BAND RECOVERIES, MORTALITY FACTORS, AND SURVIVAL OF ROCKY MOUNTAIN GREATER SANDHILL CRANES, 1969-99

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Abstract: We banded 1,907 (200 ad, 1,707 juv) greater sandhill cranes (*Grus canadensis tabida*) from the Rocky Mountain Population (RMP) during 1969-94 on summer areas in Idaho (75.7%), Wyoming (16.2%), Utah (3.4%), Colorado (3.0%), and Montana (1.7%). Capture methods included running down flightless young and the occasional molting/flighted adult from the ground (60.3%) or from a helicopter (25.1%), night-lighting (13.1%), and rocket-netting (1.5%). During 1969-99, we received 180 band recoveries including 45.0% from 5 summer area states, 15.0% from the spring-fall migration route in eastern Utah, western Colorado, and northern New Mexico, and 40.0% from winter sites in New Mexico, southeastern Arizona, and northern Mexico. The most important sites for spring-fall migration staging and wintering were the San Luis Valley (SLV) in southcentral Colorado, and the Middle Rio Grande Valley (MRGV) in westcentral New Mexico, respectively. The winter range extended 1,250 km from the MRGV to southeastern Durango, Mexico. Summer recoveries demonstrated a high degree of philopatry for respective summer areas, with 78.8% of indirect recoveries occurring within 100 km of capture sites. Dispersal, particularly northward, from summer banding sites was limited. Mean recovery age for cranes banded as juveniles was 5.9 years, with 21.4% >10 years old, 7.1% >15 years old, and a maximum age of 29 years. Most (>70%) mortalities were due to anthropogenic causes; shooting accounted for 58.3%, followed by unknown causes 24.4% (found dead), powerline and fence collisions or entanglements 10.0%, and 7.3% other factors. The proportion of cranes lost to shooting increased with age ($P < 0.001$), whereas non-shooting mortality declined with age, suggesting older cranes learned to avoid many forms of non-shooting mortality. Annual adult survival was estimated at 0.89. Recoveries and long-term marking studies show that the RMP is a discrete biological entity, does not interbreed with other crane populations, and is restricted to its seasonal ranges by philopatry. Hunt management on specific September premigration staging sites should include strategies to prevent long-term excessive harvest of local breeding flocks.

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Five populations of greater sandhill cranes, all migratory, are recognized in North America (Drewien and Lewis 1987, Drewien et al. 1995). They include the Eastern and Texas Coastal or Prairie populations in the eastern and central regions of the continent and the RMP, Lower Colorado River Valley, and Central Valley populations in western North America. The greater subspecies declined dramatically as their range was settled during the 19th - early 20th centuries (Walkinshaw 1949) and in 1966 was listed as "rare" with a continental population estimate of 6,000 (U. S. Department of the Interior 1966, Committee on Rare and Endangered Wildlife Species 1968). The "rare" classification stimulated a number of studies to assess the status of the subspecies (e.g., Littlefield and Ryder 1968, Drewien and Bizeau 1974, Drewien et al. 1976, Hunt and Gluesing 1976, Johnson 1976, Bieniasz 1979, Littlefield and Thompson 1979, Lovvorn and Kirkpatrick 1981). In 1968, Littlefield and Ryder (1968) estimated continental numbers at 10,000 and by 1971 a minimum of 10,000 was estimated for the RMP alone and the subspecies was declassified in 1972 (Drewien and Bizeau 1974). Colorado, however, listed their local breeding flock, a segment of the RMP, as endangered in 1973, downlisted it to threatened in 1993, delisted it in 1998, and currently it remains a species of concern. A September 1999 survey tallied 19,501 RMP cranes (Sharp et al. 2000).

Considerable information exists on seasonal distribution of RMP cranes from banding and marking studies (Huey 1965, Drewien and Bizeau 1974, Drewien et al. 1987*a,b*, 1996, 1999, Manes et al. 1992). These studies showed that the RMP summers in parts of Colorado, Utah, Idaho, Wyoming and Montana, migrates through Utah, Colorado, and northern New Mexico, and winters in New Mexico, southeastern Arizona, and northern Mexico. Because of increasing numbers and associated crop depredations, a limited quota hunt was authorized on RMP greaters in 1981 in southeastern Arizona. This was the first legal harvest of the greater subspecies since sandhill crane hunting was closed with ratification of the Migratory Bird Treaty in 1916. Earlier sandhill crane hunts in the Central Flyway attempted to avoid areas where the greater subspecies occurred (Boeker et al. 1961, Buller and Boeker 1965, Committee on Rare and Endangered Wildlife Species 1968). By 1996, 6 Rocky Mountain states (excluding Colorado) and Mexico were hunting RMP cranes (Lockman et al. 1987, Tessman 1997, Sharp et al. 2000). For 26 years, 1969-94, RMP cranes were banded on summer areas annually in 1 or more states. In this paper we report: 1) summer banding efforts during 1969-94 in 5 Rocky Mountain states; 2) band recovery distribution, 1969-99; 3) mortality factors associated with band recoveries; 4) estimated survival of adult cranes banded as juveniles; and 5) longevity records of RMP cranes.

STUDY AREA AND METHODS

During summer, RMP cranes are widely dispersed in pairs, family units, and in nonbreeding flocks mainly at elevations > 1,600 m from northwestern Colorado and central Utah northward through western and central Wyoming and Montana, and into eastern and southcentral Idaho (Fig. 1). They use a variety of wetland and associated upland habitats mainly in shrubland, grassland, and forested landscapes. Most nesting areas are in relatively isolated and well watered mountain valley marshes, riverine areas, beaver ponds, and wet meadows. Various RMP crane summer habitats have been described elsewhere (e.g., Drewien 1973*a*, *b*, Drewien and Bizeau 1974, Mullins and Bizeau 1978, Bieniasz 1979, Drewien et al. 1987*a*, Lockman et al. 1987, McIvor and Conover 1992, 1994, Rowland et al. 1992).

During migration and winter, RMP cranes are gregarious and use traditional areas in Colorado, Utah, New Mexico, Arizona, and northern Mexico (Drewien and Bizeau 1974). The major spring-fall population staging area is in the SLV in southcentral Colorado's upper Rio Grande drainage. These migration habitats were described elsewhere (e.g., Drewien and Bizeau 1974, Kauffeld 1982, Drewien et al. 1987*b*, 1995, Stahlecker 1992, Brown and Drewien 1995, Benning et al. 1997, Peterson and Drewien 1997). The principal winter range is the MRGV in westcentral New Mexico, mainly from the Albuquerque - Los Lunas region in Bernalillo and Valencia counties south to the Bosque del Apache NWR (Bosque Refuge), Socorro County. Smaller numbers winter in the Lower Rio Grande Valley and several other sites in southwestern New Mexico, upper Gila River Valley in western New Mexico and adjacent Arizona, the Sulphur Springs Valley in southeastern Arizona, and in the northern Mexican states of Chihuahua and Durango. These various crane winter habitats were described by Drewien and Bizeau (1974), Perkins and Brown (1981), Walker and Schemnitz (1987), Taylor and Kirby (1990), Drewien et al. (1996), and Schmitt and Hale (1997).

Cranes were captured on breeding areas in Colorado, Idaho, Montana, Utah, and Wyoming (Drewien and Bizeau 1974, Bieniasz 1979, Drewien et al. 1987*a,b*, 1999, Drewien and Clegg 1992, Manes et al. 1992) in 1969-94. Capture methods included 1) running down 5-10-week-old flightless young and occasional molting adults from the ground, or from 2) a helicopter, 3) night-lighting, and 4) rocket-netting. During ground captures, personnel working in a team of 2 or more individuals, often used 2-way radios to aid in locating flightless young which usually hid in response to human presence. One or more persons using binoculars/spotting scopes directed pursuers to hiding locations. Helicopter captures were confined to Grays Lake, Idaho, in 1976-87; Bear, Salt and Green River valleys, Wyoming in 1982, 1984; and Yellowstone National Park in 1984-85. A few flighted cranes were captured from a helicopter similar to methods described by Ellis et al. (1998). Cranes were captured by night-lighting in 1969-89 at Grays Lake, Idaho (Drewien and Clegg 1992), and by rocket-netting at Grays Lake NWR and Bear Lake NWR, Idaho during 1970 and 1972. Nets (9.1 x 18.3 m, 3.2-cm sq. mesh, 45 cm skirt) were launched from "Malheur Recoilless Rocket-launching Rails" (McLaury n.d.). A launching rail for recoilless rockets consisted of a 61 cm high angle-iron sawhorse with a 76 cm long angle iron launching rail welded to the top of the sawhorse at a 1:6 vertical angle. Launching rails quickly elevated the leading edge of nets when projected to minimize injuries to cranes.

Cranes were banded with USFWS No. 9 aluminum legbands including butt-end, lock-on, and pop-rivet styles of attachment. Most cranes were also marked with various types of leg and neck markers or patagial tags, and a few were radiotagged (Drewien and Bizeau 1974, Bieniasz 1979, Drewien et al. 1987*a,b*, 1999, Manes et al. 1992). We were unable to sex cranes because they can not be accurately sexed by plumage characteristics or cloacal examination (Tacha and Lewis 1979). Many juveniles were monitored after banding to ensure that they had reunited with their parents. Banding programs were conducted by the 1) Idaho Cooperative Wildlife Research Unit and Hornocker Wildlife Institute, University of Idaho, in Idaho (23 yrs, 1969-91), Wyoming (13 yrs, 1970-87), Utah (7 yrs, 1970-82); and Montana (3 yrs, 1970-73); 2) Colorado Division of Wildlife (8 yrs, 1976-94); 3) Utah Division of Wildlife Resources (5 yrs, 1986-90), and 4) Wyoming Game and Fish Department (2 yrs, 1992-93). Both the Utah and Wyoming Departments in their respective states were cooperators in the earlier banding programs conducted by the University of Idaho.

