Sage Grouse Hatching Success And Chronology For South-central Montana

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Abstract

A recent short-term fluctuation in sage grouse (*Centrocercus urophasianus*) abundance for south-central Montana was attributed to dramatically reduced productivity. This period of low productivity was associated with a peak hatching date 2 weeks earlier than normal. Molt patterns for adult hens indicated the early hatch was due to a shift in breeding and nesting and not reduced survival during June. These molt patterns also indicated a significant attempt at renesting by hens ≥ 2 years of age during periods of low productivity. To test the influence of climatic conditions on hatching chronology, I selected years that were at least one standard deviation above or below the long-term average for hatches occurring before 1 June. I concluded that early hatches occurred during warm dry springs, which were also associated with drought conditions. Warm dry springs also may result in earlier dates for spring green-up and grasshopper hatches. I interpret early hatches as an adaptation by sage grouse hens to take the best possible advantage of cover and forage conditions during the first critical weeks of life for their chicks.

Key words: *Centrocercus urophasianus*, climate, grasshoppers, hatching chronology, hen molt, productivity, sage grouse

Introduction

Sage grouse (*Centrocercus urophasianus*) abundance is affected by long-term and short-term population changes. In Montana, long-term population declines can be related to loss of sagebrush habitats essential to sage grouse (Martin 1970, Swenson et al. 1987). Although not irreversible in nature, conditions resulting in long-term declines are likely to persist. Within the long-term decline are short-term fluctuations in sage grouse abundance. Stochastic environmental events, e.g., weather, are important to short-term changes in abundance (Edwards 1988).

Historical records for Montana give anecdotal reference to short-term fluctuations. Declines in sage grouse populations in Montana were first noted during the late 1800s and early 1900s (Annual Report 1900, Biennial Report 1909-1910). By the 1920s, sage grouse in Garfield County had increased so much they were said to darken the sky (Eustace 1995). The Fish and Game Commission was petitioned for relief from sage grouse in northern Fergus County because "they had become a pest and something must be done" (Commission minutes 1925). This period of abundance, lasting from the 1920s to the early 1930s, saw sportsmen requesting early hunting seasons in addition to regular fall seasons. Sage grouse population declines during the mid-1930s and 1940s prompted the Fish and Game Commission to close sage grouse hunting statewide in 1938 and 1945-1951.

Systematic hunter harvest surveys, initiated in 1958, estimated an annual statewide harvest of 20,900 sage grouse in 1958-1959. Annual statewide harvest levels increased rapidly to an average of 45,500 birds during the 1960s and 1970s. The first indication that sage grouse populations had again started to decline in south-central Montana occurred in 1985 when the number of active leks being monitored began to drop. By 1998, 33 leks that had been active in 1981 were reduced to 17. Male attendance on these leks indicated populations had bottomed out by the mid-

1990s with male attendance increasing 137 percent by 2000. This increase was accompanied by a new lek in an area unoccupied by a lek since 1994. Hunter harvests also declined during the 1980s and 1990s, finally stabilizing at an annual statewide harvest of around 8,200 birds from 1993-2000. Not all of the decline in harvest directly reflected declines in sage grouse populations. As sage grouse populations waned, so did hunter interest. By 1988 hunter days were 43 percent below their levels in the mid-to-late 1970s. In 1996 the Montana Fish, Wildlife and Parks Commission reduced the daily bag limit on sage grouse to two birds and cut the season length by 42 percent. The reduction in season length had no further impact on hunter days.

As populations of a game species fluctuate, the obvious solution is often found in regulation changes. This response may or may not have any influence on the fluctuation. While this is not likely to change, a better understanding of factors influencing short-term fluctuations in sage grouse can aid in making management decisions based on reality.

Methods

Sage grouse wings were collected through hunter check stations, field checks and wing envelopes mailed to upland bird hunters. Sex determination was based on color patterns on minor wing coverts (tetrices) (Dalke et al. 1963). Age was assigned as juvenile or adult based on retention or molting and shape of the outer two primaries, or length of the outer three primaries if they were unmolted (Petrides 1942, Eng 1955). Juveniles were aged to the nearest week based on the length of the last primary(s) molted (Pyrah 1963). Hatching dates for juveniles were then determined by back dating their age in weeks from the date shot.

