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FORAGE PREFERENCE INDICES:

ADJUSTING FORAGE AVAILABILITY DATA

FOR HABITAT SELECTION

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ABSTRACT

Forage preference indices for Waterton Canyon bighorn sheep were calculated 2 ways by adjusting the forage availability data. Availability data from field measurements were (1) weighted by the proportional area of each habitat type in which each forage species occurred, to yield estimates of availability throughout the canyon (single-weighted); and (2) this availability figure was further adjusted for the proportions of times foraging bighorns were observed in each habitat type (double-weighted). With the latter adjustment, preferences for forage species occurring in "preferred" habitats decreased and preferences for species in "avoided" habitats increased. Adjusting availability data for foraging-site selection may give a more realistic measure of forage availablility.

INTRODUCTION

Many factors influence forage selection and forage preference by wild animals. Consequently, several methods for calculating and analyzing data on animal forage preference have been proposed (Krueger 1972, Neu et al. 1974, Petrides 1975, Ellis et al. 1976, Johnson 1980, Hobbs and Bowden 1982). The simplest preference index is a measure of the percent use of an item in proportion to the percent availability of the item. In food habits studies this is percent of a plant species in the total diet divided by percent of the plant species in the total available forage. A preference index greater than 1 indicates the forage species is more frequent in the diet than in the habitat and hence "preferred" (Petrides 1975). A preference index less than 1 indicates the forage species is less frequent in the diet than in the habitat and hence "avoided," or at least not sought after. More complex ratios (Krueger 1972) or ranking methods (Johnson 1980) may be used to develop preference indices and single data sets can yield different results with different methods.

For most forage preference indices, it is assumed that all vegetation is "available" forage to the herbivore, when in fact behavioral adaptations and other factors may preclude use of much "available" forage. This may be particularly true of wild sheep, which are seldom observed far from escape terrain (Flook 1962, Oldemeyer 1966, Capp 1967).

Selection of foraging sites by wildlife may be influenced by community structure as much as by availability of forage resources. Wikeem and Pitt (1979) felt that a high utilization of rough fescue (Festuca scabrella) by California bighorns (Ovis canadensis californiana) in August was due to the presence of rough fescue only in the understory of ponderosa pine (Pinus ponderosa) where bighorns sought shade. Thompson (1965) found the most preferred food of captive wild voles (Microtus pennsylvanicus) was white clover (Trifolium repens). However, in the wild, voles made very little use of white clover sites because these areas were characterized by very little surface litter and hence subjected voles to increased risks of predation and adverse temperatures. Habitat selection by Rocky Mountain bighorns (O. c. canadensis) in Waterton Canyon, Colorado was affected by visibility as bighorns selected habitats with more open vegetation (Risenhoover 1981).

If herbivores select foraging habitats for characteristics other than their forage resources, forage in nonselected habitats is unavailable to the animals. Consequently, only forages in habitats used as foraging sites should be considered as "available" when calculating forage preference indices. Furthermore, some foraging habitats may be used relatively more frequently than other habitats. Forages in the more frequently used habitats are therefore more available to the animals than are forages in the less frequently used habitats. If data on relative use of foraging habitats are obtained, data on forage resources in those habitats may be adjusted to reflect habitat selection when estimating forage availability for use in calculating forage preference indices. This paper describes a method for using data on habitat selection to adjust data on forage abundance to reflect relative forage availability.

METHODS

Data were collected in Waterton Canyon, Colorado during 16 April - 15 October 1980-81, hereafter referred to as "summer". Bighorn sheep pellet groups were collected bimonthly during 15 June - 15 October 1980 and during 15 April - 30 August 1981. Two pellets from each group were pooled into each bimonthly sample. Food habits data were obtained by microhistological analyses of feces at the Composition Analysis Laboratory, Colorado State University (Sparks and Malechek 1968).

Forage availability data were collected during July-August 1981. Availability was measured as plant canopy-coverage using a modification of the technique described by Daubenmire (1959). Transects were placed in 5 habitat types (Table 1). Forty 0.1-m^2 (20x50 cm) frames were established at 1 m intervals on alternating sides of a stretched 40 m tape in each transect.

