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Ecology and Management of Rio Grande Turkeys in the South Platte River Corridor

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Rio Grande Turkeys in the South Platte River Corridor

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Ecology and Management of Rio Grande Turkeys in the South Platte River Corridor

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ABSTRACT

The South Platte River corridor is the most popular destination for hunting Rio Grande turkeys (*Meleagris gallopavo intermedia*) in Colorado and the demand for more hunting opportunities continues to grow. However, limited information was available on the population parameters necessary to inform biologically-based management decisions. We banded 785 turkeys and of those, intensively monitored 146 radio-marked birds from 2008 through 2011 to study the ecology and population dynamics of Rio Grande turkeys in the South Platte River corridor in northeast Colorado.

The average annual home range was 3.57 km^2 for males and 4.13 km^2 for females. The average annual length of riparian corridor use was 17.01 km for males and 24.05 km for females. Across all years, winter range shifts were documented for 48 percent of radio-marked birds. Movements between consecutive wintering areas varied widely from 0–76.4 km and averaged 10.3 km from one year to the next. Movements to winter ranges occurred one to two weeks earlier for birds on public lands than for those on private land and was likely related to the amount of hunting pressure on small game and waterfowl. Wintering areas were exclusively located near corn fields, demonstrating their importance to turkey distribution and population sustainability. Nearly 20 percent of the juvenile males dispersed in excess of 25 km (15 miles) with the longest being 64 km (40 miles). Juvenile females dispersed farther than all other age-sex classes and the farthest dispersal was 76 km (47 miles), which is the largest dispersal movement ever reported anywhere for juvenile female turkeys.

Across all year, age, and sex cohorts, the annual survival rate from the Kaplan-Meier estimator was 0.593 (SE = 0.026) and survival from Barker’s Model was 0.563 (SE = 0.026). For males, annual survival from Barker's Model was 0.517 (SE = 0.028). For females, annual Kaplan-Meier survival was 0.608 (SE = 0.034) and varied from 0.586 in 2011 to 0.636 in 2009. For juvenile turkeys, annual survival from six to 18 months of age was 0.740 (SE = 0.092) and 0.675 (SE = 0.073) for males and females, respectively. Spring hunting was the primary cause of mortality for radio-marked males, averaging 53 percent of annual mortality. The average male harvest rate (30 percent; range 21–35 percent) we observed was sustainable due to high juvenile male survival, resulting in increased annual recruitment into the adult male population. Predation by mammals, primarily coyotes (79 percent), was the highest mortality factor for female turkeys, accounting for 51 percent of annual mortality. Recruitment varied by year with the highest (2.8 poults/ hen) occurring in 2009 and the lowest (1.7 poults/hen) occurring in 2010. Based on the estimates of annual female survival, we conclude that under average environmental conditions 1.5 poults/hen is the minimum recruitment rate necessary to replace current levels of annual mortality and maintain stable turkey populations along the South Platte River.

In 2010, the combined population in Game Management Units (GMU) 91 and 92 increased by 226 birds and was dominated by males with an estimated sex ratio of 4.4:1 M/F. We suspect that the spatial distribution of females for nesting habitat may have reached a threshold, which limited growth of the female population and shifted the sex ratio in favor of males. The combination of human-related development along the highway corridor that divides GMUs 91 and 96 was a significant deterrent for turkey movements between the two units, creating two distinct turkey management areas within the study area. Estimating population size and detectability of wintering turkey flocks during deer classification flights proved to be a reliable method for monitoring annual changes in the South Platte River turkey population. The number of turkeys counted during aerial flights was underestimated by 15.8 percent (range 13.6–18.4 percent) and sightability was consistent across all years, averaging 83.7 percent (range 81.6–85.6 percent). Future surveys should be conducted when snow cover is available to maximize sightability and flock size estimates.

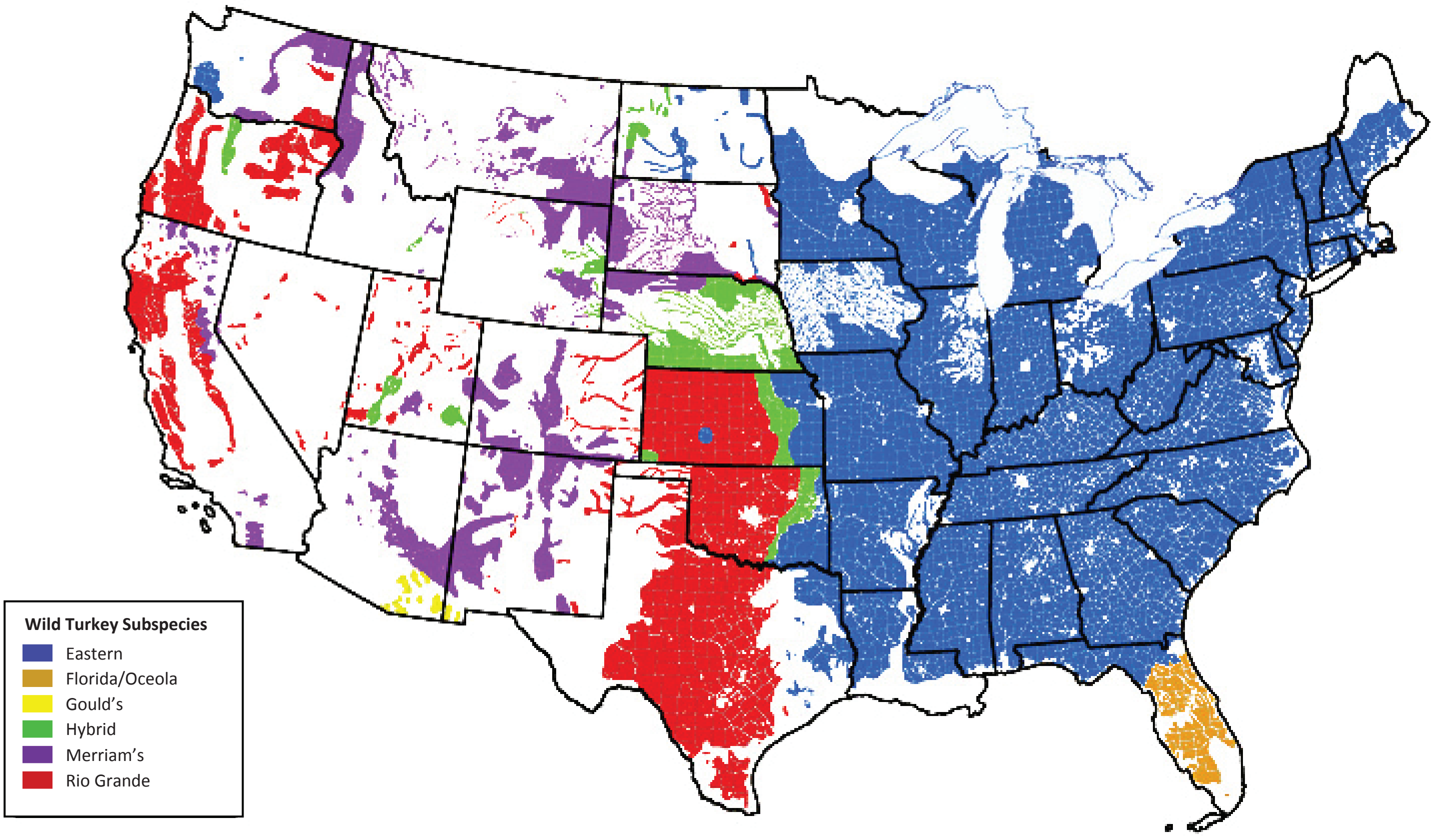

Figure 1. Distribution of Rio Grande wild turkey and other subspecies within the United States, 2011. (Reprinted from National Wild Turkey Federation)

INTRODUCTION

The Rio Grande wild turkey (*Meleagris gallopavo intermedia*) is endemic to northern Mexico, Texas, Oklahoma, and southern Kansas (Aldrich 1967). It was first described by George B. Sennett in 1879 from a specimen taken on the Lomita Ranch, Hidalgo County, Texas. He described it as intermediate in appearance between the eastern and western subspecies (Kennamer et al. 1992). Rio Grande turkeys are comparatively pale and copper colored with tail feathers and coverts tipped with yellow, buff or tan color. Although there is more variation in the color shade of the tail feathers among Rio Grande specimens, the color is consistently lighter than in the eastern (*M. g. silvestris*) or Florida (*M. g. osceola*) subspecies and darker than the same feathers in the Merriam's (*M. g. merriami*) or Gould's (*M. g. mexicana*) subspecies (Kennamer 2004).

Human expansion, habitat loss and unregulated hunting dramatically affected turkey numbers across their range, decreasing populations to their lowest levels by the late 1930s (Mosby 1975, Kennamer et al. 1992). By 1940, only about 100,000 Rio Grande turkeys remained in Texas and the subspecies was considered extirpated from Kansas and Oklahoma (Schorger 1966, Beasom and Wilson 1992). Laws enacted in the early 1900s, such as the Lacey Act and Pittman-Robertson Act, provided the necessary protection and funding to initiate wildlife recovery programs. By the early 1950s, trap-and-transplant programs within state wildlife agencies began accelerating the growth and expansion of wild turkeys throughout their native range and into many previously unoccupied regions. Today, Rio Grande wild turkeys are found at lower elevations in California, Colorado, Nevada, Oregon, South Dakota, Utah, Washington, and Wyoming, as well as Hawaii and northern Idaho (Fig. 1).

In 1980, the former Colorado Division of Wildlife (now Colorado Division of Parks and Wildlife) introduced the first Rio Grande wild turkeys into Colorado along the South Platte River near the town of Hillrose (Schmutz 1988). Prior to this time, no wild turkey populations existed on the plains of northeast Colorado (Schmutz 1988). From 1980–83, a total of 60 Rio Grande turkeys were transplanted from Kansas and Texas into the South Platte River corridor. The population quickly expanded to become a source for additional translocations. From 1988–90, approximately 110 turkeys were captured from six locations in GMU 96 and transplanted to various areas in the riverbottom from Platteville to Sedgwick, Colo. By 1990, all available habitats along the South Platte River were considered occupied by Rio Grande turkeys (T. J. Davis, Colorado Division of Wildlife, unpublished report). Since then, natural dispersals and additional transplants have further expanded the turkeys' range. Today, Rio Grande turkeys can be found in nearly all cottonwood riparian habitats throughout the eastern plains of Colorado.

Studies of Rio Grande turkey populations have been reported from Kansas, Oklahoma, Texas (Ransom et al. 1987, Buford 1993, Butler et al. 2005, Holdstock et al. 2006, Hall et al. 2007) and Colorado (Schmutz 1988; Schmutz and Braun 1989; Schmutz et al. 1989, 1990). Schmutz (1988) studied the reproductive performance and habitat use of Rio Grande turkeys along the South Platte River from 1986–87. This study provided the initial insight into nesting rates, nest success, movements, and temporal patterns in nest initiation for the newly established population in northeast Colorado.

It is well documented that rates of reproduction, mortality and movement can change dramatically under different population and habitat conditions (Bailey 1984, Krebs 1985, Welty and Baptista 1988, Stacey et al. 1997). In 1987, the South Platte turkey population, estimated at 250–300 birds (Schmutz 1988), was still in a state of rapid growth and expansion, with many segments of the river corridor still unoccupied. Today, Rio Grande turkeys have occupied the South Platte River corridor for 30 years and the dynamics of this population have likely changed since the previous study by Schmutz (1988). It could be misleading to assume the reproductive dynamics and movement patterns reported by Schmutz (1988) can be applied to the current population, because of the habitat, land use and population changes that have occurred over the past three decades. Therefore, an assessment of the reproductive performance of this population is needed to determine its annual growth and viability.

Estimating population size and density is generally a focal point in many wildlife studies. For hunted species like turkeys, understanding the distribution and population size are key components for making appropriate management decisions. In addition, determining age- and sex-specific survival rates and cause-specific mortality are important parameters for managers to assess the impacts of hunting mortality, hunter density and distribution, and season timing and length on the overall turkey population. These important statistics are necessary for determining the degree and spatial arrangement of hunting pressure and harvest that a population can sustain.

Several techniques to survey and monitor wild turkey populations have been developed; however, many of these have had limited utility for monitoring population changes over time. Techniques such as brood-count, gobbling, mail-carrier, line transect, and winter flock surveys have been used in several states with varying success (Cook 1973, Bartush et al. 1985, Weinrich et al. 1985, DeYoung and Priebe 1987, Welsh and Kimmel 1990). Variations in habitat, subspecies biology, region, and environmental conditions make the direct application of these techniques problematic across the species range.

The most common techniques still in use today are the brood-count and winter flock surveys (Kurzejeski and Vangilder 1992). In Colorado, Hoffman (1990) monitored gobbling intensity of Merriam's turkeys and concluded that, because gobbling varied greatly among individuals, gobbling routes may be of limited use as a population measure. Thus, no survey technique has been developed or used to monitor changes in turkey populations in Colorado. The lack of a reliable monitoring program often results in a conservative approach to harvest management and permit allocation for fear of overharvesting. The development of an annual survey is important for evaluating habitat conditions, harvest regulations and providing a tool to make biologically-based management decisions.