Temperature and precipitation were obtained from Montana Climatological Data (National Climatic Data Center). I averaged data for three widely spaced weather stations representing sage grouse habitat in south-central Montana (Flatwillow, Rapelje, and Billings Airport). Soil temperature data was tabulated from the Moccasin Experiment Station at 10.2 cm (4 in) below a sod surface. The Moccasin station, located in the geographical center of Montana, was the closest station with soil temperature data from a sod surface. The Palmer Drought Severity Index (PSDI) was accessed from state maps of NCDC climate zones at: http://www.ncdc.noaa.gov/onlineprod/drought/main.thml. For statistical analysis I used STATISTIX 1998; differences were considered significant at $P \leq 0.10$.

Results

Productivity

Chick survival to the hunting season, referred to here as productivity, is influenced by many interacting factors, which vary in intensity each year, e.g. weather, food, cover, predation etc. Productivity, expressed as juveniles/100 adult hens, averaged 256 juveniles/100 adult hens from 1962 to 2000 (Table 1). Productivity was divided into three time periods corresponding with relatively stable population levels from 1962 to 1983, a short-term decline from 1984 to 1995, and a period of population recovery from 1996 to 2000. Productivity averaged 292, 173, and 293 juveniles/100 adult hens for 1962-1983, 1984-1995, and 1996-2000, respectively.

Hatching

Hatch dates were available for 5837 juveniles for all years from 1962 to 2000, except 1968 (Table 2). Peak of hatch for this 38-yr period occurred during the second week of June. Plotting a hatching curve by 2-week intervals indicated 42 percent of the sage grouse chicks hatched during the first two weeks of June (Fig. 1). The peak of hatch normally occurs during 2–16 June in central Montana (Wallestad and Watts 1972). Birds hatching before June are called the early hatch, while birds hatching on or after 1 June are called the normal hatch.

Table 1. Sage grouse productivity for south-central Montana, 1962-2000.

Year	Juv/100 Adult Hens*	Year	Juv/100 Adult Hens	Year	Juv/100 Adult Hens
1962	310	1975	265	1988	77
1963	387	1976	219	1989	205
1964	184	1977	235	1990	307
1965	253	1978	339	1991	92
1966	169	1979	497	1992	197
1967	250	1980	150	1993	162
1968	436	1981	223	1994	163
1969	187	1982	210	1995	155
1970	443	1983	439	1996	433
1971	423	1984	132	1997	243
1972	286	1985	100	1998	289
1973	304	1986	243	1999	344
1974	223	1987	248	2000	158

* Number of young/100 adult hens surviving from hatch to hunting season.

Dividing the hatch into three time intervals, and matching the three productivity time intervals, indicated a large early hatch accompanied low productivity. The early hatch averaged 28.3 percent of the total hatch from 1962 to 2000 and accounted for 21, 38, and 36 percent of the total hatch for the respective years 1962-1983, 1984-1995, and 1996-2000. The size of the early hatch for1996-2000 was greater than expected considering the high productivity for this period. This is explained by 2000, which had low productivity (158 juveniles/100 adult hens) with 75 percent of the hatch occurring early. Productivity for 1996-1999 averaged 327 juveniles/100 adult hens with 26 percent of the productivity coming from the early hatch.

A large early hatch could result from: 1) an increase in early breeding, which would shift the timing of the hatch forward, or 2) reduced survival for chicks hatching in June, which would give the appearance of an early hatch. Although weather is only one of several factors influencing productivity, it directly or indirectly influences other less easily measured factors. To reduce stochastic weather factors that could influence productivity and hatching chronology, I compared years that were at least one standard deviation above or below the long-term average for an early hatch (28.3% ± 17.2%). Normal hatches (≤ 11.3 % of the total hatch) occurred in 1964-65, 1970-71, 1973-75 and 1991. Large early hatches (≥ 45.3 % of the total hatch) occurred in 1986-87, 1992-94 and 2000. Comparing hatching curves for normal and large early hatches indicated a 2-wk difference in the peak of hatching (Fig. 2).

Temperature

Eng (personal communication) suggested warm spring weather could shift breeding forward by at least a week. Bergerud and Gratson (1988) state that "the timing of breeding and nesting commonly varies a maximum of 2 weeks in grouse populations. Birds nest earlier in years when there is little snow in March and April and later when snow lingers in April." With the exception of February, all months had higher average temperatures for years with large early hatches than years with normal hatches (Table 3). Differences in temperature were significant for January, March, April, and May. The greatest difference in temperature, 6.2 °C, occurred in March, the period of initial lek attendance by hens.

Air temperature also influences soil temperature, which is important in initiating plant growth. I calculated the first date soil

Table 2. Percent of sage grouse hatching at one week intervals for south-central Montana, 1962-2000.

