A Weather Severity Index on a Mule Deer Winter Range

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Abstract

Temperature, wind, and snow conditions predictably affect the nutrition, behavior, distribution, productivity, and mortality of free-ranging cattle and big game in winter. Indexing of data obtained with commonly available weather instruments to reflect episodes of positive and negative energy balances of free-ranging ruminants could aid scheduling of feeding programs and planning of cover-forage manipulations. Such a weather severity index was developed and tested over 11 winters. Plausible levels of stress and episodes of relative severity were depicted during winters when mule deer exhibited low, moderate, and high mortality. The index curves mirrored over-winter declines of fat reserves probably sustained by mule deer. Lesser weather severity was predicted and measured in a western juniper woodland than in an adjacent rabbitbrush steppe community in southcentral Oregon.

Review of literature on ruminant physiology, microclimate, habitat structure, and diet quality suggested that productivity and survival of free-ranging ruminants could be predicted from interrelationships among those factors. Therefore, animal performance would likely be improved by managers who provided domestic and wild ruminants with shelter, to moderate effects of weather, or with a readily digestible diet, to satisfy nutrient requirements (Brody 1956, Short et al. 1969, Silver et al. 1971, Verme and Ozoga 1981, Robbins 1983).

Specific physiological responses, feeding efficiencies, behavioral reactions, and distribution patterns of deer and cattle appear related to levels of temperature, wind, radiation, and snow (Wallmo and Gill 1971, Holter et al. 1975, Subcommittee on Environmental Stress 1981, Finch et al. 1982).

Nutrient balance, feed intake, heat production, and growth rate monitored under controlled conditions indicate domestic and wild ruminants utilize similar physiological strategies to endure adverse weather and yet remain productive (Moen 1968a, Nordan et al. 1970, Robinette et al. 1973).

Structural elements of vegetation predictably influence microclimates to which free-ranging livestock and wildlife may be exposed. Geiger (1966) described how grasslands, shrublands, and forests created microclimates for animals. Reifsnyder and Lull (1965) developed models that predict temperature, radiation, and snow depth from independent variables such as tree height and crown closure. Gifford (1973) documented how radiation and wind speed changed when structures of pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) stands were altered by chainings.

Indices of severity have been used to relate weather conditions to responses of free-ranging deer. Verme (1968, 1977) found distribtuions, growth, survival, and mortality were correlated with an index derived from the chilling rate of air and the depth and hardness of snow. Roper and Lipscomb (1973) and Picton (1979) associated winter severity and climate indices with losses of deer.

Converting temperature, wind, and snow data to weather severity indices may help develop management strategies to enhance feeding efficiencies and animal performance. We describe indices derived from temperature hours, wind speeds, and snow cover and depths measured on a range grazed by cattle in spring and fall and by mule deer *(Odocoileus hemionus hemionus)* in winter. The index to weather severity is compared with observed stress on deer herds among 3 contrasting winters which reflect extremes of the 11 we monitored. We also contrast weather indices from 1 winter with structural differences between a western juniper *(Juniperus occidentalis)* plant community and a rubber rabbitbrush *(Chrysothamnus nauseosus)* plant community.

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Methods

Three weather stations were monitored from 1967 to 1978. Stations were established within plant communities where deer were systematically observed within the Silver Lake and Fort Rock management units in south-central Oregon. Station 1 was placed in a low sagebrush-antelope bitterbrush/bearded bluebunch wheatgrass *(Artemisia arbuscula - Purshia tridentata/Agropryon spicatum)* stand and monitored from 1967 to 1974. Station 2 was in a rubber rabbitbrush/bottlebrush squirreltail-cheatgrass brome *(Chrysothamnus nauseosus/Sitanion hystrix - Bromus tectorum)* stand and was monitored from 1969 to 1978. In 1974, station 1 equipment was moved to location 3, a western juniper/big sagebrush-rubber rabbitbrush/Thurber needlegrass-bottlebrush squirreltail *(Juniper occidentalis/Artemisia tridentata-Chrysothamnus nauseous/Stipa thurberiana - Sitanion hystrix)* stand and maintained for 1 winter.

Total canopy closure of juniper and shrubs was interpreted for the delineated vegetation stands by stereoscopic viewing at 3-X magnification of 1:4000 scale, natural color, aerial photographs. Average vegetation height, canopy depth, and stem density were estimated within the stand strata at random locations previously selected on the aerial photographs.