This project was designed to study the ecology and population dynamics of Rio Grande turkeys along the South Platte River in northeast Colorado. Specific objecttives were: 1) to determine annual and seasonal movements of turkeys, 2) to estimate adult and juvenile female recruitment rates, 3) to estimate annual and seasonal age-

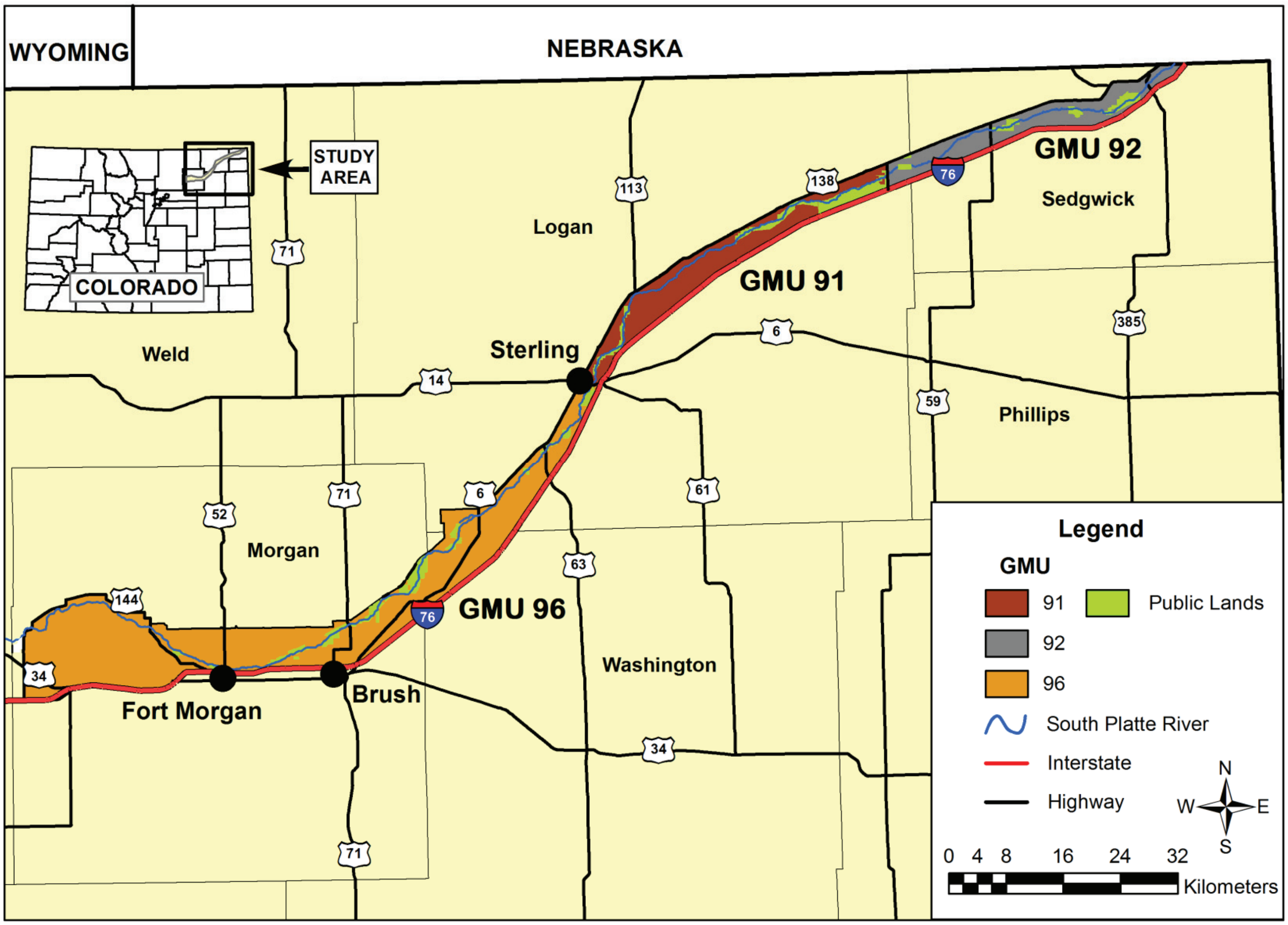

Figure 2. Geographic location of public lands in GMUs 91, 92 and 96 along the South Platte River in northeast Colorado.

and sex-specific survival and cause-specific mortality rates of turkeys, 4) to estimate the density and population size of wild turkeys in GMUs 91, 92 and 96, and 5) to develop a winter flock survey for estimating annual changes in the South Platte River turkey population.

STUDY AREA

The study area encompassed 150 km^2 of the South Platte River corridor and extended 200 km from Orchard, Colo., northeast to the Nebraska stateline in parts of Morgan, Washington, Logan, and Sedgwick counties in northeast Colorado (Fig. 2). The study area was located in GMUs 91, 92 and 96 and included all riparian habitats and parts of adjacent agricultural lands extending up to 1.0 km on either side of the South Platte River. Agricultural lands adjacent to the riverbottom were used primarily for production of alfalfa, corn, sugar beets, and wheat. Cattle grazing occurred at varying intensities in and adjacent to the riverbottom. Colorado Parks and Wildlife owned or managed approximately 25 percent of the riparian corridor within the project area (Fig. 2). Some of these lands were periodically grazed and all public lands were used for angling, hunting and wildlife viewing recreation.

Flora and Fauna

The riparian community along the South Platte River is dominated by an open-canopied plains cottonwood (*Populus sargentii*) forest. American elm (*Elmus americana*), boxelder maple (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), narrow-leaf willow (*Salix interior*), and Russian olive (*Eleagnus augustifolia*) occur in lower frequencies. Shrubs occur in discrete patches and are predominately western snowberry (*Symphoricarpos occidentalis*), although poison ivy (*Rhus radicans*) and willow (*Salix* spp.) are common in mesic areas. Common forbs include poison hemlock (*Conium maculatum*), ragweed (*Ambrosia* sp.), sunflower (*Helianthus* sp.), tall whitetop (*Lepidium latifolium*), and thistle (*Cirsium* spp.). Common grasses include cheatgrass brome (*Bromus tectorum*), inland saltgrass (*Distichlis stricta*), prairie cordgrass (*Spartina pectinata*), sand dropseed (*Sporobolus cryptandrus*), and wheatgrass (*Agropyron* spp.).

Cottonwood dominated forest along the South Platte River.

Beidleman (1978) referred to the cottonwood riparian ecosystem of the plains and lower mountains as the most productive and highly diversified ecosystem in the west. Fitzgerald (1978) identified 109 avian, 23 mammal, 14 reptile, and five amphibian species inhabiting the riparian and adjacent communities along the South Platte River. In addition, Nesler et al. (1997) documented 27 fish species occurring in the lower South Platte River Basin, of which five species are federal or state endangered, threatened, or species of special concern.

Principal game species include cottontail rabbit (*Sylvilagus* sp.), fox squirrel (*Sciurus niger*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*), along with numerous waterfowl and gallinaceous birds such as mourning dove (*Zenaida macroura*), northern bobwhite quail (*Colinus virginianus*), pheasant (*Phasianus colchicus*), and wild turkey. Bobcat (*Lynx rufus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*) are the common medium-sized mammals. Bald eagle (*Haliaeetus leucocephalus*), great horned owl (*Bubo virginianus*), and red-tailed hawk (*Buteo jamalcensis*) are the most common raptors.

Climate

Northeast Colorado is characterized by hot, dry summers and relatively mild winters. From 2008–11, annual precipitation from four weather stations ranged from 27–45 cm (11–18 inches) with most occurring during intense summer thunderstorms (Fig. 3) (National Climatic Data Center 2012). Summer rains (May–August) accounted for 50–70 percent of the annual precipitation. Snowfall was light and variable across the region. Winter precipitation (December–February) ranged from 0.8–1.5 cm (0.3–0.6 inches) falling mainly as snow, which accounted for 2–4 percent of the annual moisture (Fig. 3). Seasonal temperatures were relatively stable, varying only a few degrees across years. Average high temperature during summer ranged from 27.8–31.1° C (82–88° F) and average high temperature during winter varied from 1.7 to 6.7° C (35–44° F) (National Climatic Data Center 2012).

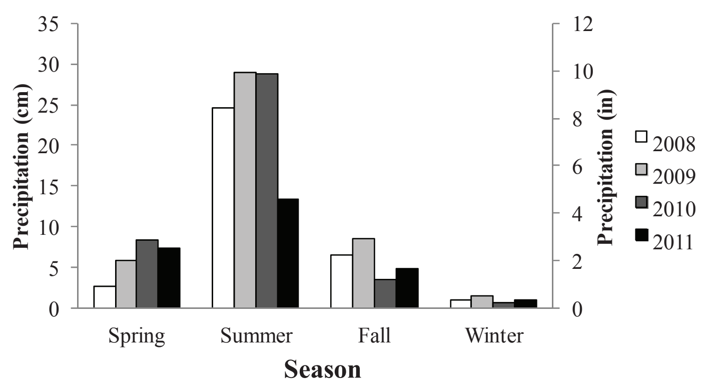

Figure 3. Seasonal precipitation along the South Platte River in northeast Colorado, 2008–2011.

Hunting Season Structure

Over the past 25 years, the season structure for spring turkey hunting along the South Platte River has gone through several changes. The first turkey hunting season was held in a portion of GMU 96 in the spring of 1985 (Fig. 4). The season was 30 days in length and opened the

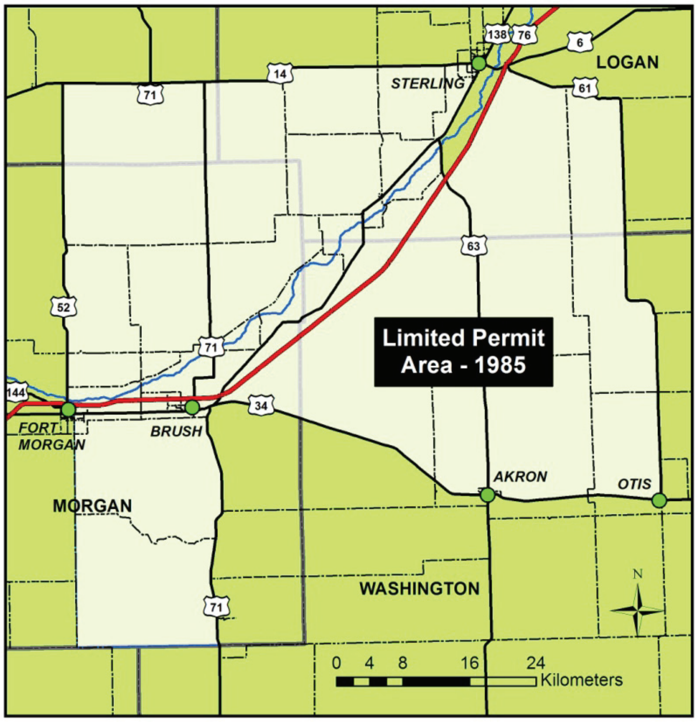

Figure 4. Boundary of the first spring turkey hunting area encompassing a portion of Game Management Unit 96 in northeast Colorado, 1985.

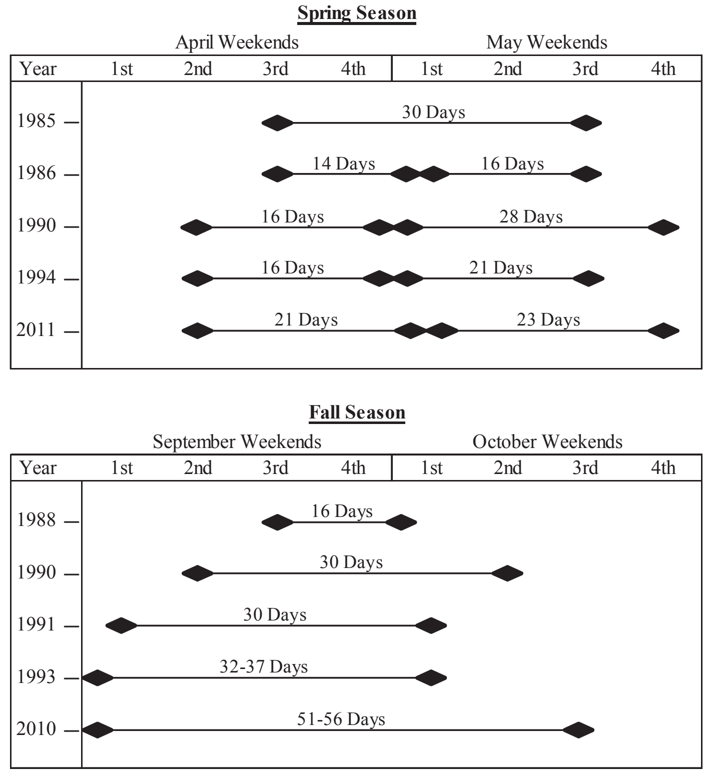

Figure 5. Historic changes in season structure for spring and fall turkey hunting in northeast Colorado, 1985–2011.

third weekend in April (Fig. 5). In 1986, spring turkey hunting was split into two seasons; the first season was 14 days long and the second was 16 days with a limited number of permits issued for each season. In 1988, all of GMU 96 was opened to spring turkey hunting. In 1990, further changes were implemented to increase turkey hunting opportunities in northeast Colorado. First, the South Platte River corridor from Interstate 25 to Nebraska was opened to limited turkey hunting. Also, the spring season was expanded to 44 days to include a 16-day first season, which opened on the second weekend in April, and a 28-day second season (Fig. 5). In 1994, the second season was reduced to 21 days in GMUs 91, 92 and 96; this season structure remained in effect until 2011. These changes were based on the nesting chronology reported by Schmutz (1988). In 2011, spring turkey hunting in GMUs 91, 92 and 96 was increased back to 44 days and the first and second seasons were modified to 21 and 23 days, respectively.

Fall either-sex turkey hunting began in northeast Colorado in 1988 when a limited number of permits were issued in GMU 96. The fall season opened the third weekend in September and was 16 days in length (Fig. 5). In 1990, the fall season was increased to 30 days and opened the second weekend in September. In 1991, hunting opportunities in the fall were expanded when GMUs 91 and 92 were opened to limited either-sex hunting and the season was changed to start the first weekend in September. In 1993, the fall season was again modified to open Sept. 1 and close the first weekend in October; this season structure remained in effect until 2010 when the season was extended an additional two weeks, ending the day before the start of the plains rifle deer season.