Year	Hatch*	May (4/10)	May (11/17)	May (18/24)	May (25/31)	June (1/7)	June (8/14)	June (15/21)	June (22/28)	June (29+)
1962		0.0	0.5	2.0	11.0	27.0	34.0	14.0	3.0	8.5
1963		0.6	0.6	4.3	15.8	21.1	26.5	20.7	5.7	4.9
1964	n	0.3	1.5	2.6	4.3	15.9	30.6	31.8	9.3	3.8
1965	n	0.0	0.6	2.3	4.1	14.6	26.3	29.2	11.7	11.1
1966		5.1	3.1	8.3	14.4	22.7	23.7	12.4	5.2	5.1
1967		1.4	0.0	6.8	4.1	6.8	6.8	27.0	17.6	29.8
1969		0.0	0.0	3.2	21.0	30.6	27.4	11.3	4.8	1.6
1970	n	0.6	1.2	1.7	1.7	5.2	30.5	36.8	12.6	9.9
1971	n	0.5	0.5	2.4	5.3	18.5	42.7	18.9	6.3	4.9
1972		0.9	0.9	5.9	18.6	30.5	24.1	6.4	8.2	4.6
1973	n	0.6	2.2	2.8	3.3	12.0	32.0	25.4	16.0	6.2
1974	n	0.4	1.7	2.0	2.9	21.0	37.0	19.8	8.0	7.2
1975	n	0.0	0.7	2.0	2.0	10.7	38.0	24.3	10.7	11.7
1976		2.8	2.2	5.5	17.5	19.4	27.4	13.5	7.1	4.6
1977		1.4	4.8	8.8	21.1	28.6	23.1	8.2	2.7	1.4
1978		3.3	3.7	7.4	12.3	19.7	20.5	11.5	10.0	11.6
1979		5.6	7.0	4.6	8.3	16.6	29.1	19.2	5.3	4.3
1980		4.9	10.7	4.4	5.4	19.5	31.7	16.1	6.3	1.0
1981		2.0	4.0	13.0	22.5	19.5	15.0	10.5	7.0	6.5
1982		4.6	6.7	8.2	9.2	10.3	29.2	19.5	6.2	6.1
1983		7.2	3.2	8.5	15.4	23.9	22.8	11.4	6.1	1.6
1984		2.8	7.1	6.4	7.1	11.4	27.7	27.0	5.7	5.0
1985		0.0	7.4	11.1	18.5	18.5	37.0	3.7	3.7	0.0
1986	e	10.5	5.3	23.7	15.8	10.5	13.2	7.9	10.5	2.6
1987	e	1.4	4.2	22.2	36.1	27.8	1.4	5.6	1.4	0.0
1988		3.6	3.6	14.3	10.7	14.3	25.0	21.4	0.0	7.1
1989		6.0	1.0	2.0	14.9	21.8	23.8	15.8	10.9	4.0
1990		6.1	6.1	8.1	18.2	18.2	16.2	6.1	11.1	10.1
1991	n	3.5	0.0	0.0	3.5	17.2	24.1	24.1	22.4	5.2
1992	e	11.4	7.6	20.8	20.8	20.8	11.3	5.7	0.0	1.9
1993	e	0.0	3.7	11.1	33.3	18.5	11.1	18.5	3.7	0.0
1994	e	9.1	9.1	14.6	16.4	21.8	14.6	9.1	0.0	5.4
1995		9.8	7.8	2.0	11.8	9.8	9.8	9.8	11.8	27.4
1996		4.8	7.1	4.8	11.9	19.1	21.4	16.7	4.8	9.5
1997		0.0	4.2	8.3	0.0	33.3	20.8	16.7	4.2	12.6
1998		0.0	3.7	7.4	22.2	18.5	33.3	14.8	0.0	0.0
1999		5.7	1.9	5.7	17.0	22.6	18.9	9.4	7.6	11.4
2000	e	14.3	7.1	25.0	28.6	10.7	3.6	3.6	3.6	3.6
Average		3.4	3.7	7.7	13.3	18.6	23.5	15.9	7.1	6.6

*n = normal hatch where $\leq$ 11.3% of the total hatch occurs before June 1.
e = large early hatch where $\geq$ 45.3% of the total hatch occurs before June 1.

temperatures at 10.2 cm depth under sod averaged a minimum of 4.4, 10.0, and 15.6 °C for seven consecutive days (Table 4). After seven consecutive days the temperature seldom dropped below the designated minimum. On average, soil temperatures reached 4.4° C on 19 March and 6 April for early and normal hatch years respectively. This difference of 18 days was significant. Differences in dates for soil temperatures reaching 10 and 15.6° C during early and normal hatch years were not significant. Early plant growth could benefit an early hatch by providing cover, forbs, and insects at an earlier date than usual.