We obtained recovery data for 1969-99 from the Bird Banding Laboratory, U. S. Geological Survey, Laurel, Maryland. We also contacted State Wildlife Departments in 6 Rocky Mountain states where RMP limited quota crane hunts are held to determine if additional recoveries were recorded in their files. All 6 states require a state permit to hunt cranes and for hunters to provide a report at the end of the season; several states require hunters to report to check stations (Lockman et al. 1987, Tessman 1997, Sharp et al. 2000). We also reviewed our files to locate information on any unreported bands. We report banding and recovery data by state with 1 exception. In Idaho, we separate data for Grays Lake, where large numbers were banded, from the remainder of the state. Recoveries reported here include only dead birds and exclude recaptured cranes and observations of marked birds.

When survival and recovery rates are expected to be age-dependent, a robust survival analysis of band recovery data requires that substantial numbers of bands be applied to birds of each age class (Brownie et al. 1985). When only juveniles are banded, confounding prevents the estimation of all parameters for 2 age classes except juvenile recovery rates. Some of the confounding can be resolved, but only with restrictive assumptions. We found only 1 of these sets of assumption to be plausible a priori: that juvenile survival rates might be constant across years. In this case, adult survival rates can be estimated. We used program MARK (White et al. 2001) to estimate these parameters. In comparing models, we chose the most parsimonious (i.e., balancing minimum bias due to many parameters with maximum precision due to few parameters) based on the small-sample version of Akaike Information Criterion (AIC_c, see Burnham and Anderson 1998).

We compared the apparent relative risk of shooting versus non-shooting mortality by age class. For a given age class, inference about relative risk based on the raw number recovered would be naive because we anticipate that the combination of retrieval and reporting rate for those that are shot (at least legally by hunters) will be higher than those which died from other factors. However, our interest is in the pattern of this relative risk across age classes. Therefore, unless differential reporting rate is age-dependent, it should not bias our inference. We restricted our analysis to those cranes recovered in 1982-94. Harvest began in earnest in 1982 (Sharp et al. 2000) and the last crane was banded in 1994. We tested for the independence of age and mortality factor using a contingency table (Agresti 1990).

RESULTS

Capture Methods, Numbers and Locations of Cranes Banded

During summers 1969-94, we captured 1,907 cranes (200 ad, 1,707 juv) on breeding areas in 5 states (Tables 1 and 2, Fig. 1). Most cranes were captured in Idaho (75.7%: [60.4%-Grays Lake, elsewhere-15.3%]), followed by Wyoming (16.2%), Utah (3.4%), Colorado (3.0%), and Montana (1.7%). All juveniles were flightless except 30-40, which had started flying short distances when captured; 98% of all cranes were color-marked. Most cranes were caught in July and August (94.2%); a few in May (0.5%), June (3.9%), and September (1.4%). Most were caught by running down flightless young and an occasional molting adult from the ground (60.3%) or from a helicopter (25.1%). Smaller numbers were captured by night-lighting (13.1%) (Drewien and Clegg 1992) and rocket-netting (1.5%); most adults were captured by the latter 2 methods (Table 3).

Catch rates per day by running down flightless cranes were generally low, 2-8 birds, with maximum daily catches of 12-14 under optimum situations. We experienced larger daily catches from a helicopter, averaging 22.1

cranes/day (SD=14.0, range, 6-46) at Grays Lake, Idaho, on 15 days, whereas 24, 30, and 32 cranes were caught during 3 days in the Bear, Green, and Salt River valleys of western Wyoming. However, in low crane density habitat we caught only 2-4 cranes per day from a helicopter in Yellowstone National Park. Night-lighting at Grays Lake resulted in a mean catch of 3.1 cranes/night (SD=2.3, range, 0-12) (Drewien and Clegg 1992). An average of 7 cranes was trapped during 4 rocket-net projections.

Cranes were banded in 35 geographical areas and capture efforts varied among locations and years (Tables 1 and 2, Fig. 1). In descending order, 9 areas where ≥25 cranes were banded included: 1) Grays Lake, Idaho (1,152), Bear River Valley, Wyoming (158), upper Blackfoot River, Idaho (157), Green River Basin, Wyoming (91), Bear River Valley, Idaho (85), Red Rock Lakes NWR, Montana (32), Salt River Valley, Wyoming (27), Camas Prairie, Idaho (25), and Elk River, Colorado (25). A total of 261 cranes was banded in the contiguous tri-state Bear River Valley in Idaho, Utah, and Wyoming. The longest banding programs were at Grays Lake, Idaho (23 yrs), upper Blackfoot River, Idaho (13 yrs), Bear River Valley, Wyoming (9 yrs), Green River Basin, Wyoming, Bear River Valley, Utah, and California Park, Colorado (7 yrs each); and Bear River Valley, Idaho and Elk River, Colorado (6 yrs each).

After banding, many juveniles were monitored following release and we did not observe any that were rejected by their parents. Observations of cranes marked during night-lighting showed that they did not vacate capture areas; 5 incubating females captured at night on nests resumed incubation and hatched eggs (Drewien and Clegg 1992). Rocket-netting proved more difficult as most birds were dispersed and they did not readily come to bait. Further, most were reluctant to approach baited sets and they vacated the area after net projections. We abandoned rocket-netting after 4 net projections due to excessive time spent preparing sites and low capture rates. No cranes were injured during rocket-netting operations. We experienced 5 mortalities during captures. Four were flightless young that had been run-down and they apparently died due to capture myopathy. All 4 succumbed during very warm afternoons suggesting that heat stress was a contributing factor. One crane broke a wing (euthanized) when it became disoriented during night-lighting and flew into the night-light operator.

During early capture efforts, we banded cranes on the leg above the foot. We observed some butt-end style bands separating apparently due to freezing and thawing action at night roosts. To minimize band losses, we used lock-on and pop-rivet style bands and attached them above the hock/tibio-tarsus joint.

Recoveries

During 1969-99, we received 180 recoveries, including 148 (82.2%) from the Bird Banding Laboratory and an additional 32 (17.8%) from state Wildlife Department files and our field records that had not been reported to the Bird Banding Laboratory. Recovery distribution included 81 (45%) from 5 summer area states, 27 (15%) from the spring-fall migration route in eastern Utah, western Colorado, and northern New Mexico, and 72 (40%) from winter sites in New Mexico, southeastern Arizona, and northern Mexico (Table 4, Figs. 2 and 3). Ages at banding of recovered cranes included 168 juveniles and 12 adults. Recoveries of juveniles were obtained for every year through age 24 except for age 20, and 1 crane at age 29 (Table 5). The percent recovery for juveniles was 9.8 and for adults, 6.0. Recovery information on the 5 oldest birds (21-29 yrs) is summarized in Table 6.

Summer area recoveries were from 24 areas with 7 locations accounting for 75.3% (Table 4) including 2 in Idaho (Grays Lake and Blackfoot Reservoir-Soda Springs area) and 5 in Wyoming (Bear and Salt River valleys, Farson and Pinedale localities in the Green River Basin, and Wind River Basin). During spring-fall migration, the SLV was the most important location, accounting for 11.1% of all recoveries. The 72 winter area recoveries were distributed over a 1,250 km north-south gradient from near Albuquerque, New Mexico to southeastern Durango, Mexico and a 550 km east-west gradient between Ft. Sumner, New Mexico and Willcox Playa, Arizona (Fig. 3). Most winter area recoveries (n = 49) were from the MRGV, New Mexico, along a 120 km strip from Albuquerque to the Bosque Refuge. The second most important winter recovery region was in Chihuahua and Durango, Mexico (n = 12), followed by the Lower Rio Grande Valley (n = 7) in southcentral New Mexico, the Pecos Valley (n = 2) in eastern New Mexico, and the Willcox Playa (n = 2) area in southeastern Arizona (Table 4, Fig. 3). The longest distance between a banding and recovery site was approximately 2,500 km and involved a crane hatched at Grays Lake, Idaho, and harvested at the Malaga marshes in southeastern Durango, Mexico (Fig. 3).

Most recoveries were from the same region where cranes were banded or southward along the migration route or from winter sites (Table 7). On summer areas, few cranes were recovered north of their respective banding states. No cranes banded in Colorado or Wyoming were recovered in states to the north and the single recovery in Montana was from a Montana banded bird. No birds banded in Wyoming, Utah, or Colorado were recovered in Idaho although 18 Idaho banded cranes were recovered east and northeast in Wyoming (Grays Lake-14, elsewhere-4). However, all 18 recoveries were of cranes banded in Idaho <50 km from the Wyoming border.

Eighty-one recoveries were from summer areas, including 15 obtained the same year of banding (direct) and 66 that were recovered 1-29 years after banding (indirect). Recoveries included 3 birds banded as adults and 78 juveniles banded on natal areas. Of 15 direct recoveries, all were recovered near banding sites or < 100 km. Of 66 indirect recoveries, 52 (78.8%) were recovered near banding sites or < 100 km, and the remaining 14 (21.2%) were 100-260 km from capture sites. The longest movements from natal sites to other summer areas (240, 260 km), involved 2 yearlings from Grays Lake, Idaho, recently separated from their parents. Both were recovered during the year following banding in central and northcentral Wyoming. Affinities for banding areas were illustrated by 2 of the oldest recoveries, including a 29-year-old shot 35 km from its natal area and a 23-year-old that died < 2 km of its natal area (Table 6). Ages of 66 cranes from indirect summer area recoveries were: 1-5 years (n = 34), 6-10 years (n = 15), 11-15 years (n = 12), and 16-29 years (n = 5).