License and Harvest History

From the inception of spring turkey hunting in 1985 on Colorado's northeastern plains, the number of licenses allocated that are valid on public lands has remained virtually unchanged. In GMU 96, the number of public land licenses has remained the same since 1987 (Table 1). Similarly, since 1993, the number of public land licenses has remained unchanged in GMU 91 and has changed once in GMU 92. In 2003, additional turkey hunting opportunity was provided when private-land-only (PLO)

Table 1. Turkey license allocation and hunter harvest for the spring seasons in GMUs 91, 92 and 96 in northeast Colorado, 1985–2011.

	License Allocation						Hunter Harvest					
	GMU 96		GMU 91		GMU 92		GMU 96		GMU 91		GMU 92	
Year	PUB[a]	PLO[b]	PUB	PLO	PUB	PLO	PUB	PLO	PUB	PLO	PUB	PLO
1985	25						---[c]					
1986	50[d]						---					
1987	70						---					
1988	70						---					
1989	70		20				---		---			
1990	70		20		20		---		---		---	
1991	70		30		20		---		---		---	
1992	70		30		20		38		10		6	
1993	70		50		40		28		24		6	
1994	70		50		40		38		21		11	
1995	70		50		40		28		23		14	
1996	70		50		40		36		16		4	
1997	70		50		40		---		---		---	
1998	70		50		40		30		14		18	
1999	70		50		40		32		27		10	
2000	70		50		40		40		28		23	
2001	70		50		40		46		21		24	
2002	70		50		40		42		14		11	
2003	70	20	50	20	40	10	37	12	30	8	16	4
2004	70	40	50	20	50	10	43	19	23	13	32	8
2005	70	40	50	20	50	10	40	25	30	11	32	8
2006	70	40	50	20	50	10	35	11	21	13	23	7
2007	70	40	50	20	50	10	35	16	27	3	24	5
2008	70	40	50	20	50	10	39	9	24	8	30	3
2009	70	40	50	20	50	10	40	19	23	11	31	5
2010	70	40	50	20	50	10	42	17	31	15	31	5
2011	70	40	50	20	50	10	40	23	34	15	23	4

[a] Licenses valid on public and private lands.
[b] Licenses initiated in 2003 and valid on private land only.
[c] No harvest information was available.
[d] Beginning in 1986, total number of licenses issued in GMUs 91, 92 and 96 were divided equally between the 1st and 2nd season.

licenses were added in GMUs 91, 92 and 96.

Turkey harvest information for years 1985–1991 could not be found in any archived databases. Therefore, harvest information is only presented for the 20-year period, 1992–2011 (Table 1). The spring turkey harvest has varied annually over the past 20 years and has generally increased over time (Fig. 6). However, since 2003 when PLO licenses were introduced, the overall harvest has remained virtually unchanged.

The fall turkey harvest has varied widely over the past 20 years with no harvest being reported in some GMUs in multiple years (Table 1). In 2008, the number of fall licenses was increased in GMUs 91 and 96 to reflect the proportion of available turkey habitat between the three GMUs in the study area, using the number of licenses in GMU 92 as the minimum. Since then, the fall harvest has increased proportionally to the license increase with females accounting for 66 percent (range 58–88 percent) of the fall harvest over the past five years.

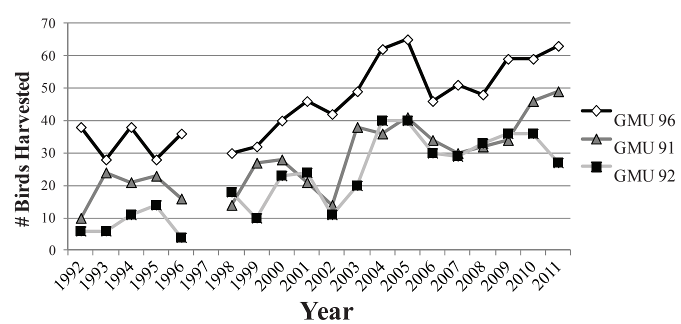

Figure 6. Spring turkey harvest in GMUs 91, 92 and 96 in northeast Colorado, 1992–2011.

METHODS

Capture and Marking

Turkeys were captured from January–March in 2008 and December–February in 2008–09 and 2009–10, using dropnet systems. Trap sites were established near feeding areas or roost sites for all known flocks ≥25 birds during winter months to increase catch-per-unit effort. Dropnet systems operated by magnetic (Wildlife Capture Services, Flagstaff, AZ) or custom electric solenoid releases (Colorado Parks and Wildlife, Fort Collins, CO) were used to suspend and deploy nets measuring 18.3 × 18.3 m (60 × 60 feet, mesh size 2.5 inches; Nichols Net and Twine, Inc., Granite City, IL) over bait. Bait consisted of whole corn scattered over wheat or oat straw to attract turkeys to trap sites.

Turkeys at a dropnet capture site.

All captured turkeys were aged, sexed, and fitted with an aluminum leg band. Each band was imprinted with a unique alphanumeric sequence and listed an address and phone number for reporting a recovered band. Females were banded with a green-enameled, butt-end leg band (Style 1242, Size 24; National Band and Tag Co., Newport, KY) and males were banded with a rivet-locking leg band (Model 1242FR9; National Band and Tag). Diefenbach et al. (2009) reported <50 percent band retention of butt-end leg bands by males, therefore a locking leg band was used for all male turkeys. Significant band loss by females has not been reported, thus butt-end bands were used on females as a cost savings measure.

Age was determined from the barred pattern on the ninth and tenth primaries and tail feather replacement characteristics at time of capture (Pelham and Dickson 1992). Birds were classified as juvenile (first winter of life) or adult (second or later winter of life). A sample of birds from each age- and sex-class were fitted with a backpack-style radio transmitter equipped with an eight-hour mortality sensor (Advanced Telemetry Systems, Isanti, MN) weighing 75–80 g. Transmitters were attached using a nylon over-braid harness following methods described by Phillips (2004) and Flake et al. (2006). All birds were released at the capture site after processing.

The initial sample size for each age- and sex-class of radio-marked birds was based on survival estimates and standard errors reported for other Rio Grande populations (Phillips 2004, Holdstock et al. 2006), to provide a coefficient of variation (CV) ≤0.15. Also, sample size by sex was calculated to provide a marked sample of approximately seven to 10 percent based on the ad hoc estimate of the 2007–08 wintering turkey population and average survival rates and sex composition of Rio Grande turkeys reported in literature (Ballard et al. 2004). Finally, transmitters were partitioned by GMU based on their proportion of available habitat within the study area. After the first year of capture, additional birds were captured and fitted with radio transmitters as needed to maintain sample size within each age- and sex-class.

Radio Telemetry

Radio-marked turkeys were monitored from January 2008 through February 2012. Most birds were located two to four times per week from April through August, which covered the breeding, nesting, and brood-rearing periods, as well as the spring turkey hunting season. For the remainder of the year (September through March), a minimum of four locations per month were collected from each bird. Monitoring began following a two-week adjustment period after capture and radio attachment. The two weeks after capture is typically the period that attributes any abnormal movement, behavior or mortality to the capture event (Phillips 2004).

Turkeys were located with a STR1000 (Lotek Wireless, Inc., Newmarket, Ontario, Canada) or R1000 telemetric receiver (Communications Specialists, Inc., Orange, CA) and a five-element, vehicular roof-mounted antenna, or two-element "H" antenna (Telonics, Inc., Mesa, AZ). Aerial flights using a Cessna 185 were conducted to locate birds during the fall and winter seasons and whenever birds could not be found from ground telemetry. Telemetry stations were established at known locations that could be accurately identified on 2009 USDA National Agricultural Imagery Program aerial photography maps. Each telemetry station was plotted and assigned an identification (ID) number and Universal Transverse Mercator (UTM) coordinates within the North American Datum 1983 coordinate system were recorded to the nearest 1 m.

Using a receiver and antenna to locate radio-marked turkeys.

Turkey locations were determined by triangulation of ≥2 azimuths from the loudest signal method (Springer 1979, Mech 1983). Azimuths were selected based on the following criteria: 1) the angle between all azimuths was between 60° and 120°, 2) the time interval between all azimuths was ≤20 minutes, 3) signal strength was good, and 4) the distance between the receiver and the bird was the closest using the selected azimuths. Locations were stratified among three diurnal sampling periods based upon general activity patterns (AM, midday, and PM) and a roost period (dusk to dawn). To ensure equal sampling among the four activity periods, sequential locations were collected during each activity period for each bird on a rotating schedule (Harris et al. 1990, Phillips 2004). The maximum likelihood estimator method (Lenth 1981) in Program LOCATE III (Nams 2006) was used to estimate bird locations. Generated output included turkey ID, date, time, and UTM coordinates.

Home Range and Riparian Use

Seasons were defined according to changes in bird behavior or distinct shifts in habitat use during the year (Vangilder and Kurzejeski 1995, Phillips 2004). Because environmental conditions, primarily weather, varied seasonally and annually, seasonal shifts for most birds were not consistent within or among years. Thus, the median start and end dates were calculated for each season based on all birds within each age- and sex-class across all years. Spring (Feb. 16–May 15) began with the breakup of winter flocks and continued through the breeding and egg-laying period. Summer (May 16–Aug. 31) corresponded with the nesting and brood-rearing period. Fall (Sept. 1–Nov. 30) was the period from the end of brood-rearing to the establishment of winter flocks. Winter (Dec. 1–Feb. 15) encompassed the period from winter flock formation to breakup.

Seasonal and annual home range distributions of turkeys were estimated using the Hawth's Spatial Analysis tools extension (Beyer 2004) for ArcGIS®, Version 9.3 (Environmental Systems Research Institute, Redlands, CA) with least-squares cross-validation (Worton 1989, Seaman and Powell 1996). The fixed-kernel (FK) method with a bandwidth of 250 m was used for determining each turkey's home range, and each home range was based on the 90 percent confidence interval to exclude outliers. Because of the serpentine configuration of the study area (Fig. 2), the commonly reported 95 percent contours were not used because it predominantly over-estimated home range size by including extensive areas that were never used by turkeys during the study. Because the riparian corridor is relatively narrow ($\bar{x}$ = 0.34 km), home range size may not provide meaningful information on use across the study area. Therefore, the length (km) of riparian corridor use for seasonal and annual home ranges was also computed to provide a better assessment of turkey use, movement and distribution within the study area.

Because movements by most animals likely depend on past experience, no two telemetry locations are truly independent (Swihart and Slade 1985, 1997). By definition, the concept of a home range involves autocorrelated movements, but estimates based on a representative sample of an animal's movement during a predefined time frame should not be affected by the sampling interval and autocorrelation (Otis and White 1999). Thus, independence among locations was not required since intensive sampling of an animal's home range should lead to improved estimates for the individual. Therefore, all locations that met the triangulation requirements described earlier were used for home range analysis.

Annual home range estimates were calculated using locations collected from the start of the spring season through the following winter. Annual home ranges were determined for individuals that had ≥50 locations (Seaman et al. 1999) and were monitored for ≥9 months. Annual home ranges were calculated for 99 turkeys (57 females [F], 42 males [M]) based on 9,210 location estimates. For juvenile turkeys, annual and seasonal home range estimates corresponded with the time period of use between six and 18 months of age. Seasonal home ranges for spring and summer were calculated for 144 (82F, 62M) and 112 (69F, 43M) turkeys based on 3,495 and 4,430 locations, respectively. Fall and winter home ranges were calculated for 97 (55F, 42M) and 128 (80F, 48M) turkeys based 1,443 and 2,942 locations, respectively. A Wilcoxon test was used to determine whether home range size and riparian length differed by age, sex, GMU, season, or year.

Movement

Winter range fidelity of individual birds was used to classify birds as residents or dispersers (Phillips 2004). To determine winter range fidelity, winter locations were used to calculate 100 percent minimum convex polygons (MCP). Any degree of overlap between consecutive winter MCP home ranges was considered winter range fidelity (Phillips 2004). Birds exhibiting permanent winter range shifts were categorized as dispersers, while those that did not were classified as residents. Seasonal and annual movements were calculated from the centroid of home range estimates to the prior years' wintering area for each radio-marked turkey. Radio-marked birds ≤18 months of age were classified as juveniles for all movement analyses. A Wilcoxon test was used to determine whether movements from wintering areas differed by age, sex, season, or year.

Recruitment

Turkey recruitment was defined as the mean number of poults >4 weeks old per hen. Recruitment was determined during the late summer because multiple hens and their broods would group together providing the opportunity to observe broods from both radio-marked and unmarked females. In August of each year, a receiver and handheld H-antenna were used to locate radio-marked females to visually count the total number of poults for all females in the group. Groups with poults ≤4 weeks old were recounted at a later time because of the high mortality that occurs during the first few weeks after hatching (Vangilder and Kurzejeski 1995). Because female turkeys can breed, nest and successfully raise young within the first year of life, females ≤15 months of age were classified as juveniles, assuming a June 1 birth date.

Hen turkey with poults.

Recruitment rates were determined from 45 (nine adult [A], seven juvenile [J], and 29 unmarked [U]) females in 2008, 68 (16A, 14J, 38U) females in 2009, 121 (26A, 12J, 83U) females in 2010, and 70 (20A, 50U) females in 2011. General Linear Model procedures (SAS Institute, Inc. 2010) were used to test for differences among ages, years and GMUs. Finally, the average annual survival rate for each age- and sex-cohort were applied to each year's beginning population to estimate the minimum recruitment rate needed to maintain a stable population level for 2009–2011.

Survival

Radio telemetry was used to estimate seasonal and annual survival for adult and juvenile turkeys within each sex-class. For the seasonal survival analysis, birds ≤15 months of age were classified as juveniles. Starting in the fall season after a new recruitment class was documented, juveniles were reclassified as adults. Therefore, seasonal survival rates for juveniles were only determined for the winter, spring and summer seasons. Annual survival estimates for juveniles represented the time period from approximately six to 18 months of age.

