

PAIRED FACTORS AND MASTER FACTORS IN ENVIRONMENTAL RELATIONS

V. E. SHELFORD
University of Illinois, Urbana

Whoever said that in experimental work only one factor is to be varied or tested at one time—all other conditions in the experiment and control to be the same—covered only about 10 percent of the story so far as living organisms are concerned. It is now about 55 years since Professor Abbe of the U. S. Weather Bureau (1898) made some studies of the sensation of comfort. There was, however, so much variation among individuals that the author illustrated the principles involved by a statement of his own sensations (fig. 1). It is evident here that humidity and temperature are paired. This is understandable by reference to the temperature regulation mechanism of warm blooded animals, especially man (Best and Taylor, 1949, Chap. 25). Hunting-

ton (1919) studied human deaths and found relative humidity and temperature paired; fewest deaths occurred at 80 percent humidity and 65° F. temperature. This probably came about through lessened work to maintain the body temperature at normal.

There are scores of figures, many of them from experimental work, showing paired factors. The writer presented one of them 32 years ago (Shelford, 1920). Recent evidence indicates pairing of radiant energy and moisture. Figure 2 shows the population of prairie chickens in Indiana, chiefly northwest of Morocco, suggesting that sunshine and rainfall are paired in the case of the prairie chicken. At best the figures presented here are only strong suggestions. Weather data were not recorded where birds were, and it was necessary to study the storm routes. This led to choosing U. S. Weather Bureau's Peoria sunshine and Kankakee temperature and rainfall to draw the figures. Furthermore the number of years is small.

There are two or more critical periods in the annual cycle of this bird. Probably the most important is the last phase of the growth of the gonads, chiefly in April. It is evi-

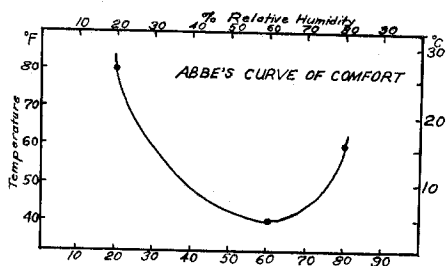


FIG. 1.—Abbe's personal comfort chart. As named in European literature it is a portion of a thermohydrogram.

dent that the combination at that time of 50 percent to 65 percent possible sunshine paired with two to three or even six and one half inches of rain was associated with the highest number of booming males in the following year. However, many things probably happen to a population in the other 11 months. What should be known is the number of eggs produced and the relative vigor of the young (Sabrosky et. al., 1933; Bailey, 1946).

If the number of males is plotted on a linear graph it is not possible to draw any conclusion as to relation to rainfall.

The second phase of the prairie chicken life cycle is concerned with

incubation, during May for the majority of individuals. This does not usually appear to be a critical period from the standpoint of the physical environment and population.

The third period falls chiefly in June when most of the population is concerned with hatching and rearing of the young. This is apparently a very critical period. Temperature and rainfall appear to be paired and important. We should have the number of young birds at the end of June, but again, only the numbers of booming males of the following spring are known. Figure 3 shows the paired factor relations. The figure suggested by these data is smoother and generally better. Less