All stations were placed on south to southeast aspect slopes of 0–10% between 1,415 and 1,430 m elevation. Station 3 was <2% greater slope and <3 m higher elevation than Station 2, which was 330 m distant.

Each station consisted of a standard instrument shelter housing a thermograph and a maximum-minimum thermometer. Totalizing anemometers were placed to measure weekly air flow at about the height of a standing deer, 1 m. Snow cover and depth were sampled on 2 permanent plots once a week at each station.

Temperature, wind, and snow data were summarized every week from November through May. We counted the number of hours per week that air temperature was scribed in 7 Fahrenheit ranges on the thermograph chart. Total air movement was actually recorded to the nearest 0.1 mi and reported as 0.2 km once each week. Average wind speed was computed as total movement divided by hours between readings. Snow was estimated as the percent area of a 10-m^2 plot that was covered and was measured to the nearest 0.1 in depth (reported as 0.2 cm) once per week.

Weighting Factors

Temperature, wind, and snow data were weighted to adjust their effects to a scale of relative stress on deer. Weights were estimated from the cited published relationships applicable to adult deer consuming submaintenance forages because energy balances were not examined on this range. Signs of weights were chosen to mimic animal energy balances; negative indices resulted during weather when energy loss was expected to exceed energy gain, and positive indices resulted when gain was expected to exceed loss.

Index values were computed from air temperature and wind speed and then modified by measured snow depth and cover. A change in a weather element produced the following average change in its weighting: 1° C of temperature 0.16 units of weight, 1 km/hr wind 0.03 units, 1% snow cover 0.02 units, and 1 cm of snow