Monthly recoveries were lower during February-August and higher during September-January when hunting seasons were underway. Peak recovery months were in September and October, whereas the lowest numbers were recovered during May-July when cranes were widely dispersed (Fig. 4).

Mortality Factors and Survival

Causes of death were known for 136 (75.6%) recoveries, whereas 44 (24.4%) deaths were due to unknown causes/found dead (Table 8). Most known mortalities were due to shooting (hunting-n = 97; illegal shooting, no season-n = 6; scientific collecting-n = 2) which accounted for 58.3%, followed by power line collisions and barbed wire fence collisions or entanglements (10.0%). Four died from avian cholera (*Pasteurella multocida*) in the SLV,

Colorado. Three cranes were predated, including 2 by golden eagles (*Aquila chrysaetos*) and 1 newly fledged juvenile by a coyote (*Canis latrans*). Unusual mortalities also occurred including 1 that starved at Monte Vista NWR, Colorado, because a plastic shot shell wad was impaled on both mandibles. Another died when struck by a rocket net during goose trapping operations at the Bosque Refuge, New Mexico. One 3.8 year-old recently paired male was killed at Grays Lake NWR during an agonistic encounter with a territorial male whooping crane (*G. americana*) from a cross-fostering experiment (Drewien and Bizeau 1978). The sandhill male was attempting to establish a nesting territory in the area occupied by the whooper. One crane was captured in a trap set in an unharvested cornfield to catch depredating waterfowl and cranes at Laguna de Babicora, Chihuahua, Mexico.

Our survival analysis produced an estimate of constant adult annual survival rate of 0.89 ($SE = 0.017$). Based on AIC_c this was much more parsimonious than the model allowing for year-specific survival rates (difference in AIC_c of 26). This is not surprising , given the sparseness of our data. Also, this inference is conditional on the necessary assumption that juvenile survival rate is constant over time.

Data in Table 9 indicate that vulnerability to non-hunting factors relative to shooting decreased with age ($X^2 = 19.3$, $df = 4$, $P = 0.001$). This pattern could be generated by 1) decreased actual vulnerability to non-shooting sources of mortality with age, 2) an increase in actual vulnerability to shooting with age, or 3) by decreasing vulnerability to non-hunting sources over time relative to shooting. Possibility 3 is plausible in our case because hunting pressure on RMP cranes has increased since a season was opened in 1981 (Sharp et al. 2000). In addition, the number of cranes banded each year (including number of young) each year decreased to a very small number by the late 1980s (Table 2). Therefore, only older marked cranes were available for mortality in later years.

To account for increasing harvest pressure over time, we looked at relative mortality across age classes (<1, 1-2, ≥ 3 yrs) annually from 1982-94, and considered only 3 age classes because our data were sparse (Table 9). We found that in each case the proportion of observed mortality attributable to non-shooting sources declined with age. The average (equal weight to each year with data) percent of apparent mortality attributed to non-shooting sources was 70% for those < 1 year old, 48% for those 1-2 years old, and 20% for those ≥3 years old. We also found that for each year where more than 2 cranes < 1 year-old were recovered, most died from non-shooting sources of mortality. This is especially noteworthy given that 1) we expect this to be an underestimate due to the anticipated greater retrieval/reporting rates for shot birds, and 2) these are based on direct recovery rates (i.e., after adjusting for retrieval/reporting rate they are a direct measure of mortality rate). Data in Table 9 also show shooting versus non-shooting mortality by ages classes for 1969-99, but the comparison is limited because hunting was allowed only in Mexico for the entire period.

DISCUSSION

Capturing Cranes

Catching large numbers of cranes, especially adults, on summer areas was difficult because they were widely dispersed, usually at low densities, and in discontinuous habitats. Over broad geographic areas, running down flightless young was the easiest method for catching cranes but catches per day were normally low (2-8 birds). Capturing cranes from a helicopter was the most efficient method at specific locations but was cost prohibitive for large geographic areas. It was most effective in a few areas of open habitats with high crane densities during good

production years when young were more abundant, such as at Grays Lake, Idaho, and the Bear, Green, and Salt River valleys of western Wyoming where maximum daily catches of 46 and 32, respectively, were recorded. In contrast, in forested habitat with low densities of cranes such as Yellowstone National Park, capture rates from helicopters were low (2-4 cranes/day).

Night-lighting proved best for capturing adults, especially on breeding territories, but was time consuming, strenuous, and success depended upon proper night weather conditions and familiarity with the wetland and night roost sites of cranes. The technique is best suited for special studies on limited areas; the mean nightly capture rate (3.1 cranes) was low (Drewien and Clegg 1992). Our limited attempts at rocket-netting suggested that it is not well suited for use in summer when cranes are dispersed, although it has been widely used to capture cranes when they are gregarious (e.g., Littlefield and Ryder 1968, Wheeler and Lewis 1972, Ramakka 1979, Tacha 1979, Williams 1981, Tacha et al. 1982, Pogson et al. 1988). During early studies of the RMP, the first author rocket-netted 31 cranes during winter 1972 at Bosque Refuge, New Mexico (unpublished data), but catches included lesser and Canadian subspecies (*G. c. canadensis and G. c. rowani, respectively*) from the Midcontinent Population (MCP) and therefore, winter marking was discontinued. Outside the summer range, RMP cranes mix with the MCP (Drewien and Bizeau 1974, Drewien et al. 1995, 1996, Benning et al. 1997) and banding programs at these locations can lead to erroneous interpretations of recovery data such as incorrectly assessing breeding population affiliations, geographic range of specific populations, or survival and mortality factors of specific populations and subspecies.

We experienced low mortality (0.26%) from all capture methods and with the exception of rocket-netting, cranes did not vacate capture areas. We did not observe aberrant behavior in cranes due to capture and marking or individuals that failed to reunite in pairs or family groups. In contrast, early cannon/rocket-netting efforts reported mortality rates of 6.9-10.1% primarily due to stress, net paralysis, and injuries, with some mortalities occurring 1 or more days after capture (Wheeler and Lewis 1972, Ramakka 1979, Tacha et al. 1982). Likewise, we did not experience aberrant or disrupted social behaviors similar to those reported for sandhill cranes captured by rocket-netting during winter and spring and marked with patagial tags and colored leg bands in Texas and Nebraska (Tacha 1979, Tacha et al. 1982). Pogson et al. (1988) also reported temporary abnormal behaviors for the lesser subspecies when rocket-netted and marked with collars during winter in California. Cranes captured with the oral tranquilizer, alpha-chloralose, experienced 4.9% mortality in Florida (Nesbitt 1984). Capturing primarily flightless cranes on summer areas, when they were dispersed, apparently minimized most problems previously noted with injuries, mortalities and abnormal behaviors among cranes trapped during the gregarious period. Other capture efforts, primarily of flightless birds on summer areas, have reported little or no mortality during capture and marking programs (Littlefield and Ryder 1968, Boise 1979). Our limited efforts with rocket-netting and findings by McLaury (n.d.) indicated that the use of "Malheur Recoilless Rocket-launching Rails" with small-mesh nets and skirts was an improvement over other rocket-netting techniques and minimized stress, injuries, and mortalities.

Recovery Distribution and Philopatry

All except 2 recoveries occurred within the known geographic range of the RMP identified during earlier studies of marked cranes (Huey 1965, Drewien and Bizeau 1974, Drewien et al. 1987*a,b*, 1996, 1999, Manes 1992).

Recoveries confirmed that the SLV, Colorado, was the only important spring-fall stopover, and that the MRGV, New Mexico, was the most important winter area. Combined, these 2 locations accounted for 69.7% of all recoveries outside the summer range. The SLV is the only staging area used by almost the entire RMP for extended periods each spring and fall (Drewien and Bizeau 1974, Kauffeld 1982, Brown and Drewien 1995, Drewien et al. 1995, Benning et al. 1997). Only 7 recoveries were received from the spring-fall migration route outside the SLV, suggesting rapid passage through the region between winter and summer areas to the SLV. Much of the migration route in eastern Utah, western Colorado, and northern New Mexico is arid or mountainous and adequate crane habitat is limited (Drewien and Bizeau 1974, Stahlecker 1992, Peterson and Drewien 1997, Drewien et al. 1999). Although approximately 50% of the RMP stop for 1 or several nights during spring migration at Harts Basin in western Colorado (Peterson and Drewien 1997), only 1 recovery was received from the area.

Winter range recoveries showed that 68.1% were from the MRGV, 12.5% from other sites in New Mexico, 2.8% from southeastern Arizona, and 16.7% from the Northern Interior Highlands of Mexico. Recoveries from major breeding areas in southeastern Idaho and western Wyoming, where more extensive banding occurred, showed that birds from these summer locations distributed themselves across major winter areas. There was no evidence that birds from a specific breeding area congregated exclusively at a specific winter site.

Two cranes were recovered in the Pecos Valley in eastern New Mexico, a known winter area for the lesser subspecies, but outside previously documented winter sites of the RMP. It was the first region reopened to sandhill crane hunting in the United States in 1961 and the greater subspecies was not found there (Boeker et al. 1961). The recovery of 2 birds in the Pecos Valley is not surprising given the close proximity (200-250 km) to the MRGV, and that crane hunting has been ongoing there annually since 1961 (Drewien and Bizeau 1974, Sharp et al. 2000).