Precipitation

Total precipitation for January-June from the three weather stations averaged 19.1 and 24.5 cm for early and normal

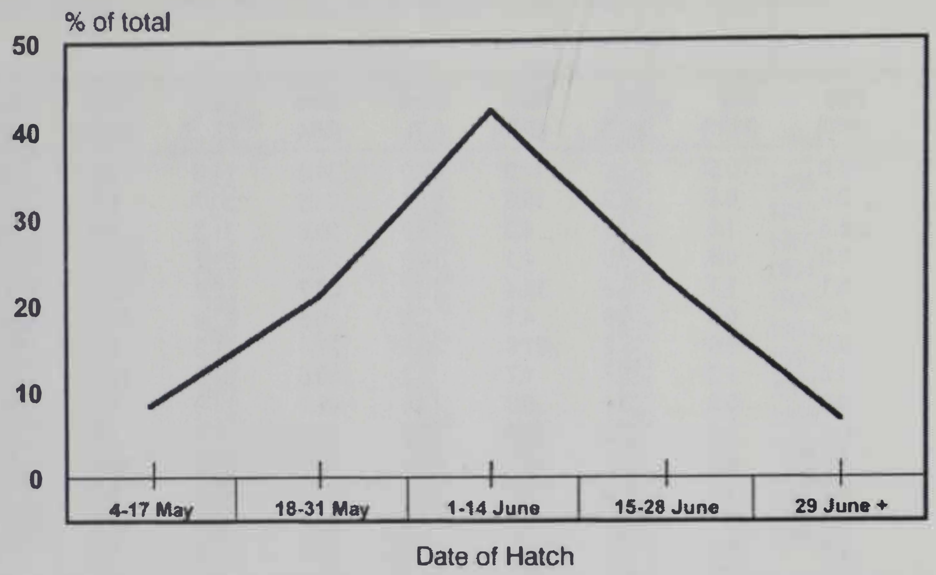

Figure 1. Sage grouse hatching dates for south-central Montana, 1962-2000

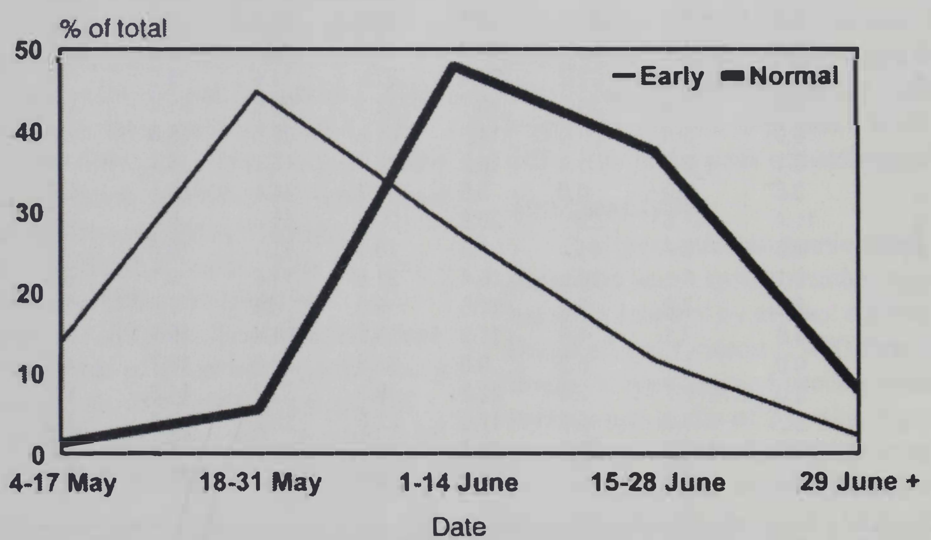

Figure 2. Sage grouse hatching dates for south-central Montana, early vs. normal hatch (early 1986-87, 1992-94, 2000; normal 1964-65, 1970-71, 1973-75)

hatches, respectively (Table 5). With the exception of February, all months had lower average precipitation for years with large early hatches than years with normal hatches. Differences in precipitation were significant for January and April, as was total precipitation for January through June. These data indicate that large early hatches were associated with dry warm springs. Bergerud (1988) suggested that "wet cool springs may provide more cover and insects for steppe grouse," which correlates with higher chick survival associated with a normal hatch.

Moisture received prior to the year of hatch can influence productivity. Bergerud,

Table 3. Temperature (°C) for early and normal hatch years , south-central Montana.

