Bald eagles of the San Luis Valley, Colorado : their winter ecology and spring migration
by Alan Robert Harmata

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Biological Sciences
Montana State University

Abstract:
Approximately 100-300 bald eagles (Haliaeetus leucocephalus) winter in the San Luis Valley (SLV) of southcentral Colorado. Between January and mid-March 1980-1981, bald eagles were captured, measured, and plumage described. An aging protocol based on plumage, iris, and mandible coloration was developed. A sexing technique was developed based on 4 measurements. Morphological differences were related to resource partitioning between age classes and sexes and also migration differences between sexes of adults. Fifteen adult bald eagles were marked with tail-mounted transmitters to study winter ecology. Over 1300 hours of monitoring showed mean seasonal home range size was 310.7 km^2 . Single day movements typically covered only a small portion of the home range. Mean daily activity was 15.5% of daylight hours and monthly activity was negatively correlated with severe weather. Human activity within 150 m of an eagle perched in a tree or 760 m of an eagle on the ground usually elicited a flush response. Perch trees were usually near irrigation ditches surrounded by agricultural land. Foraging habitat consisted of areas of brushland/cropland interspersion. Habitat use shifted from upland to riparian areas as ice-out on rivers progressed. Roost site suitability appeared dependent on distance from human activity while roost site preference seemed dependent on proximity to food. Primary food was jackrabbit (Lepus spp.) throughout the winter but varying proportions of fish and waterfowl occurred dependent on availability. Use of the SLV by wintering bald eagles is probably relatively recent and coincident with agriculture. Advancing monoculture will probably result in fewer eagles using the SLV in the future. Age ratios in wintering areas are most likely a reflection of food availability and type rather than indicative of population trends. Six eagles were tracked on spring migration. Two eagles were followed to a nesting ground and 2 others found in their summering area, all in northeastern Saskatchewan. Migration routes and wintering areas of adult bald eagles appear to be related to the watershed in which summering grounds are located.

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MONTANA STATE UNIVERSITY
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April 1984

APPROVAL

of a thesis submitted by

Alan Robert Harmata

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date 04-12-84

Recently arrived from her wintering ground in the San Luis Valley, Colorado, an adult bald eagle vocalizes from a perch near her nest in northeastern Saskatchewan.

For the 57,939 who never got the chance...

VITA

Alan Robert Harmata was born 2 June 1945 in Passaic, New Jersey to Howard John and Mabel Beatrice Harmata. He graduated from Rutherford High School, Rutherford, New Jersey in June 1963. He attended Nichols College in Dudley, Massachusetts from September 1963 to June 1964 and subsequently worked in the construction trades. On 26 February 1966 he was inducted into the U.S. Army and served in the infantry with the 1st Bn. 5th Cav, 1st Air Cav Div. in the Republic of Vietnam. He was retired from the U.S. Army on 6 February 1968 due to "disabling" wounds received in action. In September 1969 he enrolled in Fairleigh Dickenson University, Teaneck, New Jersey, transferring to the University of Illinois, Champaign in September 1970 and received a Bachelor of Science degree in Biology in June 1972. He began graduate study in wildlife during January 1973 at Colorado State University, Ft. Collins, and completed required coursework by June 1974. After working in the wildlife consulting field and for the National Audubon Society for several years, he received a Master of Science degree in wildlife biology from Colorado State University in December 1977. He began studies for a Doctor of Philosophy degree in Fish and Wildlife Management at Montana State University in March 1979. He has a daughter, Caryn Jeanne (age 13) and a son, Peter John (age 10) and is sharing life with Elizabeth Bowman Spettigue of Duluth, Minnesota.

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ABSTRACT

Approximately 100-300 bald eagles (Haliaeetus leucocephalus) winter in the San Luis Valley (SLV) of southcentral Colorado. Between January and mid-March 1980-1981, bald eagles were captured, measured, and plumage described. An aging protocol based on plumage, iris, and mandible coloration was developed. A sexing technique was developed based on 4 measurements. Morphological differences were related to resource partitioning between age classes and sexes and also migration differences between sexes of adults. Fifteen adult bald eagles were marked with tail-mounted transmitters to study winter ecology. Over 1300 hours of monitoring showed mean seasonal home range size was 310.7 km^2. Single day movements typically covered only a small portion of the home range. Mean daily activity was 15.5% of daylight hours and monthly activity was negatively correlated with severe weather. Human activity within 150 m of an eagle perched in a tree or 760 m of an eagle on the ground usually elicited a flush response. Perch trees were usually near irrigation ditches surrounded by agricultural land. Foraging habitat consisted of areas of brushland/cropland interspersion. Habitat use shifted from upland to riparian areas as ice-out on rivers progressed. Roost site suitability appeared dependent on distance from human activity while roost site preference seemed dependent on proximity to food. Primary food was jackrabbit (Lepus spp.) throughout the winter but varying proportions of fish and waterfowl occurred dependent on availability. Use of the SLV by wintering bald eagles is probably relatively recent and coincident with agriculture. Advancing monoculture will probably result in fewer eagles using the SLV in the future. Age ratios in wintering areas are most likely a reflection of food availability and type rather than indicative of population trends. Six eagles were tracked on spring migration. Two eagles were followed to a nesting ground and 2 others found in their summering area, all in northeastern Saskatchewan. Migration routes and wintering areas of adult bald eagles appear to be related to the watershed in which summering grounds are located.