Greater sandhill crane pairs are well known for their breeding territory philopatry (Walkinshaw 1949). An extreme case of philopatry was demonstrated by an Oregon pair for a breeding territory that was totally inundated by floods for 2 nesting seasons (Littlefield and Ivey 1995). Our summer area recoveries demonstrated that philopatry prevailed for vicinities near banding sites, regardless of the number of years between bandings and recoveries. Only limited regional movements away from banding sites, particularly to the north, were recorded. Further, limited-quota September crane hunts between 1982-96 (Lockman et al. 1987, Tessman 1997, Sharp et al. 2000) provided opportunities to assess such movements in 4 of 5 summer area states. Although little is known about subadult summer dispersal from natal areas, a study in northwestern Wyoming reported that all subadults were found < 65 km from natal sites in later summers (Drewien et al. 1999), further illustrating philopatry for banding areas.

Recovery data for 30 years confirmed strong philopatry of RMP cranes to their seasonal ranges, and no mixing occurred with greaters affiliated with the nearby Central Valley Population (CVP). Since 1963, > 740 greaters from the CVP have been banded, marked and monitored, with most (>530) captured at Malheur NWR in southeastern Oregon (Littlefield and Ryder 1968, Littlefield and Thompson 1979, C. D. Littlefield, Muleshoe, Tex., and G. L. Ivey, Bend, Oreg., personal communications). No recoveries or sightings of marked CVP cranes have occurred within the range of the RMP nor have any RMP cranes been recorded within the range of the CVP. Only 200-225 km separate known western RMP breeding sites in the Camas Prairie and Stanley Basin of southcentral Idaho from CVP summer sites near Jordan Valley, in southeastern Oregon along the Idaho border (C. D. Littlefield

and G. L. Ivey, personal communications). No recoveries were obtained within the range of the adjacent Lower Colorado River Valley Population (LCRVP) of greaters. However, a marking study confirmed overlap of a few RMP cranes that used the Lund stopover along with LCRVP cranes during spring migration in eastern Nevada (Rawlings 1992).

Recovery data and long-term marking studies (Drewien and Bizeau 1974, Drewien et al. 1987*a,b*, 1996, 1999, Manes et al. 1992) indicate that the RMP is a discrete biological entity. Although the RMP mixes with lesser and Canadian subspecies of the MCP during migration in the SLV and in winter (Drewien and Bizeau 1974, Brown and Drewien 1995, Drewien et al. 1995, 1996, Benning et al. 1997, Schmitt and Hale 1997), there is no evidence that any RMP cranes paired with MCP cranes or abandoned their traditional ranges to travel elsewhere.

Our data do not support reports by Tacha (1981, 1988) and Tacha et al. (1984, 1985, 1992) that "random pairing among supposed subspecies" occurs during spring migration in MCP cranes. Tacha (1981:13) stated that evidence suggested that 12-72% or 12-58% (Tacha et al. 1985:248) of these cranes crossed subspecies designations to pair (i.e., *tabida* [largest] or *rowani* [intermediate] sized cranes paired with *canadensis* [smallest]). These conclusions were largely drawn from observations of various-sized cranes "dancing" with one another during spring migration in Nebraska and assuming that dancing was the primary behavior mechanism for pair formation (e.g., Tacha 1988:29, Tacha et al. 1992:3). We have never observed pairing attempts or pairs between *tabida* and *canadensis,* nor have such pairings been observed during >30 years of study of the CVP, where both subspecies are sympatric during winter and along southern portions of the migration route (Littlefield and Thompson 1981, C. D. Littlefield and G. L. Ivey personal communications). Dancing is a common activity during spring migration in the SLV and often involves several subspecies from the RMP and MCP in the same flocks; yet we never observed pair formation resulting from these dancing activities. Studies by Baldwin (1976, 1977) showed variation in anatomy, physiology, and rates of development between young of *tabida, rowani,* and *canadensis* including ages of first flight, thermoregulation abilities of newly hatched young, length of down at hatching, and other characteristics that would not exist if random pairing among subspecies occurred. Age at fledging in *canadensis* is approximately 7 weeks (Boise *in* Pogson and Cooper 1983:7), whereas RMP *tabida* start flight at 9.5-10.5 weeks (Drewien 1973*b*). Furthermore, Gaines and Warren (1984) found a pancreas protein difference between *canadensis* and *rowani.* Reports that random pairing occurs among subspecies during spring in Nebraska are unconvincing and these conclusions are likely unwarranted.

Mortality Factors

Most mortalities were due to anthropogenic causes (>70%) with hunting (53.9%) the single most important factor. All other mortality factors were <4% except for unknown/found dead (24.4%) and power line-fence collisions/entanglements (10.0%). We suspect that nonhunting mortalities such as power line collisions, predation, and possibly diseases were under-represented by recoveries. In a power line mortality study in the SLV, 90 sandhill crane specimens were found beneath power lines and juveniles died at a higher rate than their occurrence in the population (Brown and Drewien 1995). The number retrieved under power lines was minimal and excluded cranes removed by scavengers and cripples that left study plots. Recovery data and our own observations showed that

power line collisions were wide spread but more were identified in the SLV than at any other location within the RMP range. Some recoveries from the SLV were reported as unknown causes/found dead along roadsides and were most likely power line collision mortalities. Power line collisions were the greatest known cause of mortality (39%) for fledged cross-fostered whooping cranes in the Rocky Mountains, with most losses occurring in the SLV (Brown et al. 1987, Brown and Drewien 1995). The SLV has the highest density of power lines (km of lines/km^2) of any major crane concentration area we are aware of in the western United States, primarily due to the abundance of overhead pivot sprinkler irrigation systems requiring electrical well hookups. Power line collision mortality will continue to be a perennial problem in the SLV.

As noted by Windingstad (1988), predation losses are widely scattered and more likely to occur during summer when cranes are dispersed, thus reducing opportunities to find specimens. We suspect losses to golden eagles may be a significant mortality factor although we observed only 2 fatal attacks on banded cranes. However, dozens of attacks have been observed in the range of the RMP on wild sandhill cranes and experimental sandhill cranes and whooping cranes (Perkins and Brown 1981, Windingstad et al. 1981, Bizeau et al. 1987, Clegg et al. 1997, Ellis et al. 1999, R. C. Drewien and W. M. Brown, unpublished data).

Records of 170 sandhill cranes from the RMP and MCP necropsied during 1976-85 at the National Wildlife Health Research Center, Wisconsin, identified that avian cholera (mainly RMP), avian botulism (RMP, MCP), and ingestion of mycotoxins (MCP) were leading causes of nonhunting mortality (Windingstad 1988). Mortalities from hailstones, lead poisoning, predation, avian tuberculosis and collisions with power lines also were recorded. Windingstad (1988) reported that avian botulism killed an estimated 150 MCP and RMP cranes in October 1980 at Willcox Playa, Arizona. Two die-offs from avian cholera were identified, including some 50-65 cranes at Monte Vista NWR, Colorado (SLV) in spring 1984, and an estimated 60 (Refuge records show 76) cranes at the Bosque Refuge, New Mexico, during winter 1984-85. These were the largest die-offs from avian cholera recorded for sandhill cranes through the mid-1980s (Windingstad 1988). Kauffeld (1987) described the die-off at Monte Vista NWR, which occurred under stressful environmental conditions. Cranes ran short of food in the MRGV, New Mexico winter area and migrated to the SLV 2 weeks earlier than normal. They arrived during severe winter weather while an avian cholera waterfowl die-off was in progress. Four recoveries of our banded cranes lost to avian cholera were from Monte Vista NWR and 3 were associated with the spring 1984 die-off.

Since the 1980s, incidences of avian cholera and avian tuberculosis in cranes and waterfowl have increased in the MRGV, New Mexico, and have been associated with increases in winter populations of snow geese (*Chen caerulescens*) and Ross' geese (*Chen rossii*) (Snyder et al. 1987, Taylor and Kirby 1990). Outbreaks of avian cholera in cranes at the Bosque Refuge have occurred in 9 winters during 1984-99 with $\geq$25 sandhill cranes succumbing during 5 winters including a peak of 110 in 1993-94; 10 sandhill cranes died from avian tuberculosis in 1987 (J. P. Taylor, U. S. Fish and Wildlife Service, Socorro, NM, personal communication). Two whooping cranes from the cross-fostering experiment also succumbed to avian cholera while wintering at the Bosque Refuge (Snyder et al. 1987, Drewien et al. 1997) and 5 cross-fostered whoopers have died from avian tuberculosis (Brand et al. 1991). Avian cholera has become endemic in Banks Island snow geese, a primary source of wintering geese in the MRGV, and these birds apparently have the potential to transmit the disease to other waterfowl (Samuel et al. 1999)

and cranes (Snyder et al. 1987). A survey of sandhill crane and snow geese revealed that the prevalence of avian tuberculosis was very low in these populations (0.3% in sandhill cranes) but that whooping cranes appeared to be extremely susceptible to the disease or were more frequently exposed to infective levels of the bacteria than other birds (Brand et al. 1991:74). As long as large numbers of white geese winter with cranes in the MRGV, we can expect crane losses to avian cholera and avian tuberculosis to continue.

The importance of various mortality factors changed with age ($P = 0.001$). For cranes < 1 year-old, the majority of mortalities was attributed to factors other than shooting. Non-shooting and unknown mortalities declined among older cranes relative to shooting. These data suggested that older cranes learned by experience to avoid many forms of non-shooting mortality but were less adept at avoiding shooting. Ideally, an analysis of age related mortality factors would be conducted using age-specific band return models, including cranes released in each age class of interest (Brownie et al. 1985). Under such a model, recovery rates due to each source of mortality could be estimated, conditional on the animal being alive at the beginning of the year of interest. Inferences could then be made about relative risk if some assumptions could be made about the relationship between the retrieval/reporting rates for the sources of mortality of interest. Our analysis was necessarily restricted to cranes banded as juveniles because our sample of birds banded as adults was sparse. We recognized that, due to differential retrieval/reporting rates between those cranes shot or not, our results for reported relative risk could lead to erroneous conclusions (when recoveries are higher for those shot than not shot). However, we have shown that this potential bias should not negate our conclusions about changes in relative mortality across ages, especially for the younger age classes.

