 100 (i.e., simple conversion from percent utilization to percent retention).

Where vegetation height measurements were provided for each of several treatments, the following procedures were used to crosswalk them to percent retention of herbaceous vegetation, by weight. The average height for each treatment type was either obtained from a table or the text in the given paper, or were estimated from graphs (project files). These heights were incorporated into the "Grazed/Mowed Height or Weight" column. For each of the heights in this column, grazed height was divided by the ungrazed height to determine the percent of height retained (in the "% Ret'n of Ht. or Wt." column).

Estimated percent retention by weight (x-axis of Figure A-1) was then estimated by applying the percent of height retained to the y-axis of Figure A-1 (for all vegetation except sedges, rushes, and reeds). This estimate was placed in the "Estim'd % Ret'n of Wt." column.

For the number of species or abundance, each of the figures in the "No. of Species or Abund." column (except the highest number for a given treatment) was divided against the highest number to determine the percent-of-the-highest-figure. These were incorporated into the "% of Total" column.

The percentages from the "Estim'd % Ret'n of Wt." column and "% of Total" column were then incorporated into a series of line graphs (using the graph function of Powerpoint) by applying them to the y axis and x axis, respectively (Appendix B). The dominant themes from these graphs were then incorporated into Figure 3.

Study	Graphs (Appendix B)	Number of Livestock per Ha	Grazed/ Mowed Height or Weight	% Ret'n of Ht. or Wt.	Estim'd % Ret'n of Wt.	No. of Species or Abund.	% of Total
All Insects							
Kruess and Tscharntke (2002b)	A	0	60*	100%	100%	72	100%
(# insect species)		s-t excl.	48*	*60%*	84-91%	59	82%
		1.4 c/ha	32*	53%	80-88%	55	76%
		5.5 c/ha	29*	48%	77-86%	36	50%
Kruess and Tscharntke (2002b)	B	0	60*	100%	100%	375	100%
(# individuals)		s-t excl.	48*	*60%*	84-91%	185	49%
		1.4 c/ha	32*	53%	80-88%	250	67%
		5.5 c/ha	29*	48%	77-86%	100	27%
Kruess and Tscharntke (2002b)	C		60*	100%	100%	19.5	100%
(# grassland-insect species)			48*	*60%*	84-91%	15	77%
			32*	53%	80-88%	10	51%

			29*	48%	77-86%	7	36%
Kruess and Tscharntke (2002b)	D		60*	100%	100%	130	100%
(# individuals, grassland species)			48*	*60%*	84-91%	57	44%
			32*	53%	80-88%	27	21%
			29*	48%	77-86%	17	13%
Zhu et al. (2012)	E		n/a (100%)		100%	31	91%
(Insect Species Richness)					78% cgs	34	100%
					72% s	30	88%
					73% c	29	85%
					72% g	28	82%
Zhu et al. (2012)	E		n/a (100%)		100%	610	52%
(Insect Abundance)					78% cgs	1183	100%
					72% s	897	76%
					73% c	672	57%
					72% g	1010	85%
Butterflies and Moths							
Kruess and Tscharntke (2002a)	F		60*	100%	100%	17*	100%
(# adult butterfly species)			32*	53%	80-88%	14*	82%
			29*	48%	77-86%	10*	59%
Kruess and Tscharntke (2002a)	G		60*	100%	100%	12	100%
(# larva butterfly species)			32*	53%	80-88%	9	75%
			29*	48%	77-86%	2	17%
Kruess and Tscharntke (2002a)	H		40-50	100%	100%	7	100%
(# adult butterfly species)			30	60-75%	83-95%	3	43%
			25	50-63%	78-92%	2.5	36%
			20	40-50%	73-87%	1.5	21%
Pöyry et al. (2006)	I		30-40	100%	100%	26	100%
(all butterflies and moths)			20	50-67%	78-93%	24	92%
			15	38-50%	71-87%	22	85%
			10	25-33%	58-78%	19	73%
			5	13-18%	40-63%	17	65%
Pöyry et al. (2009)	J		30-40	100%	100%	5	100%
(declining butterfly & moth spp.)			20	50-67%	78-93%	4	80%
			15	38-50%	71-87%	3	60%
			10	25-33%	58-78%	2	40%
			5	13-18%	40-63%	1	20%
Sjodin et al. (2008)	K		16.51	100%	100%	10.4	100%
(butterfly species richness)			9.14	55%	80-88%	9.1	88%
			4.63	28%	62-76%	9.4	90%
Sjodin et al. (2008)	L		16.51	100%	100%	29.5	100%
(butterfly abundance)			9.14	55%	80-88%	22.9	78%
			4.63	28%	62-76%	22.8	77%
Little (2008)		0				13.8	100%
(no. of moth species)		0.9 s/ha (cs)				11.35	82%
		0.9 s/ha				12.35	89%
		2.7 s/ha				10.6	77%
Little (2008)		0				1676	88%
(no. of moths - abundance)		0.9 s/ha (cs)				1475	78%
		0.9 s/ha				1896	100%
						1183	62%
Bees							
Kruess and Tscharntke (2002a)	M		60*	100%	100%	11.5*	100%
(# bees, wasps, parasitoids spp.)			32*	53%	80-88%	6.2*	54%
			29*	48%	77-86%	4.7*	41%
Sjodin et al. (2008)	N		16.51	100%	100%	17.3	81%
(bee species richness)			9.14	55%	80-88%	21.3	100%
			4.63	28%	62-76%	20.9	98%