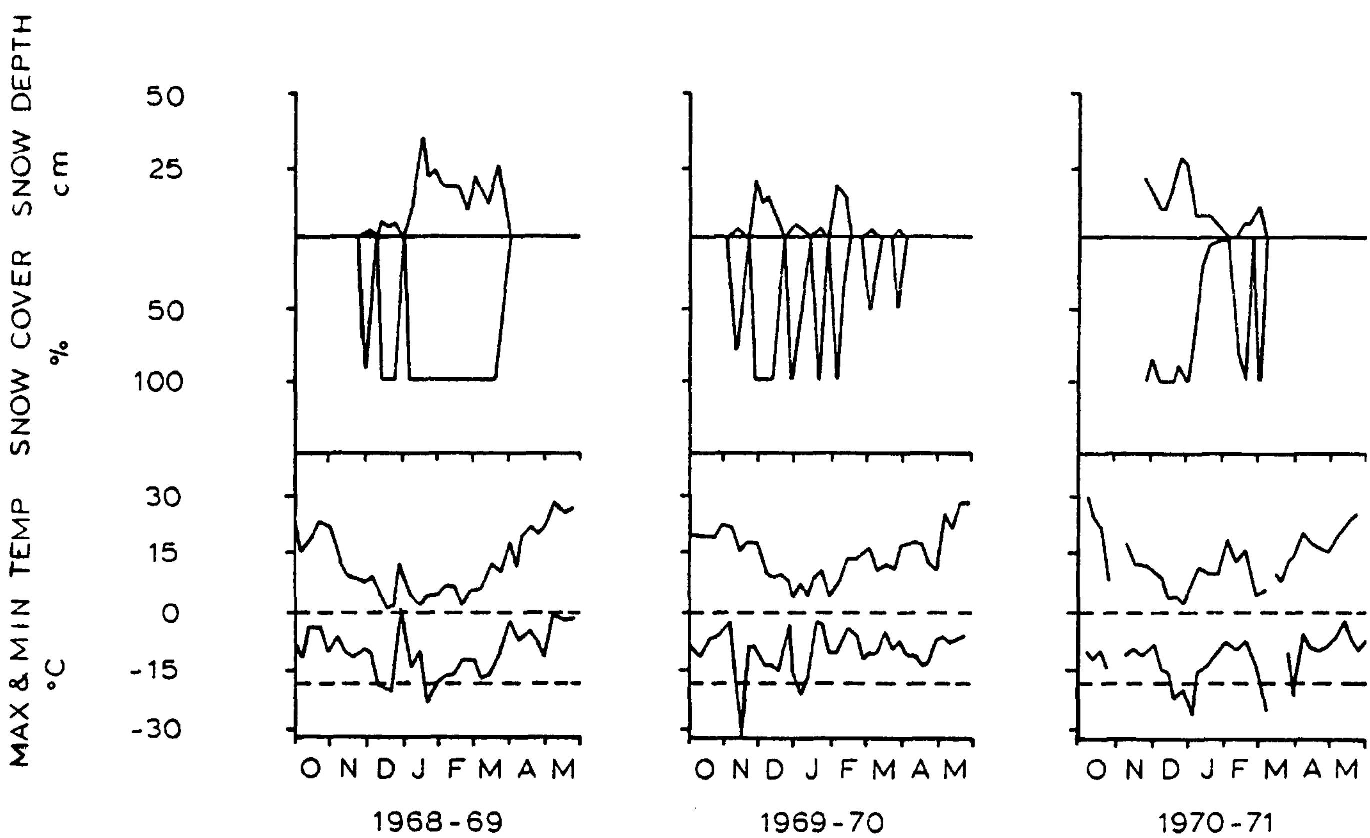

Fig. 1. *Comparison of unweighted temperature and snow data over 3 winters when weather stress was extreme (1968-69), moderate (1969-70), and average (1970-71) for southcentral Oregon.*

depth 0.03 units.

Temperature Relationships

Brody (1945), Holter et al. (1975), and Parker (1983) demonstrated that domestic ruminants, white-tailed deer *(Odocoileus virginianus)*, and mule deer increased their heat production as ambient temperatures became either cold or warm. The range of temperatures where heat production was minimal was called the thermal neutral zone. We chose temperatures from 0° C to 4.4° C to approximate the reported lower critical temperature of the thermal neutral zone (Moen 1968b). Holter et al. (1975) demonstrated that heat production of white-tailed deer in winter coat also increased in laboratory environments warmer than 12° C; therefore, we chose 10° C as our upper critical temperature because free-ranging mule deer in winter coat panted and used shady cover at temperatures warmer than that. The weights for temperature ranges produced increasingly negative indices as temperature fell below the lower critical temperature. Positive indices were computed for temperatures within the thermal neutral zone. Negative indices resulted when temperatures rose above the upper critical temperature (Table 1).

Wind Relationships

We selected wind chill derived from the cooling power of air (Siple and Passel 1945) as a first approximation for the effects of wind on energy losses of deer because the loss of energy to convection and conduction from ruminants follows physical laws of heat flow (Blaxter 1962). We adapted published rates of energy losses of mammals exposed to various temperatures and winds to define relative weights of stress for those factors (Siple and Passel 1945, Stevens and Moen 1970, Holter et al. 1975). Subsequent experiments have quantified the effect of wind on sensible energy exchanges between deer (Stevens and Moen 1970) and their environments; their results suggest our approximations were reasonable.

Table 1. Weights applied to temperature and wind data to approximate their affect on maintenace energy requirements relative to minimal heat production of free-ranging ruminants at thermal neutrality.

Temperature Range °C	Weights: Temperature	Weights: Wind[1]
> 10.0	-1.0	+0.6
4.0 to 10.0	+2.0	-0.7
0.0 to 3.9	+1.0	-0.8
-6.6 to -0.1	-1.0	-1.1
-12.7 to -6.7	-2.0	-1.1
-17.8 to -12.8	-3.0	-1.3
<-17.8	-4.0	-1.6

[1]Weight for each 1.6 km/h of wind for that temperature range.

Stress from wind chill was estimated for all temperature ranges by the average decrease of effective temperature caused by a 1.6-km per hour increase in wind speed. Unfavorable and beneficial effects from wind were shown by negative and positive signs, respectively (Table 1).

Snow Cover and Depth Relationships

Snow cover and depth modified how temperature and wind influenced energy balances. Some snow cover was considered beneficial because it compensated for reduced availability of free water. We assigned +0.25 as a weight, therefore, for snow of less than 50% cover. Increasing snow covered herbaceous forage and forced deer to browse more. Since deer may not maintain a positive energy balance while relying on browse we used a weight of -0.5

when snow was from 50% to 75% cover. Maximum negative effects were approximated by a weight of -1.0 for snow cover between 75% and 100%.