Early Hatch Years							
Month	1986	1987	1992	1993	1994	2000	Average
Jan.	2.7	-0.8	1.6	-8.7	-2.7	-3.6	-1.9
Feb.	-4.7	1.1	3.7	-6.7	-6.1	-0.7	-2.2
Mar.	7.5	2.9	5.9	4.1	7.6	8.3	6.1
Apr.	6.8	11.5	8.8	7.6	7.8	8.3	8.5
May	11.8	15.1	14.1	14.0	14.2	13.2	13.7
Jun.	20.2	19.2	18.1	15.8	18.0	16.6	18.0

Normal Hatch Years									
Month	1964	1965	1970	1971	1973	1974	1975	1991	Average
Jan.	-2.0	-3.3	-6.8	-7.5	-4.6	-5.9	-4.1	-6.4	-5.1
Feb.	-0.3	-4.3	0.3	-2.8	-1.9	1.6	-8.4	4.4	-1.4
Mar.	-1.2	-6.8	-1.1	0.8	3.3	1.8	-1.4	2.7	-0.2
Apr.	6.4	7.1	3.6	6.7	4.9	8.4	2.4	6.3	5.7
May	13.0	11.1	12.2	12.3	11.8	9.8	10.4	12.1	11.6
Jun.	16.2	15.6	18.5	17.2	17.5	18.6	15.3	17.0	17.0

(1988) developed a 23-month soil moisture index to account for vegetative residual cover and new growth and correlated it with sharp-tailed grouse brood size. The influence soil moisture had on sharptail productivity increased as the moisture gradient decreased from Minnesota to the Dakotas. Bridges et al. (2001) found the PDSI as well as raw precipitation data more closely related to annual changes in quail abundance in relatively arid vs. wet regions of Texas. The PDSI indicates the severity of a wet or dry spell based on the principles of a balance between moisture supply and demand, e.g., demand increases as temperature increases. I used the PDSI Palmer (1966) to compare moisture conditions between early and normal hatch years. The PDSI is not available for individual weather stations but is compiled for all the weather stations within a climatological division. I used the index from climatological division 5, that covers south-central Montana. A 22-month index was calculated by averaging the sum of the monthly PDSIs from September of year one

Table 4. Minimum soil temperature at 10.2 cm. Depth in sod for 7 consecutive days for early and normal hatch years, Mocassin station, central Montana.

Early Hatch Years							
Temp.	1986	1987	1992	1993	1994	2000	Ave. Date
4.4°C	16 Mar.	12 Mar.	7 Mar.	30 Mar.	7 Apr.	11 Mar.	19 Mar.
10°C	22 May	30 Apr.	NA*	9 May	24 Apr.	27 Apr.	5 May
15.6°C	5 Jun.	13 May	NA	19 May	10 Jun.	8 Jun.	20 May

Normal Hatch Years							
Temp.	1970	1971	1973	1974	1975	1991	Ave. Date
4.4°C	12 Apr.	6 Apr.	19 Mar.	7 Apr.	30 Apr.	26 Mar.	6 Apr.
10°C	10 May	28 Apr.	NA	21 Apr.	17 May	16 May	6 May
15.6°C	24 May	30 May	NA	13 Jun.	6 Jun.	8 Jun.	4 Jun.

Table 5. Precipitation in centimeters for early and normal hatch years, south-central Montana.

Early Hatch Years

Month	1986	1987	1992	1993	1994	2000	Ave.
Jan.	1.0	0.3	0.4	1.8	1.1	1.3	1.0
Feb.	3.6	1.1	0.3	0.9	0.8	2.5	1.6
Mar.	1.5	3.8	2.1	1.7	0.9	1.5	2.0
Apr.	6.4	0.7	5.0	2.2	5.0	2.4	3.6
May	6.2	10.0	3.1	3.4	5.5	3.9	5.4
Jun.	6.0	2.3	11.0	5.7	4.6	3.9	5.6

Normal Hatch Years

Month	1964	1965	1970	1971	1973	1974	1975	1991	Ave.
Jan.	0.4	1.8	1.9	3.5	2.1	1.3	3.8	1.7	2.1
Feb.	0.4	2.1	2.4	1.3	0.7	0.4	2.8	1.1	1.4
Mar.	2.6	1.8	1.9	1.9	2.8	2.2	2.5	1.3	2.1
Apr.	7.7	4.2	6.3	3.6	6.1	4.6	4.6	10.2	5.6
May	9.0	5.3	9.2	4.9	2.9	8.5	9.8	7.6	7.2
Jun.	11.7	5.7	4.5	2.8	4.0	3.7	6.9	10.3	6.2

through June of the year of hatch, year three. An unweighted least squares linear regression between productivity and the 22-month index indicated a positive correlation between productivity and increasing wetness, ($P <$ 0.01 $r^2 = 0.58$). There was no correlation between productivity and raw precipitation data averaged in the same manner for the same time periods.

