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BOBWHITE QUAIL POPULATION DYNAMICS: RELATIONSHIPS OF WEATHER, NESTING, PRODUCTION PATTERNS, FALL POPULATION CHARACTERISTICS, AND HARVEST IN MISSOURI QUAIL

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Abstract:

For 25 years Missouri has investigated bobwhite quail (Colinus virginianus) behavior, production, and population response to 4 major types of weather. Ten population parameters are examined annually to compare effects of Normal, Wet-Deluge, Snow-Cold and Drought weather years on quail populations.

Different types of weather are related to varying annual quail abundance by affecting productivity and survival and influencing relative levels of annual harvest and hunter interest. Normal and Wet-Deluge years yield favorable fall quail populations and satisfactory hunting. Years having winters of severe snow and cold have high breeder losses, low production, and reduced hunting success. In years having high temperature and drought in spring and summer, quail reproduction is inhibited, resulting in high losses of eggs and young, greatly reduced fall bird crops, and below-par hunting for many hunters. Recovery from weather-caused population lows usually occurs within 2 or 3 years after favorable weather conditions return.

Reliable techniques for sampling have been developed to yield indices of annual production and hunting success. Production curves show the value of data on the distribution of peaks in hatching for understanding annual production and fall population levels of quail in Missouri. Such data form the basis for setting annual hunting regulations of bobwhite harvest.

Successful management of bobwhite quail rests upon land-use and vegetation-manipulation practices that produce habitat capable of supporting abundant quail. An adjunct to this favorable habitat-game complex is a knowledgeable interpretation of the relationships between quail production, survival, weather, and effects of game harvest.

To learn these relationships, the annual collection of data on weather, game population dynamics, and game harvest becomes an important part of both applied and long-term research programs of many game departments. The data provide a growing understanding of species biology and serve as a basis for sound harvest regulations. These data usually represent the major information source for the managing organization and for the sporting public.

This paper presents data on the biology, population dynamics, and responses of bobwhite quail to weather in Missouri from 1948 through 1971. By extrapolation, much of the data relative to Missouri may apply to other locations in the more stable midcontinental bobwhite quail range.

Location, Topography, and Climate of Study Area

Missouri, embodying 69,420 square miles, lies between latitudes 36°30' N and 40°31' N in the basins of the Missouri and Mississippi Rivers. In longitude, the state lies between 89° E and 95°46' W.

Missouri includes portions of 4 major physiographic provinces. These provinces and the bobwhite harvest estimated for each in 1969 are: (A) The glacial or northern plain, an expanse of generally rolling-to-level land extending across the state, north of the Missouri River, in which land use is mainly for headgrains, beans, and cattle and hog farming (1,721,000 birds). (B) The Missouri Ozark highlands, bordered by the White, Missouri, and Mississippi River drainage basins, cover much land area south of the Missouri River; their rough-rolling, partly to heavily

timbered uplands, and their cleared bottomlands now support grazing, limited small-grain farming, and woodland products (621,000 birds). (C) The western plain, a broad wedge-shaped prairie penetrating the central western portion of the state, has grazing and headgrain and bean farming as the major land-use practices (1,547,000 birds). (D) The southeastern corner of Missouri, with fertile flat, Mississippi River delta lands, supports intensive production of corn, headgrains, beans, and cotton (92,000 birds).

The climate of Missouri is similar to that of the cornbelt. Average temperatures in January range from 27 F in the northwest to 37 F in the southeast. Temperatures in July average 79 F in northern counties to 80 F in the southeast. Summer temperatures throughout the state often exceed 100 F. Extremely high temperatures and dryness, producing severe droughts harmful to agriculture and quail, have occurred about 8 times in the last 45 years. Prolonged snowfall, with low temperatures, prevailed in about 1 of 11 years. Severe drought or deep, prolonged snowfall rarely occur statewide.

Average annual snowfall ranges from 6 to 8 inches in the southeast counties, 12 to 16 inches in the Ozarks, 16 to 22 inches in the central counties bordering the Missouri River, and 22 to 26 inches in northern counties. Major snowfall months are December through February and occasionally through March. When prolonged, severe, March snowfall occurs, numbers of quail decline considerably (Fig. 1).

Averages of annual precipitation (rain-snowfall) in Missouri range from 50 inches in the southeast to 34 inches in the northwest. Rain is generally well distributed throughout the year with about 42% of it occurring during the active crop-growing season of May through August. Spring-summer rains are frequent (except in drought periods) and often severe, delivering up to 10 inches within a 24-hour period. Table 1 presents normal or average monthly weather for Missouri's climatologic divisions (2).

Missouri bobwhite populations are relatively stable in accord with annual weather patterns, but both snow and drought adversely affect populations (15). Although periodic declines in quail numbers, through stress caused by severe weather, may be striking, they are short-term occurrences. Neither snow-cold nor drought occur as frequently or as severely in Missouri as in the fringe portions of the quail range: the northern heavy-snow states and the droughty western-southwestern areas.

Study Objectives

Beginning in 1946, Missouri developed a series of quail-research projects to obtain long-term information on reproduction and other biological characteristics. Project goals were:

1. To develop sampling surveys to provide annual indices of the relative abundance of bobwhite quail and to measure the related hunting success.
2. To study annually, regionally, and statewide the effects of weather upon bobwhite quail behavior, production, survival, and abundance.

3. To determine the relationship between hunter success and annual quail population levels, and the relationship between hunting effort and various annual levels of quail abundance.

4. To study nesting behavior, production chronology, fall population characteristics, and wing-molt progression of both young and adult birds.

5. In 1959 the project was expanded to include studies of nesting behavior and molt in quail collected (shot) in the wild and wild quail trapped and held as pairs in isolated field (ground) pens.

I am grateful to the research personnel, field men, rural-route mail carriers, and quail hunters who cooperated in field studies on bobwhite quail. Special acknowledgement is made of F. W. Sampson, biologist in charge of annual small game harvests.

Methods

A Bobwhite Quail Population Survey, including daily observation and recording by field observers, is operated on a 12-month basis by the Missouri Department of Conservation. Over 200 field personnel (Conservation Agents and special-area men) submit monthly survey forms summarizing daily recordings of prevailing weather conditions, quail numbers seen, and activities relative to covey breakup, pairing, mated pairs, singles, and nesting.

Production Season

A special Quail-Brood Population Index Survey is conducted during July and August as a portion of the year-round survey. This employs additional Department area personnel and 200 to 300 rural mail carriers. The ages of quail broods and field activities of adult birds are recorded.

Between 2,000 and 3,000 broods are normally observed and their ages estimated during the 60-day survey period. Data on broods whose ages have been determined are used in 2 ways:

1. To show nesting-hatching chronology from covey breakup until mid-July, and to pinpoint the first hatching peak. Fig. 2 presents typical quail production patterns based upon the average of data from 12 years. The first peak of hatching shown on the graph is based upon brood age data; the second peak is estimated from wing molt data from harvested quail.

2. To formulate an annual Production Index (PI) which is the average number of broods seen per observer during the survey period (Fig. 1, Table 2). PI's are developed on both a regional and a statewide basis.

Hunting Season

Traditional dates for the quail hunting season in Missouri were 10 November through 31 December from 1915 to 1962. Since then, the season has been extended through 15 January. During the hunting season, data

are gathered on hours hunted, coveys flushed, birds taken, related information, and 10,000 to 20,000 hen wings. These data are collected statewide through the efforts of cooperating hunters who provide information on 5,000 to 6,000 hunts, 20,000 to 25,000 hunting hours, and 20,000 to 25,000 coveys flushed. Data are analyzed regionally and statewide. Wings are collected only during the November part of the hunting season (10-30 Nov.).