Increasing snow depth magnifies energy requirements and reduces available forage. Our choice of weights caused negative effects of average depth to increase curvilinearly between 0.0 and 30.5 cm. When a trace of snow was present a weight of +0.25 was used. Depths to 5.1 cm were weighted by -0.1. Snow depths from 5.1-15.2 cm were weighted by -0.25, and those between 15.2 and 30.5 cm with -0.5. For all depths of 30.5 cm and greater a constant weight of -1.0 was used because deer on this range avoided deeper snow by moving to lower elevation.

Calculating Indices

The weighted data were used to calculate indices to the influence of air temperature (TEMP), air movement (WIND), snow cover (COVER), and snow depth (DEPTH) on energy balances of deer. The sum of the four indices (INDEX) represented relative weather severity over the week. The cumulative sum (CUMDEX) of weekly severity indices represented winter severity up through the last data week (Table 2).

Table 2. Calculations and definitions used to index weather data to relative energy balances of free-ranging ruminants on winter range.

Weather data	Index name	Calculation	Definitions
Air Temperature over week	TEMP	$\sum_{t=1}^{7} W_t h_t$	t is a temperature range W_t is weight at temperature range t h_t is hours in temperature range t
Air movement over week	WIND	$\sum_{t=1}^{7} V W_w h_t 7^{-1}$	V is average wind velocity in week W_w is weight for wind chill at temperature t
Snow cover for week	COVER	$W_c(\lvert TEMP+WIND \rvert)$[1]	W_c is weight for snow cover range observed
Snow depth for week	DEPTH	$W_d(\lvert TEMP+WIND \rvert)$[1]	W_d is weight for snow depth range observed
Weather severity for week	INDEX	$TEMP_i+WIND_i+COVER_i+DEPTH_i$	i is the data week
Winter severity to date	CUMDEX	$\sum_{i=1}^{n} INDEX_i$	n is the number of weeks in period

[1] "|TEMP+WIND|" means the absolute value of sum of TEMP and WIND

Results and Discussion

Instruments commonly available to resource managers were used to collect weather data. Chillometers, compaction gauges (Verme 1968), and other specialized instruments are not as available as thermometers, thermographs, anemometers and snow gauges. Our approach was similar to Verme's (1968); that is, both were based on the concept of balancing forage energy availability against animal maintenance requirements. We differed from his approach primarily because our base data were from standard weather instruments instead of specialized equipment.

Weather data are available that managers can use to test weather severity indices. Such data are reported, for example, by the National Oceanic and Atmospheric Administration (1983). Analyses of published data may uncover reliable correlations of weather indices with feed efficiency and animal production criteria. Such findings could justify the maintenance of additional weather stations on sites of special interest.

Unweighted weather data depicted the general severity of each winter. The relative and interactive effects of weather factors, the likely duration of existing conditions, and the cumulative stress within winters were unclear in raw data. Plots of temperature and snow data also tended to emphasize unusual but ephemeral conditions observed in severe as well as mild winters (Fig. 1). Summarizations of these data tended to emphasize extreme, short-term situations, but mask long periods when deer appeared to be stressed by weather.

Weighted temperature and wind data were the major factors of INDEX, while snow cover and depth data were adjusted on a scale relative to those major factors. We emphasized air temperature and wind speed because cattle and deer avoided stress from those elements primarily by using shelter. The animals did moderate stress from snow depth and cover by seeking shelter, but they avoided the extemes of those factors by moving to lower elevation. By such movements they could not escape maximum stress from temperature and wind, however. Thus INDEX helped us concentrate on the value of cover and forage habitat components which could be managed instead of emphasizing elevational movements which would be much more difficult to control.

Rates of energy losses for mammals traveling in snow were not available when we initiated this study. Our weights were set on a relative scale according to observed behavior of deer and cattle. Later research by Parker et al. (1984) suggests that our crude model approximates relative energy costs deer experience while traveling in either powder or wet snow. Such costs increase curvilinearly with sinking depth. Our model is curvilinear, but it contains weights that predict nearly twice the relative increase in costs to deer as costs shown by Parker et al. (1984:482). For example, we increased stress weights 150% but Parker found energy costs for travel increased only 60% over depths of 0–15 cm. Weights and costs increased about 410% and 210%, respectively, over depths of 0–30.5 cm. Much of the difference between relative increase from our model and those from measurements by Parker resulted because we allowed declining forage availability to influence the weights for snow cover and snow depth, in addition to travel costs.

