

# USING CLIMATE DATA TO PREDICT GRIZZLY BEAR LITTER SIZE

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**Abstract:** A 5-year double-blind test was conducted to test the predictive capability of a previously published (Picton 1978) regression ( $Y = 2.01 + 0.042x$ ), which described the relationship between the litter size of grizzly bears (*Ursus arctos horribilis*) and an index of climate plus carrion availability (climate-carrion index). This regression showed an efficiency in excess of 99% in predicting the observed grizzly bear litter size. The predictions made using the climate-carrion index had a mean absolute error of less than 25% of forecasts using other methods. The updated climate-carrion index regression, which includes all of the 16 years for which data are available, is  $Y = 2.009 + 0.042x$  ( $r = 0.78$ ;  $P < 0.01$ ;  $N = 16$ ). We concluded that the climate-carrion index can be a helpful tool in predicting grizzly bear litter size. The relation of this information to the effects of the closure of Yellowstone Park garbage dumps is discussed.

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The prospect of a carbon dioxide induced climate change (Hansen et al. 1981) has increased the need to sharpen the tools of predictive ecology. Effective tools would make it possible to develop and take corrective management actions before the Yellowstone grizzly bear population is severely affected by the new climate regime. Evidence for such a climate change has been increasing, and it will likely constitute the major environmental impact of the next 50 years (Dickinson and Cicerone 1986). The impact of such climate changes increases as one moves toward the poles. Therefore the climate impact at the latitude of Yellowstone National Park would be more severe than the global average (Kellogg and Schware 1981). This study represents a test of the predictive ability of a regression (Picton 1978) relating the mean litter size of grizzly bears observed during the summer in Yellowstone National Park to a modified Lamb climate index (1963) which includes precipitation and temperature covering the previous October to May period.

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## METHODS

Lamb climate indices (1963) have been used for a variety of purposes. The index modification and its use for grizzly bears stems from work done in studies of deer (*Odocoileus hemionus*) (Picton 1979). Its use has been extended to several other species of ungulates and purposes (Houston 1982, Picton 1984, Keating 1985, Douglas and Leslie 1986). These uses of the modified Lamb index are based upon the concept of the biometeorological normal (Baranowski and Gabryl 1981), which is that animals can adapt to weather conditions within 1 standard deviation (SD)

of the long-term mean and that these conditions can be easily handled by them. These biometeorological normal conditions occur 68% of the time. The major problems imposed by climate are produced by weather more extreme than 1 SD from the mean. This view has a strong basis in basimetric physiology (Wilder 1962). As applied, only the variation relative to the long-term mean is incorporated in the index and this is coded as 1 or 2 SDs from the long-term mean. The absolute values of temperature and precipitation are not included, only the relative variation about the means. Because the absolute values are not used in the index, any weather station whose weather varies with that of the animal range can be used to compute the climate index.

Standard monthly mean temperature and precipitation data (NOAA 1958-81) from the Mammoth, Yellowstone Park weather station were used. This station reflects the variation in the weather of the northern one-half of Yellowstone Park, which consistently has been a prime grizzly bear use area. One or 2 SDs from the long-term monthly means were tabulated separately for temperature and precipitation and then summed algebraically for the periods of interest. We proposed that if climate affected litter size, it would likely involve factors that killed newborn cubs; therefore, we studied the perigestational period. The October-May period that was ultimately incorporated into the regression was selected because it gave the smallest least squares sum (Bahnak and Kramm 1977).