A Hunting Index (HI) figure (Fig. 1, Table 2) based upon hours hunted and coveys flushed is computed annually for regional and statewide use. This index is used in conjunction with PI figures for evaluating annual Production-Hunting success and in making comparisons with success of other years.

Early in this study large collections of wings from quail of both sexes were analyzed annually to determine age ratios of both males and females, and of hens only. Data on adult cocks per 100 adult hens were computed from samples of wings and from records on daily hunting forms.

It was concluded that:

1. the sex ratio of young birds in the fall is 50:50,
2. adult cocks outnumber hens (similar distortions of sex ratio in Missouri quail were found previously [1,2,10]),
3. hunters' records of harvested quail provide adult sex-ratio figures comparable to those computed from wing samples, and
4. hen wings alone provide, as suggested by Petrides (11), adequate information on the young-adult ratio.

Thus for the reasons listed, plus the obvious savings in manpower, time, and money, young-adult ratios are computed from about 10,000 hen wings per year. Age-ratio figures of 85% young to 15% adult serve as the normal base figure in describing age ratios of hens in this study. These percentages resemble the figures of 80%-20% cited in sex-age ratios, including both cocks and hens, in other areas.

An associated project of the Missouri quail survey is an annual January-February trapping of wild quail which are held as pairs in isolated ground pens. Since 1960, an average of 30 wild pairs per year (as many as 100 pairs) have been used in studies of reproductive behavior and primary molt in adults (mainly hens) and young (17). Data from this long-term project, and from birds collected in summer, have added materially to interpretations and conclusions.

Table 3 summarizes basic field data and lists parameters for which the data are used.

Results

Spring Behavior, Covey Breakup, Pairing, and Nesting

Bobwhite quail populations in Missouri exist as coveys during the period of January through March. Although field records show that occasionally a few birds pair and nest extremely early, in late February or early March, most birds remain in a covey until mid-April.

As days lengthen and warming occurs in late March or during April, the calling of male "bob-whiting" is heard in fields and woodlands. Such calling usually coincides with the blooming of yellow spring mustard (*Brassica kaber* var. *pinnatifida*) and announces the breakup of wintering coveys and onset of subsequent nesting activity. From then until mid-September, the abundance of whistling males indicates nesting-hatching chronology of the production season (16).

Spring reproductive activities begin in southern Missouri and progress northward; southern counties are usually 10 to 15 days ahead of northern Missouri. Many quail in Missouri establish pair bonds before the major covey breakup, as do quail in Texas (8). These pairs leave the covey and feed and loaf together during the day, but they return to roost with the covey at night.

Covey ties usually begin to weaken in mid-March, but chilling, wet days and cold nights cause regrouping of scattered birds. Generally, covey ties are completely broken and pair bonds are well established from 15 April through the first week in May.

If cold conditions prevail late in spring, covey bonds for some birds may continue until the end of April or even mid-May. When covey breakup is delayed, pairing is often concentrated in a brief time period. In 1 week birds are mainly in coveys while the following week, after 1 or 2 days of typical spring-like weather, covey breakup occurs and pairs form.

Actual pairing, nesting, and laying undoubtedly involve a photo-period (length of daylight) affecting the bird's hormonal balance, but the time of covey breakup seems to depend mainly on a temperature-moisture relationship. Quail in Missouri follow a fairly predictable pattern of reproductive activity after covey breakup (15 April, day length of 12 hr 48 min). A few quail, however, begin nesting in early March (1 March, day length of 11 hr 20 min) and have young chicks flying in mid-April when other quail are still in coveys.

When adequate nesting cover is available near a covey's winter headquarters, many pairs may remain in that vicinity. If nesting vegetation is lacking, birds often move onto lands that lack winter survival cover but will support spring and summer reproductive activities. The population may occupy such areas during the summer and early fall then move to more secure, woody, wintering sites prior to the fall hunting season. Woody cover is emphasized because it is essential to good winter habitat.

In years having favorable spring weather, about 64% of the paired birds nest in April and May. These efforts result in a peak of hatching at about 15 June, the first of 2 major hatching periods in a typical production cycle. The second hatching peak occurs about 15 August.

Short-term weather factors that affect quail production and abundance are: (A) winter snowfall-temperature relationships involving the amount and duration of snowfall and extent and duration of low temperatures, which determine how many breeders survive; (B) spring moisture-temperature relationships (April-May) which control onset of nesting and early season production; and (C) summer moisture-temperature relationships in the nesting, hatching and rearing periods, which affect overall production and survival of young. Negative effects of 1 or more of the short-term weather factors produce noticeable to considerable fluctuations in annual quail populations. Low populations resulting from short-term adverse weather conditions are usually corrected within 2 or 3 years, unless adverse weather, such as drought, intervenes.

Arbitrary standards, based upon weather records, surveys of quail populations, and harvest records are used to classify weather conditions affecting annual production into 4 types of production seasons. The names and terms of types used in this paper are based upon United States Weather Bureau terms familiar to farmers and sportsmen. Major annual weather types affecting bobwhite quail are expressed simply: (A) Normal, (B) Wet-Deluge, (C) Snow-Cold, and (D) Drought.

Weather data for 25 years used in evaluating and distinguishing population parameters are averaged and grouped according to the 4 major types of weather in Table 4. Quail production and population parameters for the Normal year provide the basic data for comparing and evaluating changes in quail density occurring in adverse weather years.

Normal or Favorable Winter-Spring Production Year (10 Years)

In the Normal year, temperature and moisture, including snowfall, do not deviate greatly from the average of weather bureau records (Table 5). Snowfall varies from slightly above normal to average to very light amounts that, in extremely favorable years, persist briefly. While the winters of Normal years may often be stressful and cause considerable breeder mortality (when average snowfall is concentrated and accompanied by low temperatures), losses are never as great as in the severe, cold winters in which snowcover is prolonged into March.

In Normal years, as in some years having extremely wet springs, covey breakup usually occurs from mid to late April. The first hatching peak then occurs around 15 June, when about 64% of the annual bird crop is produced. A second peak in the hatching period usually occurs around 15 August when approximately 36% of the year's bird crop is produced. Fig. 2 shows the Normal-year hatching curve.

The typical covey breakup in April followed by hatching peaks on 15 June and 15 August, has happened in 15 or 25 years. These Normal years are essential for satisfactory fall quail populations in Missouri.

Ten population parameters are examined in evaluating and comparing the effects of Normal versus adverse weather years on quail (Table 4). The average of data from 10 Normal weather years serves as the base.

Fig. 3 presents a summary of annual production-season weather, distribution of hatching peaks, and some population parameters. PI's of Normal production years usually fall in the favorable to very favorable range (9-12+). The HI in Normal years ranges from 66% to 84%. The graphed relationship of PI's and HI's is shown in Fig. 1.

Primary feather molt and replacement in young quail indicate hatching chronology. In adult hens, wing molt progression often reflects the timing of nesting and production because most hens delay wing molt until after the young hatch. The delaying effects of adverse May-June weather on hen nesting and hatching will usually be shown by late wing molt in the hen.

Missouri quail studies (17) show that incomplete molt in mature hens may indicate: (A) no production in June, nesting delayed until late July or August; or (B) second nestings by hens (Fig. 2) (17). The incomplete primary molt pattern in young Missouri birds hatched during August or later in a Normal year averages 36%. An average of 66% of the adult hens shows an incomplete replacement of primaries, wherein primaries 10 and 9 (occasionally 8 also) are retained and not molted until the following fall. Wing aging of quail is based upon back-aging primary molt from 20 November, the midpoint in the November wing-gathering period.

