ual of the vascular plants of Texas. Texas Res. Found., Renner, Tex. 1881pp.

HOLECHEK, J. L. 1982. Sample preparation techniques for microhistological analysis. J. Range Manage. 35:267–268.

———, AND B. GROSS. 1982. Training needed for quantifying simulated diets from range plants. J. Range Manage. 35: In Press.

———, AND M. VAVRA. 1981. The effect of slide and frequency number on the precision of microhistological analysis. J. Range Manage. 34:338–339.

———, ———, AND R. D. PIEPER. 1982. Botanical composition determination of range herbivore diets: A review. J. Range Manage. 35:In Press.

OOSTING, H. J. 1956. The study of plant communities. W. H. Freeman Co., San Francisco, Calif. 440pp.

SCOTT, T. G., AND C. H. WASSER. 1980. Checklist of North American plants for wildlife biologists. The Wildl. Soc., Washington, D.C. 58pp.

SPARKS, D. R., AND J. C. MALECHEK. 1968. Estimating percentage dry weight in diets using a microscopic technique. J. Range Manage. 21:264–265.

STEEL, R. G., AND J. H. TORRIE. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., New York, N.Y. 481pp.

VAVRA, M., AND J. L. HOLECHEK. 1980. Factors influencing microhistological analysis of herbivore diets. J. Range Manage. 33:371–374.

Received 12 November 1980.
Accepted 26 June 1981.

CONFIDENCE INTERVALS ON FOOD PREFERENCE INDICES

N. T. HOBBS, Colorado Division of Wildlife, 317 West Prospect Road, Fort Collins, CO 80526; and D. C. BOWDEN, Statistics Department, Colorado State University, Fort Collins, CO 80523.

Preference indices are widely used to infer the relative likelihood that an animal will consume a particular food (Heady and Van Dyne 1965, Chamrad and Box 1968, Wetzel et al. 1975, Barton and Black 1978, Papageorgiou 1978, Alexander 1980, Johnson 1980, Nyström 1980, Stormer and Bauer 1980). Often preference indices are calculated as if animal diets and food availability were measured without error. This assumption can lead to erroneous conclusions. The objectives of this paper are to show a method for calculating confidence intervals on preference indices and to use this technique to illustrate the potential fallibility of inferences based on point estimates alone.

Preference indices are frequently calculated as the ratio of the estimated percentage of a food item in an animal's diet divided by the total amount of that food in the habitat where the animal feeds. Values of this index greater than 1 are thought to indicate preference, while values less than 1 indicate rejection (Heady and Van Dyne 1965, Petrides 1975). It is often suggested that one food is preferred over another because its preference index value is greater. For these inferences to be statistically valid, it is necessary to estimate the error associated with each preference index value.

Confidence intervals on simple ratio preference indices can be constructed where:

$\bar{x}$ = Mean percentage of a food item across observed diets.
$\bar{y}$ = Mean percentage of biomass, cover, or frequency of the food item in replicate study plots.
s_x = Standard deviation of percentages used to calculate $\bar{x}$.
s_y = Standard deviation of percentages used to calculate $\bar{y}$.
n_x = Number of independent replicates of diet composition.
n_y = Number of study plots.
PI = Preference index = $\bar{x} \div \bar{y}$.

Table 1. Preference indices for elk forage species in aspen communities in Rocky Mountain National Park, Colorado, 1978–79.[a]

Plant species	Percent in diet[b] $\bar{x}$	SE	Percent in biomass[c] $\bar{y}$	SE	Preference index[d]	df	95% CI
Rosa woodsii (stems)	1	0.3	4	1.2	0.25	6.82	(0.0–0.505)
Populus tremuloides (stems)	0.1	0.05	6	2.8	0.02	6.88	(0.0–0.05)
(leaves)	36	3.0	26	4.4	1.35	4.36	(0.68–2.19)
Carex spp.	3	1.0	4	1.3	0.75	7.00	(0.0–1.45)
Poa pratensis	16	6.0	10	2.7	1.60	6.82	(0.0–3.37)
Phleum pratensis	4	1.0	8	2.7	0.50	5.82	(0.0–1.02)
Calamagrostis canadensis	14	1.0	9	2.2	1.56	3.52	(0.39–2.64)
Bromus inermis	2	0.3	4	0.6	0.50	6.94	(0.23–0.66)
Juncus balticus	2	1.0	0.8	0.4	2.50	6.79	(0.0–6.57)
Forbs	3	1.0	27	0.9	0.11	4.09	(0.01–0.21)

[a] Diet data from Hobbs et al. (1981), biomass data from Hobbs (1979).
[b] Based on observations of 5 elk diets. Total diet subsample = 17,790 bites.
[c] Based on percent composition of 4 1-ha study plots, each subsampled with 30 ¼-m² clipped plots.
[d] Preference index = percent in diet ÷ percent in biomass.

SE = Standard error of the preference index.

$$\mathrm{SE}(PI) = \sqrt{\frac{1}{\bar{y}^2}\left[\frac{s_x^{\,2}}{n_x} + (PI)^2\frac{s_y^{\,2}}{n_y}\right]},$$

$$\mathrm{df} = \frac{\left[\dfrac{s_x^{\,2}}{n_x} + (PI)^2\dfrac{s_y^{\,2}}{n_y}\right]^2}{\dfrac{\left(\dfrac{s_x^{\,2}}{n_x}\right)^2}{n_x - 1} + \dfrac{\left(\dfrac{(PI)^2 s_y^{\,2}}{n_y}\right)^2}{n_y - 1}}, \text{ and}$$

$$\text{confidence interval} = PI \pm t_{(\mathrm{df}\alpha/2)}\mathrm{SE}(PI).$$

This interval is based on a Taylor series expansion for estimation of variance (Myer 1970:139). It allows assessment of the repeatability of differences among individual index values. By observing whether the interval overlaps 1, it can be inferred whether preference or rejection is statistically significant.