INTRODUCTION

Considerable public and professional attention has been focused on the bald eagle (Haliaeetus leucocephalus) since the late 1960's, when DDT and its metabolites were associated with poor reproduction and drastic decreases in numbers (Krantz et al. 1970, Wiemeyer et al. 1972). Investigations also revealed that severe losses of winter and summer habitat were contributing to the decline of this species. As a result, in 1978 the bald eagle was classified as endangered (threatened for Alaska, Michigan, Minnesota, Oregon, Washington) in the entire contiguous United States (U.S. Code of Federal Regulations: 43; 6233, 14 February 1978). Implicit in this classification is the need for more complete knowledge of the species and its habitat requirements to insure its survival.

The importance of winter habitat to populations of other avian species has been shown (Eng and Schladweiler 1972, Fredrikson and Drobney 1979). The quantity and quality of winter habitat available may determine the number of migrant birds returning to the summering grounds in breeding condition (Chadbreck 1979). With the reduction of DDT use, winter habitat may become a more critical factor in maintaining future populations of bald eagles. Each year, approximately 3,000-4,000 bald eagles winter in the Rocky Mountain region of the U.S. (Spencer 1976, National Wildlife Federation winter count 1982). Fewer than 110 pairs are known to breed in this region and the majority of wintering birds are presumed to summer in central and northern Canada. This implies that certain habitats in the lower 48 states are essential to the maintenance of a large percentage of the existing continental population.

Few data are available concerning specific aspects of this bird's winter ecology. Home range size, habitat selection and use, food habit variability, age/sex composition of the population, individual fidelity to wintering areas, roost site choice, and intra- and inter-specific competition are all aspects of the biology of bald eagles that are poorly understood. A better understanding of these factors will be of great value in development of management plans.

Bald eagles wintering in the U.S. seem to be associated with 2 main types of habitat. Some appear to be primarily associated with riparian habitats such as the Mississippi and Missouri River Systems relying heavily on fish and/or waterfowl as food (Fawks 1961, Steenhof et al. 1980, Fisher et al. 1981). In contrast, in southern Colorado (Harmata and Stahlecker 1977), central Utah (Edwards 1969) and eastern Montana (Swenson et al. 1981), eagles are associated with upland habitats characterized by prairie grassland, agricultural valleys, and mountain parks and appear to rely heavily on ungulate carrion and lagomorphs which they kill or take as carrion (Harmata and Stahlecker 1977).

Habitat used by eagles during migration is equally as important as winter and summer habitat. Certain aspects of bald eagle migration have been largely ignored due primarily to the lack of developed techniques and logistical problems. Nestling bald eagles banded and marked in northcentral Saskatchewan have been recovered or seen in Arizona, New Mexico, Utah, Wyoming, Colorado, and Montana (Gerrard et al. 1978). However, no information is available as to the exact origin of adult eagles wintering in these states. Immatures of several raptor species have been shown to wander considerably prior to selecting a breeding site (Brown 1977, Newton 1979). Thus, the breeding grounds of adult bald eagles wintering in the Rocky Mountains may be entirely different from those indicated by movements of immatures.

From January through March 1977 and 1978, 36 bald eagles were colormarked with yellow patagial wing markers in the San Luis Valley (SLV) of southern Colorado (Harmata and Stahlecker 1977). Although significant data concerning wintering ground fidelity, distribution, sexing and capture techniques, and aging by plumage were gathered, the primary objectives of determining winter home ranges, migration routes, and summering grounds were not realized by the marking program. This was due partially to difficulty of maintaining extended observation of colormarked eagles and researchers in other areas of the west also using yellow patagials. The origin of yellow-marked eagles subsequently sighted outside of the SLV was therefore questionable since the marker letter was usually not recorded. Only 3 sightings outside the SLV were of confirmed origin and none were in an established nesting area or during summer.