Onset of molt of primary feathers in adult hens may occur from May through October, with the major period of initiation occurring from June through September. About 18% of hens nesting successfully molt shortly after the mid-June hatching peak, but in most of these early nesters, onset of molt is delayed until July or August. Fig. 2 shows periods of molt onset and duration of primary-feather replacement in hens during Normal years. Nonmolting hens in late July and August are potential nesters over a 4-month period; many of these hens are potential producers of second broods (17).

An analysis of hen wings collected in November gives age ratios of young to adult birds, and hunting records provide sex ratios among adults. In years when adult sex ratios approach the normal figure of 114 cocks to 100 hens, a high proportion of juveniles in the bag indicates good production (11 young per adult hen represents the normal or favorable production year). If, as occurs in some adverse years, the proportion of juveniles is high whereas the proportion of adult hens is low (interpreted as high losses of adult hens) we must be aware that the population may actually be down because the high proportions of young in the bag may be a function of low numbers of adult hens rather than of high productivity. Thus, when interpreted properly, the proportions of young per adult hen and of adult cocks per 100 adult hens are valuable parameters for evaluating relative success or failure of annual production.

Normal years usually provide good-to-excellent quail hunting because birds are in habitat capable of supporting good populations. The average HI of 75% (Table 4) shows that Normal years provide the highest hunting success of any type of weather year. Occasionally, as shown in Fig. 1, annual hunting success may be higher or lower than the harvest prospects indicated by the annual PI.

In the case of such higher success, the answer often lies in the fact that fall hunting conditions are exceptionally favorable for a high harvest, and many birds are taken in just a fair production year because only the best bird hunters are afield and working hard. Lower hunting success than expected often occurs in a good bird year when an exceptionally warm, dry fall or an early December onset of cold-snow weather may seriously restrict hunting success and cause many hunters to forsake the field.

Annual numbers of quail hunters fluctuate in accord with high and low bird years. In seasons having poor hunting prospects, many gunners may forsake the field until years having brighter harvest prospects occur. One may ask why?

Missouri quail hunters seem to include 2 types of individuals. Some men spend considerable time in developing good dogs, seeking hunting sites, and hunting often. These hunters possess the characteristics that cause them to be afield during any type of quail year; they hunt and work hard to find game and they usually find it.

Men in the second group enjoy bird hunting, but unfortunately their time is limited for working dogs, locating a variety of hunting sites, and actually hunting. These individuals usually do considerably less hunting in adverse game years, or they may not hunt at all, because they are "fringe hunters". The fact that many "fringe hunters" often forego hunting in seasons having reduced quail prospects leaves the game supply to fewer hunters. Thus, many men afield in the poorer bird years, while not having the best of success, do pretty well. Their results often show up as fairly good HI's in poor bird years.

The average kill per hunter further reflects the effects of production-season weather on annual bird abundance; this figure helps in evaluating and comparing hunting success over the years (Fig. 1).

Wet, Above-Normal Rainfall, Deluge Spring, Production Year (6 Years)

The Wet-Deluge seasons are usually characterized by having rainfall considerably above normal in April, May and June, and often in early July. Spring moisture may be near average, but prolonged May-June torrential rains may sheet-wash fields and flood out nesting sites. The normal schedule for harvesting crops, mowing, and haying is greatly altered, adding to early-season nest disturbances and losses. The presence of many paired quail in May and June, called "road walkers" in Missouri, gives ample evidence of disrupted nesting schedules.

Table 4 and Fig. 3 illustrate the population characteristics of quail during the Wet-Deluge years. Wet year production patterns may differ from those of Normal years in several ways:

1. The June hatching peak may occur around 15 June, but a lower percentage of young is produced. The second hatching peak usually occurs near 15 August, but the total hatch increases through compensatory nesting by many hens that lost their clutches or young earlier in the

rain-soaked hatching period of June.

2. The first hatching peak may be delayed until early July as a result of cool, wet spring, and be accompanied by a drop in overall production, although in some years production may be higher than normal. The second peak is usually a week or more later than the normal date of 15 August. In some wet years, the hatching percentage in the second peak is above the normal percentage, but in deluge years, the August peak may fail to make up the early-season production losses and the annual population shows a small-to-considerable decline. Fig. 4 compares the production pattern and percentage distribution averages between Normal and Wet-Deluge years and shows the shifting of hatching peaks that often occurs in Wet-Deluge years.

3. While PI's in Wet-Deluge years may occasionally fall in the favorable range, they will often be poor to fair (Table 2, Fig. 3). The average Wet-Deluge year PI is 8, compared to 12 for Normal years.

4. HI's of some Wet-Deluge years indicate good to satisfactory hunting, but low indices of extremely wet years show that occasionally fall quail populations may be low because of excessive moisture. The HI average for the Wet-Deluge years is 66% compared to 75% in Normal years (Table 4). Both PI and HI figures indicate accurately the relative population status of quail in the Wet-Deluge years. The average kill per hunter (Fig. 1) further shows that fair-to-favorable population levels of wet years provide success for hunters afield.

5. Young-old ratios in Wet-Deluge years average 83%-17% or only a 2-point departure from the proportion of 85% young to 15% adult in the Normal year. On the surface, a small percentage-point difference such as this appears of little consequence. If we compare the difference in young per 50 pairs of adults (Table 4), we see that quite a change in production has occurred because 488 young (83% young) in wet years is 14% below that of 567 young (85% young) in Normal years.

6. The ratio of young per adult hen averages 10, and there are 116 adult cocks to 100 adult hens. When compared with Normal-year figures, the Wet-year data indicate a slight drop in production occurring with some increase in hen mortality.

7. Increased percentages of incomplete molt over that of Normal years occur in August or afterward in the Wet years; the corollary to this is in a higher percentage of adult hens carrying incomplete primary molts. Such indications of compensatory nesting in hens undoubtedly lessens the impact of early season nesting losses and raises fall population levels. (Such late compensatory nesting does not occur in severe drought years).

Wet-Deluge years, as with other adverse weather years that may limit population, may occasionally encompass much of the state. Usually not more than one-half of the state, and in some cases only 1 or 2 regions, may be affected.

While Wet-Deluge years may negatively affect annual production-survival and fall population size, such years have always supplied adequate quail crops to assure a fair-to-satisfactory hunting season. Wet-Deluge years do not have an adverse effect on subsequent production as may happen in a sequence of severe drought years.

Snow-Cold Winter-Spring Production Year (4 Years)

In Normal weather years, average snowfall, low temperature, and occasionally icy conditions cause a portion of the annual quail mortality. Such losses are increased if snowfall is concentrated, covers the ground for long periods, and occurs in late winter. At this time, some stressed birds are existing in nearly marginal habitat. Considerable losses of birds ensue, whereas if similar conditions occur early in winter, losses are less because habitat at this period is more secure and birds are in prime, fall-fat condition.

Some exceptionally mild-to-open Missouri winters, having little or no snowfall, occur periodically and permit higher breeder survival and carryover than normal. Such winters often precede exceptionally fine quail crops.

A Snow-Cold year having considerable below-normal winter temperature, coinciding with above-average snowfall prolonged into March, is a time of high winter mortality, and quail populations in the subsequent fall show a serious decline.

Masses of huddled, starving quail and uncoordinated coveys move along rural roads after being forced from snow-blanketed, submarginal home ranges. Emaciated, nonflying, or frozen birds, easily collected by man or predator, mark the Snow-Cold winter. Stanford (15) and Roseberry (12) have described in detail the catastrophic effects of the 1960 "Big Snow" winter on midwestern bobwhite (Table 5).