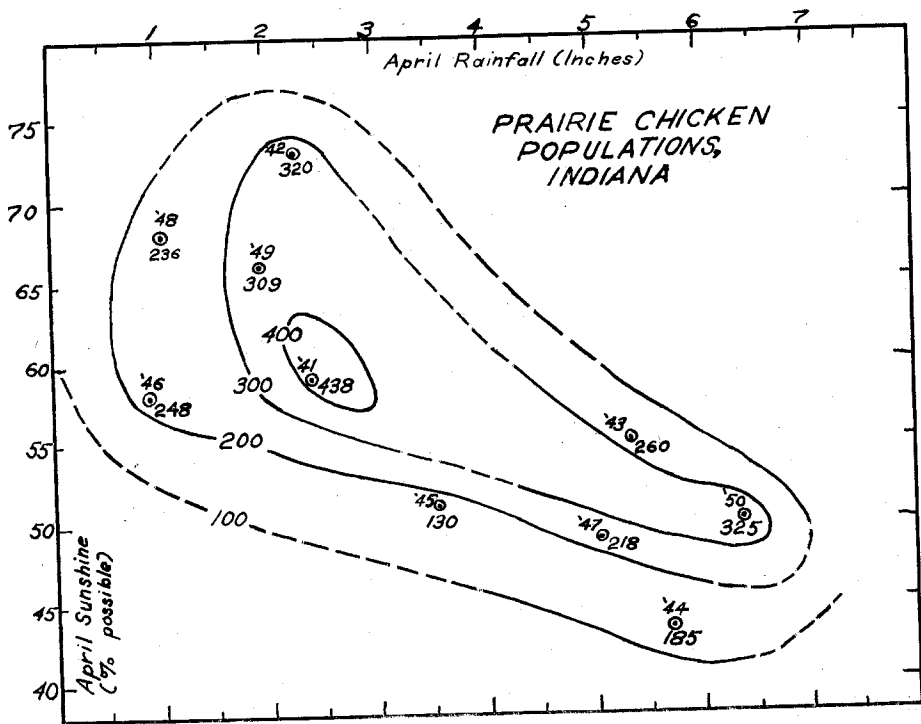


FIG. 2.—A heliohydrogram of the prairie chicken, *Tympanuchus cupido americanus* (Reichenbach), population in northwest Indiana for the sensitive period of April. Bird data (booming males in the year following) from the Ind. Cons. Dept.

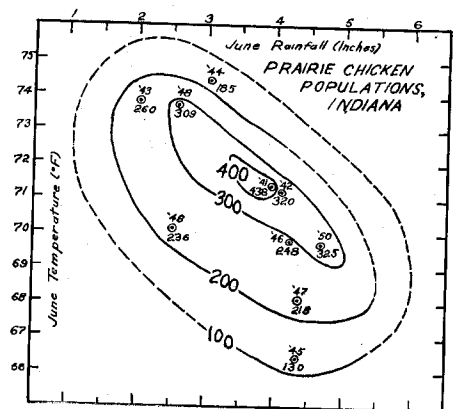


FIG. 3.—A thermohydrogram of the prairie chicken population in figure 2 for the survival-sensitive period of June; data from Indiana Cons. Dept.

happens to a population in the nine months than in the nine plus two months. The highest populations are associated with temperatures between 69° and 74°F. and rainfall of 2.5 and 4.6 inches. An inspection of these ranges shows that the entire range of population size falls within the optimum range of rainfall. The optimum range of temperature would be no better if the blanks at the right were filled.

Beginning at the end of July there is a 9-month period in which the prairie chickens, young and old, are feeding, resting, hiding, etc. The success of the group is related to the amount of cover and food, especially in winter. We have no data on the population which we have been discussing, but in Illinois the State Agriculture Department's Crop Reporting Office maintains a record of the condition of pastures which represent the gross results of the vegetative growth of plants month by month. Figure 4 shows the relation of pastures and the Hunt City, Illinois, prairie chicken population,

1935-1948. The data cover April through October. Here the largest populations came with best pasture conditions. This eight or nine months includes no critical period except for unusually severe weather. Severe food shortage may be a critical or master factor which predominates over other factors.

Larsen (1943) has referred to some internal factors as master factors. The urge to gather on the booming grounds would be an internal master factor. Furthermore, one of the two pairs of factors operating coordinately may be a master factor or at least much more important than the other one.

Ultraviolet was a master factor in the period 1924 through 1938 in the case of the quail in the entire state of Ohio and chinch bugs over a large area. In this case the short-wave radiation operated with reference to a narrow band of optimum intensity (Shelford, 1951, fig. 12, p. 169). Unfortunately neither the quail data nor the chinch bug data are so arranged that paired-factor diagrams can be drawn. In the case of the Wisconsin quail data, it was not possible to use deviation from an optimum band of ultraviolet as noted above. This may be because the critical period of gonad growth and ultraviolet sensitivity fell partly in April and partly in May, owing to the latitude. Examination of any of the paired-factor diagrams indicates the probable futility of the study of single-factor relations unless one of the factors happens to be a master factor (Marshall and Bowden, 1934).