In 1978, radio-tracking colormarked individuals provided more unique information, but inadequate funding and manpower problems prevented complete description of home ranges and ecology of wintering eagles. However, 1 adult female eagle that was radio-tagged left the SLV on 28 February 1978 and was subsequently tracked for 2 days and over 300 km of her northward migration. This effort established the feasibility of an expanded project designed to determine breeding areas and migration routes of the population.

Between 1 January and 30 April 1980 and 1981, research was conducted on bald eagles in the SLV. Objectives of this study were to: (1) document the ecology of adult bald eagles wintering in an upland area in Colorado and to describe habitats used within that area, (2) determine the exact breeding grounds of adult bald eagles from a distinct wintering population in the Rocky Mountain region, and (3) gather information regarding migration routes, duration, stopover habitats used, and other factors affecting the successful completion of migration. Information concerning ecology and movements obtained during this period was further supported by sightings and encounters of eagles banded and marked in 1977 and 1978 and reported between January 1977 and February 1983.

STUDY AREA

Geography and Hydrology

The San Luis Valley (Fig. 1) located in southcentral Colorado is the largest of 4 large intermountain basins in Colorado. The periphery of the valley floor is approximately 2,440 meters (m) above MSL and at its longest and widest extent is about 161 and 130 kilometers (km), respectively. The SLV encompasses approximately 6,475 km^2, approximately the size of the state of Delaware. It is bounded on the west by the San Juan Mountains and on the east by the Sangre de Cristo Range. These 2 ranges meet at the northern end of the valley and exceed 3,050 m in elevation. Nine peaks over 4,250 m are visible from the central valley. Mean elevation of the nearly level valley is 2,286 m.

The SLV is geologically young and is an intermountain basin filled with alluvium, volcanic debris, and tuffs of Oligocene to Holocene origin (Larsen and Cross 1956). Most of the area was occupied by an extensive lake in the early Pleistocene. Many peripheral streams flowing from the surrounding mountains filled the valley with deposits of up to 910 m deep (Gaca and Karig 1966). This left the valley floor level after the lake outlet at the south end became so deep that the lake was drained (Ramaley 1942).

Two major rivers now flow through the SLV. The Rio Grande emanates in the San Juan Mountains to the west, enters about mid-valley, and