Relative use of foraging habitats by bighorns was determined during summer of 1980-81. All observations of foraging bighorns were extracted from habitat preference data of Risenhoover (1981), Simmons (1982), Rominger (1983) and Dale (pers. comm.).

Summer forage preference indices were calculated by 2 methods for comparison (Figure 1). Percent canopy-cover for each forage species was first weighted (single-weighted) by the proportion of study area (Table 1) for each habitat type in which a forage species occurred. This provided an estimate of percent composition by forage species for the entire bighorn range. For the second method (Figure 1) the above estimate was weighted again (double-weighted) by the proportion of time foraging bighorns were observed in each habitat type in which the plant species occurred. (Table 2).

RESULTS

Forty-eight plant species or genera (identification to species is not always possible with microhistological analyses of feces) occurred in the summer diet of Waterton bighorns. Eighty-five plant species occurred in the 920 established Daubenmire frames and 339 observations of foraging bighorns occurred in the 5 habitat types measured for forage availability.

Only 6 species comprised 1 percent or more of the summer diet (Table 3). These 6 species represented 94 percent of the bighorn summer diet. Only 9 species comprised 1 percent or more of the total plant canopy-cover in Waterton Canyon. These 9 species represented 90 percent of the available summer foliage.

Forage preference indices are presented in Table 5 for the 6 species that comprised at least 1 percent of the summer diet. Species occurring in "preferred" habitat types, true mountainmahogany (Cercocarpus montanus), needle-and-thread (Stipa comata), and sand dropseed (Sporobolus cryptandrus), all had high preference indices when their availabilities were single-weighted by habitat-type availability (Table 5). Species occurring in the "avoided" habitats, Gambel oak (Quercus gambelii), and most sedges (Carex spp.), had low preference indices when availabilities were single-weighted. Adjustment of forage availabilities for observations of foraging bighorn habitat selection altered the forage availability figures (Table 4) and therefore the preference indices (Table 5). The preference index for true mountainmahogany declined from 14 to 3, for needle-and-thread it declined from 3 to 0.7, and for sand dropseed it declined from 6 to 2. Preference indices for Gambel oak and sedges increased: from 0.4 to 0.7 and from 0.1 to 0.3, respectively. Flannel mullein (Verbascum thapsus) had a preference index of 25, based on single-weighted availability, and a preference index of 5, based on double-weighted availability. Flannel mullein occurred on only 1 transect in mountain shrub habitat. Flannel mullein is a biennial that tends to grow on disturbed sites that were not measured in Waterton Canyon. This probably caused the high preference indices in both weightings and flannel mullein may not be as actively selected as the data suggest.

Table 1. Normalized[a] percent-availability of habitat types and numbers of transects sampled for available forage in Waterton Canyon.

Habitat Type	Available Area (%)	No. Transects Sampled
Grassy Opening	2	5
Open Mt. Shrub	4	4
Mountain Shrub	11	9
Conifer	41	2
Oak	42	3
Total	100	23

[a]These habitat types comprised 94.7% of the Waterton Canyon study area.

Table 2. Relative use of foraging habitats by Waterton Canyon bighorn sheep, 16 April - 15 October, 1980-81.

Habitat Type	Foraging Observations (%)
Grassy Opening	2
Open Mt. Shrub	23
Mountain Shrub	60
Conifer	8
Oak	6

Table 3. Plant species comprising at least 1% of the summer diet and their relative availabilities on Waterton Canyon bighorn summer range, 16 April - 15 October, 1980-81.

Species	Diet (%)	Availability (%)
Mountainmahogany	70	5
Gambel oak	17	41
Sedges	3	23
Sand dropseed	2	tr[a]
Needle-and-thread	1	tr
Great mullein	1	tr

[a]tr = <1%

Table 4. Availabilities of selected forage species in Waterton Canyon: a comparison of availabilities weighted by habitat composition (single-weighted) vs. availabilities weighted by habitat composition and by bighorn foraging site selection during summer (double-weighted).

