EFFECTS OF WEATHER ON PRODUCTIVITY AND SURVIVAL OF MOOSE IN NORTHEASTERN ONTARIO

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Abstract Weather has been shown to be an important factor affecting calf production and survival, in many parts of the moose range. This effect has not been demonstrated for Ontario. Winter severity, positive energy period, May rainfall and summer rainfall were compared with calves per female in the kill and percent yearlings in the kill by means of multi-variate analysis. Weather, primarily winter severity, was important in affecting production of calves up to the mid-1960's. After 1966, the weather variables tested showed no significant relation to calf production. It is likely that disruption of social structure and umwelt through excessive hunting and habitat destruction became more important influences on production, masking any effects of weather.

Weather can act on a moose population directly by affecting individual survival (Knorre 1959, Coady 1973), or indirectly through effects on the rate of production (Markgren 1969) and level of predation (Peterson and Allen 1974).

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Work in Alaska has shown substantial losses in body weight during winter due to a reduced metobolic rate in response to lower levels of nutrition (Gasaway and Coady 1974). They showed that extreme cold (-50 degrees C) or abnormally deep snow conditions decreases the availability of food by restricting mobility. This results in lower rumen microbial activity and reduces the level of nutrition. A lowered nutritional plane can also result from a late leaf flush in spring (Stewart et al. 1977) or due to hot dry summers which lower the quality of browse (Markgren 1969). The resultant poor condition of the animal may affect its survival and reproductive capacity.

Ling (1972) reported a high correlation between winter severity and the percentage of calves in the population (although not stated, this is presumably from summer observation or in the aerial survey the next winter). His view was that winter severity acted through reabsorption of the foetus, foetal morality, post-natal morality and reduced reproduction in yearlings. Both Pimlott (1959) and Markgren (1969) believed that the fertility of yearlings is affected by nutrition during the first winter. However, Markgren was unable to decide whether winter or summer food was a more important factor. Stewart et al. (1977) concluded that the theoretical energy budget of moose is dependent on annual variations in the quality of browse. Browse quality is determined in part by the length of the positive energy period from leaf flush to leaf fall, and is undoubtedly affected by rainfall during the summer period.

Peterson (1974) reported sightings of calves on Isle Royale in spring and summer decreased 15 to 20 percent following winters with unusually deep snow, whereas more were seen after mild winters. In addition, the percentage of cows accompanied by twins on Isle Royale decreased sharply from 32 percent after moderate winters to 9.5 percent after a harsh winter (Peterson and Allen 1974). Similar reductions in twins have been reported in Estonia (Ling 1972), in Russia (Knorre 1959) and in Sweden (Markgren 1969) after harsh winters. Of these authors, only Peterson and Allen defined their "harsh winters" (80-112 cm of snow from January through March).

High winter mortality of calves (and adults) has been recorded in many areas: For example, in the Tanana Valley of Alaska, a moose herd at or above the carrying capacity of the area suffered severe mortality of up to 60% of the herd, during the harsh winters of 1965-66 and 1966-67. Calf survival was 50-100 percent less than during milder winters. Snow depths here were reported at 92 cm in December and continued to rise until March (Coady 1973; 1976). High winter mortality has also been recorded in other areas. Peek (1971) reported 24 percent calf mortality in mild winters as opposed to 61 percent during harsh winters in Minnesota. In Saskatchewan, MacLennan (1975) suggested winter losses may have been a major factor in the decline of the moose herd in that province. Severe winters were reflected in a low kill of yearlings the following fall. Bishop and Rausch (1974) found a strong correlation between winter severity and declines and increases of moose herds in several areas of Alaska. There it was noted that the quality of the range was poor. (Moose mortality was high when snow depth exceeded 90 cm for 3 months.) They suspected a total mortality of 50 percent during a year of total accumulation of 371 cm coupled with cold temperatures. Of the moose which starved, calves comprised 63 percent. The number of yearling in the fall hunter kill were also found to be very low.

Stewart et al. (1977) and Swenson (1973) indicated that a late spring could result in a high new born calf mortality due to a lowering of the nutritional plane of cows. Lactating females are generally lower in weight and in poorer condition than 'dry' cows (Gasaway and Coady 1974).

Studies have shown that rates of predation on moose by wolves increase markedly during severe winters (Peterson and Allen 1974). This is particularly true when there is a crust thick enough to support wolves (Formosov 1946; Nasimovitch 1955; Mech et al. 1971). During years of unusually deep snow, the number of moose killed by wolves has been found to double on Isle Royale (Peterson and Allen 1974). This same study indicated 18 percent more calves were taken in years when snow depths exceeded 76 cm (31% of total in moderate years up to 49% in severe winters) than in milder winters.