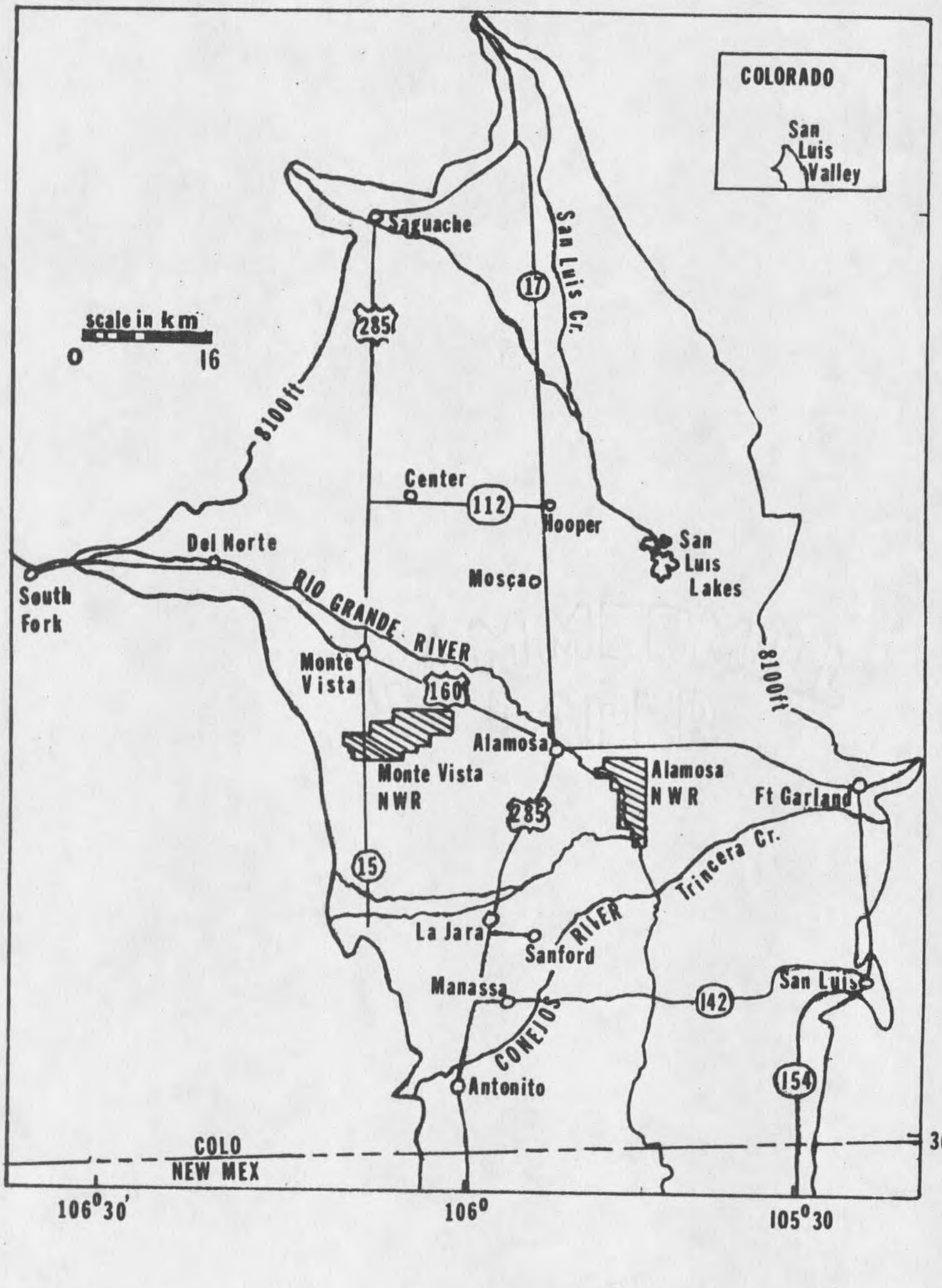

Figure 1. Locator and political map of the San Luis Valley, CO.

flows generally east then south. The Conejos River also begins in the San Juans but enters the valley farther south and flows northeast to the confluence with the Rio Grande River (Fig. 1). The total annual water supply to the SLV averages 2.5 million acre-feet. About 60% is streamflow, collected from about 12,200 km^2 of surrounding mountain watershed. Precipitation on the valley floor contributes the remainder (Emery 1972). About 80% of the annual water supply is lost primarily through evapotranspiration of phreatophytes such as greasewood (Sarcobatus spp.) rabbitbrush (Chrysothamus spp.), and salt grass (Distichlis spp.) (Emery 1972).

Ground water is derived from unconfined and confined aquifers. The depth to water in the early 1970's averaged less than 3.6 m and the unconfined aquifer extended from 0 to 60 m below the surface. Recharge to the unconfined aquifer comes primarily from infiltration of peripheral streams, leakage from ditches and canals, applied irrigation water, and seepage from the confined aquifer. All streams flowing into the northern half of the valley are emptied by percolation into beds of sand at the edge of the valley floor (Fenneman 1931) where a deeper clay layer is absent. Water drains towards the valley center and is trapped under the layer of clay recharging the confined aquifer. The only outlet is through artesian wells (Hopper et al. 1975). Between 1910 and the 1970's irrigation water from the major rivers raised the level of the unconfined aquifer between 1 and 2.5 m (Ramaley 1942, Dillon 1981). There is a daily fluctuation in the water table of between 2.5 and 20 centimeters (cm), reaching its lowest stage at 1800 to 1900 hours (hrs) MDT then rising until 0900. The amount and timing of the fluctuation presumably depends on evapotranspiration of plants and evaporation from the soil.

Climate

Classified as cold desert (Lantis 1949) the SLV has cool dry summers and cold winters. Mean annual temperature is 5.5 centigrade (C). Nighttime temperatures in January commonly reach -30 C and occasionally lower than -45 C. Precipitation averages less than 30 cm per year and is lowest in the central valley (Ramaley 1942). Snow depths seldom exceed 15 cm, with average annual snowfall about 63.5 cm (Colorado State Planning Division 1964). Humidity is low, and evaporation high. Ramaley (1942) reported a summer average humidity of 41% and an average per annum evaporation of 126.8 cm, the highest of all Colorado recording stations. Winds prevail from the southwest and are strongest in late March and early April, when entire days with 40 km per hour (km/hr) winds are common. Sunny weather predominates and seldom are there more than 5 days per month with cloud cover of 75% or more.

Vegetation

The valley floor is approximately 70% brushland. The vegetation of the northern valley, with a high water table and alkaline soils is primarily black greasewood (*Sarcobatus vermiculatus*) also known as chico, and inland saltgrass (*Distichlis stricta*). In the southern valley, with a lower water table rabbitbrush (*Chrysothamnus* spp.) predominates (Costello 1954). Big sagebrush (*Artemisia tridentata*) is common on well drained margins of the peripheral valley.