There is little information on the size of seed crops from year to year that can be compared with animal

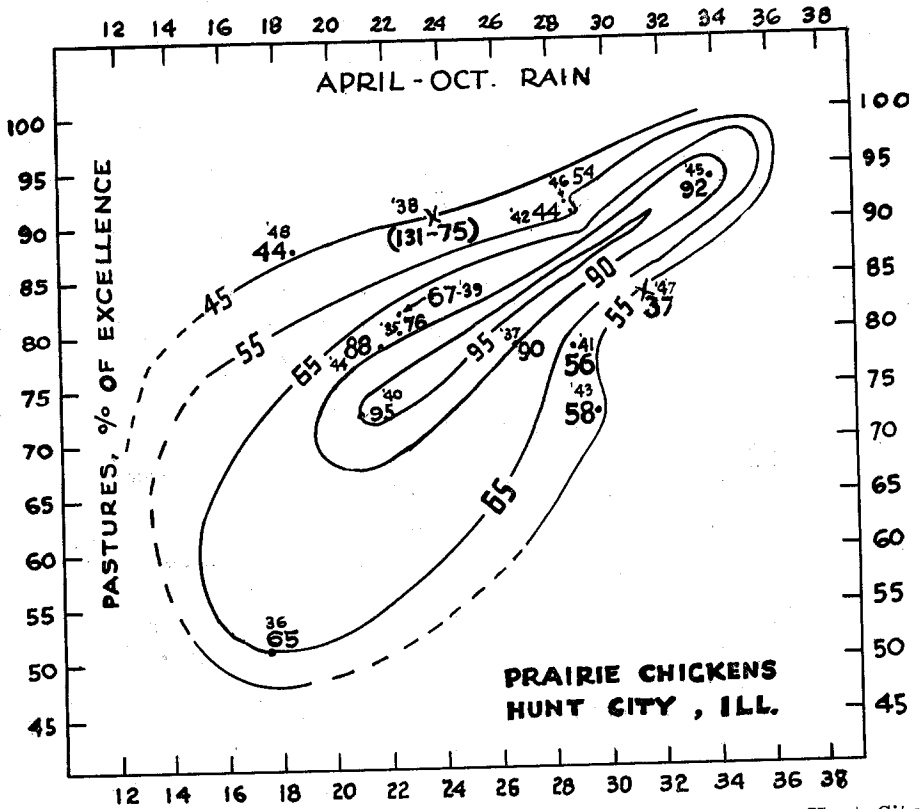


FIG. 4.—A phytohydrogram indicating food and plant cover for Hunt City prairie chickens. Bird data from the Illinois Nat. Hist. Survey. Rainfall, U. S. Weather Bur., Newton. X = discordant values, 1947 change in crops, 1938 cause unknown (possible inward migration). Calculated value, 75.

population fluctuations. In the case of cultivated plants it appears that the only paired-factor diagrams are concerned with plant diseases (Tehon, 1924, 1927). With all that is at stake it seems strange that no studies of crop production have been made by this method.

Part of the uncertainty in planning research results from the lack of weather records on the areas of population being studied. Recording rainfall gages and temperature, humidity, and sunshine recorders have been available for many years.

Most require attention once a week, but with slight modification they can be adapted to fortnightly servicing. Field measurement of ultraviolet is by no means impossible, especially where electric current is available. Thirty years ago field instruments were probably in more common use than at present, probably because of the small value they appear to have from the single-factor viewpoint.