Deep snow also has effects on the rates of predation on moose other than calves. Peterson (1974) reported that bulls on Isle Royale appeared to suffer higher mortality through predation than do females. He attributes this to their poorer condition in later winter. Generally, wolves take older animals (7½+) and calves. However, in years of deep snow, Peterson and Allen (1974) reported age classes 1 to 3 suffered higher predation than during milder winters. Up to 38% of the total animals taken were comprised of these ages in severe winters.

Weaker animals are not necessarily taken by wolves during some winters. Femurs of wolf-killed adults and calves contained statistically similar amounts of fat in the marrow compared to accidentally killed animals during the same severe winter in Alaska (Franzman and Arneson 1976).

Cumming (1975) examined several winter parameters, including four measures of temperature and two of snowfall in Northwestern and Northeastern Ontario in relation to moose production and survival. In spite of 55% to 76% of the variance explained by various combinations of these variables, he felt there was no relationship between weather conditions and moose mortality. This conclusion was drawn because of a lack of consistency in correlation among the variables and moose mortality between the two areas, and lack of correlation with the two important variables of snow depth and minimum temperature.

This study attempts to combine measures of weather throughout the year shown or suspected to be important individually to moose production and survival.

METHODS

Variables chosen for inclusion in the model include: 1) winter severity (Ling 1972, Gasaway and Coady 1974); 2) positive energy period (Stewart et al. 1977, Gasaway and Coady 1974); 3) May rainfall (Stewart et al. 1977); and 4) summer rainfall, June through August (Markgren 1969).

Winter severity was initially measured in three ways: 1) using the additive method of Passmore and Hepburn (1953), 2) by integrating the areas under the curve of snow on the ground for each entire winter (Coady 1973), and 3) by integrating the area under the snow curve above 76 cm.

The beginning of the positive energy period was calculated using the formula:

$$\frac{\Sigma(h - 12.22°C)}{2} = 41.67 \text{ degree days}$$

where h was the maximum daily temperature (after Stewart et al. 1977). The end of the positive energy period was taken as the first day in the fall where a -5 degree C temperature was recorded. Temperatures, May rainfall and summer rainfall were taken from district records at Cochrane (49°04'N, 81°00'W) and Transport Canada records at Kapuskasing (49°26'N, 82°30'W). Winter severity was calculated from District data at Hearst, Kapuskasing and Cochrane. These districts are adjacent, with the west border of the Old Kapuskasing district located 230 miles from the eastern border of Cochrane. Weather patterns are similar, but not identical.

Harvest data were taken from Cochrane and Kapuskasing Administrative Districts of the Ontario Ministry of Natural Resources. Some harvest data points were excluded due to small samples (n <6 calves), or obviously erroneous values such as no bulls or no yearlings in the kill. Data were expressed as calves per female based on adult females older than 1.5 years. All harvest data in Ontario have been collected on a voluntary basis. After 1967 a crest was offered in exchange for a moose jaw as an incentive to increase sample size.

A stepwise multiple linear regression was performed on the variables in the following combinations (using 1976/77 as an example):

1) Winter severity 1976/77, May rain 1977, summer rain 1977, 1977 positive energy period vs calves per female in the fall 1977 kill.
2) 1976 May rain, 1976 summer rain, 1976 positive energy period, winter severity 1976/77 vs calves per female in the fall 1977 kill and vs % yearlings in the fall 1977 kill.

Calculation 1) was used to measure effects of weather from winter to fall of the same year (1977 in this example) on the survival of calves. Calculation 2) was used to measure effects of conditions of winter and the preceding summer on rate of production of the 1977 calves and of survival of the 1976 calf crop. The stepwise procedures and interpretation are outlined in Draper and Smith (1966). Variables were added in the stepwise procedure if the partial F value was significant at the 0.2 level. This rather low level was chosen due to the difficulty of obtaining significance with meteorological data (Crête 1976).

Two major changes affecting moose occurred in northeastern Ontario in the mid-1960's. These were the widespread use of wheeled skidders for logging operations and a substantial increase in hunters and subsequent kill. A further change was the reduction in acreage lost to fire. For this reason the data sets were examined both in their entirety and for the period prior to and after the mid-1960's. Slightly different periods were used for the two areas due to sample sizes and data available.

RESULTS

The weather variables were individually highly correlated ($P < .01$) between the two stations, indicating similar weather patterns (Tables 1 and 2). Results from the three methods of measuring winter severity were highly correlated, therefore the simplest expression, Passmore and Hepburn (1953) was used. A comparison of winter severities indicated winters were similar before and after 1967.