Sjodin et al. (2008)	O		16.51	100%	100%	43.4	69%
(bee abundance)			9.14	55%	80-88%	62.5	100%
			4.63	28%	62-76%	51.8	83%
Kimoto et al. (2012)	P		n/a		100%	17.0	100%
(Bee species richness - 2007)					85%	11.5	68%
					70%	6.0	35%
Kimoto et al. (2012)	Q		n/a		100%	3.0	100%
(Bombus species richness)					80%	1.5	50%
					70%	1.0	33%
					50%	0.5	17%
Kimoto et al. (2012)	R		n/a		100%	0.4	44
(Andrena species richness)					80%	0.6	67%
					70%	0.7	78%
					50%	0.9	100%
Kimoto et al. (2012)	S		n/a		100%	0.26	100%
(Bombus # trapped / hour)					80%	0.10	38%
					70%	0.06	23%
					50%	0.03	12%
Kimoto et al. (2012)	T		n/a		100%	+1.1	100%
(Bee Species Comp - MMS)					80%	+0.25	?
					70%	-0.20	?
					50%	-1.00	?
Hoverflies							
Sjodin et al. (2008)	U		16.51	100%	100%	10.6	100%
(hoverfly species richness)			9.14	55%	80-88%	9.9	93%
			4.63	28%	62-76%	7.5	71%
Sjodin et al. (2008)	V		16.51	100%	100%	44.4	100%
(hoverfly abundance)			9.14	55%	80-88%	35.4	80%
			4.63	28%	62-76%	28.3	64%
Beetles							
Sjodin et al. (2008)	W		16.51	100%	100%	5.1	100%
(beetle species richness)			9.14	55%	80-88%	3.8	75%
			4.63	28%	62-76%	2.8	55%
Sjodin et al. (2008)	X		16.51	100%	100%	15.0	100%
(beetle abundance)			9.14	55%	80-88%	6.9	46%
			4.63	28%	62-76%	4.5	30%
Auchenorrhyncha.							
Dennis et al. (2015)	AA		48.2*	100%	100%	50	91%
(Auchen. Abundance 2003)			47.5	98%	97%	55	100%
			40.0	83%	92-96%	40	73%
			33.8	70%	87-93%	36	65%
2004	BB		40.7*	100%	100%	154	100%
			39.8	98%	97%	143	93%
			30.5	75%	90-95%	102	66%
			34.0	84%	92-96%	75	49%
Dennis et al. (2015)	CC		48.2*	100%	100%	6.4	97%
(Auchen No. Species 2003)			47.5	98%	97%	6.5	98%
			40.0	83%	92-96%	5.8	88%
			33.8	70%	87-93%	6.6	100%
2004	DD		40.7*	100%	100%	9.0	76%
			39.8	98%	97%	11.8	100%
			30.5	75%	90-95%	9.2	78%
			34.0	84%	92-96%	11.3	96%
Little et al. (2012) - D-Vac	EE	0				3.08	100%
(no. of Auchen Species)		0.9 s/ha (cs)				2.2	71%
		0.9 s/ha				2.27	73%

		2.7 s/ha				1.8	58%
Little et al. (2012) - Sweep	FF	0				4.4	100%
(no. of Auchen Species)		0.9 s/ha (cs)				3.6	82%
		0.9 s/ha				3.03	69%
		2.7 s/ha				3.9	89%
Little et al. (2012) - D-Vac	GG	0				24	100%
(no. of Auchen - Abundance)		0.9 s/ha (cs)				6.3	26%
		0.9 s/ha				8.0	33%
		2.7 s/ha				4.5	19%
Little et al. (2012) - Sweep	HH	0				32	100%
(no. of Auchen - Abundance)		0.9 s/ha (cs)				11.5	36%
		0.9 s/ha				19.0	59%
		2.7 s/ha				17.5	55%
Odonates							
Foote and Rice Hornung (2005)	II		60*	100%	100%	0.9-1.25	100%
(Odonates in scirpus)			28*	47%	65%	0.4-0.5	32-55%
			21.5*	36%	55%	0.4-0.5	32-55%
Foote and Rice Hornung (2005)	KK		50*	100%	100%	0.9-1.25	100%
(Odonates in carex)			26*	52%	70%	0.4-0.5	32-55%
			18*	36%	55%	0.4-0.5	32-55%
Foote and Rice Hornung (2005)	JJ		50-60	100%	100%	0.9-1.25	100%
(Odonate diversity in scirpus)			40	67-80%	82-90%	0.5	40-55%
			30	50-60%	68-77%	0.4-0.5	32-55%
			20	33-40%	50-58%	0.4-0.5	32-55%
			10	17-20%	27-35%	0.15	12-17%
Foote and Rice Hornung (2005)	LL		43-60	100%	100%	0.9-1.25	100%
(Odonate diversity in carex)			30	50-70%	68-84%	0.5	40-55%
			20	33-47%	50-65%	0.46	37-51%
			10	17-23%	27-40%	0.38	30-42%