Annual and seasonal survival estimates were generated for radio-marked birds using the Kaplan-Meier product-limit estimator modified for staggered entry (Pollock et al. 1989), which allowed for staggered entries due to multiple capture dates. The survival interval that birds were considered at risk was one week. Differences between age and sex cohort survival distributions generated by the Kaplan-Meier approach were tested using the log-rank test (Pollock et al. 1989). Differences in seasonal survival rates were tested by comparing weekly rates of survival in each season in a two-way analysis of variance (ANOVA) with year and season as main effects along with the interaction of year and season (general linear models procedures [SAS Institute, Inc. 2010]).

To determine the extent that the inclusion of banded birds recovered during the hunting seasons could improve survival estimates, survival rates were also estimated for adults and juveniles by sex using Barker's Model for joint live and dead encounters (Barker 1997, 1999) in program MARK (White and Burnham 1999). Barker's model is an extension of the Both Live and Dead Encounter model of Burnham (1993) that allows resightings of marked animals between live recapture intervals to improve estimates of survival. Barker's model allowed 117 banded birds that were recovered during the spring and fall hunting seasons to be included in the survival estimates. Survival estimates from only band-recovered birds were also calculated for comparison with estimates from radio-marked birds.

Cause-Specific Mortality

When a mortality signal was heard, the bird was located to determine if it had died. Cause of death was determined by field necropsy (when possible) and by searching the area for evidence (Vangilder and Kurzejeski 1995). The median date between the last two locations was used as the date of death unless evidence at the recovery site proved the kill date to be different from the median. Mortalities were classified as avian, mammal, harvest, and other. Avian included mortalities from bald eagles, great-horned owls and hawks. Mammal included those caused by bobcat, coyote, and red fox. Harvest included birds killed by hunters during the hunting seasons. Hunters reported a harvested bird by calling a phone number listed on the leg-band or radio transmitter. Hunters were also asked if they harvested a banded turkey during the spring turkey harvest survey. Phone calls were made to hunters that responded yes to the question to obtain additional information. Harvest information included band ID number, date of kill, GMU, and kill location. Other mortalities included disease, injury or unknown cause.

Population Estimation

Radio-marked birds were used to estimate winter population size, using a mark-resight technique via a double-count procedure (Collins 2007). Aerial counts of turkey flocks were conducted in mid-winter (Dec. 22–Jan. 7) of each year using a helicopter in conjunction with the Colorado Parks and Wildlife annual deer sex- and age-ratio counts. When a turkey flock was encountered during the flight, the total number of birds was estimated and then a receiver and handheld H-antenna were used to determine whether or not the flock contained radio-marked birds. Within each flock, if radio-marked birds were detected, then the total number of radio-marked birds was recorded. To maintain an unbiased estimate of detecting flocks from the air, radio telemetry was only used after flocks were visually located. A second survey count was conducted from the ground within one to three days after the aerial survey and the same information was collected.

It was assumed that observations from the ground provided an accurate count of the true number of birds within each flock. Ground counts were conducted on all flocks observed during the aerial flights, as well as all other known flocks not encountered during the aerial surveys.

Aerial count of turkey flock along the South Platte River.

The formulas used to estimate the group detection probability and population size for the double-count procedure (Collins 2007) are as follows:

$$\hat{p}_g = \frac{m_d}{m_t}$$

where

$\hat{p}_g$ = group detection probability,

m_d = number of groups detected from the air containing a radio-marked bird,

m_t = total number of groups available containing radio-marked birds,

and

$$\hat{N} = \frac{n_g}{\hat{p}_g}\frac{\overline{y}}{\overline{x}}\overline{x}'$$

where

$\hat{N}$ = estimated population size,

n_g = number of groups detected from the air,

$\hat{p}_g$ = probability of detecting a group from the air,

$\overline{y}$ = average group size counted on the ground,

$\overline{x}$ = average group size counted from the air for groups also counted on the ground, and

$\overline{x}'$ = average group size for all groups counted from the air.

If all groups with radio-marked birds were detected during the aerial survey, then $\hat{p}_g = 1$ and variance $(\hat{N}) = 0$.

If not all groups with radio-marked birds were detected, then a ratio estimator and its associated standard error (Snedecor and Cochran 1967, Collins 2007) were calculated using the following formulas:

$$r = \frac{\sum_{i=1}^{n} x}{\sum_{i=1}^{n} x'}$$

where

r = ratio of average group size from ground counts to average group size counted from the air,

x = average group size detected from the ground,

x' = average group size detected from the air,

and SE (r) =

$$\sqrt{\text{var}(\hat{N}) = \left(\frac{1}{n'} - \frac{1}{t_g}\right)s_y^2 + \left(\frac{1}{n} - \frac{1}{n'}\right)\left(s_y^2 - 2rs_{xy} + r^2 s_x^2\right)}$$

where

t_g = total number of groups,

n = number of groups detected from the air,

n' = number of groups detected from the ground,

s_y^2 = variance of average group size counted from the ground,

s_x^2 = variance of average group size counted from the air for groups also counted on the ground,

s_{xy} = covariance of the average group size counted from the ground and air.

Finally, SE ($\hat{N}$) = (n)(SE [r]) where

n = total number of flocks within the study area.

Density estimates were also calculated by sex, GMU and year to further evaluate changes in individual parameters over time. To determine the accuracy of the aerial surveys to estimate population size over time, the ratio estimates for number of groups and group size compared to ground count estimates were compared to determine the variation in aerial detection across years.

RESULTS

Capture and Marking

In 2008, we trapped 14 different sites along the South Platte River in GMUs 91, 92, and 96. In 2009 and 2010, we trapped nine and 13 sites, respectively, within the three GMUs. Over three years, we recorded 812 captures (449F, 363M) and banded 785 birds (428F, 357M) within the South Platte River corridor (Table 2). We recaptured 17 turkeys (14F, 3M), had eight birds (6F, 2M) escape prior to banding, and experienced two mortalities (1F, 1M) during capture events over the three-year period.

Table 2. Number of banded and radio-marked Rio Grande turkeys by sex and age in GMUs 91, 92 and 96 in northeast Colorado, 2008–2010.

		Adult Female		Adult Male		Juvenile Female		Juvenile Male	
Year	GMU	Bands	Radios	Bands	Radios	Bands	Radios	Bands	Radios
2008	91	18	12	0	0	15	3	11	0
	92	5	2	0	0	0	0	21	11
	96	66	10	7	3	47	7	66	12
	Total	89	24	7	3	62	10	98	23
2009	91	22	0	10	8	9	7	0	0
	92	25	8	4	0	25	4	26	2
	96	28	2	0	0	27	8	45	5
	Total	75	10	14	8	61	19	71	7
2010	91	0	0	0	0	31	5	60	3
	92	30	4	0	0	24	6	32	3
	96	22	0	1	1	34	10	74	10
	Total	52	4	1	1	89	21	166	16
Grand Total		216	38	22	12	212	50	335	46

In 2008, we fitted 60 turkeys (34F, 26M) with a radio transmitter (Table 2). In 2009 and 2010, we fitted an additional 44 (29F, 15M) and 42 turkeys (25F, 17M), respecttively, with radio transmitters. From 2008–10, the overall distribution of transmitters by age-at-capture was 50 adults (38F, 12M) and 96 juveniles (50F, 46M) (Table 2). The sample size of radio-marked birds by year was 7 percent of the population in 2008, 9 percent in 2009, and 7 percent in 2010 which provided an overall CV of 0.11 ranging from 0.10 to 0.13 across the three years of live-trapping.

Banded adult male turkey.

Radio Telemetry

We collected 12,584 location estimates from 146 radio-marked turkeys (88F, 58M) during the study. We obtained 3,510 of those locations during aerial tracking flights, primarily during the fall and winter seasons. We used 12,310 locations to estimate annual and/or seasonal home range distributions for 137 individual turkeys (81F, 56M) that had sufficient data for years 2008–2011.

Home Range and Riparian Use

Home ranges were larger for females than males and were largest in the spring with only a slight difference among years and no difference between GMUs or by age. Across all years, there was a difference (χ_1^2 = 17.404, P = 0.001) in annual home range size and length of riparian corridor use (χ_1^2 = 18.058, P = 0.001) between males and females (Table 3). The average annual 90 percent FK home range was 3.57 km^2 for males (n = 58) and 4.13 km^2 for females (n = 91). The average riparian corridor length of annual home ranges was 17.01 km for males and 24.05 km for females.

Table 3. Estimates of annual fixed-kernel home range size (km^2) and length (km) of riparian corridor use by Rio Grande turkeys in GMUs 91, 92 and 96 in northeast Colorado, 2008–2010.

Year			Females					Males				
			Home Range		Riparian Length			Home Range		Riparian Length		
GMU	Age	*n*	Mean	Range	Mean	Range	*n*	Mean	Range	Mean	Range	
2008												
91	Adult	7	4.1	3.2–5.8	22.8	20.0–31.5	0	---	---	---	---	
	Juvenile	2	3.1	2.3–4.0	20.4	20.2–20.7	0	---	---	---	---	
92	Adult	2	2.7	2.2–2.3	18.3	16.5–20.2	0	---	---	---	---	
	Juvenile	0	---	---	---	---	10	3.8	2.9–5.5	13.2	8.5–46.4	
96	Adult	5	3.8	3.0–4.3	23.4	13.9–41.2	1	3.5	---	12.2	---	
	Juvenile	6	4.4	2.7–5.0	36.1	10.0–60.0	7	3.3	2.9–4.0	16.4	10.4–30.5	
2009												
91	Adult	6	3.9	3.2–4.5	23.8	7.7–37.8	6	3.2	2.8–3.8	19.0	13.8–21.3	
	Juvenile	6	3.9	3.1–4-8	30.7	5.7–63.0	1	3.7	---	20.4	---	
92	Adult	3	4.0	1.8–5.8	13.4	2.6–20.3	4	2.7	2.1–3.4	7.9	7.0–8.3	
	Juvenile	1	4.6	---	23.8	---	0	---	---	---	---	
96	Adult	7	4.9	3.7–6.0	19.3	7.1–25.0	2	2.9	---	10.9	6.6–15.1	
	Juvenile	5	3.6	2.3–4.3	27.0	9.3–55.1	5	3.7	3.0–4.4	18.2	8.4–35.5	
2010												
91	Adult	12	4.0	2.1–5.5	20.6	4.5–46.5	5	3.8	3.0–4.3	15.4	8.7–19.0	
	Juvenile	4	4.5	3.8–5.2	29.3	19.8–48.6	3	4.5	4.2–4.9	43.7	28.1–64.4	
92	Adult	5	4.2	2.8–5.1	21.1	9.8–31.2	2	4.7	4.6–4.8	9.4	8.9–9.9	
	Juvenile	3	4.6	3.2–5.3	22.1	4.4–43.4	2	3.3	3.0–3.5	34.4	18.3–50.5	
96	Adult	11	4.1	2.7–5.5	18.1	7.5–43.1	3	3.9	3.4–4.2	8.7	5.8–10.9	
	Juvenile	6	4.6	3.2–5.7	35.2	11.6–65.9	7	3.6	2.8–4.9	18.2	10.1–36.0	

There was no difference (P = 0.877) between adult (n = 81) and juvenile (n = 68) annual home range size and a weak difference in riparian corridor length (χ_1^2 = 2.812, P = 0.094). The average annual home range for both adults and juveniles was 3.91 km^2 and the annual length of riparian corridor use was 18.46 km and 24.71 km for adults and juveniles, respectively (Table 3).

There was a slight difference in annual home range size among years (χ_2^2 = 5.499, P = 0.064). Annual home ranges in 2010 were larger (P = 0.024) than those in 2008, but there was no difference among the other year comparisons and there was no difference (P = 0.956) in length of riparian corridor use between years. When annual home ranges were compared among the three GMUs, no difference (P = 0.729) was detected. However, there was a difference (χ_2^2 = 13.631, P = 0.001) in the length of riparian corridor use with turkeys in GMU 92 using 25–31 percent less on an annual basis than birds in GMUs 91 and 96.

Overall, seasonal home ranges varied from 1.0 km^2 (range 0.3–2.2) in the fall to 1.5 km^2 (range 0.3–4.9) in the spring. The length of seasonal riparian corridor use varied as well, from an average of 3.5 km (range 0.8–12.9) during the summer to 13.5 km (range 0.9–64.4) during the spring. Across all years, there was a difference (χ_1^2 = 40.359, P = 0.001) in seasonal home range size and length of riparian corridor use (χ_1^2 = 7.773, P = 0.005) between males and females (Table 4). Seasonal home ranges and length of riparian corridor use were larger for females than males. There was also a difference in home range size (χ_3^2 = 207.787, P = 0.001) and length of riparian corridor

Table 4. Estimates of seasonal fixed-kernel home range size (km^2) and length (km) of riparian corridor use for adult (A) and juvenile (J) Rio Grande turkeys in the South Platte River corridor in northeast Colorado, 2008–2011.

		2008		2009		2010		2011	
Sex	Season	A	J	A	J	A	J	A	J
Female									
	Spring	12.4	12.8	13.1	13.3	11.3	22.0	8.9	--
	Summer	10.2	14.0	12.0	16.9	10.6	14.4	12.1	--
	Fall	17.4	16.6	11.7	17.8	11.9	17.9	--	--
	Winter	6.9	29.9	11.3	10.8	13.7	15.4	--	--
	Average[a]	11.7	17.2	12.2	14.8	11.7	18.0	10.3	--
Male									
	Spring	8.2	4.7	10.5	10.0	5.1	16.6	6.4	--
	Summer	12.3	5.9	11.4	12.3	4.9	4.2	5.4	--
	Fall	0.5	2.8	11.0	10.8	3.9	7.0	--	--
	Winter	11.6	5.2	6.8	9.0	0.5	4.3	--	--
	Average	8.2	4.7	10.1	10.5	3.8	8.7	6.0	--

[a] Overall seasonal average

use (χ_3^2 = 355.829, P = 0.001) between seasons. For females, home ranges were largest in the spring followed by summer and length of riparian corridor use was largest in spring followed by fall with birds having the smallest linear use during summer. For males, home ranges were also largest in the spring followed by winter. Length of riparian corridor use followed the same pattern as that for females, with the largest use occurring in the spring followed by fall and the smallest use was observed in the summer.

