A SCALED INDEX OF WINTER SEVERITY

by

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INTRODUCTION

Various methods have been used to represent winter severity and usually include temperature and some measure of snowfall or winter precipitation. Most represent winter severity as some departure from normal or as percent of average. Likewise, most use mean monthly temperatures or monthly snowfall or precipitation. In many cases, the mean monthly temperature does not fully explain the stresses that are imposed on wildlife during extremely cold periods that persist for periods less than a month. Also, it is difficult for non-technical people and even some professionals to quantify how severe or mild a given winter might be. The scaled index of winter severity (IWS) was developed to assist both wildlife managers and the general public better understand how mild or severe a given month or season might be or might have been compared to the historical variations. An index of -4 represents the most severe condition while a +4 represents the mildest condition. An index of 0 represents average or 50 percent probability of occurrence.

VARIABLES

Various climatic factors can influence unconfined wildlife during winter. Availability of forage, amount and condition of snow, and cold temperatures are the most common. Different species may also react differently to each of these variables and different winter ranges may have different limitations. The lower part of the northern winter range in and north of Yellowstone National Park will be used for this example as it is the most critical part of the northern range. During severe winters, elk from the upper and middle northern range move down to the lower northern range. Elk make up the largest number of wintering animals. Over the past 40 years, the number of elk wintering on the northern range has varied from about 4,600 to 22,000 animals with the lowest numbers in the late 1960's and the largest around 1987-88.In general, mild winters permit the elk to scatter over more of the winter range while severe winters have a tendency to concentrate more animals into smaller areas thereby reducing the amount of available forage. The majority of the animals winter at elevations between 1500 m and 2200 m. However, some elk may utilize south-facing slopes up to 2700 m in low snow years. There are two snow courses in this area, Crevice Mountain (2560 m) and Lupine Creek (2249 m). For this example, the April 1 snow water equivalent (SWE), which is generally the maximum for the year, is used to quantify the snow variable. Analysis of earlier months measurements can be used to evaluate snow conditions earlier in the winter. The snow index becomes more severe as the SWE increases. In areas not having snow courses or snow pillows, it may be possible to use data from climatic stations for the snow index. The precipitation that occurs when the depth of snow on the ground exceeds a threshold such as 25 cm or the number of days that snow depth on the ground exceeds a threshold are variables that can be used when climatological data rather than snow course data is available.

The accumulated sum of daily minimum temperature below -18^{o}C for the Yellowstone Park (Mammoth) (1899 m) climatic station is used as the temperature index. When minimum temperatures are above -18^{o}C, the stress to the animal is thought to be minimal compared to stress at the colder temperatures. For species other than elk, the threshold temperature could be raised or lowered, depending on the animals hardiness and susceptibility to cold temperatures. The temperature index becomes more severe as the accumulated temperature sums become larger. This does require analysis of the daily temperatures and data does need to be complete for each day each winter. Missing values are estimated from adjacent climatological stations before analysis. Accumulated sums of the daily temperatures below -18^{o}C are tabulated for each month starting in the first month of cold weather and adding each additional month until the end of the cold season. Analysis of these earlier periods could be used to determine temperature conditions as the winter progresses. For this example, the accumulated sum of minimum daily temperatures below -18^{o}C for October through March is used as the winter temperature index.

Precipitation at Yellowstone Park (Mammoth) for June plus July for the previous summer is used to represent summer growth of forage on the winter range that is available to the elk during the winter months. As the summer precipitation amounts become smaller, the forage variable becomes more severe. In areas where forage production on the winter range is not a limiting factor, this variable may be eliminated. In the Yellowstone National

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Park and areas north of the park in Montana, forage production on the winter range is a significant factor to survivability.

INDEX

To obtain the index, it is necessary to first calculate the probability of non-excedence (PN) for each variable. This integrates the variability of each component and permits comparison of components of different scales. A normal probability analysis is used to calculate the PN because the arithmetic average of the variable is equal to a 50% probability. Routines for calculating probability are available in most statistical textbooks or computer statistical packages.

$$\text{INDEX} = \frac{\text{PN} - 50}{12.25}$$

The division by 12.25 compresses the range of 1% to 99% probability of non-excedence to a range of -4 to +4.

For example, the index for a 1% probability of non-exceedence is $\frac{1-50}{12.25}$ or $\frac{-49}{12.25}$ or -4. A 50 percent probability is $\frac{50-50}{12.25}$ or 0 and a 99 percent probability of non-exceedence is $\frac{99-50}{12.25}$ or $\frac{49}{12.25}$ or +4. An index is calculated for each variable and then weighed to determine the index of winter severity. For the lower part of the northern range, the IWS for the winter season is calculated by weighting the sum of SWE for Crevice Mountain and Lupine Creek snow courses as 40%; the accumulated sum of daily minimum winter temperatures below -18^{o}C at Yellowstone Park (Mammoth) as 40%, and the June plus July precipitation at Yellowstone Park (Mammoth) as 20%. The index for each variable and the IWS is tabulated in Table 1. Figure 1 shows the index of winter severity for the lower northern range for the 1949-90 period.