Literature Cited

Cited literature is listed under “Basis of Graphed Lines” in the main body of the document, except:

Bureau of Land Management (BLM), U.S. Forest Service, USDA Natural Resources Conservation Service, Cooperative Extension Service. 1999 (revised from 1996). Utilization studies and residual measurements. U.S. Department of the Interior, Bureau of Land Management, Technical Reference 1734-3. National Business Center, Denver, Colorado.

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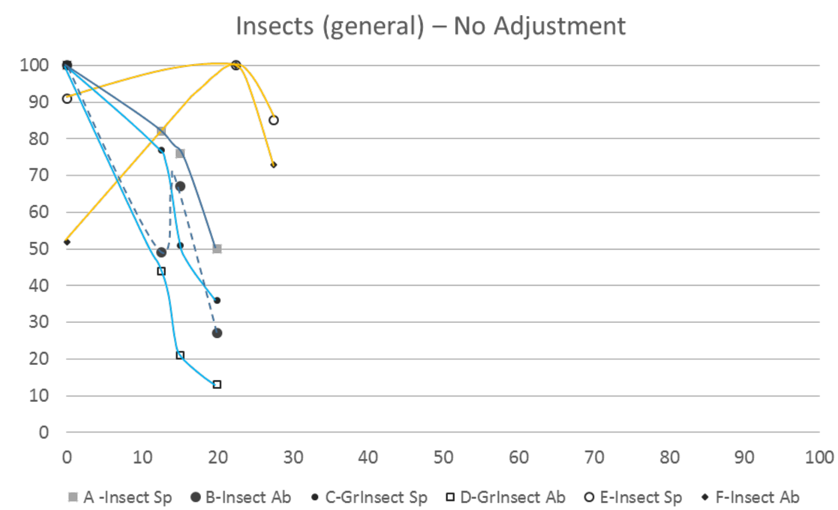
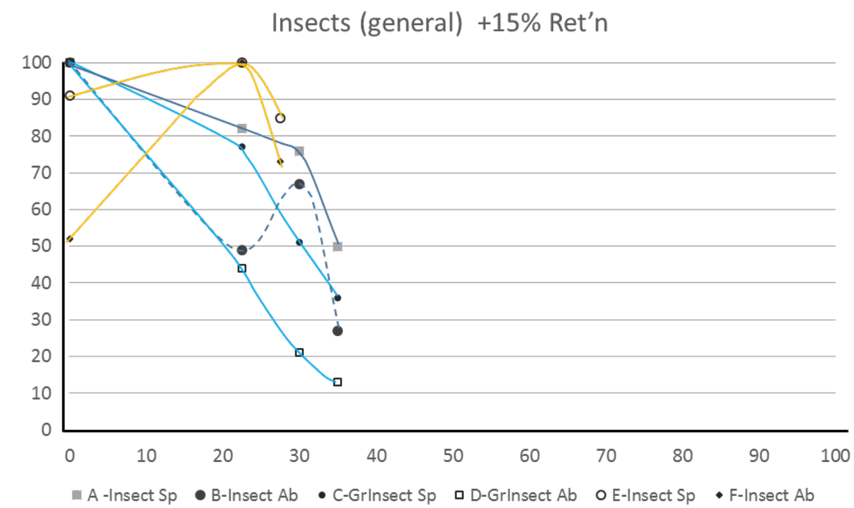
Vartha, E. W. and A. G. Matches. 1977. Use of a weighted-disk measure as an aid in sampling the herbage yield on tall fescue pastures grazed by cattle. Agronomy Journal 69, September-October.