Survival and Longevity

We estimated adult annual survival to be constant at 0.89. This estimate is slightly lower than previous estimates (0.91-0.97) for RMP cranes (Drewien et al. 1995, 1999), but is similar to the combined estimate of 0.88 for all age groups of nonhunted Eastern greaters and Florida sandhill cranes (*G. c. pratensis*) (Tacha et al. 1994:78). Bennett and Bennett (1990) reported mean annual survival of 0.89 for the Florida subspecies in the Okefenokee Swamp of Georgia. Our survival estimate (0.89) is conditional on the assumption that juvenile survival rate is constant across time. Although this assumption is plausible, it is nevertheless restrictive. Studies that rely strictly on band recoveries are poorly designed if they include banding juveniles only (Brownie et al. 1985). Although this estimate has limitations, most of these birds were also marked. We collected observations at breeding, migration, and winter areas from 1970-94. The fact that mainly juveniles were banded does not cause serious problems with capture-resighting methods because an adult that is sighted is then "re-released" to the population. Future analyses will combine resighting and recovery data to estimate annual adult and juvenile survival rates.

Recoveries attest to the long life of greater sandhill cranes in the wild: 21.1% were older than 10 years, and 2.8% older than 20 years, with a maximum age of 29 years, 3 months. The 29-year-old recovery is currently (Sept 2000) the oldest wild sandhill crane on record at the Bird Banding Laboratory (M. K. Klimkiewicz, U. S. Geological Survey, Laurel, MD, personal communication). During September 2000, the first author observed a 31 year, 4 month old crane 6 km from its natal site at Grays Lake. This bird had been caught as a flightless young in July 1969, and was recaptured and remarked 2 km from its natal site in September 1989. We suspect that additional cranes

from early banded cohorts are still alive but most have lost markers. During June 2000, the first author read bands with a spotting scope on 2 nesting cranes at Grays Lake and determined that they were 24 and 28 years old. Both cranes had lost markers and were originally captured as flightless young at Grays Lake. To our knowledge, the oldest wild greater sandhill crane is from the CVP and was marked at Malheur NWR, Oregon, in April 1969 by C. D. Littlefield (personal communication) as a breeding adult and was $\geq$ 3 years old. It was recaptured and remarked in August 1985. This male still occupied its breeding territory during summer 2000 (G. L. Ivey, personal communication) and was $\geq$ 34 years old.

During winters 1958-59, 1959-60, and 1962-63, 104 sandhill cranes, mainly adults, were banded at the Bosque Refuge, New Mexico; 100 were judged to be greater subspecies and marked with yellow plexiglass collars (Huey 1965). Collars were plain and lacked identification although 1 individual had a distinctive white plumage pattern on the neck and upper body, but we were unable to determine year of banding for this crane. During 1969-71, 9-13 years following marking, Drewien and Bizeau (1974:737) reported on sightings of these birds. Observations were continued by R. C. Drewien and W. M. Brown (unpublished data) until the last bird, the white plumaged crane, disappeared after March 1991, 28-32 years after banding. Interestingly, all of these collared birds had lost USFWS metal leg bands by late winter 1978-79, 16-20 years following banding.

Our longevity records of wild RMP and CVP cranes exceed the maximum ages of 19.4 years reported for a MCP crane (Klimkiewicz and Futcher 1989) and 21.6 years for a Florida sandhill crane (Tacha et al. 1992:15).

MANAGEMENT IMPLICATIONS

Future banding programs for RMP cranes should focus efforts along the eastern and western peripheries of current summer areas (Fig. 1). Our banding efforts during the 1970s-80s were concentrated primarily in the center of RMP abundance in southeastern Idaho and western Wyoming and nearby areas in northern Utah, northwest Colorado, southcentral Idaho and extreme southwestern Montana. The population has expanded its range in recent years (see Tessman 1997) compared to where they were found during the 1970s (see Drewien and Bizeau 1974:725). The eastern boundary of current crane summer habitat is from Grand and Jackson Counties, Colorado (Barrett 1998), northward through eastcentral Wyoming, and throughout much of western Montana where suitable habitat exists. Scattered but increasing numbers are summering on the high plains of central Montana (Montana Bird Distribution Committee 1996). Recent records also confirm breeding in extreme southwestern Alberta (Semenchuk 1992), which probably involve RMP pioneers following the Rocky Mountain Front northward from Montana.

The western boundary of the RMP summer range is poorly defined and is complicated by the presence of greater subspecies affiliated with CVP and LCRVP. Due to limited marking programs, boundaries separating the RMP, CVP, and LCRVP have not been identified, yet these 3 populations converge within a relatively limited but undefined region centering in northeastern Nevada, southeastern Oregon, adjacent southwestern Idaho, and northwestern Utah (Fig. 1). Summering birds within this region migrate to 3 geographically distinct winter areas. In addition to the RMP, the LCRVP winters in the lower Colorado River Valley along the Arizona-California border and the nearby Imperial Valley of California (Drewien et al. 1976, Rawlings 1992), whereas the CVP winters in the Central Valley of California (Littlefield and Thompson 1979, Littlefield et al. 1994). A banding and marking program is needed to assess population affiliations for cranes summering in the above described region and

northward along the Idaho-Oregon border to northwestern Montana. Likewise, the seasonal distribution of cranes expanding into summer ranges in central and eastern Montana and Wyoming presumably follows that of the RMP but has not been confirmed by banding. To minimize band losses on long-lived cranes, we recommend that future programs place bands above the tibio-tarsus joint and preferably use stainless steel lock-on bands to more accurately assess longevity.

The sandhill crane, a K-selected species, has the lowest recruitment rate of any avian species hunted in North America, and due to delayed sexual maturity, caution is needed in managing hunted populations (Drewien et al. 1995). In the MCP, older cranes ($\geq$ 8 yrs old) produced most of the young (Tacha et al. 1989) and similar findings were observed in marked RMP cranes where the most productive birds were > 7-8 years old (R. C. Drewien and W. M. Brown, unpublished data). Due to low reproductive characteristics of the RMP, the high degree of philopatry for specific summer areas, and susceptibility of older cranes to shooting mortality, future RMP Management Plans should include strategies to prevent long-term excessive harvest of local breeding flocks at September premigration staging areas.

Limited quota hunts on summer areas are held during September at premigration staging sites to aid in reducing crop depredations. Management should establish objectives for desired long-term crane numbers for individual premigration staging areas with local harvest strategies being modified as warranted. Otherwise, crane numbers at individual staging areas could decline significantly while the overall population is thriving. Monitoring population changes at individual areas can be accomplished with current September premigration staging area counts (Tessman 1997, Sharp et al. 2000). For example, data collected in western Wyoming for September hunts initiated in 1982 in the Salt River (Star) Valley and the Bear River Valley showed mean populations of 793 (range, 611-938) and 1,304 (range 991-1,607) during 1982-84, respectively (Lockman et al 1987:51). September crane numbers for these same valleys during 1995-2000 averaged 479 (range, 254-549) and 716 (range, 596-773), respectively (1995-2000, unpublished annual survey reports filed at Division of Migratory Bird Management, USFWS, Portland, Oregon). These examples illustrate long-term declines of 40.6% and 45.1% since hunts were started in 1982, but the current RMP Management Plan does not provide adequate guidelines to address such changes (Tessman 1997). In contrast, recovery data from winter areas and observations of marked RMP cranes (Drewien and Bizeau 1974) indicated that flocks are of mixed origin with respect to their breeding areas and they mix with other subspecies from the MCP. Thus, hunting on winter areas does not appear to be nearly as selective for cranes from specific summer locations.

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Table 1. Locations and numbers of greater sandhill cranes banded on summer areas in Idaho, Wyoming, Colorado, Utah , and Montana, 1969-94. Number of recoveries are through winter 1999. Cranes were banded by the Idaho Cooperative Wildlife Research Unit and Hornocker Wildlife Institute (n = 1,775), Colorado Division of Wildlife (n = 58), Utah Division of Wildlife Resources (n = 44), and the Wyoming Game and Fish Department (n = 30). [Location numbers in Fig. 1 are in brackets].