Adult Hen Molt

Eng (1963) and Pryah (1963) have suggested that sage grouse hens are in the same stage of molt as their brood. A juvenile with a molt pattern that indicates a hatching date during the first week of June should be accompanied by a hen with a similar molt pattern. Thus, a shift in the hatching curve for juveniles should be reflected by a similar shift in the adult hen molt curve. When the molt of the adult hen in weeks is plotted against the hatching curve for juveniles, hens falling outside the juvenile curve are considered unsuccessful either at breeding, nesting, or brood rearing (Wallestad and Watts, 1972). Juvenile and hen molt curves for the normal hatch mirror one another (Fig. 3) with the majority of unsuccessful hens molting from 4 to 31 May. The almost total lack of molting hens lying outside the hatching curve from 29 June on suggests that very little renesting occurred during years with a normal hatch, or those hens that did, had good success. The juvenile and hen molt curves for the early hatch were not as synchronous (Fig. 4). However, I believe the data suggested early breeding for the following reasons. There was a relatively large increase in the percent of juveniles hatching from 4 to 31 May, which it can be argued is to be expected considering the similarly large decline for June. However, I believe conditions sufficiently severe to reduce productivity by 58 percent during June would not favor a 7- to 8-fold increase in productivity during May. Almost no hatch occurred after 29 June and very few unsuccessful hens, both of which suggested a forward shift. The lack of a significant peak in the hen molt from 18–31 May, may be due to the large percent of unsuccessful hens during other time periods. The largest percent of hens in the molt curve occurred during 4-17 May. This represented a substantial number of hens that failed to nest, abandoned or lost their nest, or lost their brood.

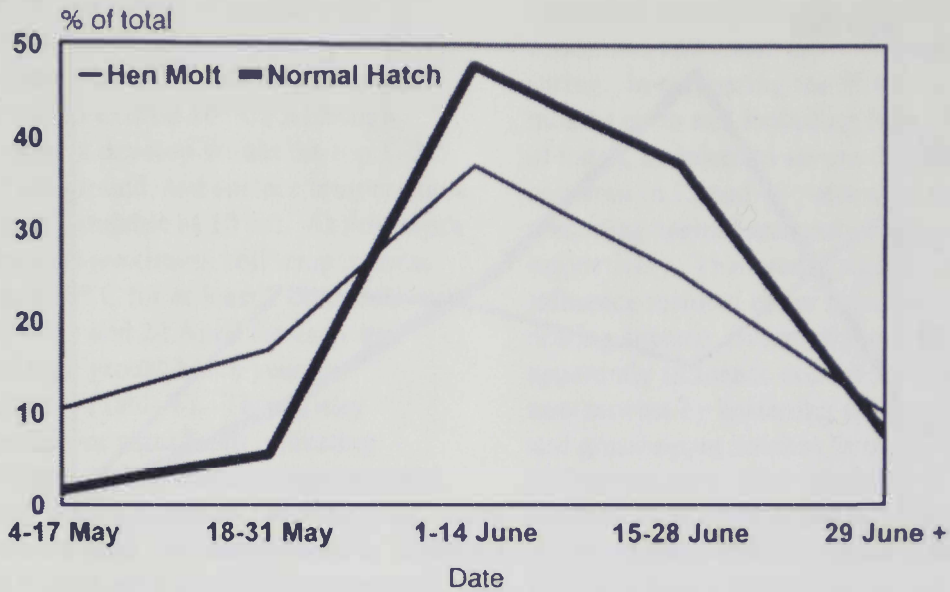

Figure 3. Sage grouse hen molt vs. normal hatch for south-central Montana (1964-1965, 1970-1971, 1973-1975).

During the normal hatch years the molt pattern of hens ≥2 years old indicated they made up 43, 36, 46, 70, and 75 percent of all adult hens in the 4-17 May through 29 June + time periods, respectively. During the early hatch years hens ≥2 years old made up 58, 53, 59, 94, and 100 percent of all adult hens in the respective five time periods. The almost total absence of yearling hens from mid-June on in early hatch years indicated to me a significant renesting attempt by more experienced age classes and virtually no renesting by yearling hens. If this assumption is correct, the time needed to breed, lay, and incubate a second clutch would indicate that these hens were originally associated with the unsuccessful hens from the 4-17 May time period. This further suggested that conditions during the early part of the hatching season were not markedly more favorable to producing a brood than in June, which would lend credence to earlier breeding and nesting during early hatch years.