Species	Relative Forage Availability (%)	
	Single-weighted	Double-weighted
Gambel Oak	41	25
Sedges	23	12
Mountainmahogany	5	23
Needle-and-thread	0.5	2
Sand dropseed	0.3	0.8
Great mullein	tr[a]	tr

[a]tr= <1%

Table 5. Preference indices for selected forage species in Waterton Canyon: a comparison of preferences when forage availabilities are weighted by habitat composition (single-weighted) vs. when forage availabilities are weighted by habitat composition and by bighorn foraging site selection during summer (double-weighted).

Species	Preference Index	
	Single-weighted Availabilities	Double-weighted Availabilities
Gambel Oak	0.4	0.7
Sedges	0.1	0.3
Mountainmahogany	14	3
Needle-and-thread	3	0.7
Sand dropseed	6	2
Great mullein	25	5

DISCUSSION

In the above example, forage preference indices were altered by adjusting availability data for foraging-habitat selection by bighorns. Although the rankings of preference values did not change (Table 5), such rankings could change in other situations. Furthermore, for some purposes such as computer-simulating of grazing systems (Cooperrider and Bailey 1981), it may be desirable to separate habitat selection from forage selection. This may be accomplished using forage preference indices based on double-weighted estimates of forage availabilities.

Single-weighted by habitat availability, true mountainmahogany represented only 5 percent of the total available forage in Waterton Canyon. Using this availability figure produced a preference index of 14 for mountainmahogany. However, during summer 60 percent of observations of foraging bighorns occurred in the mountain shrub type wherein mountainmahogany comprised 46 percent of the available forage. This habitat type offered good escape terrain and was near the only source of water available to Waterton bighorns in summer. If selection of the mountain shrub type was not entirely because it contained mountainmahogany forage, but partly because of escape terrain and availability of water, the preference factor of 14 overrates the attractiveness of mountainmahogany. Double-weighting the forage availability figure to account for habitat selection reduced the preference index for mountainmahogany to 3. We suspect this is more realistic when compared to other preference indices based on double-weighting in Table 5.

By contrast, single-weighted by habitat availability, Gambel oak represented 41 percent of the total forage in Waterton Canyon. Use of this figure produced a preference index of 0.4. Much of the oak forage in Waterton Canyon occurs in vegetation avoided by bighorns because it is physically impenetrable and also because visibility is poor in the oak type. Thus its availability as forage was overrated in single-weighted calculations. For a short period in spring, when Gambel oak leaves were young, oak comprised 73 percent of the bighorn diet. Consequently the larger preference index of 0.7, obtained when availability of oak is calculated using bighorn foraging site selection (double-weighting) seems more realistic than does the lower index of 0.4.

Selection of foraging habitat by a herbivore may be largely a function of the abundance of preferred forages in the habitat. When evidence suggests this is true, the double-weighting of forage availability data, as suggested here, will be unnecessary for calculating forage-preference indices. However, if evidence suggests that selection of foraging habitat is based on factors other than the abundance of preferred forages, biologists should consider adjusting forage availability data to account for habitat selection.

LITERATURE CITED

Capp, J. C. 1967. Bighorn sheep, elk, and deer competition. M.S. Thesis. Colorado State Univ., Fort Collins. 132pp.

Cooperrider, A. Y., and J. A. Bailey. 1981. Analysis of Competition between domestic livestock and wild ungulates with computer simulation. Pages 421-440 in L. Nelson, Jr., and J. M. Peek, eds. Proc. Wildlife-livestock Relationship Symposium. Coeeur d'Alene, Idaho. Forest, Wildl. and Range Exp. Sta., Univ. Idaho, Moscow. 614pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-96.

Ellis, J. E., J. A. Wiens, C. F. Rodell, and J. C. Anway. 1976. A conceptual model of diet selection as an ecosystem process. J. Theoretical Biology 60:93-108.

Flook, D. R. 1962. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Symp. on Grazing, Brit. Ecol. Soc. April:119-128.