Confidence intervals on preference indices for elk (*Cervus elaphus*) winter diets selected in aspen communities in Rocky Mountain National Park, Colorado (Hobbs et al. 1981) illustrate the danger of inferences based on point estimates alone (Table 1). In the absence of interval estimates it might be surmised that Kentucky bluegrass (*Poa pratensis*), bluejoint reedgrass (*Calamagrostis canadensis*), Baltic rush (*Juncus balticus*), and quaking aspen (*Populus tremuloides*) leaves are preferred elk foods since their index values are greater than 1. However, none of these indices differ ($P < 0.05$) from unity. Similarly, it could be inferred that rushes are more likely to be eaten than woods rose (*Rosa woodsii*) stems, since the preference index for rushes is 10 times greater than the value for rose. Examination of the confidence interval on those indices shows that conclusion is unfounded.

While large variances are associated with these diet and biomass data, such variability is common, particularly for species which occur infrequently in the diet or are rare in the habitat (Heady and Van Dyne 1965:484, Martin 1970:97–98, Medin 1970:134–135, McIntyre 1978:17). Consequently, unless care is taken to obtain precise use and availability data, the preference index will not provide meaningful inferences.

Point estimates of preference indices

unaccompanied by confidence intervals could be misleading. Their use should be avoided.

LITERATURE CITED

ALEXANDER, L. E. 1980. Forage selection by mule deer at Rocky Flats, Colorado. M.S. Thesis. Colorado State Univ., Fort Collins. 98pp.

BARTON, D. H., AND H. C. BLACK. 1978. Feeding habits of mazama pocket gophers in south-central Oregon. J. Wildl. Manage. 42:383–390.

CHAMRAD, A. D., AND T. W. BOX. 1968. Food habits of white-tailed deer in south Texas. J. Range Manage. 21:158–164.

HEADY, H. F., AND G. M. VAN DYNE. 1965. Botanical composition of sheep and cattle diets on a mature annual range. Hilgardia 36:465–492.

HOBBS, N. T. 1979. Winter diet quality and nutritional status of elk in the upper montane zone, Colorado. Ph.D. Diss. Colorado State Univ., Fort Collins. 131pp.

———, D. L. BAKER, J. E. ELLIS, AND D. W. SWIFT. 1981. Composition and quality of elk winter diets in Colorado. J. Wildl. Manage. 45:156–171.

JOHNSON, B. K. 1980. Bighorn sheep food habits, forage preferences, and habitat selection in alpine and subalpine communities. Ph.D. Diss. Colorado State Univ., Fort Collins. 170pp.

MARTIN, S. C. 1970. Relating vegetation measurements to forage consumption by animals. Pages 93–99 *in* Range and wildlife habitat evaluation—A research symposium. U.S. Dep. Agric. Misc. Publ. 1147.

MCINTYRE, G. A. 1978. Statistical aspects of vegetation sampling. Pages 8–21 *in* L. t'Mannetje, ed. Measurement of grassland vegetation and animal production. Commonwealth Agric. Bur. Hurley, Berkshire, U.K.

MEDIN, D. E. 1970. Stomach content analysis: collections from wild herbivores and birds. Pages 133–145 *in* Range and wildlife habitat evaluation—A research symposium. U.S. Dep. Agric. Misc. Pub. 1147.

MYER, P. 1970. Introductory probability and statistical applications. 2nd ed. Addison-Wesley, Reading, Mass. 367pp.

NYSTRÖM, A. 1980. Selection and consumption of winter browse by moose calves. J. Wildl. Manage. 44:463–468.

PAPAGEORGIOU, N. R. 1978. Food preference, feed intake, and protein requirements of red deer in central Greece. J. Wildl. Manage. 42:940–943.

PETRIDES, G. A. 1975. Principal foods versus preferred foods and their relation to stocking rate and range condition. Biol. Conserv. 7:161–169.

STORMER, F. A., AND W. A. BAUER. 1980. Summer forage use by tame deer in northern Michigan. J. Wildl. Manage. 44:98–106.

WETZEL, J. F., J. R. WAMBAUGH, AND J. M. PEEK. 1975. Appraisal of white-tailed deer winter habitats in northeastern Minnesota. J. Wildl. Manage. 39:59–66.

Received 13 November 1980.
Accepted 26 June 1981.

BATPROOFING OF BUILDINGS BY INSTALLATION OF VALVELIKE DEVICES IN ENTRYWAYS

DENNY G. CONSTANTINE, State of California Department of Health Services, 2151 Berkeley Way, Berkeley, CA 94704.

Bats (Chiroptera) can be permanently excluded from most buildings by closing exit holes after bats fly out at night to feed or after they leave for the winter (Silver 1935, Constantine 1979). The inspiration to batproof is greatest when bats are present, but it wanes in winter. The fear of high ladder work at night, required to close the last exit hole, is a primary deterrent to batproofing when bats are in residence. A 1-way valve, permitting bats to exit the roost but not allowing re-entry could be installed in daytime, greatly facilitating batproofing as a means of control. This paper describes such a device and the results of laboratory and field tests to determine its efficacy. Application has been made for a patent covering relevant methods and mechanisms.

DESCRIPTION OF DEVICES

Preliminary laboratory observations had indicated that, while bats could re-