There was no seasonal difference in home range size (P = 0.369) or length of riparian corridor use (P = 0.313) between adult and juvenile turkeys (Table 4). Likewise, there was no difference in home ranges (P = 0.514) or length of riparian corridor use (P = 0.673) among GMUs. There was an overall difference in seasonal home ranges (χ_3^2 = 163.562, P = 0.001) and riparian corridor lengths (χ_3^2 = 56.320, P = 0.001) among years. There was no difference between 2008 and 2009 (P = 0.773), but there was a difference (P = 0.001) between those years and 2010 and 2011. For adults, spring and summer home ranges were largest in 2011.

Movements

Annual movements varied by year. In 2009, turkeys spent most of the year significantly (χ_3^2 = 13.563, P = 0.004) farther from wintering areas than in other years, averaging 12.3 km (Table 5). In 2011, the average movement distance was 8.5 km, which was substantially different (P = 0.046) than 2009; however, 2011 movement data were comprised of adults only and were only calculated for the spring and summer seasons. There was a difference (χ_1^2 = 70.437, P = 0.001) in movements between males and females (Table 6). On average, females moved 13.3 km from wintering areas compared to 7.0 km for males. There was no difference (P = 0.153) in distances between adult and juvenile males, but there was a difference (χ_1^2 = 8.401, P = 0.004) between adult and juvenile females with juvenile females moving farther ($\bar{x}$ = 17.2 km) from wintering areas than any other age-sex cohort (Table 5).

Table 5. Estimates of seasonal movement distances (km) from the prior years' wintering areas for adult (A) and juvenile (J) Rio Grande turkeys in the South Platte River corridor in northeast Colorado, 2008–2011

	Home	Spring		Summer		Fall		Winter	
Sex-Year	Range	A	J	A	J	A	J	A	J
Female									
2008	Size	2.0	1.6	1.4	1.2	0.7	0.9	0.6	0.7
	Length	11.9	16.0	5.1	3.1	11.5	10.0	2.1	2.3
2009	Size	1.1	0.9	1.5	1.7	0.8	0.8	1.3	1.3
	Length	12.4	19.8	2.6	4.6	7.7	7.5	2.9	3.4
2010	Size	1.5	1.7	1.4	1.2	1.4	1.5	1.3	1.2
	Length	11.2	23.3	3.4	3.0	10.5	12.9	10.9	10.1
2011	Size	1.5	--	1.9	--	--	--	--	--
	Length	12.4	--	3.6	--	--	--	--	--
Male									
2008	Size	1.3	1.8	0.7	1.1	0.6	0.6	0.8	0.7
	Length	9.5	9.5	2.5	3.3	5.2	5.5	2.7	2.4
2009	Size	1.1	1.1	1.0	1.2	1.0	0.9	0.9	1.0
	Length	11.6	13.5	3.6	3.8	7.0	6.3	1.7	1.8
2010	Size	1.4	1.5	1.1	0.9	1.2	1.4	1.1	1.1
	Length	8.1	21.6	3.8	3.3	5.6	9.7	6.1	6.1
2011	Size	1.9	--	1.8	--	--	--	--	--
	Length	11.3	--	3.3	--	--	--	--	--

Seasonally, there was no difference (P = 0.243) in movement distances, although turkeys tended to be farther from their wintering areas during the fall season ($\bar{x}$ = 11.3 km) than in other seasons. Comparisons among the sex and age cohorts showed a difference in movements among seasons for female (χ_3^2 = 7.927, P = 0.048), male (χ_3^2 = 19.948, P = 0.001), adult (χ_3^2 = 18.942, P = 0.001), and juvenile turkeys (χ_3^2 = 9.864, P = 0.020). There was no difference among seasons in 2008 (P = 0.246) or between spring and summer in 2011 (P = 0.546), but there was a difference in 2009 (χ_3^2 = 10.252, P = 0.017) and 2010 (χ_3^2 = 20.367, P = 0.001). In both years, the average distance between consecutive winter ranges was significantly less than distances for other seasons.

Across all years, winter range shifts were documented for 48 percent of radio-marked birds. The distance between consecutive wintering areas varied widely (range 0–76.4 km) and averaged 10.3 km from one year to the next. Adults accounted for 52 percent of all dispersers to new wintering areas and 54 percent of those remained as residents of the new wintering area for the remainder of the study. Females accounted for 65 percent of all dispersers and 55 percent of those became residents.

Recruitment

Recruitment varied by year with the highest average (2.8 poults/hen) occurring in 2009, which was higher (χ_3^2 = 12.137, P = 0.007) than in any other year. In contrast, the lowest average (1.7 poults/hen) was in 2010 (Table 6). There was no difference in the average poults/hen between 2008, 2010, and 2011 (P ≥ 0.05). Recruitment also varied by GMU, with the highest average across all years (2.5 poults/hen) occurring in GMU 91, which was different (χ_2^2 = 8.339, P = 0.016) from the other GMUs. The lowest average was observed in GMU 92 at 1.5 poults/hen, which was not different (P = 0.459) from rates in GMU 96 (Table 6).

Table 6. Estimates of annual recruitment rates for female Rio Grande turkeys in GMUs 91, 92 and 96 in northeast Colorado, 2008–2011. Estimates = average number of poults per hen.

GMU	2008 A[a]	2008 J[b]	2008 U[c]	2009 A	2009 J	2009 U	2010 A	2010 J	2010 U	2011 A	2011 J	2011 U	Total
91	1.5	3.7	1.6	3.4	3.4	3.8	2.8	1.0	1.4	4.4	---	1.8	2.5
92	0.0	0.0	3.0	3.0	2.4	2.3	1.4	0.8	1.0	1.2	---	2.0	1.5
96	3.6	0.3	2.1	2.6	1.2	1.9	1.6	1.5	2.2	1.8	---	1.4	1.8
Mean	1.8	1.7	1.9	3.0	2.5	2.8	2.1	1.1	1.6	2.7	---	1.6	
Combined		1.9			2.8			1.7			1.9		2.0

[a] Adult hens
[b] Juvenile hens
[c] Unmarked hens of unknown age

Within years, there was no difference in recruitment between GMUs in 2008 (P = 0.681), 2010 (P = 0.427), and 2011 (P = 0.251). However, there was a difference (χ_2^2 = 11.430, P = 0.003) in 2009 with recruitment in GMU 91 being significantly higher than in the other GMUs. Across all years there was no difference (P = 0.714) in recruitment between adults, juveniles and the unknown age class of unmarked birds. Likewise, there was no difference in average poults/hen within any year (P = 0.493) or GMU (P = 0.315), although recruitment from juvenile females was predominantly lower than the other age classes in all years and GMUs (Table 6). When the average survival rates were applied to each year's beginning population, the estimated minimum recruitment rate needed to maintain the same population level was 1.45 poults/hen and varied from 1.3–1.7 poults/hen, depending on the size of the initial male and female populations for years 2009–2011.

Survival

Annual survival estimates for radio-marked birds varied by year, age and sex (Table 7). The overall annual survival rate for radio-marked birds from Kaplan-Meier was 0.593 (SE = 0.026, CI = 0.542–0.645) and varied from 0.529 in 2011 to 0.646 in 2010. When banded birds recovered during the hunting seasons were included, overall survival from Barker's Model was 0.563 (SE = 0.026, CI = 0.512–0.612).

For males, annual Kaplan-Meier survival was 0.561 (SE = 0.041, CI = 0.480–0.641) and varied from 0.455 in 2011 to 0.747 in 2010. When band-recovered males were included, annual survival was 0.517 (SE = 0.028, CI = 0.462–0.572). For females, annual Kaplan-Meier survival was 0.608 (SE = 0.034, CI = 0.542–0.674) and varied from 0.586 in 2011 to 0.636 in 2009. When band-recovered females were included, annual survival was 0.594 (SE = 0.038, CI = 0.518–0.666).

For adult males, annual survival from Kaplan-Meier was 0.475 (SE = 0.042, CI = 0.392–0.558) and varied from 0.455 to 0.588. For adult females, annual Kaplan-Meier survival was 0.599 (SE = 0.038, CI = 0.524–0.673) and varied from 0.536 to 0.653. When adult banded birds were included, adult male survival from Barker's Model was 0.456 (SE = 0.051, CI = 0.359–0.556) and adult female survival was 0.564 (SE = 0.047, CI = 0.471–0.652) (Table 8).

For juvenile turkeys, annual survival estimates represent the time period from approximately six to 18 months of age. For juvenile females, annual survival from Kaplan-Meier was 0.675 (SE = 0.073, CI = 0.533–0.818) and juvenile male survival was 0.740 (SE = 0.092, CI = 0.561–

Table 7. Estimates of annual survival ($\hat{S}$) from the Kaplan–Meier product-limit estimator using staggered entry procedures for radio-marked turkeys along the South Platte River in northeast Colorado, 2008–2011. Juvenile estimates represent survival from six to 18 months of age.

Year	Sex-Age	Survival $\hat{S}$	SE	95% CI
2008				
	Female	0.600	0.069	0.464 – 0.736
	Adult	0.581	0.082	0.420 – 0.742
	Juvenile	0.625	0.135	0.360 – 0.890
	Male	0.582	0.080	0.425 – 0.739
	Adult	0.278	0.057	0.166 – 0.390
	Juvenile	0.667	0.272	0.133 – 1.000
	Combined	0.599	0.053	0.496 – 0.702
2009				
	Female	0.636	0.054	0.529 – 0.742
	Adult	0.536	0.066	0.407 – 0.664
	Juvenile	0.813	0.078	0.658 – 0.967
	Male	0.556	0.070	0.419 – 0.694
	Adult	0.524	0.088	0.352 – 0.696
	Juvenile	0.909	0.083	0.747 – 1.000
	Combined	0.604	0.043	0.520 – 0.688
2010				
	Female	0.588	0.067	0.458 – 0.719
	Adult	0.653	0.068	0.520 – 0.787
	Juvenile	0.571	0.104	0.368 – 0.775
	Male	0.747	0.080	0.590 – 0.904
	Adult	0.588	0.081	0.431 – 0.746
	Juvenile	0.933	0.070	0.797 – 1.000
	Combined	0.646	0.052	0.543 – 0.748
2011[a]				
	Female	0.586	0.094	0.401 – 0.770
	Male	0.455	0.106	0.247 – 0.663
	Combined	0.529	0.071	0.390 – 0.669

[a] Survival estimates from adult turkeys only.

0.920). For juvenile females, survival varied from a low of 0.571 in 2010 to a high of 0.813 in 2009 and juvenile male survival varied from 0.667 in 2008 to 0.933 in 2010 (Table 7). When juvenile banded birds recovered during the hunting seasons were incorporated, annual survival for juvenile females from Barker's Model was 0.651 (SE = 0.066, CI = 0.513–0.767) and juvenile male survival was 0.733 (SE = 0.059, CI = 0.603–0.833) (Table 8).

There was a difference ($\chi_1^2 = 6.639$, P = 0.010) in survival distributions between males and females. On average, females survived three months longer than males.

Table 8. Estimates of annual survival ($\hat{S}$) from Barker's joint live and dead encounter model for radio-marked and banded turkeys recovered during spring and fall hunting seasons along the South Platte River in northeast Colorado, 2008–2011. Juvenile estimates represent survival from six to 18 months of age.

Sex	Age	Type[a]	Survival $\hat{S}$	SE	95% CI
Male					
	Adult				
		Radio	0.473	0.058	0.362 – 0.586
		Band	0.412	0.099	0.239 – 0.610
		Combined	0.456	0.051	0.359 – 0.556
	Juvenile				
		Radio	0.720	0.063	0.581 – 0.827
		Band	0.913	0.017	0.872 – 0.941
		Combined	0.733	0.059	0.603 – 0.833
Female					
	Adult				
		Radio	0.567	0.047	0.474 – 0.656
		Band	0.438	0.294	0.070 – 0.890
		Combined	0.564	0.047	0.471 – 0.652
	Juvenile				
		Radio	0.640	0.068	0.499 – 0.760
		Band	0.994	0.006	0.957 – 0.999
		Combined	0.651	0.066	0.513 – 0.767

[a] Survival estimates for banded turkeys are based on the estimated number of birds available for harvest at the beginning of each hunting season.

Also, there was a difference ($\chi_1^2 = 8.227$, P = 0.004) between males and females within the two age groups with adult females and juvenile males living longer than their age-sex counterparts. Based on the age-at-capture, there was no difference in survival distributions between adults and juveniles (P = 0.893) or between GMUs (P = 0.163). Likewise, there was no difference in survival between adults and juveniles within GMUs (P = 0.576) or by sex (P = 0.737).

Seasonal survival rates were relatively consistent across most years, but there was an overall difference ($\chi_3^2 = 11.206$, P = 0.011) between seasons (Table 9). Overall, turkeys experienced their lowest survival in spring and the highest during fall. Within years, there was no difference among seasons in 2008 (P = 0.278), 2010 (P = 0.975), and 2011 (P = 0.123), but there was a difference ($\chi_3^2 = 10.285$, P = 0.016) in 2009. In 2009, turkeys had lower survival during spring and summer than in fall and winter.

Table 9. Estimates of seasonal survival ($\hat{S}$) across all years from the Kaplan–Meier product-limit estimator using staggered entry procedures for radio-marked turkeys along the South Platte River in northeast Colorado, 2008–2011.