Banding location [Fig. 1 loc.]	Adults	Juveniles	Total	n recoveries
MONTANA				
Red Rock Lakes NWR, Beaverhead Co. [1]		32	32	3
Madison Valley, Madison Co. [2]		1	1	1
subtotal		33	33	4
IDAHO				
Grays Lake, Bonneville & Caribou Cos. [3]	173	980	1,153	97
Blackfoot River, Caribou Co. [4]		157	157	17
Bear River Valley, Bear Lake Co. [5]	21	64	85	2
Camas Prairie, Camas Co. [6]		25	25	1
Stanley Basin, Blaine -Custer Cos. [7]		8	8	1
Chilly Slough, Custer Co. [8]		4	4	
Carey area, Blaine Co. [9]		3	3	
Oxford Slough, Franklin Co. [10]		3	3	1
Silver Creek, Blaine Co. [11]		3	3	1
Island Park, Fremont Co. [12]		2	2	
subtotal	194	1,249	1,443	120
WYOMING				
Bear River Valley, Lincoln Co. [13]		158	158	16
Green River Basin, Sublette & Lincoln Cos. [14]	3	88	91	17
Salt River Valley, Lincoln Co. [15]		27	27	8
Wind River Basin, Fremont Co. [16]		11	11	
Yellowstone Natl. Park [17]	1	8	9	2
Sweetwater River, Fremont Co. [18]		6	6	3
Jackson Hole, Teton Co. [19]		3	3	
Hoback Basin, Sublette Co. [20]		2	2	
Little Snake River, Carbon Co. [21]		1	1	
subtotal	4	304	308	46
UTAH				
Great Salt Lake Basin				
Brigham City area, Box Elder Co. [22]	1	17	18	2
Locomotive Springs WMA, Box Elder Co.[23]		1	1	
Ogden area, Davis & Weber Cos. [24]		5	5	1
Bear River Valley, Rich Co. [25]	1	17	18	1
Cache Valley, Cache Co. [26]		13	13	1
Echo & Snyderville, Summit Co. [27]		8	8	1
Desert Lake WMA, Emery Co. [28]		2	2	
subtotal	2	63	65	6

Table 1 (continued)

Banding location [Fig. 1 loc]	Adults	Juveniles	Total	n recoveries
COLORADO				
White River, nr Meeker, Rio Blanco Co [29]		2	2	
Yampa River Basin, Routt & Moffat Cos.				
Elk River, Steamboat Lake State Park and vicinity [31]		25	25	2
Elkhead River, California Park [30]		13	13	1
Little Snake River [32]		4	4	
Yampa River				
Milk Creek [33]		5	5	1
Morgan Bottom [34]		6	6	
Craig [35]		3	3	
subtotal		58	58	4
TOTAL	200	1,707	1,907	180

Table 2. Annual numbers of greater sandhill cranes banded at summer sites in Colorado, Idaho, Montana, Utah, and Wyoming, 1969-94. All cranes banded were flightless young except for small numbers of adults shown in parentheses. Number of recoveries by year class are through winter 1999. Banding programs were conducted by the Idaho Cooperative Wildlife Research Unit and the Hornocker Wildlife Institute (n = 1,775), Colorado Division of Wildlife (n = 58), Utah Division of Wildlife Resources (n = 44), and the Wyoming Game and Fish Department (n = 30).

Year	Colo.	Ida.-Grays L	Ida-other	Mont.	Ut.	Wyo.	Total	No. recoveries
1969		53 (10)	4				57 (10)	3
1970		107 (62)	18	13	3	19	160 (62)	8
1971		21	13				34	3
1972		75 (14)	42 (8)	10	3	17	147 (22)	15
1973		81 (12)	73 (12)	10	3	45	212 (24)	17
1974		48 (19)	25			10	83 (19)	5
1975		6					6	1
1976	3	23					26	3
1977	3	27	5				35	5
1978		83 (14)	4		3	18	108 (14)	11
1979		86 (6)	6		5	13	110 (6)	14
1980		87 (1)	15		3	12	117 (1)	7
1981		97 (8)	26				123 (8)	6
1982		79 (3)	41 (1)		1	54	175 (4)	25
1983		76	19			1	96	9
1984		66				45 (4)	111 (4)	21
1985		49 (3)				26	75 (3)	10
1986		18			12	9	39	3
1987	3	34 (4)			17 (2)	9	63 (6)	8
1988		21 (14)			6		27 (14)	0
1989		6 (3)			6		12 (3)	1
1990	4	3			3		10	0
1991	14	6					20	1
1992	23					2	25	3
1993	5					28	33	1
1994	3						3	0
TOTAL	58	1,152 (173)	291 (21)	33	65 (2)	308 (4)	1,907 (200)	180

Table 3. Greater sandhill crane capture methods on summers areas in Colorado, Idaho, Montana, Utah, and Wyoming, 1969-94.

Method	Adults	Juveniles	Total
Run-down	8	1,142	1,150
Helicopter	9	470	479
Night-lighting	157	93	250
Rocket-net	26	2	28
Total	200	1,707	1,907

Table 4. Number of recoveries, 1969-99, of greater sandhill cranes banded on summer areas in Colorado, Idaho, Montana, Utah, and Wyoming, 1969-94. See Figs. 2 and 3 for recovery locations.

Recovery location	No. recoveries	(%)
SUMMER AREAS		
MONTANA		
Dillon, Beaverhead Co.	1	(0.6)
IDAHO		
Grays Lake, Bonneville & Caribou Cos.	16	
Blackfoot Reservoir-Soda Spr., Caribou Co.	8	
Upper Blackfoot River, Caribou Co.	1	
Bear River Valley, Bear Lake Co.	1	
Crow Creek Caribou Co.	1	
Camas Prairie, Camas Co.	1	
Kilgore, Clark Co.	1	
Oxford Slough, Franklin Co.	1	
subtotal	30	(16.7)
WYOMING		
Bear River Valley, Lincoln Co.	14	
Salt River Valley, Lincoln Co.	14	
Green River Basin,		
Farson, Sweetwater Co.	5	
Pinedale area, Sublette Co.	4	
Big Piney, Sublette Co.	1	
Darby Mtn, Sublette Co.	1	
Hams Fork, Lincoln Co.	1	
Wind River Basin, Fremont Co.	3	
Foster Reservoir, Park Co.	1	
Yellowstone Natl. Park	1	
subtotal	45	(25.0)
UTAH		
Bear River Valley, Rich Co.	1	
Cache Valley, Cache Co.	1	
Plain City, Weber Co.	1	
Snyderville, Summit Co.	1	
subtotal	4	(2.2)
COLORADO		
Steamboat Springs, Routt Co.	1	(0.6)
SPRING - FALL MIGRATION		
UTAH		
Stewart Lake, Uintah Co.	2	(1.1)

Table 4 (continued)

COLORADO		
Harts Basin, Delta Co.	1	
Blue Mesa Reservoir, Gunnison Co.	1	
San Luis Valley		
Alamosa, Conejos, Rio Grande , Saguache Cos.	20	
subtotal	22	(12.2)
NEW MEXICO		
Cimarron, Colfax Co.	2	
Arroyo Hondo, Taos Co.	1	
subtotal	3	(1.7)
WINTER GROUNDS		
NEW MEXICO		
Middle Rio Grande Valley, Bernalillo, Valencia, Socorro Cos.		
Albuquerque - Bosque del Apache NWR	49	
Lower Rio Grande Valley		
Elephant Butte Reservoir, Sierra Co.	1	
Caballo Reservoir, Sierra Co.	2	
Percha Dam-Arrey area, Sierra Co.	2	
Rincon, Doña Ana Co.	1	
Mesquite, Doña Ana Co.	1	
Pecos Valley		
Santa Rosa, Guadalupe Co.	1	
Ft. Sumner, DeBaca Co.	1	
subtotal	58	(32.2)
ARIZONA		
Willcox Playa, Cochise Co.	2	(1.1)
CHIHUAHUA, MEXICO		
Ascension Valley	4	
Galeana, Rio Santa Maria	1	
Laguna de Encinillas	1	
Laguna de Babicora	2	
Laguna de los Mexicanos	1	
Lago Toronto	1	
Unknown location	1	
DURANGO, MEXICO		
Cienagas de Malaga	1	
subtotal	12	(6.7)
TOTAL	180	(100.1)

Table 5. Age distribution of 180 recoveries during 1969-99 of greater sandhill cranes (ad = 12/200, juv = 168/1,707) banded during summers 1969-94 in Colorado, Idaho, Montana, Utah, and Wyoming.

Age (yrs)	Juvenile	Adult	Total
<1	40	1	41
1	20	3	23
2	11	2	13
3	10		10
4	5		5
5	5	2	7
6	6	1	7
7	12		12
8	10		10
9	6	1	7
10	7		7
11	8		8
12	7		7
13	4		4
14	4	1	5
15	1		1
16	2	1	3
17	1		1
18	2		2
19	2		2
20			
21	1		1
22	1		1
23	1		1
24	1		1
29	1		1
Total	168	12	180

Table 6. Longevity records of the 5 oldest Rocky Mountain greater sandhill cranes banded as flightless young and recovered during 1969-99.

Crane Ident.	Banding			Recovery			
	Location	Date	Est. age (days)[a]	Location	Date	Age (yr. mo)	Mortality factor
1.	Grays Lake, Ida.	24 Jul 70	55-58	Soda Springs., Ida.	9 Sept 99	29.3	shot
2.	Grays Lake, Ida.	11 Aug 73	63-65	Laguna de Babicora, Chihuahua, Mex.	4 Jan 98	24.7	shot
3.	Grays Lake, Ida.	29 Jul 69	65-67	San Antonio, N. M.	13 Dec 93	24.6	shot
4.	Grays Lake, Ida.	24 Jul 73	50-52	Grays Lake, Ida.	1 Sept 96	23.3	wire fence
5.	Daniel, Wyo.	20 Jul 72	48-50	San Antonio, N.M.	3 Dec 93	21.6	shot

[a] Estimated age in days at banding based upon morphometric measurements (R. C. Drewien unpublished data).

Table 7. Origin and distribution of recoveries, 1969-99, of greater sandhill cranes banded in 5 Rocky Mountain states, summers 1969-94.

Recovery state	Banding state						Total	%
	Mont.	Ida.-Grays Lake	Ida.-other	Wyo.	Ut.	Colo.		
Mont.	1						1	0.6
Ida.-Grays Lake		16					16	8.9
Ida.-Other		10	4				14	7.8
Wyo.		14	4	26	1		45	25.0
Ut.		2		1	3		6	3.3
Colo.		15	4	2		2	23	12.8
N. M.	2	33	7	15	2	2	61	33.9
Ariz.		1	1				2	1.1
Chih., Mex.	1	5	3	2			11	6.1
Dgo., Mex.		1					1	0.6
Total recoveries	4	97	23	46	6	4	180	100.1
Total banded	33	1,153	290	308	65	58	1,907	
% recovered	12.1	8.4	7.9	14.9	9.2	6.9	9.4	

Table 8. Causes of mortality of banded greater sandhill cranes of the Rocky Mountain Population recovered throughout their seasonal range, 1969-99. Cranes were banded on summer areas in Colorado, Idaho, Montana, Utah, and Wyoming during 1969-94.