Carrion is known to be important to grizzly bears in Yellowstone Park (Mealey 1980). Elk (*Cervus elaphus*) are the major source of carrion in the Park. No satisfactory long-term surveys of the availability of carcasses exist for Yellowstone, thus a rough estimate of the variation in the number of elk carcasses was made using the standard deviation tabulation

approach. Information incorporated into this judgment included the size of the Northern Yellowstone elk herd (Houston 1982), a 5-month Lamb type index of winter severity as calculated for ungulates (Houston 1982, Picton 1984), probable wounding loss based on hunter kill, and the age structure of the elk herd. Monthly trips to Yellowstone Park were made to confirm the weather and carcass availability indications of the index calculations but the information gathered was not used to change the indices. It should be noted that carrion, as used in this paper, also includes "walking carrion," or debilitated animals that make easy prey. The carrion index values are consistent with the independent estimates of Houston (1977) and the results of the intensive carcass surveys that Houston (1982) conducted for several years. The carrion index value was summed algebraically with the climate index for that year to obtain a climate-carrion index (CCI).

We conducted a double-blind test of the predictions from 1977 to 1981. The indices were computed and both point and trend predictions of grizzly bear litter sizes were made. The field observations and tabulations of litter size were made without knowledge of the predicted values. We then compared the mean cumulative litter sizes from the aerial surveys of the Interagency Grizzly Bear Study Team (Knight et al. 1980) to the predicted values. Both the climate index regression ( $Y = 2.052 + 0.0289x$ ) (Picton 1978) and the climate-carrion index regression ( $Y = 2.01 + 0.042x$ ;  $r = 0.76$ ;  $P < 0.01$ ) were used to make test predictions. We also used other predictive methods for comparison, 1 of which was the simple historical mean litter size as a prediction of the future. This is a common type of trend line forecast. Another ap-

proach used a random number table to select a litter size from those listed in the historical records (random draw) of the area to provide a baseline for comparisons of predictive efficiency. This method or similar methods are often incorporated in computer simulation models.

## RESULTS

The CCI performed better as a predictor than any of the other predictive approaches (Table 1), with a mean absolute error (Bowerman and O'Connell 1979) of less than 25% of the other forecasts. The CCI predictions were within 0.1 cub of the observed litter size. The CCI also performed better in forecasting the year-to-year variation in litter sizes. Because each prediction is computed separately, cumulative errors did not develop.

The random draw predictions varied widely with their efficiency ranging 81.9%–96.2%. To conserve space, only the best of the random draw predictions is presented in Table 1. This method was included because we believed that any useful predictive tool must at least be better than random. The additional 5 years of data (Table 2) were incorporated into updated regressions. The updated October–May climate index to litter size regression is  $Y = 2.054 + 0.036x$  ( $r = 0.68$ ;  $P < 0.01$ ;  $N = 23$ ). The current climate-carrion index regression, which includes the new data, is  $Y = 2.009 + 0.042x$  ( $r = 0.78$ ;  $P < 0.01$ ;  $N = 16$ ).

## DISCUSSION

Climate variation, as summarized by the climate index, is sufficiently related to litter size variation to

Table 1. A comparison of predictions made of the litter sizes of grizzly bears in Yellowstone National Park for 1977–81.

Year	Observed litter size	Predictions			
		Mean projection	Random draw	Climate index	Climate + carrion index
1977	1.8	2.1	1.9	1.9	1.8
1978	2.1	2.1	2.1	2.1	2.1
1979	1.9	2.1	1.9	1.9	1.9
1980	2.0	2.1	2.3	2.1	2.1
1981	1.9	2.1	1.9	2.1	1.9
$r^2$		—	0.471	0.519	0.899
Mean absolute error		0.16	0.08	0.08	0.02
Mean square error		0.036	0.02	0.012	0.002
Forecast efficiency <sup>a</sup>		92.4%	81.9%–96.2%	96.2%	99.05%
Correct trend forecasts		0%	36% (mean of 7)	60%	100%

<sup>a</sup> Forecast efficiency =  $[1 - (\text{MAE}/\text{long term mean litter size})] \times 100$ .

Table 2. The October–May climate and carrion indices for the 1959–81 period in Yellowstone National Park.