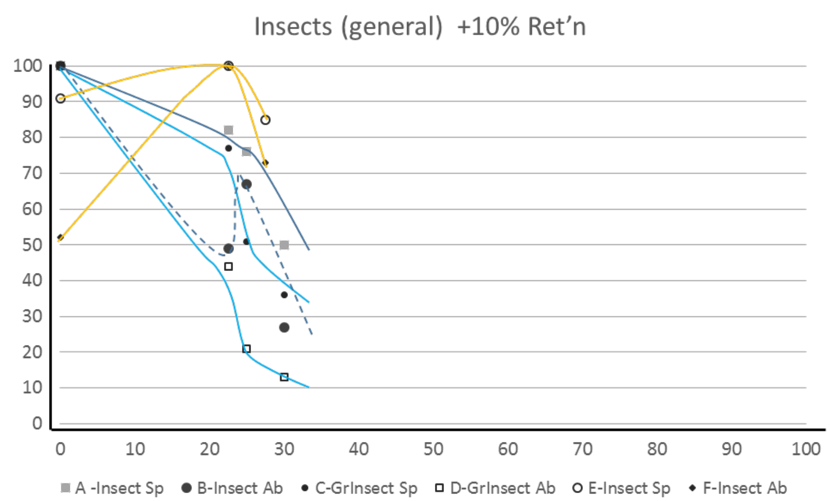
Appendix B — Individually Plotted (Graphed) Information Presented on Pages 13-16 of Appendix A

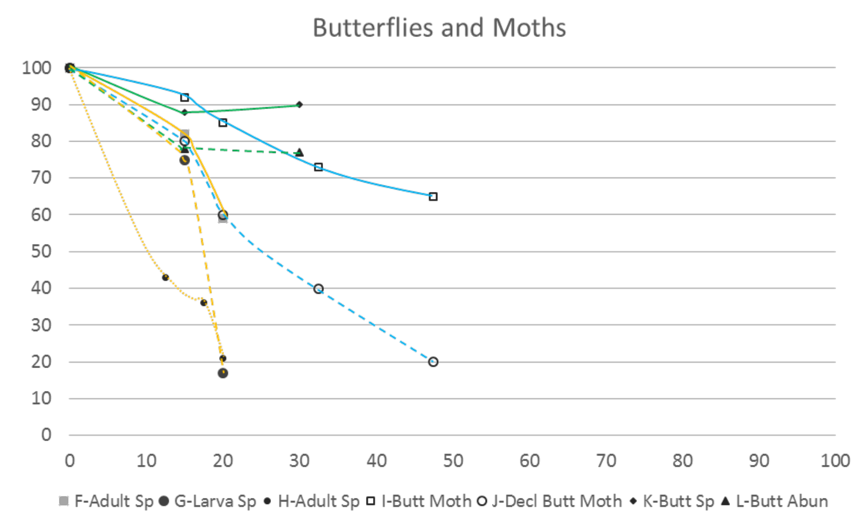
Don DeLong, West Zone – BTNF (April 5, 2018)