Mortality factor	Mont.	Ida.-Grays Lake	Ida.-other	Wyo.	Ut.	Colo.	N. M.	Ariz.	Mex.[a]	Total	%
Hunting		2	3	30	2		48	2	10	97	53.9
Illegally shot (no season)		1	3		1		1			6	3.3
Unknown (found dead)	1	2	7	12	2	10	9		1	44	24.4
Power line collision		1	1	1	1	5	1			10	5.6
Fence collision/entanglement		4		2		2				8	4.4
Avian cholera						4				4	2.2
Scientific collecting		1				1				2	1.1
Killed by golden eagle		2								2	1.1
Other										7	3.9
Caught in trap									1	(1)	
Killed by coyote		1								(1)	
Killed by whooping crane		1								(1)	
Carcass at red fox den		1								(1)	
Starved - bill caught in shot shell wad						1				(1)	
Killed by rocket-net, goose trapping							1			(1)	
Collision with building (euthanized)							1			(1)	
Total	1	16	14	45	6	23	61	2	12	180	
%	0.6	8.9	7.8	25.0	3.3	12.8	33.9	1.1	6.7	100.1	99.9

[a] Includes states of Chihuahua (n=11) and Durango (n=1).

Table 9. Changes in mortality factors with age of greater sandhill cranes banded in the Rocky Mountain Population, 1969-94, and assessed from recoveries during 1969-99 (n = 180) and 1982-94 (n =115). Relative mortality risk from shooting versus non-shooting was compared for 1982-94 by 3 age classes (<1, 1-2, > 3 yrs) when hunting started in Rocky Mountain States and expanded to 6 states by 1996. Hunting in northern Mexico was ongoing during 1969-99.

Recovery age (yr)	Mortality factors			
	shooting[a]		nonshooting-unknown	
	1969-99 (%)	1982-94 (%)	1969-99 (%)	1982-94 (%)
< 1	10 (24.4)	6 (27.3)	31 (75.6)	16 (72.7)
1-2	17 (47.2)	11 (55.0)	19 (52.8)	9 (45.0)
3-5	14 (63.6)	11 (73.3)	8 (36.4)	4 (26.7)
6-10	32 (74.4)	25 (73.5)	11 (25.6)	9 (26.5)
11-15	20 (80.0)	20 (83.3)	5 (20.0)	4 (16.7)
16-29	12 (92.3)		1 (7.7)	
Total	105	73	75	42

[a] Shooting mortality (hunting n = 97, illegally shot/no season n = 6, scientific collecting n = 2)

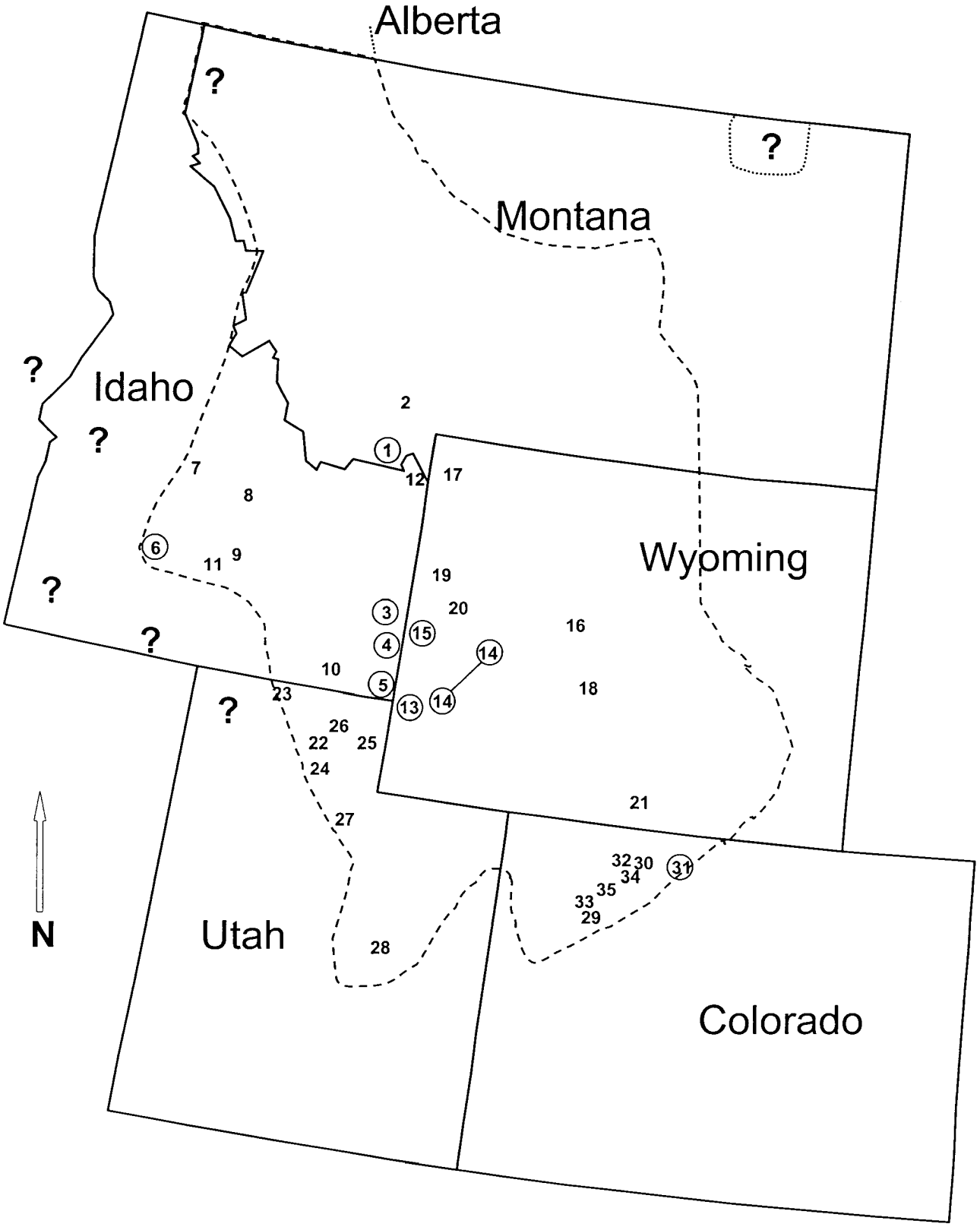

Fig. 1. Summer banding locations for the Rocky Mountain Population of Greater Sandhill Cranes (RMP), 1969-94. Locations where ≥ 25 cranes were banded are circled. See Table 1 for location names and number of banded cranes. Summer distribution of RMP shown for 1990s (adapted from Drewien and Bizeau 1974, Semenchuk 1992, Montana Bird Distribution Committee 1996, Barrett 1998) including areas where population affiliations are uncertain (?).