Year	Climate index	Climate + carrion index	Litter size
1959	+2		1.9
1960	-7		2.1
1961	+3		2.3
1962	-1		2.3
1963	+8		2.5
1964	0		2.2
1965	+2		2.1
1966	-4	-3	2.1
1967	+7	+8	2.5
1968	+6	+5	2.5
1969	+2	+1	2.0
1970	0	-1	1.8
1971	-2	-3	1.9
1972	+1	+2	2.0
1973	-7	-6	1.9
1974	-1	0	1.7
1975	-12	-11	1.6
1976	+3	+2	1.9
1977	-4	-5	1.8
1978	+1	+2	2.1
1979	-5	-3	1.9
1980	+1	+1	2.0
1981	0	-2	1.9
Mean	-.304	-.813	2.04

Climate index regression;  $Y = 2.054 + 0.036x$ ,  $r = .68$   
Climate + carrion index regression;  $Y = 2.009 + 0.042x$ ,  $r = .78$

justify using the climate index as a predictive tool. This may be a useful tool in helping to adjust management for the expected human induced climate change. The total variation in litter size was 0.9 cub. The  $r^2$  values indicate that the climate index explained 46% of this variation. The combination of the climate and carrion indices accounted for 61% of the variation in litter size. The remaining 39% of the variation is probably due to a number of heavily confounded factors: (1) the closure of the garbage dumps within Yellowstone Park by 1971 while phasing out those at the boundaries of the Park by 1981, (2) the large number of bears removed from the population in the early 1970s, (3) the doubling of the Northern Yellowstone elk herd during the dump closure period, which is not completely compensated for by the carrion index, and (4) long-term climatic changes during this period that are not fully compensated for by the annual climate index used in this study. When precipitation data from all 6 weather stations in the Yellowstone area are combined, 8 of the 10 years before the Park dump closure were wetter than the long-term mean; 7 of the 10 years following closure were drier than normal. This drought period

began in 1973, when 73% of the normal moisture was recorded.

The climate  $r^2$  value for the period before Park dump closure (1959–71) is 0.37 compared to 0.45 for the 1972–81 period. This suggests that the dump closure and the associated removal of animals, long-term climate changes and other factors increased the climate response by 8%. Before Park dump closure, the mean litter size for all years in the biometeorological normal range (CI +4 to -4) was 2.07 cubs (Table 2); following closure it was 1.91 cubs (Table 2). The difference of 0.16 cubs suggests that the dump closure events produced an increased variation in litter size of 18%. The delay in the age of 1st reproduction noted by Knight and Eberhardt (1985) can be expected to produce an equal or greater decline in cub recruitment than the weather associated variation in litter size discussed here. The effects of a diet supplemented by food from dumps on body size, and thus the age of 1st reproduction (Blanchard, unpubl. data), support the view that the number of females breeding may be influenced by the nutrition level during a different portion of the year than that having major effects on litter size. This interpretation

is consistent with the observed relation of climatic conditions to food habits, home range size, weight gain and bear mortality rates (Picton et al. 1985).

Several hypotheses for the effect of the October–May climate upon the litter size observed the following summer are possible. October weather may be important because it determines whether the female will continue adding to her energy reserves or begin using them. Rogers (1976) speculated that black bears take stock of their stored nutrient reserves in fall and may prevent implantation in years when nutrient reserves are low. The cold, low-snow winters associated with low cub ratios may well increase winter energy expenditure in the den and thus increase cub mortality rates. Low snow depths also make it easier for elk to feed thus reducing their mortality rate and the spring carrion supply. The soil profile is recharged with moisture during the September–April period with the moisture peak being reached by May and then becoming limiting to plant growth by mid-June (Mueggler 1971) on sites providing early spring forage for the bears. Plant phenology varies considerably during this spring period (Schmidt and Lotan 1980), which is important for lactation, and has substantial effect upon the availability of grizzly bear foods (Graham 1978). This can be expected to influence the survival of the young of the year. Mattson (unpubl. data) has documented the critical nature of forage and other foods during May in his detailed analysis of food habits and energetics. Inadequate snow cover also permits the ground to freeze, increasing spring runoff and decreasing the water available to plants. It is likely that many of these factors enter into the relationships described here.

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