Hobbs, N. T., and D. C. Bowden. 1982. Confidence intervals on food preference indices. J. Wildl. Manage. 46(2):505-507.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61(1):65-71.

Krueger, W. C. 1972. Evaluating animal forage preference. J. Range Manage. 25(6):471-475.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38(3):541-545.

Oldemeyer, J. C. 1966. Winter ecology of bighorn sheep in Yellowstone National Park. M.S. Thesis, Colorado State Univ., Ft. Collins. 106pp.

Petrides, G. A. 1975. Principal food versus preferred foods and their relation to stocking rates and range condition. Biol. Conserv. 7:161-169.

Risenhoover, K. L. 1981. Winter ecology and behavior of bighorn sheep, Waterton Canyon, Colorado. M.S. Thesis, Colorado State Univ., Fort Collins. 111pp.

______, and J. A. Bailey. 1980. Visibility: An important habitat factor for an indigenous, low-elevation bighorn herd in Colorado. Proc. Bienn. Symp. North Wild Sheep and Goat Counc. 2:18-28.

Rominger, E. M. 1983. Waterton Canyon bighorn sheep: Food habits and habitat management. M.S. Thesis. Colorado State Univ., Ft. Collins.

Simmons, B. W. 1982. Summer and fall ecology and behavior of bighorn sheep, Waterton Canyon, Colorado. M.S. Thesis. Colorado State Univ., Fort Collins. 211pp.

Sparks, D. R., and J. C. Malechek. 1968. Estimating dry weight in diets using a microscope technique. J. Range Manage. 21(4):264-265.

Thompson, D. Q. 1965. Food preference of the meadow vole (Microtus pennsylvanicus) in relation to habitat affinities. American Midland Naturalist 74:76-86.

Wikeem, B. M. and M. D. Pitt. 1979. Interpreting diet preference of California bighorn sheep on native rangeland in south-central British Columbia. Rangelands 1(5):200-202.

Fig. 1. Formulae for (1) forage preference index (FPI) with forage availability data weighted by habitat composition (single-weighted) and for (2) FPI with forage availability weighted by both habitat composition and herbivore foraging-site selection (double-weighted). Examples using true mountainmahogany (Cemo), which occurs in 2 habitat types in Waterton Canyon. i=forage species, j=habitat types, Di=proportion of species i in diet, Fij=proportion of species i in all forage of habitat type j, Aj=proportion of total study area comprised of habitat type j, Uj=proportion of foraging observations within habitat type j. In the examples, P. represents "proportion;" and will usually be expressed as a decimal.

FORMULA	EXAMPLE
(1) With single-weighted availability	(1) With single-weighted availability
$$FPI = \frac{D_i}{\sum_j F_{ij} A_j / \sum_i \sum_j F_{ij} A_j}$$	$$\frac{\text{P. Cemo in diet}}{\left(\text{P.Cemo in Habitat A}\right)\left(\text{P.Avail.of Habitat A}\right)+\left(\text{P.Cemo in Habitat B}\right)\left(\text{P.Avail.of Habitat B}\right) \Big/ \Sigma\left(\text{P.Forage in Each Habitat Type}\right)\left(\text{P.Avail.of Each Habitat Type}\right)}$$
(2) With double-weighted availability	(2) With double-weighted availability
$$FPI = \frac{D_i}{\sum_j F_{ij} A_j U_j / \sum_i \sum_j F_{ij} A_j U_j}$$	$$\frac{\text{P. Cemo in diet}}{\left(\text{P.Cemo in Habitat A}\right)\left(\text{P.Avail.of Habitat A}\right)\left(\text{P.Foraging Obs. in Habitat A}\right)+\left(\text{P.Cemo in Habitat B}\right)\left(\text{P.Avail.of Habitat B}\right)\left(\text{P.Foraging Obs. in Habitat B}\right) \Big/ \Sigma\left(\text{P.Forage in Each Habitat Type}\right)\left(\text{P.Avail.of Each Habitat Type}\right)\left(\text{P.Foraging Obs. in Each Habitat Type}\right)}$$