Various combinations of TEMP, WIND, DEPTH, and COVER produced similar INDEX values, but different management actions were suggested by specific combinations. For example: (1) whenever measured snow exceeded 75% cover and 30.5 cm depth, the sum of COVER and DEPTH was at least twice that of TEMP + WIND, totally negative, and comprised 67% of INDEX; or (2) when snow measured 50–75% cover and 15-30.5 cm deep, COVER + DEPTH at least equaled TEMP + WIND, was again negative, and comprised 50% of INDEX; but (3) when snow cover was less than 50% and only a trace of depth existed then COVER + DEPTH was half that of TEMP + WIND, was positive, and comprised only 33% of INDEX. If COVER and DEPTH comprised most of the INDEX in late winter then supplemental feeding could be a justifiable management action because of the probable period when forage would be covered and unavailable (example 1). During such conditions, mixed diets of forbs, grasses, and browse were unavailable and supplemental feeding was required for animals to mainain body weight. Conversely, frequent stress comprised primarily of TEMP and WIND (example 3), therefore unlikely to persist through early spring, probably would not warrant a supplemental feeding program but could justify a cover enhancement objective.

Of the 11 winters, 3 sequentially depicted conditions when deer exhibited high (1968–69), low (1969–70), and moderate (1970–71) symptoms of stress. Patterns of indices over those winters depicted duration and intensity of stress more clearly than did the raw data (Fig. 1, Fig. 2). The INDEX patterns for the 3 winters portray plausible levels and episodes of relative severity (Fig. 2). Because of our choice of weighting factors, the area below zero INDEX and enclosed by each curve should have been proportionate to the time deer were in negative energy balance. It should indicate relative rates of loss of carcass fat over that winter. Such losses were reported from Colorado by Anderson et al. (1972). INDEX might be calibrated with changes in physical condition such as those