Productivity, Early vs. Normal Hatch

Productivity averaged 195 and 273 juveniles/100 adult hens for early and normal hatches, respectively. Generally, highest productivity for early hatches corresponded with lowest productivity for normal hatches except during 1964 and 1991. Wallestad and Watts (1972) showed a negative correlation between productivity and rainfall >2.54 cm during the egg laying period for central Montana. The period for egg laying was determined by combining the 10-11 days necessary to lay a clutch of 7-8 eggs (Patterson 1952) and 26 days for incubation (Pyrah 1963). Egg laying for a normal hatch occurs from 24 April to 8 May. A total of 10.1 cm. of rain fell during this 2-wk period in 1964 that could account for lower production. Rainfall during this same time period was favorable for a good hatch in 1991, however, temperatures were more in line with an early hatch. February 1991 was 6.1° C warmer than average and warmer than any other February since 1962. March temperatures were mid-way between those for early and normal hatches. The egg laying period for an early hatch is 10–23 April. Temperatures averaged 12.4, 1.6, and 3.9° C the first, second and third week in April, respectively. A total of 71 cm of snow fell during 8-17 April with a maximum ground accumulation of 35.6 cm.

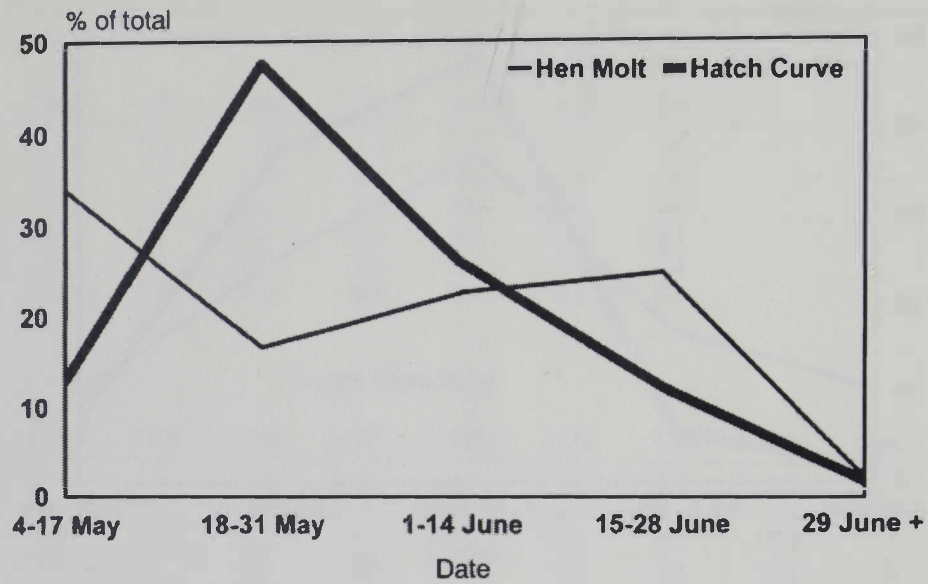

Figure 4. Sage grouse hen molt vs. early hatch for south-central Montana (1986-1987, 1992-1994, 2000).

of snow and 8.9 cm of moisture. Temperatures and the extremely low productivity that would be associated with early egg laying during a heavy snowfall indicated that 1991 fits the early hatch better than a normal hatch. Excluding 1964 and 1991 from the normal hatch increased productivity for normal years to 318 juveniles/100 adult hens. No other years appeared affected by precipitation during the egg-laying period, which averaged 2.0 and 2.9 cm during the egg laying period for respective early and normal hatches.