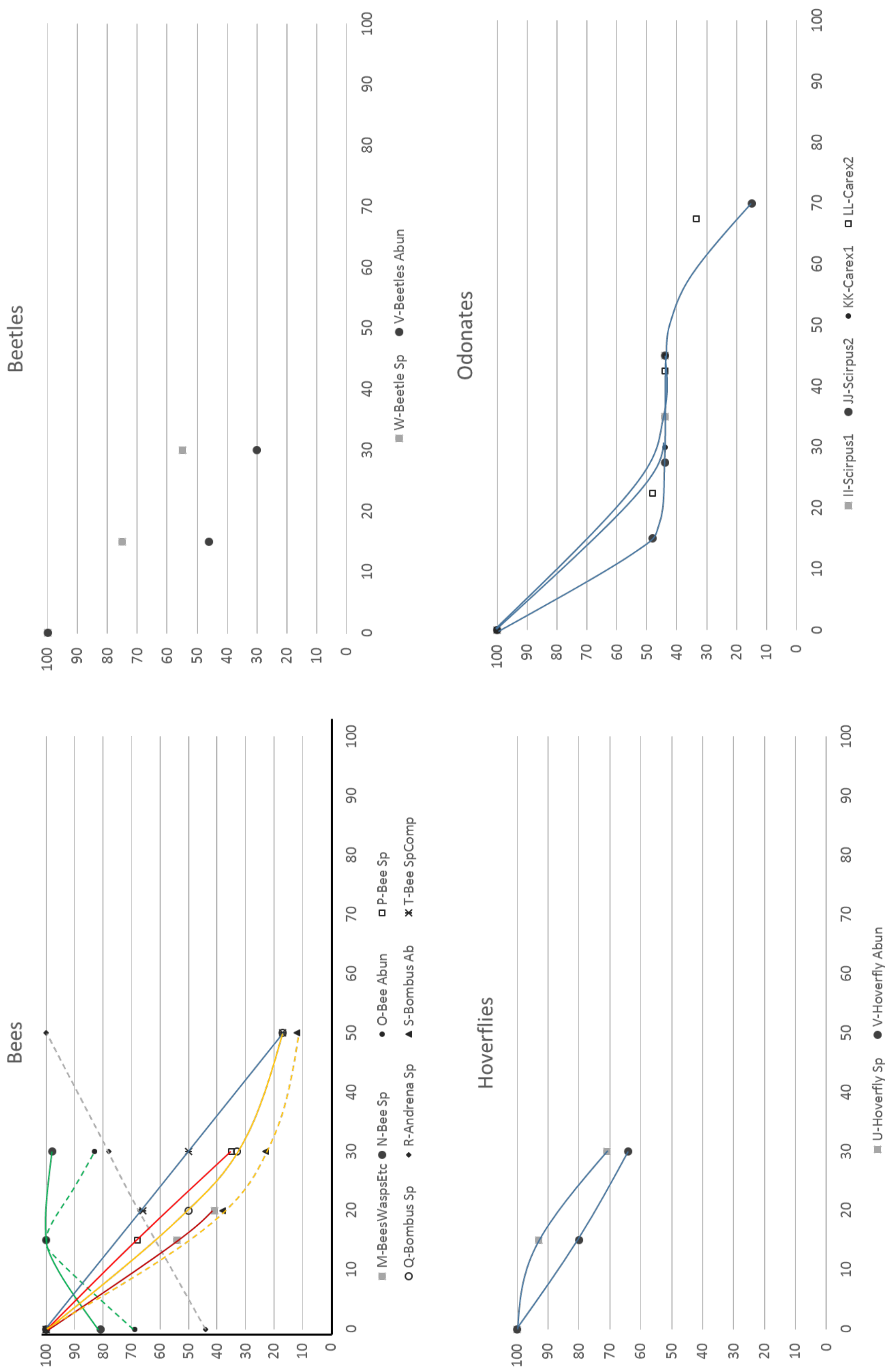
The letters in the legends of the following graphs refer to letters in the table on pages 13-16 of Appendix A. From this table, data in the “Estim’d % Ret’n of Wt.” column were plotted using the y-axis, and the corresponding data in the “Estim’d No. of Species or Abund.” column were plotted using the x- axis.


Insects (general) – No Adjustment
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100
A -Insect Sp
B-Insect Ab
C-GrInsect Sp
D-GrInsect Ab
E-Insect Sp
F-Insect Ab

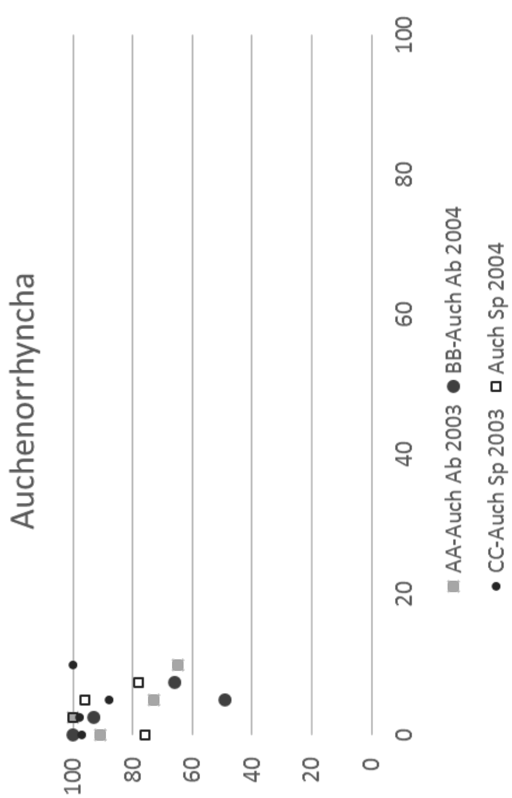

Insects (general) +15% Ret'n
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100
A -Insect Sp
B-Insect Ab
C-GrInsect Sp
D-GrInsect Ab
E-Insect Sp
F-Insect Ab