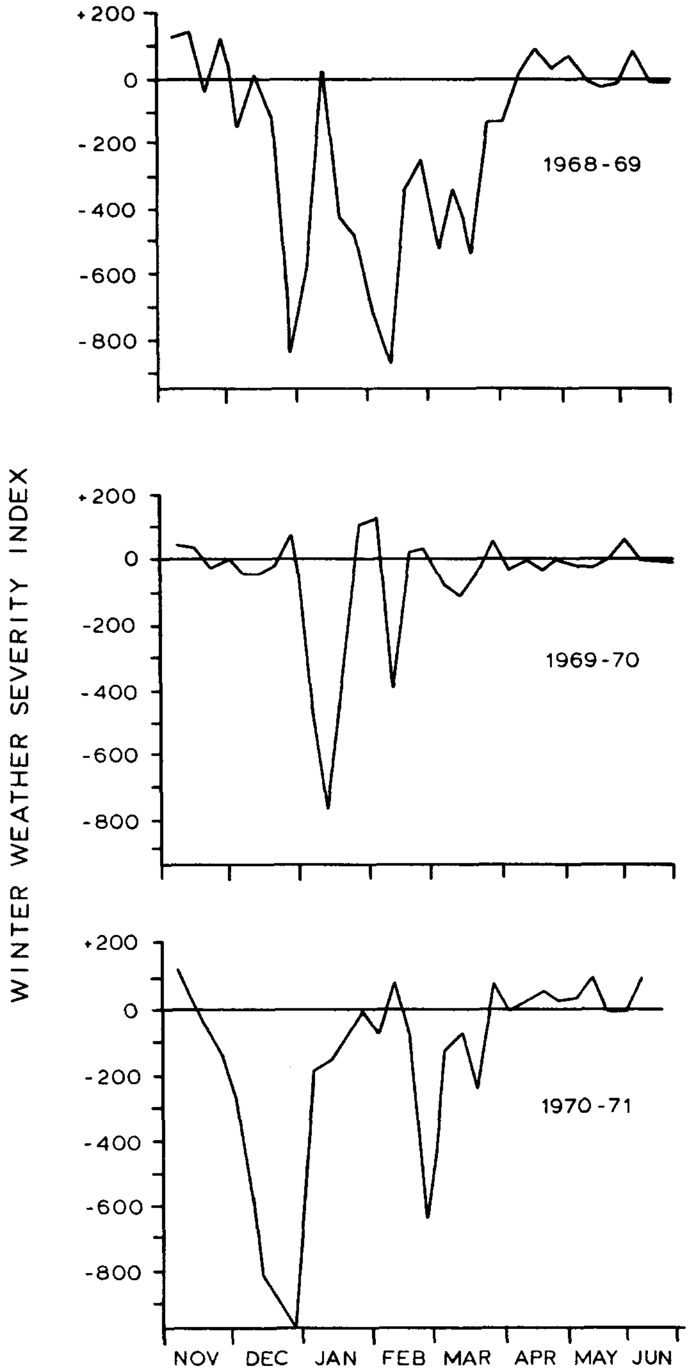

Fig. 2. *Weather severity INDEX patterns over winters when mule deer herds exhibited symptoms of high (1968-69), low (1969-70), and moderate (1970-71) stress in southcentral Oregon.*

measured by Verme (1977) and Kistner et al. (1980). Calibrated indices could be used to predict management needs before critical losses of body condition occur and to substitute for periodic sampling of carcass fat.

CUMDEX at any date portrayed stress accumulated since the beginning of winter. Levels through May assessed relative severity among winters. CUMDEX levels were related to percent fawn survival over winter (r=0.95, p<0.05) among the illustrated years (Fig. 2). A 56% fawn survival (average of samples from the Silver Lake and Fort Rock management units) occurred with a −5798 CUMDEX in spring 1969, 80% survival with −1873 in 1970, and 70% survival with −4634 in 1971. The predictive equation based on those 3 winters was %-fawn survival = 0.0057 CUMDEX + 92% with a standard-error-of-estimate of 5.5% and 1 degree of freedom. This model estimated fawn survival on the average within −1.6% units of the observed survival over the 11 winters. The extreme underestimate of 18% units occurred in 1968 and the extreme overestimate of 24% units in 1974.

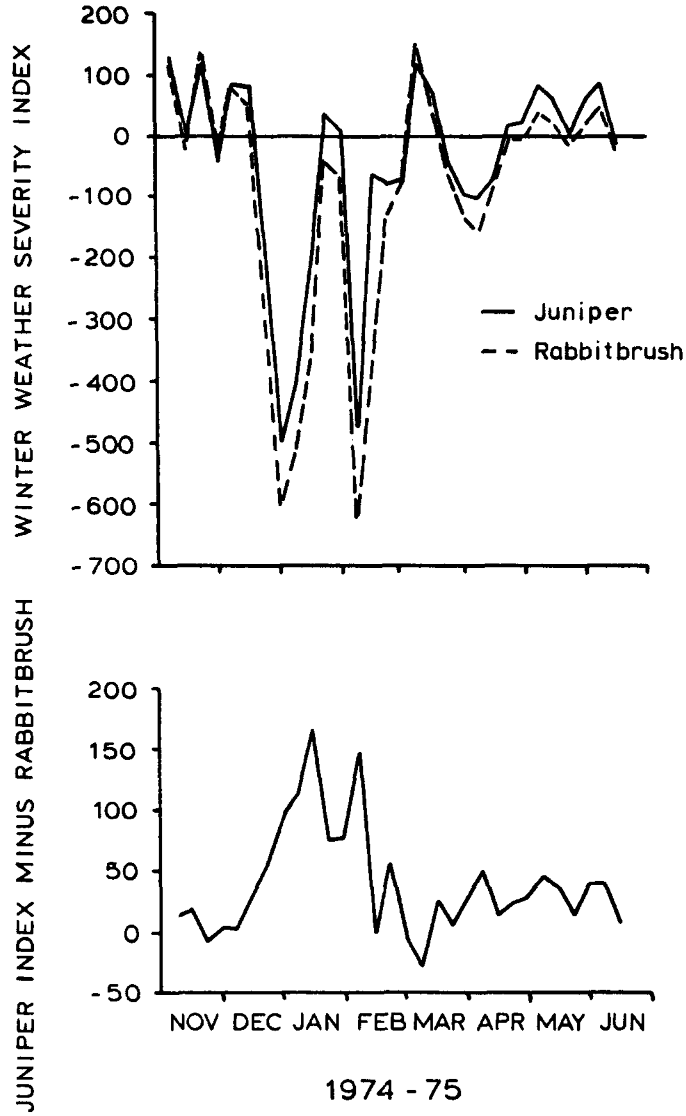

Fig. 3. *Canopy closure, canopy depth, and stand height of a juniper community were greater than in an adjacent rabbitbrush stand. Juniper structure was associated with less-negative weather severity indices and more positive differences in INDEX values than in the shrub community.*

The CUMDEX values in 1969 and in 1978 delineated extremes of severe and mild winters witnessed during 11 years on this range. Managers reported the winter ending in 1969 (CUMDEX -5798) was the most severe in 20 years, and losses of deer were greater than normal in central and southeastern Oregon (Oregon State Game Commission 1969). They observed the winter ending in 1978 (CUMDEX -1072) was mild and wet in central and southeastern Oregon and no deer losses were reported (Oregon Department of Fish and Wildlife 1978).