Grasshoppers

Peterson (1970) documented grasshoppers as the most important insect in sage grouse diets in central Montana with heavy utilization beginning at 5 weeks of age. From 5 to 12 weeks of age grasshoppers occurred in 38 percent of 101 crops examined and averaged 19 percent of the volume for those crops. Forbs constituted over 70 percent of the volume in juvenile chicks ≤12 weeks of age (Peterson 1970). In addition to its influence on vegetation development, moisture can have a profound influence on insect populations. Annual grassland biomass production in Montana and the proportion utilized by most grasshopper species are largely determined by environmental conditions during January through July (Kemp and Gigliano 1994). They found dry springs were detrimental to the development of forbs and annual grasses upon which grasshoppers depend. They documented a 56-percent decline in grasshopper species richness in eastern and south-central Montana following the severe 1988 drought. The influence of that decline was still apparent in insect abundance in 1992, indicating relatively long-lasting impacts of drought to some insect species. Extremely dry conditions did not have a direct negative effect on the growth or survival of eggs and small nymphs. Population losses were disproportionately associated with the large nymph and adult life stages (Kemp and Gigliano 1994). The small nymph stage covers the first 30 days of life followed by 20 days as a large nymph. This indicates that early hatches of grasshoppers, which normally occur during mid-to-late May in south-central Montana (Sword, personal communication) would start significant declines in mid to late June under very dry conditions. Fisher et al.

(1996) indicates that soil temperature influences the timing of grasshopper hatches with normal embryonic development commencing whenever soil temperatures exceed 10° C. Although grasshoppers develop within the top 1–2.5 cm. of the ground, sod surface temperatures were only available at 10 cm. At this depth the first date maximum soil temperatures averaged 10° C for at least 7 consecutive days was 13 and 24 April for early and normal sage grouse hatch years, respectively (Table 6). This 11-day difference was significant indicating grasshopper embryonic development, and hatching should occur sooner during early than normal sage grouse hatch years. This would benefit early hatching sage grouse chicks, but in extremely dry years could reduce the abundance of large nymphs available for chicks hatching during June. In summary then, dry warm springs would be detrimental to both forb and grasshopper production, which are important to juvenile sage grouse.

Discussion

Sage grouse populations in Montana have exhibited dramatic short-term swings in abundance. These periods of scarcity and abundance are driven by significant changes in productivity. The last major decline in productivity from 1984-1995 also was clearly accompanied by a 2-wk shift in the peak of hatching from early June to late May. Early hatches and low productivity coincided with a period of extended drought conditions and warm dry weather during spring. In comparing the PDSI for the 22 months up to and including June of the year of hatch, incipient to severe drought occurred in 13 and 43 percent of the months preceding normal and early hatch years, respectively. This would significantly influence residual cover important to nesting success. Warm dry springs apparently influence conditions favorable to nest success by hastening spring green-up and grasshopper hatches through elevated soil temperature. The influence of elevated soil temperatures and low precipitation also can shorten the duration of conditions favorable to chick survival through desiccation of vegetation and declines in the number of large nymph and adult grasshopper life stages. Molt patterns of adult hens with early hatches indicated significant numbers of unsuccessful hens, either through nest loss and abandonment or poor chick survival. Molt patterns also indicated a significant renesting effort by hens ≥2 years of age, which would be expected with nest loss and abandonment. The PDSI indicated dramatically improved moisture conditions during the latter half of 1993 through 1998, but it took over 2 years for this to be reflected in dramatically improved productivity. The improved productivity resulted in a 145 percent increase in male lek attendance between

Table 6. Maximum soil temperature at 10.2 cm. Depth in sod for 7 consecutive days for early and normal hatch years, Mocassin station, central Montana.

Early Hatch Years						
Temp.	1986	1987	1993	1994	2000	Ave. Date
10°C	7 Apr.	11 Apr.	7 Apr.	17 Apr.	21 Apr.	13 Apr.
15.6°C	23 May	1 May	16 May	14 May	24 May	16 May
Normal Hatch Years						
Temp.	1970	1971	1974	1975	1991	Ave. Date
10°C	10 May	13 Apr.	15 Apr.	16 May	7 Apr.	24 Apr.
15.6°C	20 May	8 May	11 May	19 May	23 May	16 May

1994 and 2000. Following 1 year of drought conditions in 1999, productivity again declined.

Conclusion

Gradual long-term declines in sage grouse populations are associated with habitat loss. Dramatic short-term population fluctuations are driven by changes in chick productivity. Drought conditions existing at least 20 months prior to hatching and warm dry springs during the year of hatching often accompanied reduced productivity. Productivity also can be reduced by exceptionally heavy precipitation during the egg laying period. Warm dry springs apparently favored an advance in the peak of hatching by at least two weeks over the normal hatching peak of 1-14 June. Warm dry springs also may result in earlier growth of vegetation and earlier hatching of some insect species, notably grasshoppers. I interpreted earlier hatching as an involuntary response by sage grouse to take the best possible advantage of earlier cover and forage conditions during the first critical weeks of life for chicks. Protection and improvement of existing sagebrush habitats offer the best means of preserving sage grouse in the long term. Short-term fluctuations are best corrected by rainfall, which we must leave up to someone else.

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