Table 1. Harvest and weather values for Cochrane

Year	Calves/Female Fall Kill	% Yearlings Fall Kill	Winter Severity Index*	May Rainfall (cm)	Summer Rainfall June-Aug.(cm)	Positive Energy Period (Days)
1977	.458	18.0	23	3.00	26.07	152
1976	.232	16.5	36	3.66	19.89	157
1975	.444	18.6	16	8.89	23.27	137
1974	.562	27.4	27	5.87	32.50	110
1973	.471	28.9	20	11.15	29.12	125
1972	.442	39.2	41	4.72	27.05	143
1971	.383	26.3	37	8.05	21.87	132
1970	.636	-	26	7.09	29.13	140
1969	.373	23.2	45	4.62	36.57	142
1968	.522	18.8	29	1.70	38.83	186
1967	.446	17.1	60	9.14	32.66	99
1966	-	-	37	3.99	29.61	122
1965	.555	28.6	48	14.00	28.65	137
1964	.160	34.4	49	10.62	30.43	145
1963	.600	22.4	11	3.91	-	124
1962	.333	-	33	16.97	25.33	161
1961	.333	15.6	10	18.82	22.30	132
1960	.233	20.4	45	11.33	30.03	119
1959	.182	17.8	29	5.16	26.08	144
1958	.906	20.8	10	6.91	34.79	152
1957	.286	14.3	41	4.44	37.38	145

*winter ending year of record, e.g. 1976/77 recorded for 1977

Table 2. Harvest and weather values for Kapuskasing (WMU23)

Year	Calves/Female Fall Kill	% Yearlings Fall Kill	Winter Severity Index*	May Rainfall (cm)	Summer Rainfall June-Aug.(cm)	Positive Energy Period (Days)
1977	.370	29	27.5	3.73	25.76	147
1976	.160	46	22.5	3.12	22.14	139
1975	.360	33	15	3.07	22.64	134
1974	.310	41	33.5	7.70	22.73	114
1973	.230	22	25	11.81	33.33	135
1972	.340	30	43	3.33	22.71	146
1971	.540	25	39	8.38	26.27	134
1970	.470	20	23.5	7.90	23.32	140
1969	.150	16	46	5.99	40.13	144
1968	.190	19	16	1.04	39.75	162
1967	.130	26	56	5.36	23.56	102
1966	.360	-	39.5	3.96	31.91	125
1965	.500	-	36.5	10.64	21.34	142
1964	.360	-	37	13.77	42.55	146
1963	.670	-	10.5	6.78	28.10	118
1962	-	-	16	16.20	33.15	161
1961	.700	-	23	9.17	33.34	128

*Winter ending year of record (averaged for Hearst and Kapuskasing stations)

Using variables from winter and following summer (calculation 1) (Table 3), winter severity was a major factor in all significant regressions. Prior to the mid-1960's, winter severity accounted for 54 percent of the variance at Cochrane and 75 percent at Kapuskasing. Summer rainfall accounted for a further 34 percent at Cochrane and 3 percent at Kapuskasing. Non-common variables were May rainfall (9 percent at Cochrane) and positive energy period (22 percent) at Kapuskasing. From the mid-1960's to the present, there were no significant regressions. All years combined produced a significant regression at Cochrane, but this was probably due to the 1956-1964 period (Table 3) (correlation matrices are shown in Appendix 1).

When summer variables combined with the following winter severity were examined (calculation 2), the factors related to calves in the kill were not found to be consistent between the areas (Table 4). Winter severity remained important in three of the six year groups examined.

Results of regressions were poor in the case of percent yearlings in the kill one year later. This was an attempt to see if effects on calves would show for that cohort as yearlings. At Cochrane, no correlation was found. A significant ($P < .1$) regression occurred with winter severity (22% variance) and May rainfall (21%) using the Kapuskasing data as a whole.

DISCUSSION

The multiple regression technique is used here not as a predictor but rather to determine if in fact a relationship exists between the weather variables chosen and calf production. Therefore,

Table 3. Results of stepwise regression of calves per female in the harvest vs weather variables (winter and following summer - calculation 1). Variation explained is bracketed. Sign indicates direction.

Location	Years	Variables	F
Cochrane	1956-1977	-Winter Severity (21)	
		+Summer Rain (22)	6.34***
	1956-1964	-Winter Severity (54)	
		+Summer Rain (34)	57.82***
		-May Rain (9)	
	1965-1977	No correlation	
Kapuskasing	1961-1977	+Summer Rain (18)	2.06
		+May Rain (11)	
	1961-1966	-Winter Severity (75)	
		+Positive Energy Period (22)	117.88***
		+Summer Rain (2)	
	1967-1977	No correlation	

***.001

(+ = positive effect; - = negative effect)

the R^2 values are in a sense idiosyncratic and should not be viewed as absolute values.