Hypothesized effects of vegetation structure on weather severity were tested by comparing indices from a western juniper plant community with those from a rubber rabbitbrush plant community. Reifsnyder and Lull (1965) and Geiger (1966) reported moderation of temperature, radiation, wind, and snow was correlated with increasing canopy closure, canopy depth, stand height, and stem density. The structure of the juniper community we sampled was as follows: canopy closure 30%, canopy depth 3.0 m, stand height 4.5 m, and density 33 stems/ha. Comparable measures in the rabbitbrush community were: canopy closure 20%, canopy depth 0.6 m, stand height 0.8 m, and density 6,000 stems/ha.

Because of its greater structural shelter, we anticipated less negative indices in the juniper community. WIND, COVER, and DEPTH were less severe in the juniper than in the rabbitbrush community at least 70% of the winter. TEMP was less severe in the juniper community only 47% of the winter. Fluctuations were generally less extreme at the juniper station than at the rabbitbrush station. INDEX computed from weather in the juniper community was less negative than in the rabbitbrush community 87% of the winter (Fig. 3), although the stations were only 330 m apart. INDEX averaged 39 units (SE+8) less severe in the juniper than in the rabbitbrush (Fig. 3). It was 14 units less severe during the mildest period, 11 November, and 95.8 units milder during the most severe episode, 30 December. The largest difference between INDEX values occurred, 13 January, when weather in the juniper community was 166 units less severe than in the rabbitbrush community. CUMDEX from the juniper (-1377) was half as severe as from the rabbitbrush (-2538) that winter. The milder patterns and less-negative indices we observed were consistent with the greater canopy closure, canopy depth, and stand height of the juniper community.

Mule deer occupied juniper communities primarily when weather stress seemed severe, INDEX values exceeding -100. This use occurred even though there was a high browseline on most juniper, understory shrubs were decadent, and grasses were scarce. Many juniper stands were older, taller, and more closed than where we recorded weather data. Deer used older juniper communities intensively during episodes of weather stress (Leckenby 1978). Severity should have been proportionately less in older stands of thermal cover because their structure would have moderated weather even more than in the younger juniper stand we sampled.

Conclusions

An index to winter severity increased our awareness of habitat needs of free-ranging ruminants. Our severity indices suggested when and where conditions became most stressful. In that sense, indices could aid short-term planning for supplemental winter feeding programs. The indices could also help to quantify the shelter value of thermal cover and to justify long-term cover management objectives where supplemental feeding is not an acceptable option.

Range managers in the Intermountain West might find weather indices helpful when they assess the performance of free-ranging domestic and wild ruminants. Relative stress depicted by index values should be comparable between years and geographic areas provided the weather stations are located in similar habitats and occur within an area of uniform weather patterns. Refined interpretation of animal behavior, distribution, feed efficiency, and production may be possible from indices of temperature, wind, and snow conditions over winter. Spatial distributions of weather severity indices could suggest areas where cover and forage management strategies would likely improve livestock and wildlife production.

Literature Cited

Anderson, A.E., D.E. Medin, and D.C. Bowden. 1972. Indices of carcass fat in a Colorado mule deer population. J. Wildl. Manage. 36:579-594.

Blaxter, K.L. 1962. The energy metabolism of ruminants. Hutchinson Scientific and Technical, London.

Brody, S. 1945. Bioenergetics and growth. Reinhold, New York.

Brody, S. 1956. Climatic physiology of cattle. J. Dairy Sci. 39:715-725.

Finch, V.A., I.L. Bennett, and C.R. Holmes. 1982. Sweating response in cattle and its relation to rectal temperature, tolerance of sun and metabolic rate. J. Agr. Sci. Camb. 99:479-487.

Geiger, R. 1966. The climate near the ground. Harvard Univ. Press, Cambridge, Massachusetts.

