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## THE EFFECT OF FLOODING ON NORTHERN BOBWHITES

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Effects of flooding on mammals (Yeager and Anderson 1944) and reptiles (Stickel 1948) have been documented, and Northern Bobwhites (*Colinus virginianus*) have been known to drown (Schorger 1946, Mullan and Applegate 1969). However, on landscape and population scales, the implications of mortality from extensive flooding are undocumented for birds. We document mortality of bobwhites, possibly by drowning, because of flooding in east central Kansas.

From 31 October through 2 November 1998, 21 cm of rain fell in Lyon County, Kansas (Kansas Precipitation Report <ftp://oz.oznet.ksu.edu>). Water levels in all rivers and streams in the area overflowed their banks for the 3rd time in the decade (1993, 1995, 1998). The Cottonwood and Neosho rivers and their tributaries flooded a minimum area of 130 km<sup>2</sup> of Lyon County. During this period we observed the effects of flooding on Northern Bobwhites.

We conducted research on 12 independent 259-ha parcels of private and public land. Study areas were separated by at least 1.6 km. Distances between study areas were small enough to eliminate confounding climate and habitat heterogeneity effects on the population and yet large enough to avoid bobwhite interchange between study sites. Study areas were located in eastern Lyon County, western Osage County, and western Coffee County, Kansas. All study areas (1) were composed of habitat that was representative of east central Kansas and (2) allowed no hunting of bobwhites. Additionally, 5 of the 12 study areas were entirely or partially within the floodplain of the Cottonwood and Neosho rivers (termed floodplain study areas, FSA). The remaining 7 study areas were considered to be outside the

floodplain in upland areas (termed upland study areas, USA).

Bobwhites were captured 1 October–1 December 1998 using bait-traps (Stoddard 1931) and night-lighting (Labisky 1968). Upon capture, birds were sexed, aged (Rosene 1969), and weighed to the nearest gram. From each covey we randomly selected 3 birds that were fitted with a necklace-type radio-transmitter weighing <6 g (Burger et al. 1995). Birds weighing <150 g were not radio-marked to avoid stress from radio-collars weighing >5% of body mass (Samuel and Fuller 1994). All other birds captured in the covey were leg-banded. We immediately released all birds at the capture location. Radio-tagged individuals were located 5–7 times per week by homing (White and Garrott 1990) until death, radio failure, or 31 January. We recorded individual locations as Universal Transverse Mercator (UTM) coordinates with a resolution of 1.00 ha (Exum et al. 1982).

We monitored bobwhite survival during the period of flooding (31 October–1 December 1998). Survival rates were calculated with staggered entry additions, and all assumptions were met (Kaplan and Meier 1958, Pollock et al. 1989). We allowed birds to adjust to radio-collars for 7 days before they were included in survival analysis. We right-censored birds when fate was unknown or there was radio failure or loss, emigration from the study area, or survival beyond 31 January. Additionally, we estimated cause-specific mortality rates, classifying mortality agents as flooding or natural mortality. Both survival and mortality rates were calculated within the staggered entry survival model between treatments with log-rank tests ( $P \leq 0.10$ ; Pollock et al. 1989).

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We measured the effect of flooding on covey daily movement to investigate the possible effect of migration as a means to avoid natural catastrophe stochasticity. We estimated movement by calculating a mean daily distance between radio-locations for the initial 2 weeks after the flood. We used an independent  $t$  test ( $P \leq 0.10$ ) to compare movement between treatments. All means are reported  $\pm$  standard error.

Between 31 October and 1 December 1998, 66 individuals within 24 coveys in USA and 43 individuals within 11 coveys in FSA were used to estimate survival and cause-specific mortality. After the floodwaters receded, 5 radio-collared birds from 2 coveys were found under flood debris and silt in the FSA. Five radio-collared birds from 3 coveys were never relocated. While we cannot be certain, it is probable that these 5 coveys were decimated in the flood. Additionally, after a 2.7-cm rain event on 30 November 1998 (Kansas Precipitation Report <ftp://oz.oznet.ksu.edu>), we found 2 radio-collared birds, representing 2 different coveys (1 in USA and 1 in FSA), dead under flood debris and silt. Even this smaller flash flood event was not without impact on the local bobwhite population. Final survival estimate between 31 October and 1 December 1998 on USA was  $0.875 \pm 0.048$  (natural mortality =  $0.104 \pm 0.044$ , flood mortality =  $0.021 \pm 0.021$ ). Final survival estimate on FSA was  $0.417 \pm 0.091$  (natural mortality =  $0.364 \pm 0.091$ , flood mortality =  $0.218 \pm 0.247$ ). Survival was significantly lower on FSA ( $\chi^2_1 = 67.61$ ,  $P < 0.01$ ). Although flooding mortality was higher on FSA ( $\chi^2_1 = 28.72$ ,  $P < 0.01$ ), interestingly, natural mortality was also higher on FSA ( $\chi^2_1 = 36.86$ ,  $P < 0.01$ ). It is possible that displaced coveys, as a result of the flood, became more vulnerable to predation.

Coveys on FSA that did not go extinct from the flood moved their range to avoid floodwaters. We found that coveys in FSA moved more during the 2-week period after the flood (FSA:  $200.90 \pm 29.50$ , USA:  $149.93 \pm 12.61$ ,  $t_{33} = 1.878$ ,  $P = 0.69$ ). Additionally, on 3 November 1998, a covey of 12 Northern Bobwhites was observed in a residential neighborhood of Emporia, Kansas, approximately 0.4 km from the nearest known bobwhite habitat in the flooded lowlands of the Neosho River. Bob-

whites had not been present in this neighborhood before the flood and have not been seen since 8 November when the covey consisted of 10 birds. This covey was likely displaced from its usual range by the floodwaters. Yeager and Anderson (1944) found that flooding displaces certain mammals.

Assuming we did record the complete extinction of 5 coveys in FSA, we estimate that  $0.39$  coveys  $\cdot$  km<sup>-2</sup> would have been lost within the floodplain. Assuming similar losses throughout the county impacted by the flood (130 km<sup>2</sup>), 50 coveys could have been lost in Lyon County alone during the 31 October to 2 November flood event. In addition, an unknown number of coveys was likely displaced to adjacent upland habitat during the flood. Additional birds were likely lost during the smaller 30 November event.

Flooding reduced populations of mammals in some studies (Blair 1939, Yeager and Anderson 1944, McCarley 1959, Turner 1966). Mammal (Yeager and Anderson 1944, Stickel 1948, Wetzel 1958, Blem and Blem 1975, Ellis et al. 1997) and reptile (Stickel 1948) numbers were not affected in others. The direct impact of flooding on bobwhite populations may be as significant as severe winter weather (Roseberry 1962, 1964) and could depress local bobwhite populations. Additional mortality due to displacement and concentration during floods is unknown. However, because natural mortality in FSA was very high compared with USA, increased crowding on available dry ground possibly prompted a density-dependent feedback. Regardless, our analysis indicates flooding in this region can provide significant environmental stochasticity, and such variance should be considered in future predictive population models.

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