		Season							
		Spring		Summer		Fall		Winter	
Sex	Age	$\hat{S}$	SE	$\hat{S}$	SE	$\hat{S}$	SE	$\hat{S}$	SE
Female									
	Adult	0.885	0.028	0.825	0.035	0.884	0.029	0.943	0.022
	Juvenile	0.894	0.043	0.857	0.050	---	---	0.961	0.027
	Combined	0.888	0.024	0.835	0.029	---	---	0.940	0.021
Male									
	Adult	0.657	0.047	0.837	0.052	0.930	0.029	1.000	0.000
	Juvenile	0.841	0.051	1.000	0.000	---	---	0.938	0.041
	Combined	0.700	0.038	0.912	0.030	---	---	0.977	0.016

Across years, there was evidence of a difference (χ_1^2 = 3.091, P = 0.079) in seasonal survival between males and females, but it was not substantial. For the age-class comparison, there was a difference (χ_1^2 = 4.412, P = 0.036) between adult and juvenile females, with adults having lower seasonal survival than juveniles. In contrast, there was no difference (P = 0.366) between adult and juvenile males.

Cause-Specific Mortality

Based on the cumulative sample of 266 radio-marked turkeys, the annual mortality rate for turkeys along the South Platte River was 0.406 (± 0.045) and varied from 0.349–0.462 among years (Fig. 7). The annual mortality rates were 0.569 (± 0.046) and 0.443 (± 0.050) for adult males and females, respectively. For juveniles, the mortality rates between six and 18 months of age were 0.227 (± 0.109) for males and 0.319 (± 0.110) for females.

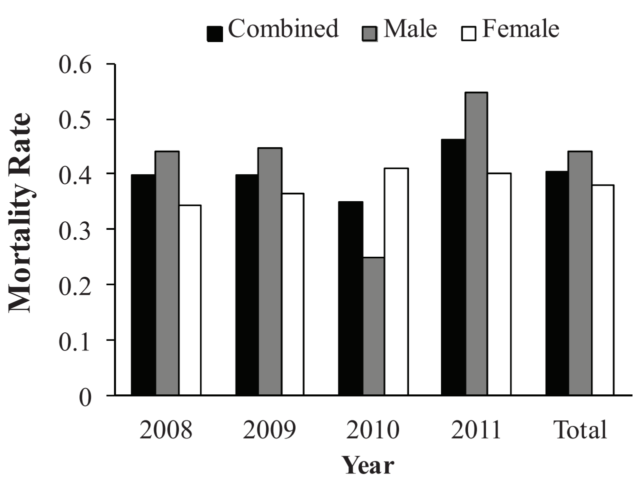

Figure 7. Estimated annual rates of mortality for male and female Rio Grande turkeys in the South Platte River corridor in northeast Colorado, 2008–2011.

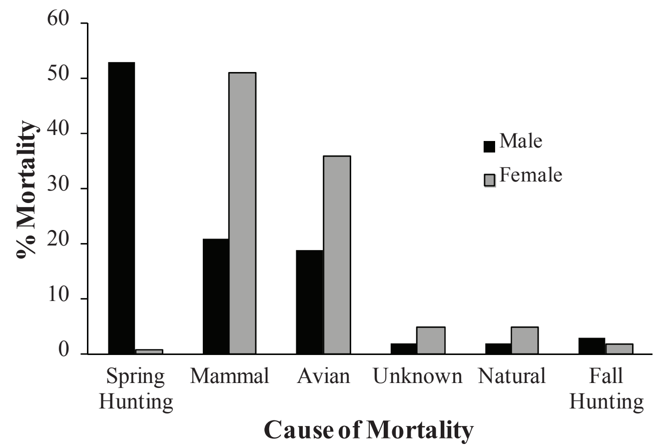

Figure 8. Cause-specific mortality for male and female Rio Grande turkeys in the South Platte River corridor in northeast Colorado, 2008–2011.

Spring hunting was the primary cause of mortality for radio-marked males during the four-year study, averaging 53 percent of the annual male mortality (Fig. 8). Fall hunting accounted for 3 percent of the male mortality and varied from 0–11 percent among years. The majority of hunting mortality was on adult males, averaging 44 percent annually compared to 10 percent for juvenile males. Mammal and avian predation accounted for 21 percent and 19 percent of the annual male mortality, respectively (Fig. 8). Coyotes and great-horned owls were the primary predators on male turkeys, accounting for 81 percent of the non-hunting mortality. Across all years, the non-hunting mortality on males was relatively consistent between winter (24 percent), spring (32 percent), and summer (32 percent) and lower in the fall (12 percent) (Fig. 9). When hunting was included, on average 83 percent of the annual male mortality occurred during the spring, followed by nine percent in the fall, five percent in the summer, and three percent in the winter (Fig. 9).

Predation by mammals, primarily coyotes (79 percent), was the highest mortality factor for female turkeys, accounting for 51 percent of the annual mortality (Fig. 8). Bobcats and red foxes were responsible for the remaining 15 percent and 6 percent of the mammal predation, respectively. Avian predation accounted for 36 percent of the annual female mortality. Great-horned owls were responsible for 70 percent of the avian predation on females, with most of the predation occurring in the summer and fall. Spring and fall hunting combined represented three percent of the annual female mortality (Fig. 8) and the annual proportion of hunting mortality was consistent across the four years. As expected, summer was the period of highest female mortality, accounting for 47 percent of the annual non-hunting mortality (Fig. 9). Non-hunting mortality of females was fairly consistent among the other seasons, ranging from 15 percent in spring to 20 percent in winter (Fig. 9).

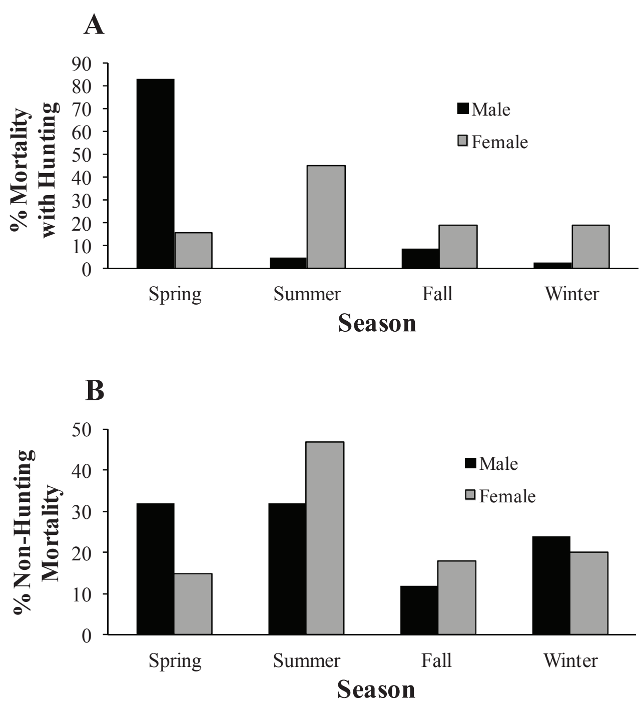

Figure 9. Seasonal mortality with and without hunting included for male and female Rio Grande turkeys in the South Platte River corridor in northeast Colorado, 2008–2011.

Population and Density Estimation

The South Platte turkey population was estimated at 941 (SE = 24.85) birds in the winter of 2008–09 (Fig. 10). The population increased over the next two years to an estimated size of 1,594 (SE = 34.06) birds in the winter of 2010–11. In 2011, the population remained stable at an estimated size of 1,607 (SE = 46.45) in the winter of 2011–12 (Fig. 10). From 2008 to 2012, the density of birds increased from 6.3 turkeys/ km^2 to 10.6 turkeys/km^2. GMU 92 consistently had the highest density of birds in each year, while GMU 91 had the lowest density. During the study, the density of males ranged from 2.5 males/km^2 in 2008 to 6.0 males/km^2 in 2011. Within GMUs, the density of males ranged from 1.9 males/km^2 in GMU 91 in 2008 to 11.3 males/km^2 in GMU 92 in 2011. The density of females was less variable across years and GMUs, ranging from 3.6 to 4.6 females/km^2 during the four-year study.

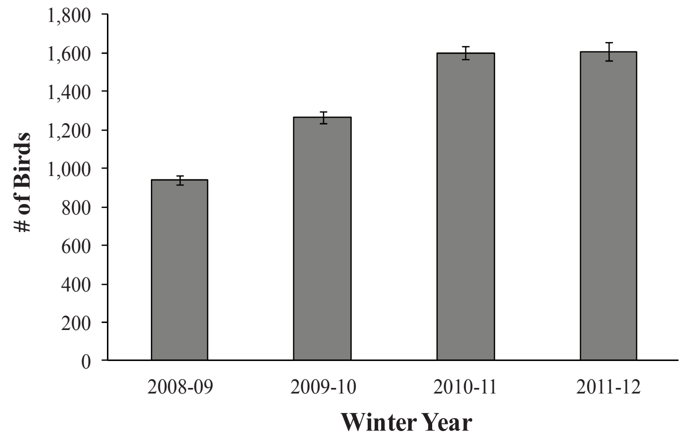

Figure 10. Winter population estimates (mean ± SE) for Rio Grande turkeys in GMUs 91, 92 and 96 in northeast Colorado, 2008–2012.

The number of turkeys counted during aerial flights was underestimated by 15.8 percent (range 13.6–18.7 percent) compared to ground counts across the four years. Sightability was consistent across all years and averaged 83.7 percent (range 81.6–85.6 percent). Therefore, the ratio of population to aerial estimates resulted in a population correction factor of 1.195 (SE = 0.017). The ratio estimate for number of groups detected between ground and aerial surveys was 1.045 with only three of 69 flocks not being detected during aerial surveys over the four years. The ratio for group size between ground and aerial counts was 1.156 with aerial counts averaging 10 fewer birds (range 0–59) per flock than ground counts and the degree of underestimation increased as flock size increased, especially for flocks ≥75 birds. The number of wintering flocks was fairly stable across all years, with 2008–09 having 17 flocks varying in size from three to 200 birds. In the winters of 2009–10 and 2010–11, there were 18 flocks in each year varying in size from three to 224 birds in 2009–10, and six to 260 in 2010–11. In the winter of 2011–12, there were 17 flocks ranging in size from 12 to 254 birds.

DISCUSSION

Home Range and Riparian Use

Annual and seasonal home ranges of Rio Grande turkeys along the South Platte River were similar to birds in south-central South Dakota (Laudenslager 1988), but much smaller compared to other populations in South Dakota, Kansas, Oregon, and Texas (Miller 1993, Keegan and Crawford 1999, Flake et al. 2006, Spears et al. 2006). The smaller home ranges may be related to the quality of habitats that are found in the riverbottom to meet the annual needs of turkeys. As in other studies, turkeys shifted from using larger areas in the spring to smaller areas as the year progressed with varying degrees of home range overlap among seasons. Following the spring breeding season, males became relatively sedentary and were resigned to using the same areas throughout the remainder of the year. Seasonal home range shifts by males were less distinct and were likely precipitated only by changes in seasonal food availability and abundance (Flake et al. 2006, Spears et al. 2006).

In contrast, females displayed more distinct home range shifts throughout the year. Spring is the time of breeding and searching for nest sites, which accounts for the larger home range (1.5 km^2) and length of riparian corridor (14.5 km) used during this time period. Summer home ranges and length of riparian corridor use were typically smaller (1.1 km^2 and 3.1 km, respectively) for nesting females because of their restricted movements associated with egg incubation, which generally takes 25–29 days to complete (Williams et al. 1974, Healy and Nenno 1985, Healy 1992). In addition, the first two to three weeks of brood-rearing also restricted movements because young chicks have poor thermal regulation, are incapable of flight, and are too small to efficiently traverse through the generally thick riparian understory, thus requiring close attendance by their mothers for survival. The length of riparian corridor use for non-nesting females was much more extensive, resulting in a higher degree of seasonal overlap.

Fall was the beginning of a more mobile lifestyle for females with poults, which generally began in late August or early September. By this time, turkey poults were well developed for flight and could easily match the pace of adults. As the fall season progressed, birds steadily moved towards their preferred wintering areas, not residing in any area for more than a few days.

For most birds, there was an abrupt and sometimes extensive final movement to their wintering areas that generally occurred in mid-November. This sudden shift coincided with the influx of hunter activity along the South Platte River. The transition to the wintering areas typically occurred within three to seven days after the opening of the pheasant, quail, and second-split of the waterfowl seasons. Because the timing of this movement varied from area to area and year to year, we believe the amount of hunter activity was the primary catalyst dictating how quickly turkeys made the shift to their wintering areas. Areas with a higher amount of hunter activity (i.e., public lands) saw turkeys transition to wintering areas one to two weeks earlier than areas with lower hunter activity (i.e., private lands). The median date that birds on public land transitioned to wintering areas was Nov. 13 compared to Nov. 24 for birds on private land.

Wintering areas were almost exclusively on private lands that provided a sufficient number of roost trees in close proximity to corn fields. In most cases, roosting and feeding areas were <1 km apart. Turkeys limited their movements to the area that circumscribed the field and the roosting area. This reduction in activity is common with most wildlife species due to limited food availability and their need to increase available energy for thermal regulation to endure the sometimes extreme and prolonged winter conditions (Beasom and Wilson 1992, Healy 1992). Under normal winter conditions, turkeys rarely ventured more than 1.6 km from their roosting and feeding areas until late winter. The winter of 2010–11 was the exception with birds moving three to four times farther than in previous years. Movements in December 2010 reflected the fall-like conditions that persisted when temperatures averaged 42° F and no snow was recorded for the month. Mild winters were also suspected in larger winter home ranges reported for eastern turkeys in South Dakota (Flake et al. 2006).