Subnormal numbers of breeding birds in spring, greatly reduced fall populations, and a poorer hunting season are the aftermath of the Snow-Cold winter.

Quail production patterns and some population parameters for individual Snow-Cold years of 1947, 1948, 1960 and 1970 are shown in Fig. 3.

Although some statewide production and harvest parameters of 1970 fail to compare with those of other Snow-Cold years, 1970 is placed in this classification because southwest Missouri and much of the Ozarks had severe winter snow conditions resulting in population decline and extremely low hunting success. Statewide data tend to mask the effect of these high winter losses because of exceptionally high quail populations and hunting success in the rest of the state during 1970.

Effects of Snow-Cold are shown in Table 4. Quail populations of heavy snow years vary from Normal in the following respects:

1. A marked reduction in spring breeder carryover is caused by high bird mortality in late winter, resulting in a noticeable scarcity of birds in the nesting season. This condition is clearly reflected in a greatly reduced average PI of 5, compared to 12 for the Normal year (Table 4).

2. In Snow-Cold years (and often in years of cool, wet springs) quail behavior may include either normal onset of pairing and nesting, with the first hatching peak around 15 June, but with fewer hens nesting and contributing young to the first peak hatching period, or delayed covey breakup resulting in a first peak of hatch near 1 July or slightly later, with fewer chicks than normal being brought off. 1 July first-hatching peaks have occurred in 5 of 25 nesting seasons.

3. The second major hatching period in Snow-Cold years may peak around 15 August or as in Normal years it may be a week later or very much later as in 1947 (Fig. 3).

4. In Snow-Cold years, the first hatching peak produces fewer birds and the second hatching peak provides more young than in Normal quail years. Overall total production usually falls considerably below that of Normal years (Table 4).

5. The average of 82% young in the Snow-Cold years (Table 4) is only 3 percentage points from normal. But 456 young from 50 pairs shows more clearly a decline of 19%. The figure of 124 adult cocks per 100 adult hens (compared to a Normal of 114-100) indicates greater losses of hens in Snow-Cold years than in Normal seasons. In very severe years, high loss of hens may be paralleled by high losses of males. Statewide data averages (Table 4) may fail to show the true extent of high regional bird losses which occur in areas receiving the brunt of winter storms. Data for individual years provides a clearer understanding of the degree of quail decline.

An example is the Snow-Cold of late winter in 1960 when southern Ozark timber lands were snow blanketed and many areas suddenly became submarginal for birds. Regional data showed 77% young and only 335 young per 50 pair or 41% below Normal-year abundance.

Annual data for individual years can be misleading unless all parameters are carefully considered. For example, the "Big Snow" year of 1960 provided the best data on quail behavior on record. Careful field observations clearly indicated that Missouri's quail populations declined 50% to 75% in various regions. The state PI of 3 was the lowest on record and similar to that of drought year 1953. Yet, under such conditions, 1960 data showed favorable figures of 84% young, 11 young per adult hen, 525 young per 50 pair (nearly the normal of 567 young) and 114 adult cocks per 100 hens, the same as a Normal-year cock-hen ratio. The conclusion drawn is that high mortality served as a common leveler for both sexes. The results were Normal appearing but deceptive in some parameters.

The Snow-Cold conditions in years 1947 and 1948 were less severe on quail than were conditions in 1960. Yet data for these 2 years, while showing favorable figures for young-old ratios and young-per-adult-hen ratios, clearly revealed, through large distortion in adult cock-hen ratios, the high loss of hens. This distortion caused the deceptively favorable-appearing data on young.

The need for several parameters for ample interpretation of population data becomes evident.

6. The Snow-Cold data show a 24% increase over Normal in the size of the August peak hatch and in incomplete molt in birds hatched during August or later. Numbers of adult hens molting late show an 11% increase above Normal, indicating production losses in the early nesting season and compensatory nesting during the August hatching period.

In evaluating effects of the Snow-Cold weather on quail, bird losses often appear severe and similar to those of some drought years. Hunting success in the 1960 "Big Snow" year rated poorer than in severe drought years (Fig. 1).

Reduced bird populations in Snow-Cold years cause reduced hunting effort as many fringe hunters do not hunt. Hunters find the bird crop down and coveys sparse. Birds are gone from areas that support them in mild winters. Hunting efforts provide reduced bags, and the average kill sets a record low for all types of adverse-weather years.

Quail populations usually show rapid recovery to favorable levels within 2 or 3 years following a Snow-Cold year. One year's production is usually required for developing an ample supply of potential breeders; by the second year (sometimes the third) populations are at or near Normal. Numbers of hunters afield then increase with the growing quail population.

Drought Production Year (6 Years)

Of the 3 major types of weather effecting changes in the Normal production and survival curve of Missouri bobwhite, drought is undoubtedly the most dramatic. In Drought years, high prevailing ground temperatures and much-below-normal moisture prior to and throughout the production period affected quail behavior in various ways and at important stages of the production cycle. Such conditions have prevailed in 6 quail production seasons in 25 years. Oddly enough, these 6 Drought years occurred consecutively, during 1952-1957 inclusive, and this undoubtedly accentuated effects of drought on quail in the more stable portion of the bobwhite's range. These data clearly illustrate the more serious effects that drought can exert on quail populations in midcontinental United States.

Regional droughts of season duration occur periodically in Missouri. These are not considered here because such conditions usually affect only the fall behavior and movement of birds rather than significantly reduce populations. In such years, birds often forsake drought-seared

and overgrazed areas and seek refuge in woodlands where they are usually unavailable to hunters. The effect of drought on bobwhite quail has been studied widely (3, 4, 5, 6, 7, 8, 9, 13, 14, 18, 19). Drought-caused effects and changes from Normal are as follows:

1. Onset of pairing, covey breakup, and nesting is delayed.
2. In a severe drought year in which spring moisture shows a cumulative deficiency (often from a previous drought year), many birds may fail to break coveys and to pair. Some covey units remain partially or nearly intact through June, July, and August.
3. Limited nesting occurs during May, June, July.
4. Many nests containing full clutches are abandoned.
5. Hens become emaciated and die on the nests.
6. Smaller clutches are incubated.
7. Eggs are prematurely incubated by high ground temperatures prior to incubation by the hen. Much egg spoilage occurs.
8. Unhatched chicks pip and partially ring their eggshells, but rapid desiccation traps them in half-opened eggs. Uneven hatching, with a few eggs hatching early, causes hens to leave nests with fewer young, often as few as 2-4 chicks.
9. Marked scarcity of broods during June and July.
10. Large numbers of adult pairs and single birds lack chicks from June through September.
11. An above-normal number of adult males, minus females, care for small clutches of young during the production season.
12. The most noticeable and important result of severe Drought years is few to no broods of extremely young chicks during August and September. The second, or August, hatching peak does not occur.

Overall effects of drought on production patterns, fall population levels, and hunting success are shown in Fig. 5 and by parameters for the individual Drought years shown in Fig. 1 and 3.

Average parameters for the 6 Drought years are compared with Normal years in Table 4. A PI of 4 falls 66% below the Normal PI of 12, and thus rates the Drought years as the most damaging to Missouri quail in the 25 years of study.

The record Drought year of 1953, with a low PI of 3, was 75% below Normal. This compares with the Snow-Cold PI of 3 during 1960.

In 4 of the 6 Drought years, the 15 June hatching period shifted 1 to 2 weeks later. These first hatching peaks, while averaging around 92% of the annual production, actually produced 50% to 75% fewer birds than the first peak hatch of a Normal year.