One factor of caution which needs to be mentioned is that the sample size and methods of data collection for the harvest information varied. Data after 1967 generally had larger sample sizes because of the initiation of the crest-for-a-jaw program. In four years prior to 1967, telephone surveys were done to obtain jaws, while in other years voluntary returns were obtained. However, the high R^2 values, significant regressions and consistency of important variables between the two areas indicate that in spite of the rough nature of the harvest data, they are useful in this analysis.

Weather variables are often weak statistically when used in regression with biological observations (Crête 1976, Cumming 1975). However, weather has been shown to be important in a measurable fashion to moose in many parts of its range. For Ontario, no relationship between weather and moose has previously been demonstrated (Cumming 1975).

Data presented here indicate that certain weather factors, particularly winter severity, were related to production of moose calves during the late 1950's to mid-1960's. After that period the relationship is not apparent. Moose populations in the Cochrane and Kapuskasing areas have decreased by 40 to 60% since 1955 with most of the reduction occurring after 1965-1967 (Thompson 1979). It is probable that the relationship between calf production and weather has been substantially affected by hunting and habitat changes during recent years. The most probable effects are an increased survival of calves which is range related, and altered age structure of the breeding

Table 4. Results of stepwise regression of calves per female in the harvest vs weather variables (summer and following winter - calculation 2). Variation explained is bracketed. Sign indicates direction.

Location	Years	Variables	F
Cochrane	1956-1977	-Winter Severity (20)	3.27*
		+Summer Rain (9)	
	1956-1964	-Winter Severity (29)	2.50
	1965-1977	No correlation	
Kapuskasing	1961-1977	+May Rain (55)	16.16***
	1961-1966	-Winter Severity (93)	41.90***
	1967-1977	+May Rain (26)	2.75

***.001

*.1

(+ = positive effect; - = negative effect)

females. These latter factors have likely become important influences on production, masking those of weather.

The calculation which showed the best results was based on variables during the period from the winter through to fall of the same year. This indicates weather acts on survival of the calf as a foetus or on lactation of the female in the spring. If positive energy period and rainfall effects on the nutritive value of browse were to have a major influence on the reproductive capacity of females, then calculation 2, using data from the summer and following winter would be expected to show significance. This was not the case with any consistency (Table 4).

Weather conditions examined apparently did not have any effect on survivorship of the calves past the first summer, as measured by percent yearlings in the kill. However, this relationship can be clouded by several factors such as aging problems (Addison and Timmerman 1974) and varying vulnerability of yearlings with season dates (in eastern Ontario, harvest data show that the later the season the greater the percentage of yearlings in the kill).

Most of the effects of weather on the production of calves is accounted for by winter severity at both districts. This has also been demonstrated elsewhere (Bishop and Rausch 1974, Markgren 1969). Interestingly, summer rainfall was a common variable in the regression at both Cochrane and Kapuskasing although it had relatively little effect at the latter area during the early years. How summer rainfall increased survival of calves is unclear. It may reflect higher quality of browse or perhaps some negative effect on predation. On the other hand, the lack of consistency in magnitude of effect between the two areas could mean summer rain was not of any real consequence. The inconsistency of positive energy period (Kapuskasing 1961-66) and May rain (Cochrane 1956-64) should also be viewed with caution.

The question which Ontario moose managers need answered is "has weather resulted in a decline in the moose population of northeastern Ontario?" These data indicate that during the mid-1950's to mid-1960's calf production was affected by weather variables primarily winter severity. A comparison of severity indices before 1966 and after 1966 indicated there was no difference in severity. Harsh winters (those significantly greater than the 21 year average) occurred four times prior to 1967 and three times after. Therefore, the weather variable which affects the animals most has not changed during the past 21 years. Yet the variance which the weather variables explained in the regressions dropped sharply after the mid-1960's. It appears that other factors became over-riding in their effects on productivity. It is not likely that the weather variables tested have played a major individual role in reducing moose populations in northeastern Ontario.

ACKNOWLEDGEMENTS

Dave Fraser and Dan Welsh aided in analysis of the data and in reviewing the manuscript. Vince Crichton reviewed the final drafts.

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Appendix 1. Correlation matrices for the variables tested.

	Positive Energy Period	May Rainfall	Summer Rainfall	Calves /female
Cochrane				
Winter severity	-.2545	-.0684	.2604	-.4172
Positive energy period		-.3020	.0620	.0221
May rainfall			-.3765	-.1204
Summer rainfall				.3287
Kapuskasing				
Winter severity	-.3616	.1415	-.0062	-.3555
Positive energy period		.1933	.3755	-.0125
May rainfall			.2326	.3545
Summer rainfall				-.1427