Gifford, G.F. 1973. Influence of chaining pinyon-juniper on net radiation, solar radiation, and wind. J. Range Manage. 26:130-133.

Holter, J.B., W.E. Urban, Jr., H.H. Hayes, H. Silver, and H.R. Skutt. 1975. Ambient temperature effects on physiological traits of white-tailed deer. Can. J. Zool. 53:679-685.

Kistner, T.P., C.E. Trainer, and N.A. Hartmann. 1980. A field technique for evaluating physical condition of deer. Wildl. Soc. Bull. 8:11-17.

Leckenby, D.A. 1978. Mule deer occupancy of plant communities on a south-central Oregon winter range. Oregon Dep. of Fish and Wildl. Final Rep. Proj. W-53-R and W-70-R Sub B, Study I Job 5.

Moen, A.N. 1968a. Energy exchange of white-tailed deer, western Minnesota. Ecology 49:676-682.

Moen, A.N. 1968b. The critical thermal environment: a new look at an old concept. BioScience 18:1041-1043.

National Oceanic and Atmospheric Administration. 1983. Climatological data, Oregon, August. Vol. 89, No. 8.

Nordan, H.C., I. McT. Cowan, and A.J. Wood. 1970. The feed intake and heat production of the young black-tailed deer *(Odocoileus hemionus columbianus).* Can. J. Zoo. 48:275-282.

Oregon Department of Fish and Wildlife, Wildlife Division. 1978. Annual report. Portland, Ore.

Oregon State Game Commission, Game Division. 1969. Annual report. Portland, Ore.

Parker, K.L. 1983. Ecological energetics of mule deer and elk: locomotion and thermoregulation. Ph.D. Diss. Washington State Univ., Pullman. (Diss. Abstr. 44:3329).

Parker, K.L., C.T. Robbins, and T.A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. J. Wildl. Manage. 48:474-488.

Picton, H.D. 1979. A climate index and mule deer fawn survival in Montana. Int. J. Biometeor. 23:115-122.

Reifsnyder, W.E., and H.W. Lull. 1965. Radiant energy in relation to forests. USDA Forest Serv. Tech. Bull. 1344.

Robbins, C.T. 1983. Wildlife feeding and nutrition. Acad. Press. New York.

Robinette, W.L., C.H. Baer, R.E. Pilmore, and C.E. Knittle. 1973. Effects of nutritional change on captive mule deer. J. Wildl. Manage. 37:312-326.

Roper, L.A., and J.F. Lipscomb. 1973. Estimating winter losses of mule deer in northern Colorado using a winter severity index. Proc. Annu. Conf. Ass. State Game Fish Comm. 53:142-147.

Short, H.L., J.D. Newsom, G.L. McCoy, and J.F. Fowler. 1969. Effects of nutrition and climate on southern deer. Trans. North Amer. Wildl. and Nat. Resour. Conf. 34:137-146.

Silver, H., J.B. Holter, N.F. Colovos, and H.H. Hayes. 1971. Effect of falling temperature on heat production in fasting white-tailed deer. J. Wildl. Manage. 35:37-46.

Siple, P.A., and C.F. Passel. 1945. Measurements of dry atmospheric cooling in subfreezing temperatures. Proc. Amer. Philos. Soc. 89:177-179.

Stevens, D., and A.N. Moen. 1970. Functional aspects of wind as an ecological and thermal force. Transactions North Amer. Wildl. Conf. 35:106-114.

Subcommittee on Environmental Stress. 1981. Effect of environment on nutrient requirements of domestic animals. Natl. Acad. Press. Washington, D.C.

Verme, L.J. 1968. An index of winter weather severity for northern deer. J. Wildl. Manage. 32:566-574.

Verme, L.J. 1977. Assessment of natal mortality in upper Michigan deer. J. Wildl. Manage. 41:700-708.

Verme, L.J., and J.J. Ozoga. 1981. Appraisal of autumn-spring weather severity for northern deer. Wildl. Soc. Bull. 9:292-295.

Wallmo, O.C., and R.B. Gill. 1971. Snow, winter distribution, and population dynamics of deer in the central Rocky Mountains. p. 1-15. *In:* A.O. Haugen (ed.), Proceedings of the Snow and Ice in Relation to Wildlife and Recreation Symposium. Iowa Cooperation Wildlife Research Unit, Iowa State Univ., Ames.