The second hatching peak of Normal weather years occurs around 15 August and contributes about 36% of the annual quail crop. In the severe drought years, this second peak of hatching may disappear or contribute only 5 to 6% of a Normal bird crop. A small percentage of hens in drought years may produce 2% to 15% of the year's quail crop in an August or later hatch, resulting in extremely young birds through mid-September, as shown in Fig. 3. As shown in Fig. 3, the hatching period of 1 July 1953 accounted for 98% of the annual production; hatching in August and later was nearly nonexistent.

The chronology and amount of production in drought years depart so far from the Normal that population levels and hunting success for many hunters reach a forecastable low.

Young-old ratios and young-per-adult-hen figures for the Drought years, as in other types of weather years, often fail to convey fully the degree of population decline. In fact, as in ratios of Snow-Cold years, these figures if evaluated alone, falsely indicate exceptional quail production. Young-hen ratios alone too often are believed to indicate excellent quail production and high populations. High young-hen ratios could occur in the last remaining 100 birds in an endangered population. Only by noting (A) actual population levels through a game survey (the PI), (B) ratios of adult cocks to 100 adult hens, and (C) numbers of young per 50 pairs of adults, and by comparing all with the Normal condition can we analyze a population and learn why young-hen ratios and young-per-adult figures appear so favorable. The high loss of hens marks the reality in such ratios. By considering distortion of adult cock-hen ratios, we can align our thinking more clearly, and hope that our interpretations are accurate.

The ratio of young per 50 pair of adults in drought years is 456, or only 19% below Normal. A similar decrease is noted for the Snow-Cold years. These figures may well represent the existing population that is present and being measured; they are deceptive when, as often occurs, they fail to reveal that a huge segment of a Normal population is absent. The actual degree of quail mortality and population loss in drought years must be discerned from other population parameters and from comparisons between years.

In Missouri's southern Ozark regions, where effects of drought are most severe, data from 1952 and 1953 show that the percentage of young dropped to 74% and 73%, with young-per-adult ratios of 5 to 1 and 6 to 1, respectively. Ratios of young per 50 pairs of adults for these 2 years were 285 and 270, respectively, a departure from Normal of 50% and 53% respectively. Thus in areas and years where drought is extremely severe, annual ratios for young per adults, young per adult hen, and young per 50 pairs of adults may reflect more realistically population characteristics during drought.

Data on incomplete molt in years of drought show that production of the second (August) hatching period, and presence of extremely late-hatched young, averages 9%, or 73% below Normal. During the severest drought year, 1953, molt figures dropped to 2%, or 91% below the Normal year. In such poor production years, production and hunting success rest solely on early-season production.

Total statewide kill and regional harvest in the most drought-ravished regions drops considerably, as fewer birds afford less harvest. Restrictions on season length and daily harvest, while saving some birds through direct harvest reductions, have greatest effect in restricting total kill by discouraging hunting effort, as shown by reduced hunting by avid hunters and no hunting by casual hunters.

A noticeable improvement in annual harvest, as shown by PI's, (Fig. 1) occurs with but the slightest rise in annual production in drought years. The slight rises in PI figures of drought years 1955, 1956, and 1957 imply that improvement in spring moisture improved habitat conditions. Many acres lacked grazing pressure after vast cattle sell-offs, and they gradually began to recover carrying capacity for birds through replacement of natural food and cover.

Following a short-term occurrence of adverse weather, Missouri bobwhite quickly respond to improved conditions of moisture and restoration of natural habitat where land-use practices permit it. After 1 or 2 seasons of breeder buildup, populations return to Normal-season bird densities, consistent with habitat quality and favorable production weather.

As shown in Fig. 1, drought-stricken quail populations returned to the very favorable PI of 10 by 1959, with a corresponding good bird harvest.

These data emphasize that annual quail abundance and satisfactory-to-good hunting success in Missouri are dependent upon a favorable June quail hatch and a near average or better August production peak.

Summary and Conclusions

Weather during 25 years of study on the biology and population dynamics of Missouri quail has been classified into 4 major types according to moisture-temperature characteristics. They are: the favorable normal years and the less-favorable years of Wet-Deluge, Snow-Cold, and Drought. Ten population parameters are measured to compare weather effects of the 4 types of years on quail production, fall population size and composition, and hunting success.

Although weather of the Wet-Deluge years often changes the times of hatching peaks and the percentages of hatch in each, and may cause some population decline, such years are not overly harmful to annual quail populations, and hunting success in these years is never a "bust".

Table 1. Missouri Climatology Normals by Climatological Division

Station	Month												Ann. Aver.
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Temperature (F)													
Northwest Prairie Div.	27.7	31.6	40.6	53.8	64.0	73.7	78.7	76.9	68.7	57.8	42.1	31.9	54.0
Northeast Prairie Div.	29.8	33.0	41.5	54.2	64.4	74.1	78.5	76.8	69.0	58.1	43.1	33.1	54.6
West Central Plains Div.	32.2	35.7	43.7	55.9	65.3	74.8	79.5	78.3	70.3	59.6	44.8	35.6	56.3
West Ozarks Division	35.1	38.5	45.6	56.9	65.4	74.5	78.8	78.1	70.6	60.1	46.2	38.0	57.3
East Ozarks Division	34.8	37.9	45.4	56.9	65.4	74.3	78.2	77.3	69.7	59.0	45.5	37.0	56.8
Bootheel Division	37.5	40.3	48.0	59.1	68.2	77.0	80.3	79.1	71.9	61.2	47.8	39.3	59.1
Precipitation (Inches)													
Northwest Prairie Div.	1.40	1.33	2.37	3.58	4.10	5.43	3.43	4.06	3.53	2.63	1.93	1.54	35.36
Northeast Prairie Div.	1.83	1.79	2.83	3.51	4.20	4.61	3.47	3.50	3.29	2.95	2.47	1.92	36.37
West Central Plains Div.	1.76	1.89	2.61	3.66	4.93	5.08	3.38	3.84	4.01	3.40	2.41	1.91	38.88
West Ozarks Division	2.15	2.39	3.05	4.14	5.41	4.95	3.56	3.19	3.91	3.65	2.82	2.27	41.49
East Ozarks Division	2.98	2.85	3.76	4.32	5.01	4.43	3.35	3.42	3.42	3.32	3.44	2.83	43.13
Bootheel Division	4.33	3.71	4.86	4.29	4.46	3.94	3.34	3.19	3.41	3.12	3.89	3.67	46.21

Table 2. Explanation and Rating Values of Production Index (PI) and Hunting Index (HI)

PRODUCTION INDEX (P.I.)

Based on broods observed in 60 days-July-August

P. I. = AVERAGE BROODS PER OBSERVER PER REGION

P.I. RATINGS

- | | |
|--------------|------------------------|
| (1) POOR-3-5 | (3) FAVORABLE-9-11 |
| (2) FAIR-6-8 | (4) VERY FAVORABLE-12+ |

HUNTING INDEX (HI)

Based on ratings of coveys flushed per 8 hour hunting day

EXCELLENT 8 COVEY PER DAY 1-1.1 Hrs/covey or better	GOOD 6 COVEY PER DAY 1.2-1.5 Hrs/covey	FAIR 5 COVEY PER DAY 1.6-2.5 Hrs/covey	POOR 3 COVEY PER DAY 2.6+Hrs/covey
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Expressed as the combined percentage of hunters rating Good to Excellent hunting success.