RATING SCALE

The following rating scale is suggested for describing various IWS's.

RATING SCALE FOR IWS

+ 3 to + 4 very mild	0 to +1.0 slightly mild	- 1 to - 2 moderately severe
+ 2 to + 3 mild	0 average (normal)	- 2 to - 3 severe
+ 1 to + 2 moderately mild	0 to -1 slightly severe	- 3 to - 4 very severe

USES OF IWS

The IWS can be used to help quantify numerically the severity of any given winter or portion of winter and to select years having similar winter conditions. The IWS can also be used to help explain winter mortality. In figure 1 most of the periods cycle above and below an index of 0 every two or three years. However, it is interesting to note the series of generally mild winters from 1980 through 1988. This prolonged period of mild winters enabled the elk herd to increase approximately 60 percent. The winter mortality as result of the severe winter of 1988-1989 reduced the herd by approximately 25 percent. This severe winter followed the extensive fires in the summer and fall of 1988 and many casual observers blame the fires for the large mortality. In reality, it appears that the fires were not the major factor in this mortality and a large mortality would have been observed even if the fires had not developed. In the winter of 1988-89, temperatures were the 4th coldest, SWE 14th highest, and summer of 1988 the driest in the previous 40 years. The IWS was the 3rd lowest in the past 40 years.

The IWS may also represent some indication of the survivability of newborn calves. Young produced by animals that survive a severe winter will probably have a poorer chance of surviving to adults than do those born to animals having just experienced a mild winter. By combining a spring survivability index calculated in a similar manner (only using spring temperatures and spring precipitation) with the IWS and other mortality such as hunting, disease and predation, it should be possible to explain or to project population trends.

CONCLUSION

The IWS provides wildlife managers, and the public with an easily understood numeric measure of how mild or severe any period or winter, or series of winters may be or have been. It provides a method for combining different variables such as temperature, snow, and precipitation into a single index. It also enables indexes to be calculated for different areas and to be tailored to different species of animals. As more experience is gained with the IWS, the procedures for determining the weightings of each variable for each species should become more scientific and effects of winter severity on populations should become more evident.