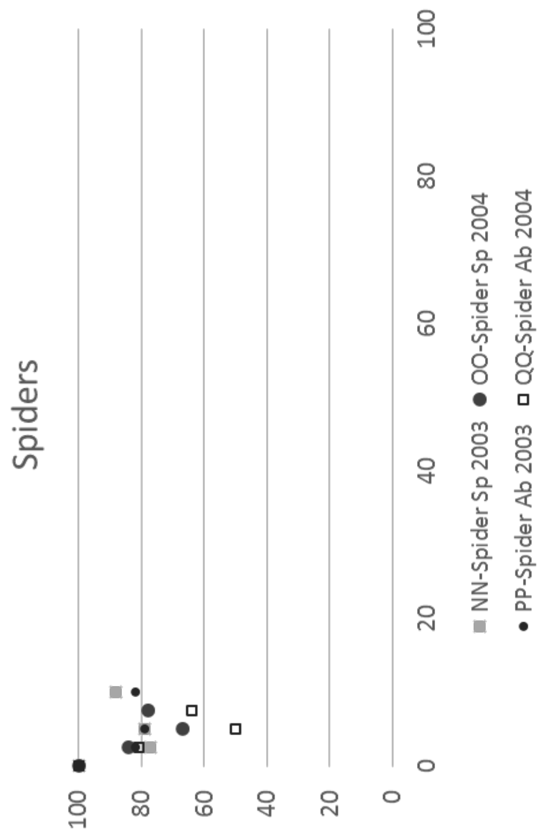

Insects (general) +10% Ret'n
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100
A -Insect Sp
B-Insect Ab
C-GrInsect Sp
D-GrInsect Ab
E-Insect Sp
F-Insect Ab

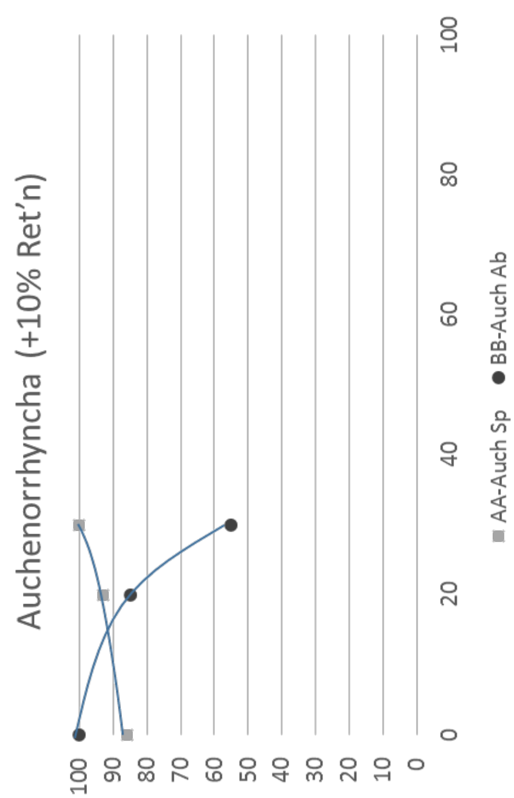

Butterflies and Moths
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100
F-Adult Sp
G-Larva Sp
H-Adult Sp
I-Butt Moth
J-Decl Butt Moth
K-Butt Sp
L-Butt Abun