EXAMPLE: Hunters rating excellent hunting success 50%
 Hunters rating Good hunting success 25%

HUNTING INDEX (HI) Equals 75%

Table 3. Bobwhite Quail Studies - Basic Field Data: Yield Parameters: 1948-1971

Production Survey - July-August

BROODS 69,000	Nesting Activity - Chronology Hatching Patterns - First Peak Indication of Second Hatching Peak Effects of Weather P. I. - Production Index
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Hunting Season Survey - November-January

WINGS 222,000	Young - Old Ratios Young Per Adult Hen
Young Primary Feather Molt	Back Aging - Second Hatching Peak
Adult Primary Feather Molt	Nesting Pattern-Hens - Second Brood Indicator
COVEYS FLUSHED 255,000	Bird Abundance - H. I. Hunting Indexes
HOURS HUNTED 321,000	Bird Abundance - H. I. Hunting Indexes
KILL BY SEXES 396,000	Age Ratios - Young Per Adult Hen Adult Cocks Per 100 Adult Hens

Ten Month Field Survey - Quail Behavior-Activity

COVEYS 100,000	Covey Breakup - Shuffles - Nesting - Non-Nesting
PAIRS 100,000	Pairing - Nesting - Non-Nesting - Nest Losses - Desertions
SINGLES 100,000	Nesting - Non-Nesting (Road Walkers)

Table 4. Missouri Bobwhite Quail Population Parameters Averages by Type of Production Weather Year: 1947-1971

PARAMETERS	CHARACTERISTICS OF TYPE PRODUCTION YEAR			
	"NORMAL" OR FAVORABLE WINTER-SPRING -10 YEARS-	WET - DELUGE RAINFALL ABOVE NORMAL-SPRING SUMMER ** -6 YEARS-	SNOW-COLD WINTER-SPRING -4 YEARS-	DROUGHT RAINFALL MUCH BELOW AVERAGE PROLONGED HIGH TEMPERATURES ABOVE 100° -6 YEARS-
PRODUCTION INDEX	12	8	5	4
HUNTING INDEX %	75%	66%	53%	51%
% YOUNG - FIRST PEAK HATCH PERIOD	64%	55%	59%	92%
% YOUNG- SECOND PEAK HATCH PERIOD	36%	45%	41%	8%
YOUNG - OLD RATIO %	85% - 15%	83% - 17%	82% - 18%	82% - 18%*
YOUNG PER 50 PAIR (100 ADULTS)	567	488 (14% below normal year of 85% yg.)	456 (19% below normal year of 85% yg.)	456 (19% below normal year of 85% yg.)
YOUNG PER ADULT HEN	11	10	12	9
ADULT COCKS PER 100 ADULT HENS	114	116	124	130
% YOUNG WITH MOLT INCOMPLETE	33%	45%	41%	9%
% ADULT HENS WITH MOLT INCOMPLETE	66%	72%	73%	15%

*IN THE MOST SEVERE DROUGHT REGION OF SOUTHERN MISSOURI, YOUNG PERCENT DROPPED TO 73% WITH 5.4 YOUNG PER ADULT HEN AND 270 YOUNG PER 50 PAIR.

**1970 YEAR CLASSED AS BOTH A WET-DELUGE AND SNOW-COLD YEAR.

Table 5. Average Annual Winter Snowfall, Average Annual Temperatures for January, February and March; Snowfall and Winter Temperatures in 1960; According to Climatological Divisions in Missouri

Division	Averages							
	Winter snowfall (inches)	Temperatures (F)			Snowfall	1960 Temperature (F)		
		January	February	March		January	February	March
Northwest Prairie	23.4	27.7	31.6	40.6	52.0 +19	27.9 -0.1	26.0 -6.1	26.8 -14.1
Northeast Prairie	19.7	29.8	33.0	41.5	45.0 +25	30.4 -0.3	28.2 -5.4	27.9 -14.1
West Central Plains	17.1	32.2	35.7	43.7	35.0 +18	32.8 -0.1	30.9 -5.5	31.4 -12.8
West Ozarks	12.6	35.5	38.5	45.6	28.0 +15	35.5 -0.0	33.0 -6.0	34.4 -11.7
East Ozarks	10.8	34.8	37.9	45.4	25.0 +14	35.4 -0.1	33.5 -5.0	32.5 -13.6
Bootheel	7.2	37.5	40.3	48.0	32.0 +25	38.6 -0.8	36.9 -3.9	35.2 -13.5

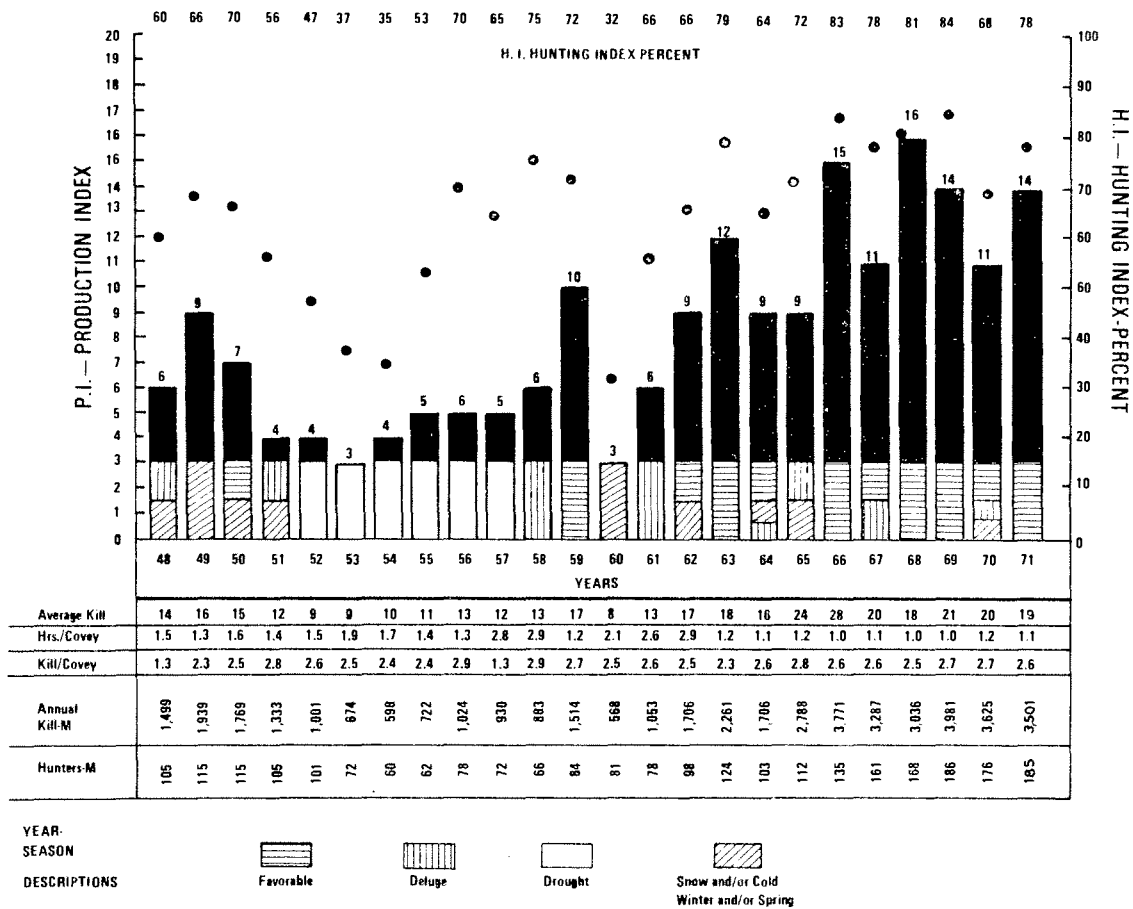


Figure 1. Missouri Bobwhite Quail Production Indexes (Bars) and Hunting Indexes (Dots) for years 1948-1971. Major Weather Type Affecting Populations and Production are Shown by Bar Cross-Hatching. Harvest Data Show Effects of Weather on Annual Production and Fall Bird Crop.