Movement and Dispersal

Spring movements by males are generally associated with breeding behaviors and searching for females with which to mate (Kelley et al. 1988, Hurst et al. 1991, Holdstock et al. 2006). Along the South Platte River, adult males moved on average 7.1 km (4.4 miles) from their resident wintering areas and only two adult males moved farther than 17 km (10 miles), both moving 25 km (15 miles). Juvenile males generally did not move as far, averaging 4.4 km (2.7 miles). The movements by adults were similar to movements by Rio Grande turkeys in Kansas and Texas (Holdstock et al. 2006), but two to three times farther than other studies of eastern and Rio Grande turkeys (Logan 1973, Holbrook et al. 1987, Flake et al. 2006). Hoffman (1991) reported spring movements of 8.7 km (5.4 miles) and 5.3 km (3.3 miles), respectively, for juvenile and adult male Merriam's turkeys in southern Colorado. Because spring movements by males are associated with finding females (Kelley et al. 1988), the social dominance of adults within localized areas may suppress juveniles from pursuing local females unless they make a large-scale movement. In the panhandle of Texas, short-distance movements of <4 km were common for juvenile males (Phillips 2009).

Spring movements by females were similar for adults and juveniles averaging 11.0 km (6.8 miles) and 10.8 km (6.7 miles), respectively. These distances are similar to those reported for females in Kansas (Miller et al. 1995) and less than the distances reported for this population from the mid-1980s (14.3 km [A], 35.5 km [J]) (Schmutz and Braun 1989). However, in those studies the average distances included those from permanent dispersing females. For females that return to the same wintering area in consecutive years, our results showed longer migration movements than any other study. In South Dakota, Flake et al. (2006) reported spring migrations of 4.3 km for adult and 10 km for juvenile eastern turkeys, 4.8 km for Rio Grande turkeys, and 3.1 km for Merriam's turkeys. In Missouri, the longest movement by eastern turkeys was 11.5 km (Kurzejeski and Lewis 1990). We suspect the longer migrations by females are due to the disjunct availability of quality nesting habitat in the South Platte River corridor.

Quality nesting habitat for turkeys can be characterized by low disturbance areas that provide concealment in dense herbaceous or woody vegetation, both around and above the nest (Schmutz and Braun 1989, Beasom and Wilson 1992, Miller et al. 1995, Flake et al. 2006, Hall et al. 2007). Along the South Platte River, turkey locations revealed that quality nesting habitat is relatively disjunct and varies widely throughout the riparian corridor. Based on telemetry data, areas disturbed by human activity or intensive cattle grazing, which can negatively impact turkey habitat use (Spears et al. 2006, Hall et al. 2007), were routinely avoided by turkeys. Some of these areas extended >8 km (5 miles), necessitating longer movements to reach preferred nesting areas.

Our findings concur with other studies that juveniles disperse with greater frequency and females disperse farther than males (Greenwood 1980, Phillips 2009). Dispersal movements by adults were limited to adult females with more than 50 percent making one or more dispersal movements to new wintering flocks during the study. Phillips (2009) projected that 16 percent of adult females dispersed annually for three Rio Grande populations in the Texas panhandle. A high proportion of female dispersals indicate a strategy of inbreeding avoidance to maintain genetic heterogeneity (Waser et al. 1986, Phillips 2009). The largest dispersal by an adult female in our study was 47 km (28.6 miles) which was substantially farther than those reported in literature (Kurzejeski and Lewis 1990, Flake et al. 2006, Spears et al. 2006, Hall et al. 2007, Phillips 2009).

No dispersal movements were documented for adult males in our study. Short-distance movements and fidelity to localized areas is common for adult males (Badyaev et al. 1996a, b; Phillips 2009). A combination of social dominance and site fidelity predisposes adult males to spend winters near their spring displaying grounds, thereby minimizing spring dispersal and maximizing their reproductive success (Badyaev et al. 1996a, b). Winter and spring home ranges for individual adult males routinely overlapped, despite some groups of males' wintering 10–20 km (6 to 12 miles) from the nearest hen group.

Nearly 20 percent of the juvenile males dispersed in excess of 25 km (15 miles) from their natal wintering area with the longest being 64 km (40 miles). Several other studies reported juvenile male dispersals up to 44 km (27 miles) (Badyaev et al. 1996a, Flake et al. 2006, Holdstock et al. 2006, Phillips 2009), but none to this extent. Dispersal movements by young males entering their first breeding season are common in many turkey populations

(Miller et al. 1995, Holdstock et al. 2006, Phillips 2009). Their subordinate social status commonly induces juveniles to leave natal areas in search of low-density areas or areas occupied by unrelated birds (Badyaev et al. 1996a, Phillips 2009), which may make it easier to gain social acceptance or status.

Juvenile females dispersed farther than all other age-sex classes with 55 percent of radio-marked birds' dispersing from natal wintering areas. Long dispersal movements by juvenile females were also found in several other turkey populations (Kurzejeski and Lewis 1990, Flake et al. 2006, Holdstock et al. 2006, Phillips 2009). The longest dispersal by a juvenile female in this study was 76 km (46 miles), compared to 21 km and 25 km for eastern turkeys in Kentucky (Wright and Vangilder 2005) and Missouri (Kurzejeski and Lewis 1990), respectively, and 41–64 km for Rio Grande turkeys in Texas (Thomas et al. 1966, Phillips 2009), South Dakota (Flake et al. 2006), and Kansas (Spears et al. 2006). Schmutz and Braun (1989) reported dispersal movements of >60 km (37 miles) for juvenile females during the initial years following the introduction of turkeys to the South Platte River. This literature shows that Rio Grande turkeys tend to disperse farther than other subspecies and our findings appear to include the largest dispersal movement reported for a juvenile female turkey.

Although extensive movements occurred every year, no turkeys were documented migrating or dispersing outside the South Platte River riparian corridor; three juveniles (2 M, 1 F) were known to disperse downstream across the stateline into Nebraska but remained in the South Platte riverbottom. Movements were common in all years between GMUs 91 and 92, but movements between GMUs 91 and 96 were rare. Although birds in all years spent extensive periods of time adjacent to the highway corridor that separated the units, only one bird (a juvenile female) was known to cross over during the four-year study, dispersing from GMU 91 into GMU 96. This suggests that the human-related development along the highway corridor was a significant deterrent to turkey movements. In effect, the US highway 6 corridor resulted in two distinct turkey management areas within the study area.

No study has reported dispersal movements of the magnitude we found, especially for females. Avoidance of inbreeding along with social and resource competition have been speculated to be the driving instinct to disperse from natal areas (Waser et al. 1986; Badyaev et al. 1996a, b; Phillips 2009). This likely holds true for turkeys along the South Platte River. These common mechanisms, coupled with the limited and disjunct preferred habitats, play a role in the atypical female movements that occur within the river corridor.

Nesting Chronology

Turkey nest found in mid-April.

Nesting chronology (as measured by median date of nest initiation) varied annually but was consistent with previous research on this population (Schmutz and Braun 1989) and findings for Rio Grande turkeys in southwest Kansas (Spears et al. 2006). Although some females initiated nests as early as Mar. 30 and as late as Jun. 6, the peak of nest initiation occurred in late April (range Apr. 19–27) with adults averaging one week earlier than juveniles.

Vegetational structure around turkey nest.

We did not specifically confirm each nesting attempt. However, based on their restricted activity and movement patterns, along with frequent investigations, we were confident in our ability to identify when females were initiating nesting activity. Therefore, we believe ≥90 percent of females along the South Platte River make at least one nesting attempt annually. Shortly after this population was introduced, Schmutz and Braun (1989) reported that 97 percent of all females made ≥1 nesting attempt annually. Similarly, in northern Missouri, 90 percent of females were documented to make ≥1 nesting attempt (Vangilder and Kurzejeski 1995). Like other populations, it was also observed that many first nesting attempts failed, primarily from nest depredation (Vangilder and Kurzejeski 1995, Paisley et al. 1998, Keegan and Crawford 1999, Norman et al. 2001, Spears et al. 2006).

There was a general trend that adults were more likely to renest than juveniles, which agrees with findings from other studies (Wertz and Flake 1988, Roberts et al. 1995, Paisley et al. 1998, Norman et al. 2001, Spears et al. 2006). The amount of time invested in incubating eggs is presumed to play a significant role in the likelihood of renesting (Vangilder and Kurzejeski 1995). Vangilder and Kurzejeski (1995) reported that the probability that a hen would renest decreased as the number of days incubating increased, which was the general trend we observed from radio-marked hens along the South Platte River.

Nesting rates vary widely both within and among populations. Like other studies, we observed exceptions to the norm that demonstrate the extreme variability that occurs in the natural world. One female, radio-marked as a juvenile and monitored through four nesting seasons, never attempted to nest. In contrast, an adult female was documented making four nesting attempts in a single summer. For three of those nesting attempts, she incubated the eggs for 12–21 days before the nests were depredated. The final nesting attempt was initiated the first week of August and was estimated to be within one to three days of hatching (assuming a 28-day incubation cycle) when the nest was depredated in early September. In northern Missouri, only one female was reported to renest after being disrupted 23 days into incubation and no other females attempted to renest after 19 days of incubation during a nine-year study (Vangilder and Kurzejeski 1995). In Florida, Williams and Austin (1988) reported that no hen renested after continuous incubation for >18 days.

Recruitment

Recruitment is a major factor dictating the growth or decline in turkey populations (Warnke and Rolley 2005, McGhee et al. 2008). Recruitment represents the product of many parameters; fertility, clutch size, nesting rate, hen success, and poult survival. Recruitment varied annually and among GMUs and was consistently higher for adult hens than the other age groups across all years. Female survival also played an important role in the growth of the South Platte turkey population. In both 2008 and 2011, population estimates showed no growth following the recruitment of 1.9 poults/hen. Conversely, in 2010, the population increased by 20 percent following even lower recruitment of 1.7 poults/hen. However, in 2010, adult female survival was 33 percent higher than in the other years, which substantiates the importance of female survival on annual population change cited in other studies (Alpizar-Jara et al. 2001, Brunjes 2005).

Our recruitment rates were comparable with rates reported by others for stable to increasing turkey populations (Rolley et al. 1998, Butler et al. 2005, Lusk et al. 2005). Recruitment rates ≤1.3 poults/hen have been associated with declining populations in southwest Kansas (Spears et al. 2006) and elsewhere (Palmer et al. 1993, Miller et al. 1998b, Paisley et al. 1998, Thogmartin and Johnson 1999, Lusk et al. 2005). In Missouri, Vangilder and Kurzejeski (1995) conducted modeling simulations that showed recruitment rates of 1.5–1.6 poults/hen were adequate to maintain a stable to increasing population out to 40 years. Based on our estimated minimum recruitment rates, we also conclude that 1.5 poults/hen would be sufficient to replace current levels of annual mortality and maintain a stable turkey population along the South Platte River.

Survival

Our cumulative survival rate was higher than rates reported for Rio Grande populations in Kansas and Texas (Spears et al. 2006, Phillips 2009). Overall male survival was higher than rates reported for eastern turkeys in Indiana (Humberg et al. 2009), Missouri (Vangilder and

Kurzejeski 1995), Iowa (Little et al. 1990), New York, Pennsylvania, and Ohio (Diefenbach et al. 2012), lower than males in South Dakota (Flake et al. 2006), and similar to eastern populations in Wisconsin (Paisley et al. 1995) and Rio Grande populations in Kansas and northern Texas (Holdstock et al. 2006). Male survival was higher than in most other hunted turkey populations.

Among years, adult males had lower survival than juvenile males, which is consistent with other Rio Grande populations and other subspecies (Wright and Vangilder 2005, Holdstock et al. 2006). However, seasonal patterns in adult male survival were different than most other Rio Grande populations. Spring survival for adult males was lower than those reported from Kansas and Texas, while survival in other seasons was 10–20 percent higher (Holdstock et al. 2006), which is consistent with, but not evidence of, a compensatory effect. Annual survival for juvenile males was higher while seasonal survival was similar to Rio Grande populations in Kansas and Texas (Holdstock et al. 2006). The high juvenile male survival likely offset years of above-normal adult male harvest because more males were recruited into the spring adult male population. Male survival was highest during the winter at 98 percent (± SE 0.016) and no radio-marked adult males died during the winter. In Kansas and Texas, winter survival was 79 percent for adult male Rio Grande turkeys (Holdstock et al. 2006). For most turkey populations, winter survival of males varies from 70–90 percent (Little et al. 1990, Vangilder and Kurzejeski 1995, Holdstock et al. 2006, Diefenbach et al. 2012), making our results the highest reported.

Female survival (60 percent) was higher than rates reported for eastern females in New York (Roberts et al. 1995), Wisconsin (Wright et al. 1996), Mississippi (Miller et al. 1998a), and Rio Grande females in southwest Kansas (Spears et al. 2006) and Texas (Brunjes 2005). Female survival was lower than eastern females in Iowa (Hubbard et al. 1999), Mississippi (Palmer et al. 1993), South Dakota (Flake et al. 2006), and Rio Grande females in Oregon (Keegan and Crawford 1999), but similar to Rio Grande females in southcentral Kansas (Miller et al. 1995). Seasonally, females experienced the highest mortality during the summer, which is common among turkey populations regardless of subspecies or locale (Vangilder 1992, Flake et al. 2006). Females are generally more vulnerable to predators during summer while incubating and brood-rearing than in other seasons.

Among years, adult female survival was predominantly lower than juvenile female survival, both annually and seasonally. In Missouri, Vangilder and Kurzejeski (1995) reported no difference between adult and juvenile female survival. In southwest Kansas, adult female survival in a declining population was higher than juvenile female survival (Brunjes 2005, Spears et al. 2006). In contrast, Hubbard et al. (1999) reported 68 percent and 71 percent annual survival for adult and juvenile females, respectively, for a declining population in southcentral Iowa, which is much higher than our results (57 percent and 65 percent, respectively). Despite the variability in survival rates among populations, generally studies where juvenile female survival equaled or exceeded adult female survival, turkey populations exhibited a stable to increasing trend (Vangilder 1992, Flake et al. 2006). Adult females are prone to a higher risk of mortality because they are more likely to nest than juveniles (Keegan and Crawford 1993, Palmer et al. 1993, Rumble and Hodorff 1993, Flake et al. 2006); therefore, high juvenile female survival is necessary to replenish the adult female population from year to year, which can have a significant influence on the annual stability of a population.