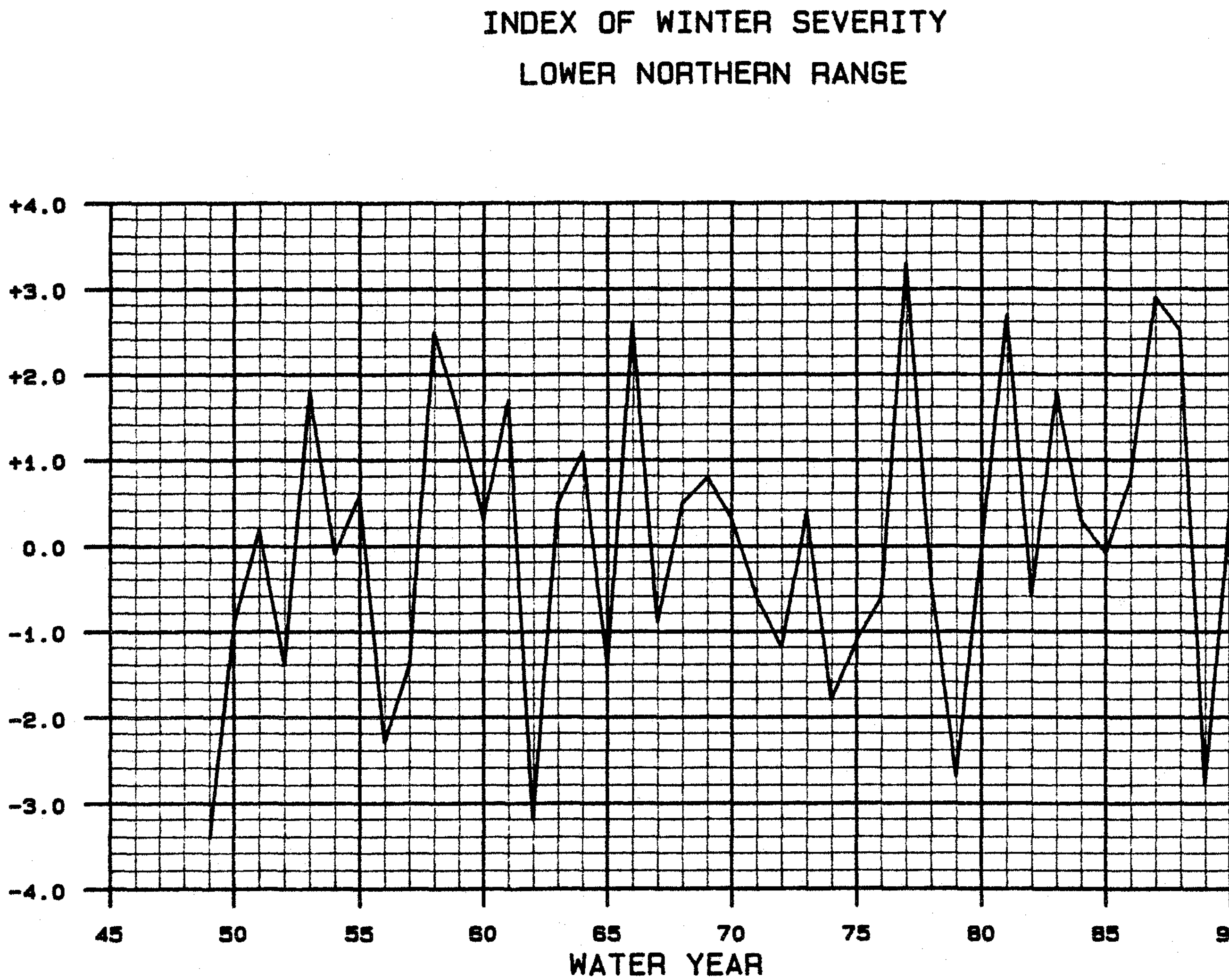

Figure 1. Index of Winter Severity for Lower Northern Winter Range 1949-90.

TABLE 1. INDEX OF WINTER SEVERITY FOR THE LOWER NORTHERN RANGE

YEAR	TEMP. INDEX[1]	SNOW INDEX[2]	FORAGE INDEX[3]	IWS[4]
48-49	- 4.0	- 3.3	- 2.2	- 3.4
50	- 1.1	- 0.3	- 1.7	- 0.9
51	- 0.8	- 0.3	+ 3.3	+ 0.2
52	+ 0.2	- 3.9	+ 0.2	- 1.4
53	+ 2.4	+ 0.9	+ 2.6	+ 1.8
54	+ 2.9	- 1.6	- 3.0	- 0.1
55	- 0.7	+ 0.8	+ 2.8	+ 0.6
56	- 3.3	- 2.9	+ 1.1	- 2.3
57	- 3.0	+ 0.4	- 1.5	- 1.4
58	+ 3.6	+ 3.3	- 1.1	+ 2.5
59	+ 0.9	+ 1.2	+ 3.3	+ 1.5
60	- 3.2	+ 3.7	+ 0.3	+ 0.3
61	+ 3.1	+ 2.8	- 3.3	+ 1.7
62	- 3.8	- 2.5	- 3.3	- 3.2
63	- 2.9	+ 3.3	+ 1.6	+ 0.5
64	+ 2.4	+ 0.2	+ 0.3	+ 1.1
65	- 2.0	- 2.7	+ 2.6	- 1.4
66	+ 2.1	+ 3.0	+ 2.9	+ 2.6
67	+ 2.6	- 3.7	- 2.4	- 0.9
68	+ 2.0	- 2.0	+ 2.6	+ 0.5
69	+ 1.8	- 1.1	+ 2.6	+ 0.8
70	+ 1.2	- 1.3	+ 1.6	+ 0.3
71	+ 1.5	- 3.2	+ 0.4	- 0.6
72	+ 0.7	- 2.6	- 2.4	- 1.2
73	- 2.9	+ 2.9	+ 2.0	+ 0.4
74	0.0	- 3.8	- 1.5	- 1.8
75	+ 0.7	- 2.0	- 3.1	- 1.1
76	+ 2.0	- 3.4	- 0.2	- 0.6
77	+ 3.1	+ 3.3	+ 3.8	+ 3.3
78	+ 1.1	- 2.4	+ 0.3	- 0.4
79	- 4.0	- 1.6	- 2.4	- 2.7
80	- 0.4	+ 1.4	- 2.0	0.0
81	+ 3.0	+ 3.8	- 0.3	+ 2.7
82	- 0.3	- 1.9	+ 1.2	- 0.6
83	+ 3.1	+ 1.0	+ 0.8	+ 1.8
84	- 2.9	+ 2.1	+ 3.3	+ 0.3
85	- 2.6	+ 0.3	+ 3.5	- 0.1
86	+ 0.9	+ 1.4	- 0.8	+ 0.8
87	+ 2.7	+ 3.7	+ 1.9	+ 2.9
88	+ 1.5	+ 3.1	+ 3.5	+ 2.5
89	- 3.3	- 1.9	- 3.4	- 2.8
89-90	+ 1.5	- 0.6	+ 0.1	+ 0.4

[1] Obtained from accumulated daily TMIN below -18°C at Yellowstone Park (Mammoth) October through March.

[2] Obtained from snow water equivalent, Crevice Mountain plus Lupine Creek, April 1.

[3] Obtained from June plus July precipitation at Yellowstone Park (Mammoth) for previous summer.

[4] Index of winter severity equals .4 times temperature index plus .4 times snow index plus .2 times forage index.