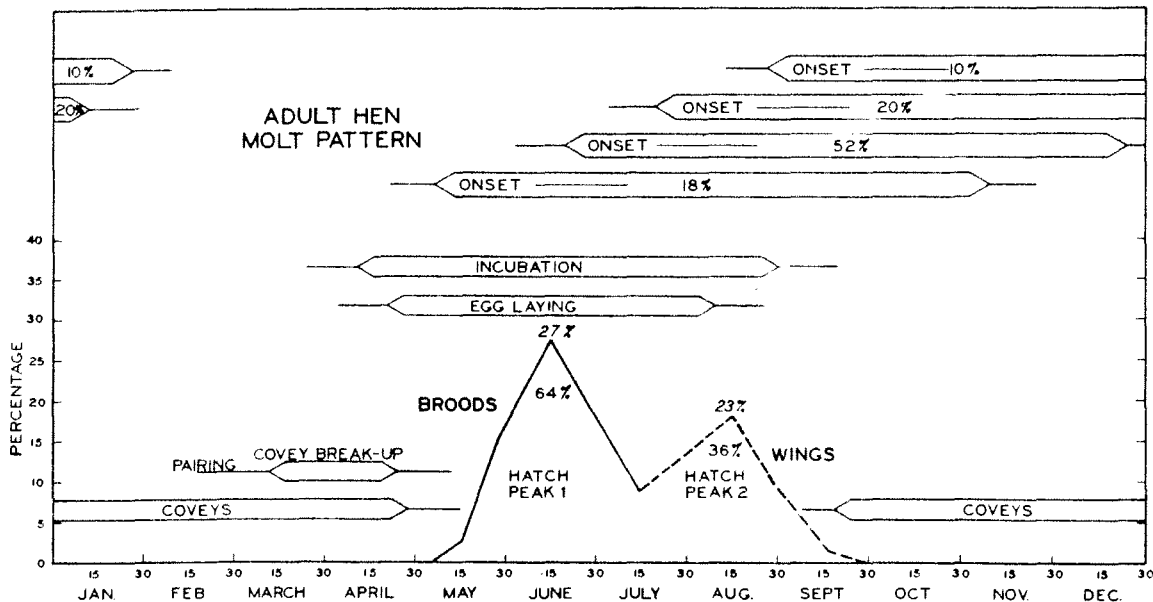
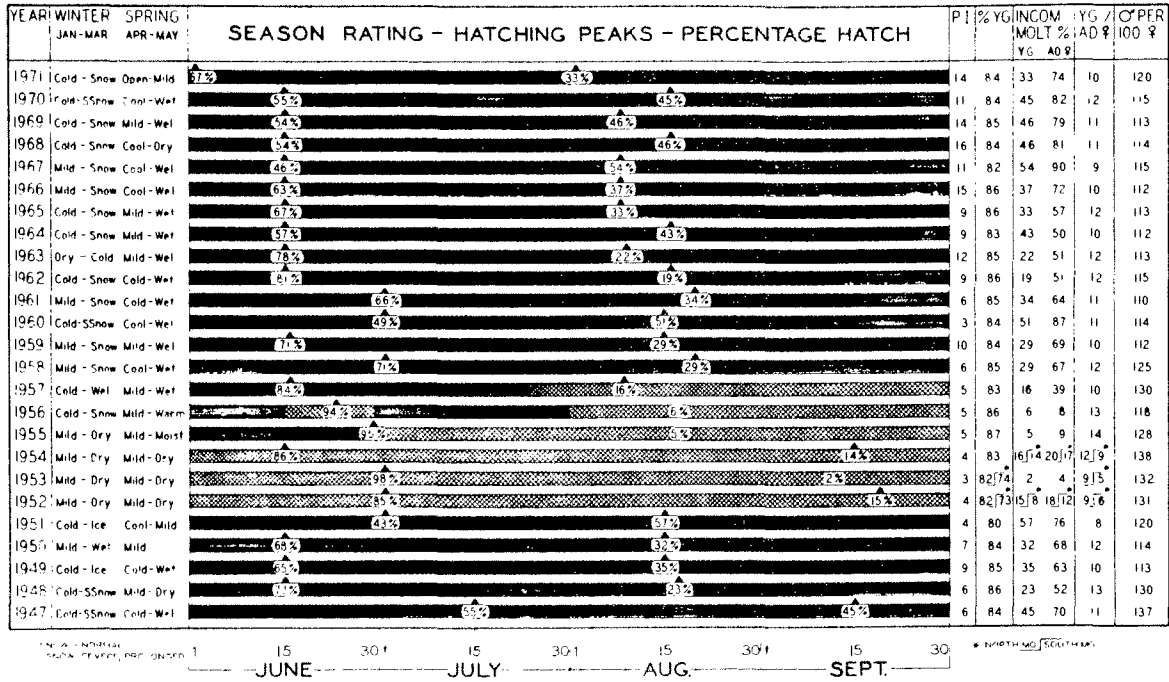


Figure 2. Missouri Bobwhite Quail Average Production Pattern: Peak Hatch Percentages (27%-23%), Hatch Distribution (64%-36%) and Adult Hen Molt Variations.



SEASON DESCRIPTIONS
 ■ FAVORABLE ■ DELUGE ■ DROUGHT/HOT

Figure 3. Bobwhite quail Production Seasons - Population Composition - Missouri 1947-1971. (Terminology used in Describing Winter-Spring Weather is from U. S. Weather Bureau).

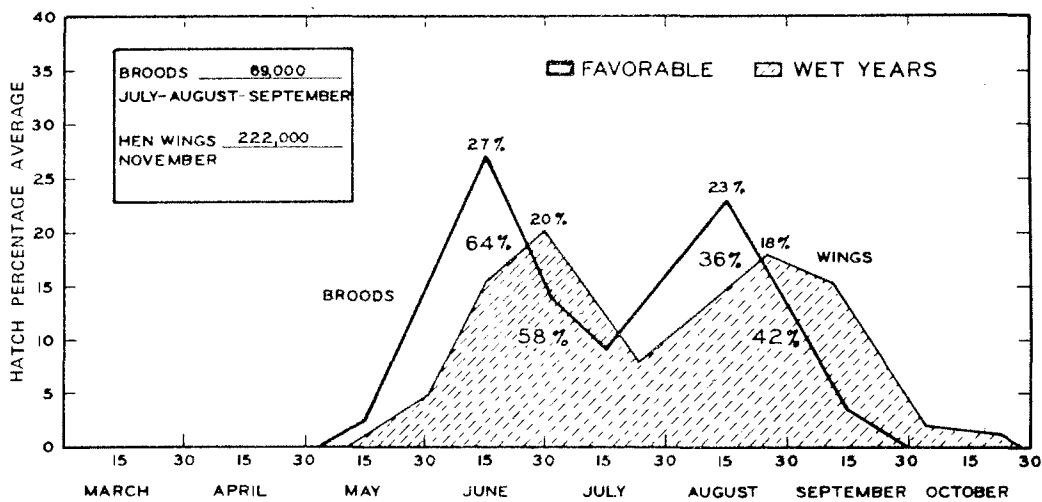


Figure 4. Bobwhite Quail Production Hatch Percentage Averages of Normal or Favorable Weather Years and Wet Years 1947-1971.