Like the male cohort, female survival was highest during the winter averaging 94 percent and 96 percent for adults and juveniles, respectively. In northeast Colorado, winters tend to be mild with limited snow accumulation and short durations of sub-zero temperatures. This likely contributes to higher winter survival than in other populations in more eastern and northern climates. In addition, corn fields adjacent to the riverbottom provide a supplemental food source to sustain wintering flocks through periods of extreme winter weather conditions. Other studies have also shown higher overwinter survival for turkeys that lived in agricultural habitats or that had access to corn food plots (Porter et al. 1980, Gray and Prince 1988, Roberts et al. 1995, Pekins 2005). In Minnesota, Kane et al. (2007) reported >30 percent increase in winter survival for birds that had access to a supplemental food supply compared to those without. All wintering flocks along the South Platte River were exclusively located adjacent to corn fields and daily use was seen throughout the winter. In addition, flocks moved to new wintering areas when corn fields were changed to another crop in subsequent years. Thus, the value of corn fields to the winter survival of turkeys, especially during extreme weather conditions, should not be underestimated.

Cause-Specific Mortality

Like most hunted populations, the primary cause of male mortality was hunting. While illegal kills and crippling loss during the spring season have been shown to be a significant contributor to annual male mortality in other turkey populations (Vangilder and Kurzejeski 1995, Hubbard and Vangilder 2005, Diefenbach et al. 2012), there was no evidence of these activities during our study. The average harvest rate of adult males (0.39) was lower than what has been reported for studies in Kentucky, Louisiana, and Mississippi (0.52–0.61; Godwin et al. 1991, Wright and Vangilder 2005, Chamberlain et al. 2012), similar to those in New York, Ohio, Pennsylvania (0.35–0.39; Diefenbach et al. 2012), and Wisconsin (30–37; Paisley et al. 1995), and higher than those of eastern turkeys in Missouri (0.23; Hubbard and Vangilder 2005) and Rio Grande turkeys in Kansas and Texas (0.19; Holdstock et al. 2006). However, spring harvest rates for juvenile males (0.14) were lower than those reported from the same studies (0.16–0.27).

Adult male turkey harvested during the spring season, 2011.

Vangilder and Kurzejeski (1995) indicated that spring harvest rates of more than 30–35 percent of the male population adversely affected hunter satisfaction because the proportion of adults in the population and harvest were predicted to decline. The male harvest rate (30 percent; range 21–35 percent) we observed would suggest that spring harvest is near a level that turkey hunting quality could be adversely impacted. However, the predicted harvest threshold by Vangilder and Kurzejeski (1995) was based on modeled survival rates of approximately 40 percent for adults and 45 percent for juveniles. In comparison, we found adult survival was 46 percent and juvenile survival was 74 percent. Because harvest was lower and survival was higher for juveniles, the male harvest rate we observed is sustainable due to the increased annual recruitment of juveniles into the adult male population (Diefenbach et al. 2012).

Although historic license allocations in GMUs 91, 92 and 96 for the spring season have been viewed as conservative, our results would suggest otherwise. Harvest rates at or higher than our observed rates have been implicated in declines in male age structure, hunting quality, and hunter satisfaction and were considered unsustainable (Ielmini et al. 1992, Paisley et al. 1995, Hubbard and Vangilder 2005, Wright and Vangilder 2005, Chamberlain et al. 2012). Our findings are comparable to or exceed the rates reported for other stable to increasing turkey populations. So long as the juvenile harvest rate remains low (≤15 percent), a stable age structure should continue to maintain turkey hunting quality along the South Platte River. Thus, juvenile male harvest should be closely monitored for an increasing trend, which would result in a younger male age structure and a potential decline in turkey hunting quality.

Comparing spring harvest to male population size over time illustrated that there was additional hunting opportunity available in 2010 and 2011. In those years, the number of licenses and subsequent harvest was conservative for the size of the male population. In contrast, the same license allocation and harvest was appropriate for the population levels in spring of 2008 and 2009. Because the number of spring turkey licenses went virtually unchanged for 20 years, there is a high likelihood that underutilization of the resource occurred in some years following above normal recruitment. Our results provide the information necessary to determine the level of hunting that is available and annually adjust harvest objectives and license allocations to maximize opportunity without compromising hunting quality and hunter satisfaction.

Fall turkey hunting was not a substantial source of mortality for turkeys along the South Platte River. While fall harvest rates of ≥10 percent of the female population have been shown to adversely affect population stability and growth (Suchy et al. 1983, Vangilder and Kurzejeski 1995, Pack et al. 1999, Alpizar-Jara et al. 2001, McGhee et al. 2008), current fall harvest rates (3 to 4 percent) along the South Platte River are not consistently at a level to warrant concern. However, the annual variability merits continued monitoring of the fall harvest, especially in years of poor recruitment if a higher proportion of adult females were to be harvested (Little et al. 1990).

Predators accounted for 40 percent of the annual mortality on male turkeys and the proportion was similar between avian (19 percent) and mammalian (21 percent) predators. Holdstock et al. (2006) reported that 81 percent of all male mortality was from natural causes, including predation, for Rio Grande populations in southwest Kansas and the Texas panhandle. Likewise, predators were responsible for 51 percent of the annual male mortality in the Missouri Ozarks (Vangilder 1995). Compared to these populations, the overall impact of predation on our male population is relatively low as demonstrated by high seasonal and annual survival rates.


Adult female turkey depredated by coyote.

For females, mammalian predators were responsible for 52 percent of the annual mortality, which is compareable to predation rates on Merriam's turkeys in the Black Hills and sympatric eastern and Rio Grande populations in South Dakota (45–47 percent; Lehman et al. 2000, Lehman et al. 2005). While coyotes were the most common predator in our study, bobcats are generally the most commonly reported predator of turkey hens, especially among eastern turkey populations (Hughes et al. 2005). Bobcats were not a significant predator along the South Platte River, only accounting for 10 percent of the overall mortality, which is a reflection of their lower density compared to other states (Anderson and Lovallo 2003).

Great horned owls preyed on both males and females and, like other studies, were the most common avian predator. As in our study, others have also documented adult males being killed by great horned owls (Vangilder 1995, Wright and Vangilder 2000). Bald eagles also were a contributing predator during the winter and early spring seasons. On several occasions during the winter, bald eagles were seen attacking turkeys; however, no successful attempt was ever observed.

Excluding hunting and predation, very few deaths were attributed to natural causes. One adult tom was killed after colliding with a fence and two adult females died; one from a puncture wound that caused an infection and the other from a lung infection caused by a parasite. Although we are confident in our assignment of cause of death, we acknowledge that some mortality that we attributed to coyote predation could have been from coyotes scavenging kills made by other predators or by other causes. Thus, the overall predation rates of 40 percent (males) and 87 percent (females) are the most meaningful and accurate estimates to consider, while all other categorical estimates should be viewed with caution.


Lung infection in an adult female turkey.

Population Estimation

The South Platte River turkey population showed the variability in growth that commonly occurs over time. Based on winter population estimates, we observed no growth in 2008, then 25–34 percent growth in each of the next two years, followed by no growth during the final year of the study. The annual variation in survival rates, recruitment, habitat conditions, and harvest all played a role in annual population changes. Among the three GMUs, growth was not consistent. In 2009, GMU 91 increased 184 percent, while GMU 92 decreased by 10 percent and GMU 96 increased by 33 percent. In 2010, GMU 91 decreased by three percent, GMU 92 increased by 77 percent, and GMU 96 increased by 17 percent. Although environmental conditions in 2009 and 2010 appeared relatively uniform across the region, it is apparent there were critical differences between GMUs and years that were not readily obvious.

Natural selection favors parents that modify their investment in offspring when fitness differs between sexes (Trivers and Willard 1973, Clutton-Brock 1986); thus, unequal sex ratios are common in many avian species (Hardy 1997). Examination of the annual changes in the sex and age cohorts indicated that some mechanism(s), whether social, physiological, or environmental, were triggered to shift sex ratios in favor of males. Collier et al. (2007) reported that brood sex ratios in Rio Grande turkeys were not at unity (1:1 ratio) for populations in central and southern Texas. They noted that sex ratios were male dominant; ranging from 56–59 percent males depending upon locale.

When we separated the winter ground counts by sex, age and GMU, and examined the changes over time, the growth in 2010 showed significant deviations from parity (1:1 ratio) in GMUs 91 and 92. Because turkeys frequently moved and intermixed between GMUs 91 and 92, annual changes in the sex and age classes were combined; thus in 2009, the combined population for the two units increased by 187 birds. Applying the estimated survival and recruitment rates to the 2009 beginning population, a near equal sex ratio (1:1.08 M/F) was observed. However in 2010, the combined population increased by 226 birds and was dominated by males with an estimated sex ratio of 4.4:1 M/F based on winter ground count surveys. In 2010, the number of females in the population declined by 65 birds, while the number of males increased by 291 birds. In 2011, the population remained stable and the sex ratio was less skewed at a ratio of 1.7:1 M/F in GMUs 91 and 92 combined. In contrast, the estimated sex ratios in GMU 96 were near parity in 2009 and 2010 at 1.1:1 M/F and 1:1.09 M/F, respectively. In 2011, we observed more males in GMU 96 with an estimated sex ratio of 1.5:1 M/F.

One of several possible explanations for this pattern is that the spatial distribution of females for nesting habitat may have reached a threshold. Hardy (1997) described this as the local resource competition theory, which predicts that females should reduce competition among their offspring by biasing the sex ratio towards the sex that competes least for limiting resources. Because females compete for nesting habitat and are not colony nesters, some degree of spatial segregation is required. Despite a 36 percent increase in the female population and a 60 percent turnover in radio-marked females from 2009 to 2010, no radio-marked females used new areas beyond those that were used in previous years. This was followed by a 20 percent decline in the number of females in 2010 with no discernible changes in habitat quality or environmental conditions from the previous year. This suggests that a possible resource threshold may have been reached, limiting growth of the female population by shifting the sex ratio in favor of males. In contrast, as the number of males increased so did the number of new areas used with no decrease in male survival, suggesting that adequate habitat was available to accommodate additional males. The possibility that the female population in GMUs 91 and 92 reached a nesting carrying capacity warrants consideration and further inquiry.

Estimating population size and detectability of wintering turkey flocks during deer classification flights proved to be a reliable method for monitoring annual changes in the South Platte River turkey population. Aerial estimates of flock size were underestimated by 15.8 percent; thus, abundance estimates from aerial counts were biased low by a factor of 0.195. Using turkey decoys and a fixed-wing aircraft to estimate sightability and detection probabilities in Texas, Butler et al. (2007) reported underestimating flock size by 30 percent and abundance by only

10–15 percent. However, their computer simulations were based on a distribution of estimated flock sizes collected opportunistically over a number of years, and actual flock sizes were unknown (Butler et al. 2007). Our estimates were based on actual flock sizes for the entire wintering population for each year's estimate, which provided a high degree of precision and accuracy.

The accuracy of our helicopter-based counts was primarily affected by two factors: 1) the presence of snow cover, and 2) flock size. In 2009 and 2010, snow cover provided a contrasting background which increased flock detection (97 percent) and percentage of birds counted (86 percent) by aerial observers. In contrast, there was no snow cover in 2011 resulting in only 89 percent of the flocks and 68 percent of the total birds being observed. Using similar methods in Wisconsin, Kubisiak et al. (1997) reported seeing 86 percent of known flocks and 80 percent of the birds with snow cover present. They noted that aerial surveys were only conducted when snow depths were ≥15 cm to maximize visibility and detection of flocks in deciduous woodlands. Future surveys should be conducted during times when snow cover is available to maximize sightability and flock size estimates.

The degree of underestimation increased as flock size increased, especially for flocks ≥75 birds, which was the general trend found in other studies (Kubisiak et al. 1997, Butler et al. 2007). Larger flocks required more time to count, increasing the likelihood that birds would retreat or flush to thicker wooded cover and confound our aerial estimates. Along the South Platte River, there were six primary flocks (≥75 birds) that consistently wintered in the same locales and comprised 80–85 percent of the turkey population in any year. Therefore, in years with no snow cover when smaller flocks may be missed, estimates from these primary flocks can still provide a reliable representation of the overall changes in the population.

MANAGEMENT IMPLICATIONS

Managers should consider turkeys in GMUs 91 and 92 as a single and separate cohort from those in GMU 96 when making management decisions. The proportion of juvenile males in the spring harvest should be closely monitored for shifts in age structure, which could affect hunting quality and hunter satisfaction. Likewise, the harvest of adult females in the fall varied annually, warranting annual surveys especially in years suspected of low recruitment when a higher proportion of adult females could be harvested.

The use of aerial surveys has proven to be an effective means to assess the status and annual population changes of turkeys along the South Platte River. This technique could be used to monitor other turkey populations in eastern Colorado, including those associated with the Arikaree River, Arkansas River, Big Sandy Creek, and Republican River drainages to name a few. We recommend aerial surveys are conducted in years when snow cover is present to maximize sightability and provide the most accurate estimates of number of flocks and flock size.

Currently, the timing for setting license numbers occurs in late summer and early fall, which is problematic because limited information is available to make defensible management decisions. Because population levels can be determined a few months prior to the spring hunting seasons, we recommend that the license setting process occur in late winter to utilize this additional information so the number of licenses can be set to coincide with current population levels. This would provide a meaningful annual process for managing turkeys in eastern Colorado and elsewhere.

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