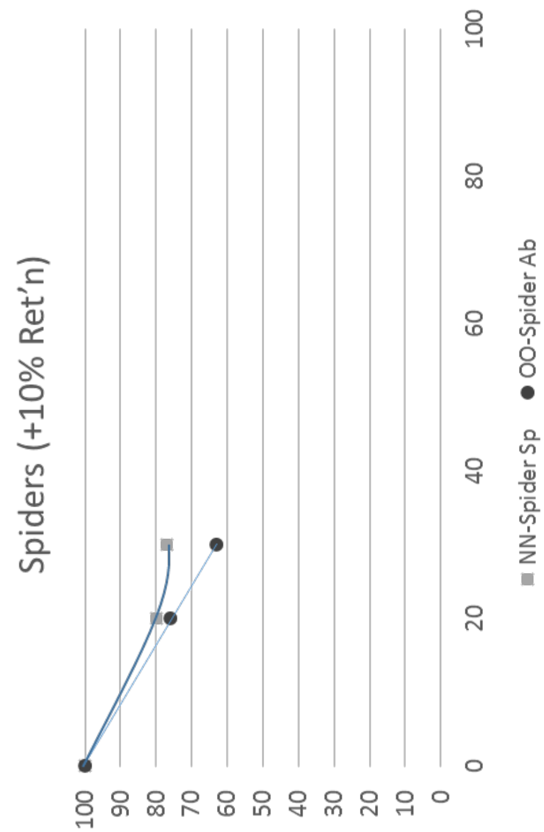


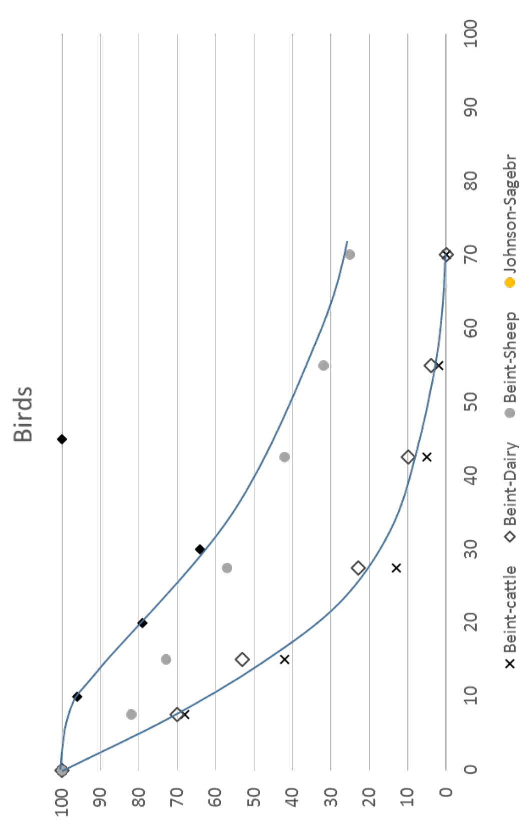
Beetles
W-Beetle Sp
V-Beetles Abun
Odonates
II-Scirpus1
JJ-Scirpus2
KK-Carex1
LL-Carex2
Bees
M-BeesWaspsEtc
N-Bee Sp
O-Bee Abun
P-Bee Sp
Q-Bombus Sp
R-Andrena Sp
S-Bombus Ab
T-Bee SpComp
Hoverflies
U-Hoverfly Sp
V-Hoverfly Abun

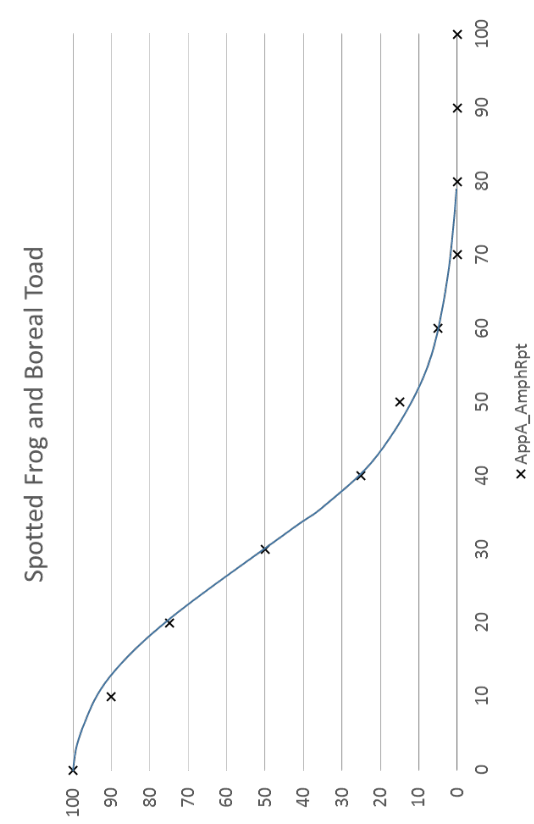

Auchenorrhyncha
AA-Auch Ab 2003
BB-Auch Ab 2004
CC-Auch Sp 2003
Auch Sp 2004
0
20
40
60
80
100

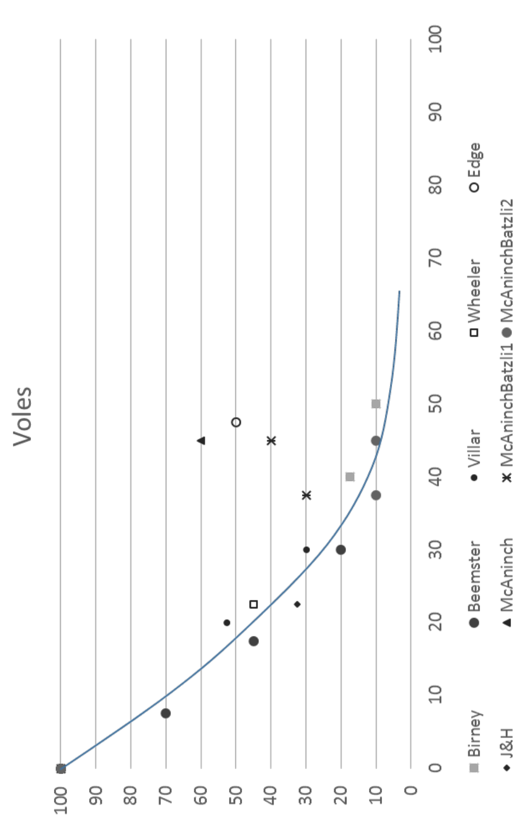

Spiders
NN-Spider Sp 2003
OO-Spider Sp 2004
PP-Spider Ab 2003
QQ-Spider Ab 2004
0
20
40
60
80
100