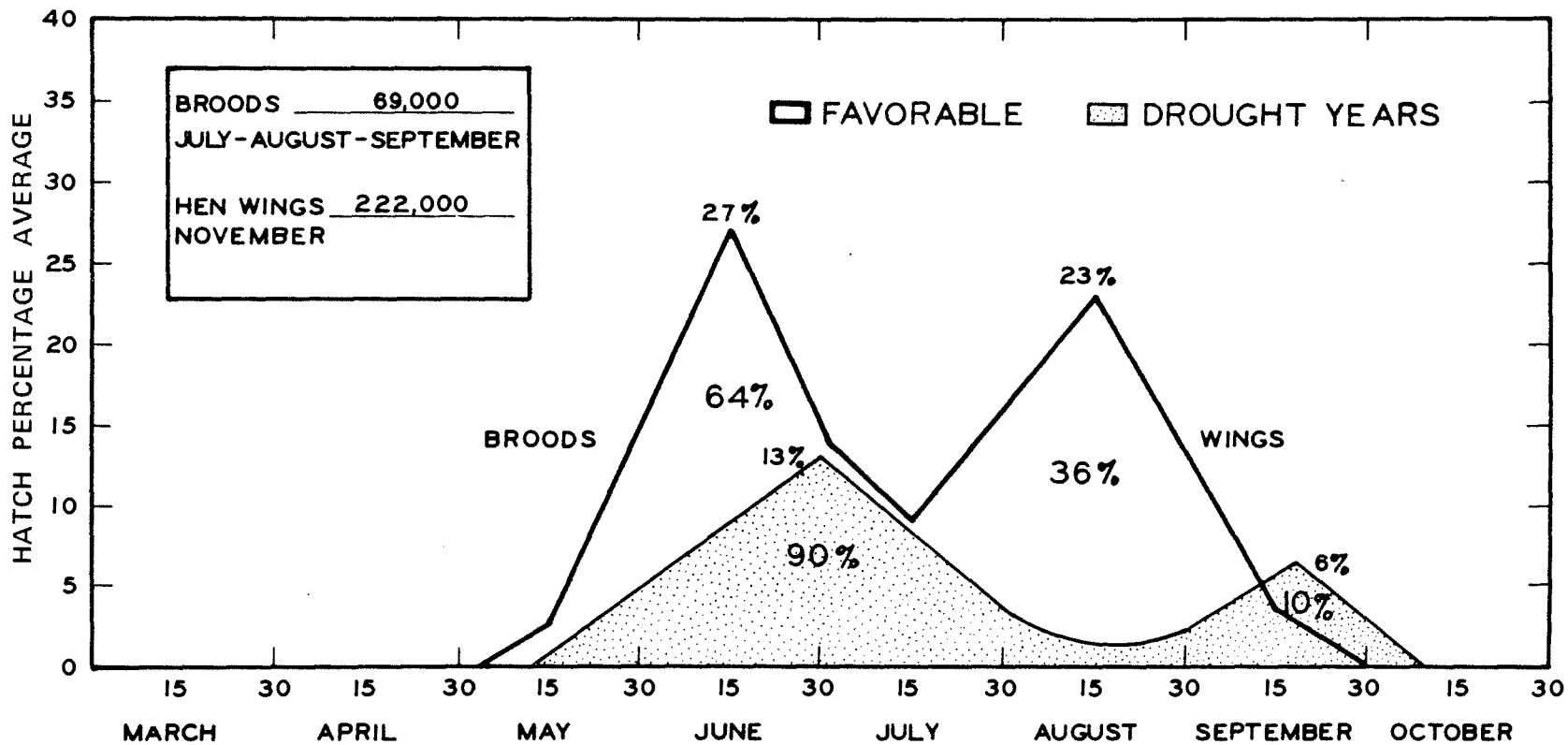


Figure 5. Bobwhite Quail Production Hatch Percentage Averages of Normal or Favorable Weather Years and Drought Years 1947-1971.

The Snow-Cold year seriously reduces annual bird abundance through a scarcity of breeders and reduced production. Both hunting pressure and rate of hunting success declines.

Severe drought with high temperatures is the type of weather most damaging to quail reproduction. Hatching peaks occur later than in Normal years; production in the first peak of hatching is strongly reduced; and production in the second hatching peak is either reduced or eliminated. Hunting success in such years is usually poor. The total effects of adverse weather is that the double hatching peak, typical of the Normal year, is disrupted to the extent that birds may be produced later and fewer in number from either the first or second hatching peak or from both.

Periodic bobwhite declines or "lows" so popularly referred to as "the quail cycle" are not regarded as cycles, but only as temporary fluctuations caused by short-term variations in weather. Such population lows are self-corrective (habitat permitting) with the return of 2 or 3 consecutive years of "normal" weather conducive to bird production and survival.

But the level to which quail can increase, even under favorable weather conditions, depends on the capacity of the habitat to support birds. If long-term trends of land use and vegetation succession are in or approaching a stage of negative value for quail, the chance for favorable production weather to provide bird abundance is definitely limited. In such situations, the negative trend of land-use must be corrected and directed in a positive direction that will produce favorable food-cover conditions for birds.

If sportsmen are to continue enjoying the sport of quail hunting in many localities, they must take a greater interest in the biology of the bird and derive added pleasure from understanding the annual problems encountered by quail under varying weather situations affecting production and survival. With fewer hunting areas in prospect, the effects of weather upon huntable quail populations will become more noticeable. To understand more fully the problem is to be better prepared to meet setbacks; and the quail problems of tomorrow will bring plenty of setbacks. Hunters should be aware that good hunting is impossible every year, and that because of the effects of weather on quail, in about 11 of 25, or 44% of the hunting years (as judged by the past) the bird harvest will fall below the average.

The only way to improve this situation is through good quail-land management designed to produce more bobwhite under all conditions of weather.

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BODY FAT CONTENT OF BOBWHITES IN RELATION TO FOOD PLANTINGS IN KANSAS

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Abstract:

A wildlife habitat improvement program was initiated on the Fort Riley Military Reservation in 1961 to increase winter food supplies for bobwhite quail (Colinus virginianus). As part of an ongoing evaluation of this program, 164 bobwhite quail were collected during the fall and winter of 1968-72 for fat analysis. Fat content in carcasses of birds collected <600 m from a food plot was compared with fat content of birds collected >900 m from a food plot.

During winter months, birds collected near a food plot were significantly ($P < 0.10$ to $P < 0.05$) heavier than birds not having access to a food plot. Fat content of birds close to a food plot was likewise greater ($P < 0.10$ to $P < 0.01$) than fat content in birds not using food plots. Calculations indicate that birds close to food plots have sufficient energy reserves to provide a 79% greater protection against brief periods of food deprivation than birds far from a food plot. Fat energy reserves alone in a quail close to a food plot could provide sufficient energy for 2.0 days of survival whereas quail far from food plots contained fat energy reserves sufficient for only 1.1 days of survival.

Reserve energy for animals is stored in the body mainly in the form of fatty acids. The quantity of stored reserve energy (fat) may be critical to the animal's survival during periods of food scarcity or extremely cold weather. Much work has been done on fat content, composition, and regulation in songbirds (8, 9, 10, 11, 12, 15, 16, 23, 24). Only recently has any attention been given to body fat reserves of wild gallinaceous birds under natural conditions. West and Meng (25) reported on the relationship of total fat and fatty acid composition to diet of willow ptarmigan (Lagopus lagopus) in Alaska while Moss and Lough (14) presented similar data for 3 species of grouse in Scotland.

Almost no attention has been given to fat reserves of bobwhite quail even though it is known that fat reserves may be essential for bird survival during periods of dietary stress (15, 23 and others). The most recent book on bobwhite quail (22) does not even discuss the