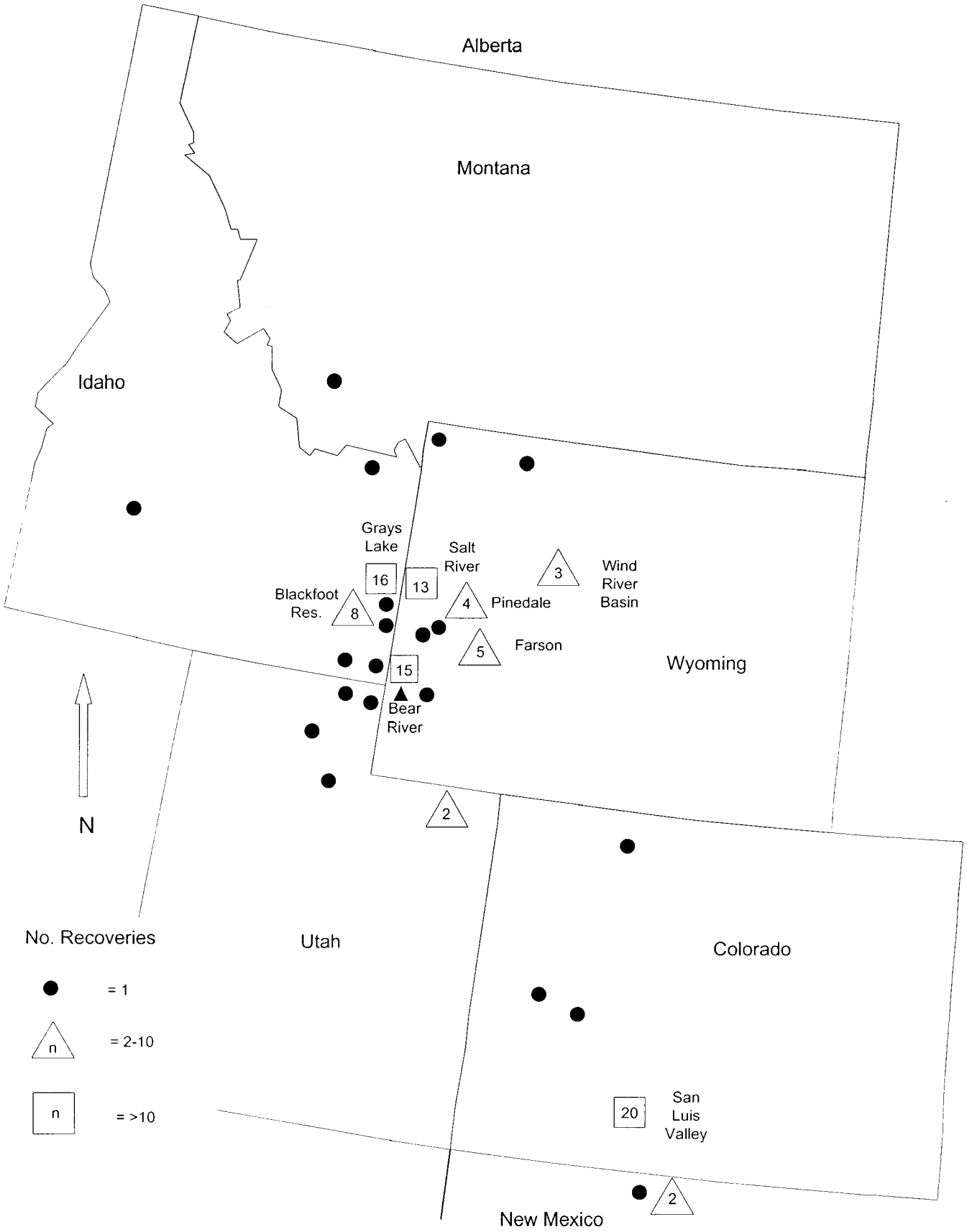

Fig. 2. Recoveries from summer areas (n=81) and the spring-fall migration route (n=27), 1969-99, of Rocky Mountain Greater Sandhill Cranes banded during summers 1969-94 in Colorado, Idaho, Montana, Utah and Wyoming.

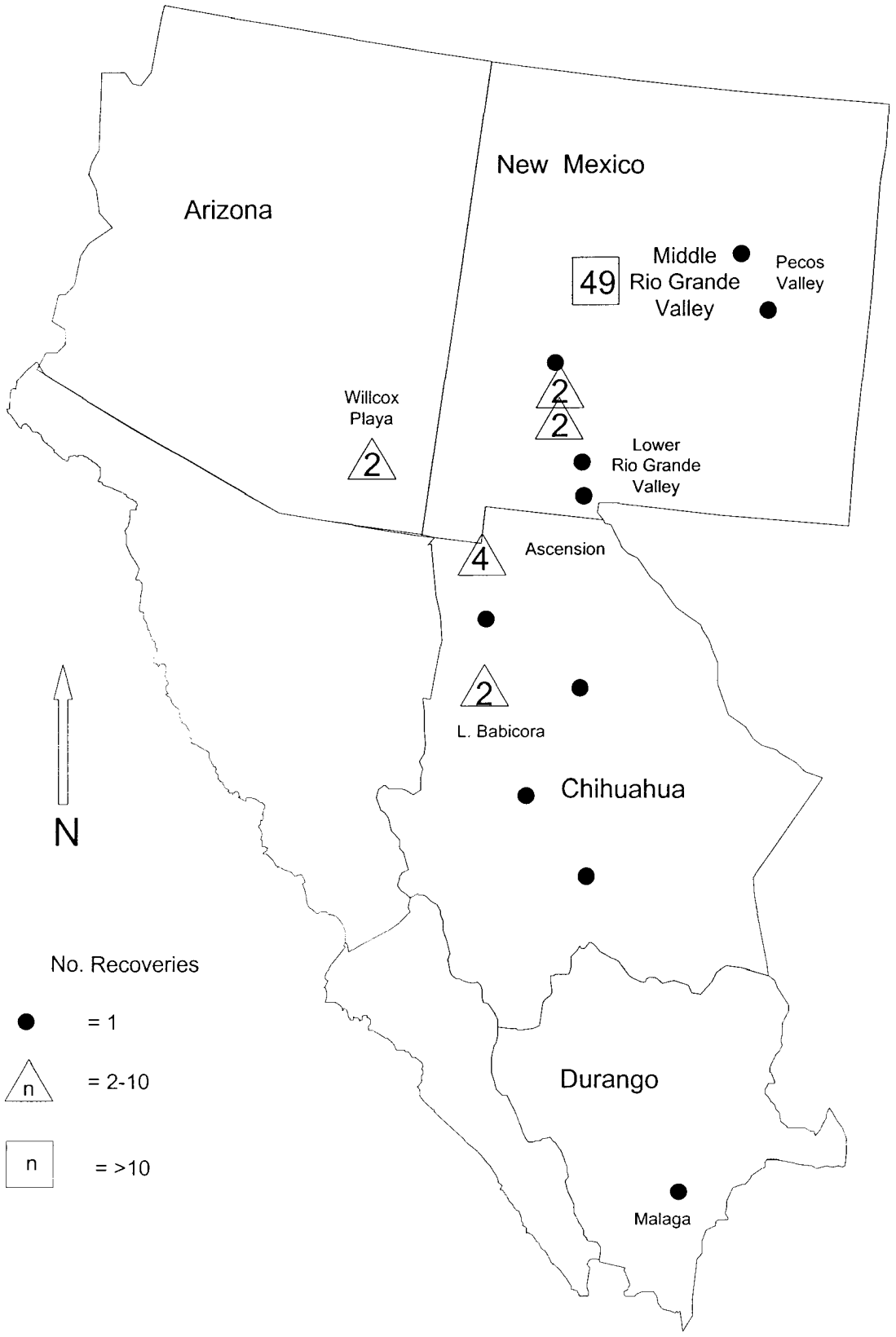

Fig. 3. Recoveries (n=72) from winter areas, 1969-99, of Rocky Mountain Greater Sandhill Cranes banded during summers 1969-94 in Colorado, Idaho, Montana, Utah, and Wyoming. One recovery from an unknown location in Chihuahua is not shown.

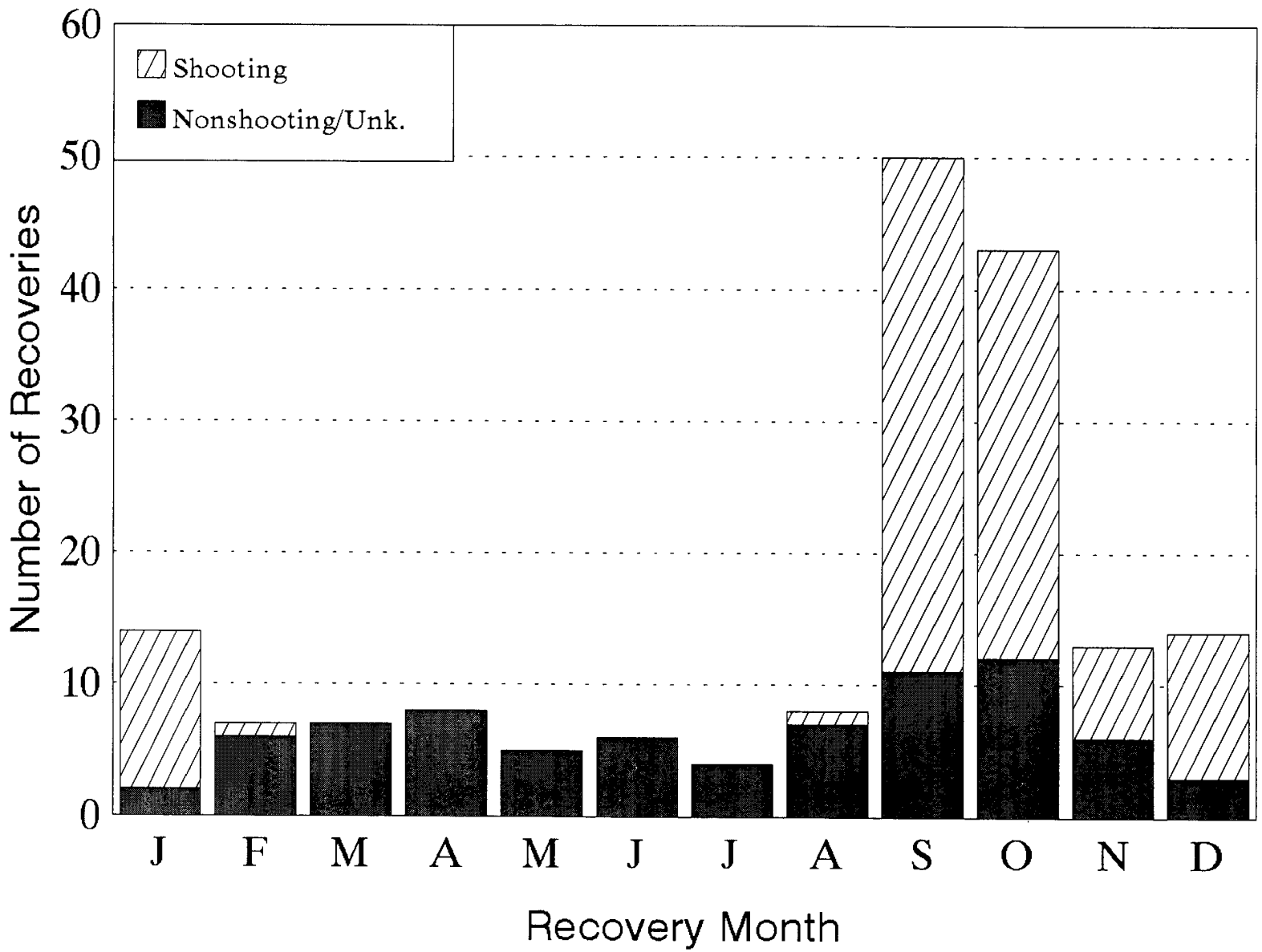

Fig. 4. Monthly distribution of recoveries (n=179) and causes of mortality of greater sandhill cranes of the Rocky Mountain Population, 1969-99.