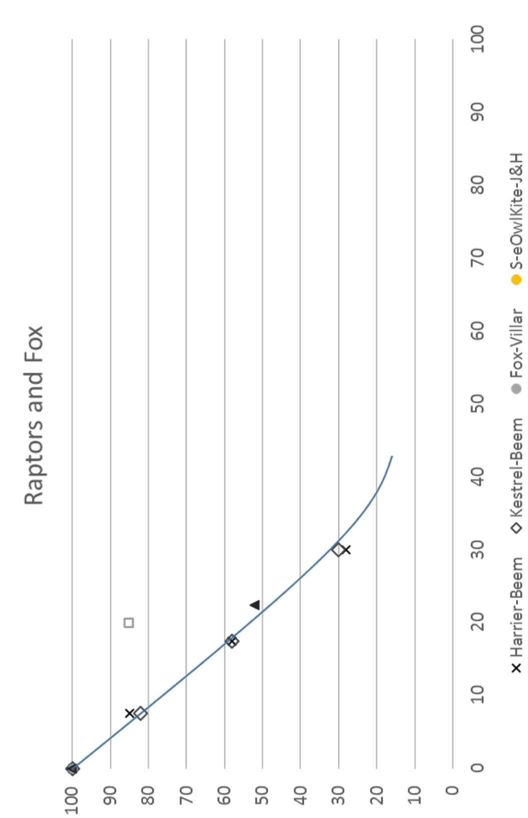

Auchenorrhyncha (+10% Ret'n)
AA-Auch Sp
BB-Auch Ab
0
10
20
30
40
50
60
70
80
90
100

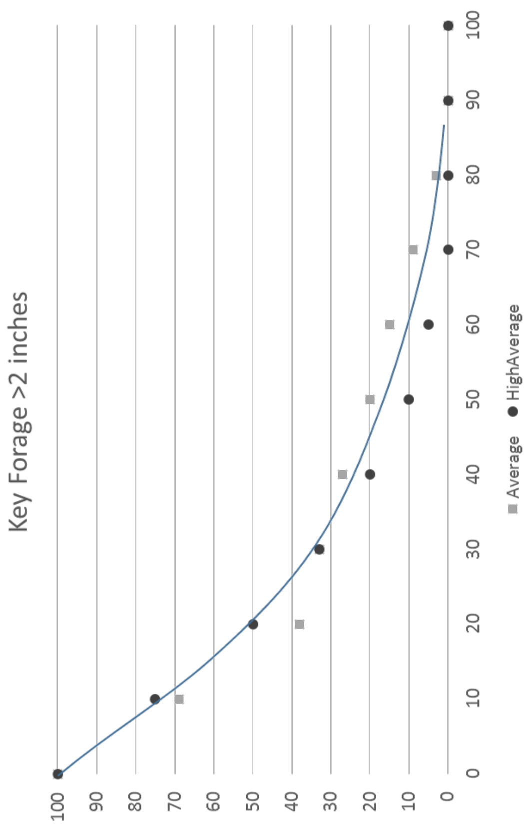

Spiders (+10% Ret'n)
NN-Spider Sp
OO-Spider Ab
0
10
20
30
40
50
60
70
80
90
100

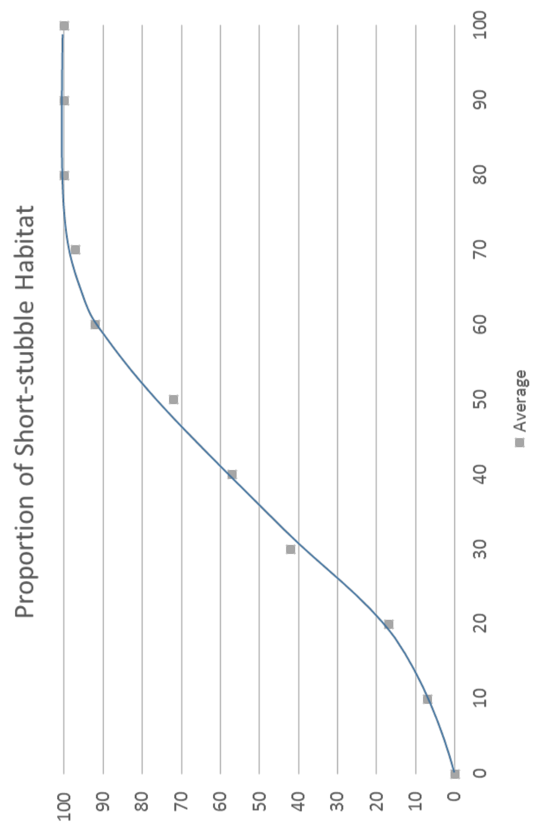

Birds
Beint-cattle
Beint-Dairy
Beint-Sheep
Johnson-Sagebr


Spotted Frog and Boreal Toad
AppA_AmphRpt


Voles
Birney
Beemster
Villar
Wheeler
Edge
J&H
McAninch
McAninchBatzli1
McAninchBatzli2


Raptors and Fox
Harrier-Beem
Kestrel-Beem
Fox-Villar
S-eOwlKite-J&H


Key Forage >2 inches
Average
HighAverage
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0


Proportion of Short-stubble Habitat
Average
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0