Laboratory facilities have been wanting in many cases. Ecology, wildlife management, parasitology and other subjects require outdoor

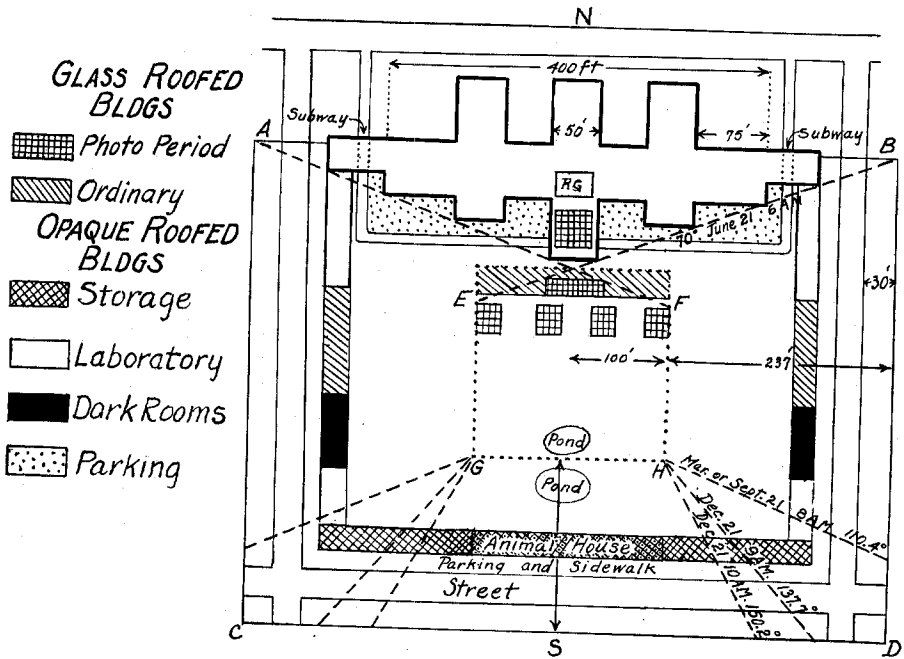


Fig. 5.—Life science building with a south yard enclosed by one-story buildings. Area E F G H, a little less than 200 feet square at 40°N ., has no shadows from about an hour after sunrise to an hour before sunset when objects 70 feet high are 237 feet from its east or west border. The distance from its south border in winter is a little less. The four small green houses are so arranged that special glazing or treatment of the roof of one will not interfere with the others. The main building casts no shadows on the well-lighted area, EFGH. Its roof can provide small garden space (RG) and a glass-roofed house for summer use. This is an improvement of the plan described earlier (Shelford, 1952), based on the practices and difficulties of investigators using such facilities.

space and glass-roofed rooms. Figure 5 is a plan proposed for a life science building. For fields of research requiring outdoor space, the main building is of little concern. Only the roof features are for practical use in the growing season. The yard to the south of the main building is of critical importance. It must be surrounded by useful and necessary one-story buildings. The dark rooms make possible the drawing of plants and animals into the yard for any period of length of day. Length-of-day effects have been reported for everything from aphids to zinnias

and bulls to Xanthium, but very few wild plants and animals have been studied. Facilities should be available for adding a very small amount of ultraviolet to the light under which the experimental animals are living. This calls for electrical and other facilities not available or easily used in the field. Refined measurements are needed. To make the results applicable in nature, all suggested interpretations of experiments and weather analyses must be checked out-of-doors experimentally.

One institution in each large state should provide such facilities. In

Illinois two of the state-supported institutions of higher education have turned down every suggestion for such facilities. Some of the others have a special obligation to provide such facilities; they are essential for the study of the ecological, wild-life, and general conservation problems of Illinois.

ACKNOWLEDGEMENTS

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used in figures 2 and 3. This is from the files of the Indiana Department of Conservation. Similar acknowledgement is due R. E. Yeatter (1943) of the Illinois Natural History Survey for the release of the Hunt City, Illinois, prairie chicken data used in figure 4. Dr. Yeatter contributed much in other ways also. Thanks is due J. A. Ewing of the Illinois Crop Reporting Service for the pasture data.

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