Artesian wells and high water table have created many wetlands. Vegetation in natural lakes, ponds, marshes, and wet meadows consists primarily of spike sedge (*Eleocharis* spp.), baltic rush (*Juncus balticus*), and sedges [*Carex* spp., (Hopper et al. 1975)].

River bottom forest/shrub communities consist mostly of cottonwood (*Populus angustifolia*) and willows (*Salix* spp.), with rabbitbrush, roses (*Rosa* spp.), currants and gooseberries (*Ribes* spp.). Common grasses include wheatgrass (*Agropyron* spp.), blue grama (*Bouteloua gracilis*), smooth brome (*Bromus inermis*), muhly (*Muhlenbergia* spp.), bluegrass (*Poa* spp.), and dropseed (*Sporobolus* spp.). In more mesic riparian areas, *Smilacina* spp. and meadow rue (*Thalictrum* spp.) are common.

Human History and Ecology

The Folsom points which many SLV residents own are mute testimony that humans inhabited the valley more than 10,000 years ago. Folsom culture is thought to have come to the SLV via the eastern plains, as nomadic hunters wandered down the front range of the Rocky Mountains and into the valley in pursuit of game (Roberts 1948).

On 8 September 1598, Don Juan de Oñate of Spain and governor of New Mexico, established the first permanent European settlements in the New World after St. Augustine. These settlements were on the southern tip of the SLV in present day New Mexico (Simmons 1980). The first European to set foot in Colorado was actually Juan de Archuleta in 1664. He entered the SLV while chasing runaway Indian slaves from Taos (Hafen 1948).

By 1807 when the first Americans entered the SLV, a road on the eastern side of the valley was "well worn" (Jackson 1966). This road was used by the Spanish as a supply route from Taos to forts just east of the Sangre de Cristos on the Arkansas and Huerfano Rivers.

Thomas Jefferson charged Lt. Zebulon Montgomery Pike to explore the Louisiana Territory, and on 28 January 1807 Pike entered the SLV from the east. He spent most of the winter along the Conejos River. Other surveys entered the SLV in the mid 1800's to map railroad routes and document geography and natural history. The Hayden Survey looked for a railroad route and documented natural history in 1873 and 1874 (Toll 1929). The Wheeler Survey was the first to map the SLV in June 1875 (Bartlett 1962).

Today the SLV supports a population of over 36,000 people, most of whom live in 3 central valley counties: Alamosa, Rio Grande, and Conejos. Major population centers are Alamosa, Monte Vista, Center, Del Norte, and LaJara (Fig. 1). The remaining population is somewhat evenly distributed throughout the remaining 2 counties of Sagauche and Costilla. The economy is based on irrigated crop production and commercial livestock enterprise. The SLV is noted for its potato industry and the production of high quality barley, the latter used primarily for ingredients in Coors beer. Approximately 25% of the valley (128,600 hectares) is cultivated (Dillon 1981). Crops in descending order of planted hectares (ha) are: alfalfa, barley, grass hay, potatoes, spring wheat, and oats. Sheep operations seem to outnumber cattle ranches, especially in the central valley.

Flood and subirrigation were the primary means of irrigation prior to the late 1960's. Water for irrigation was derived at the time from the major rivers (Rio Grande and Conejos) and mountain streams (Alamosa, Saguache, Trinchera, and LaJara creeks) in addition to existing artesian and shallow wells. Many large canals were built between 1880-90 to irrigate the eastern and central part of the valley and many new cottonwood stands were established as a result. Intensive irrigation early in the century artificially raised the water table rendering originally valuable cropland useless by 1920. The water-soaked condition of previously tillable land increased the soil salinity and some soils now have a pH of 9.0. These areas, long since left fallow have returned or are returning to their native condition of greasewood, rabbitbrush, native grasses, and herbs (Ramaley 1942).

Since 1975 the use of center pivot irrigation systems has proliferated. These systems are much more efficient than flood irrigation often increasing yields by 120%. Center pivots require flat unobstructed fields, averaging 0.6 km^2 but often as large as 2.59 km^2. These systems do not normally utilize ditch or river water, but well water derived from artesian or drilled wells. Consequently, the number of large capacity wells (>1300 liters per minute) has increased dramatically since 1975, depleting the water resource in the shallow (unconfined) aquifer. Wetlands which existed prior to the arrival of European man in the SLV are drying up because the aquifer is not being recharged. As of January 1982, 1,724 center pivots were operational in the SLV (Fig. 2) and the number increases an estimated 10% per year. A moritorium on new wells has been imposed in some areas of the valley.

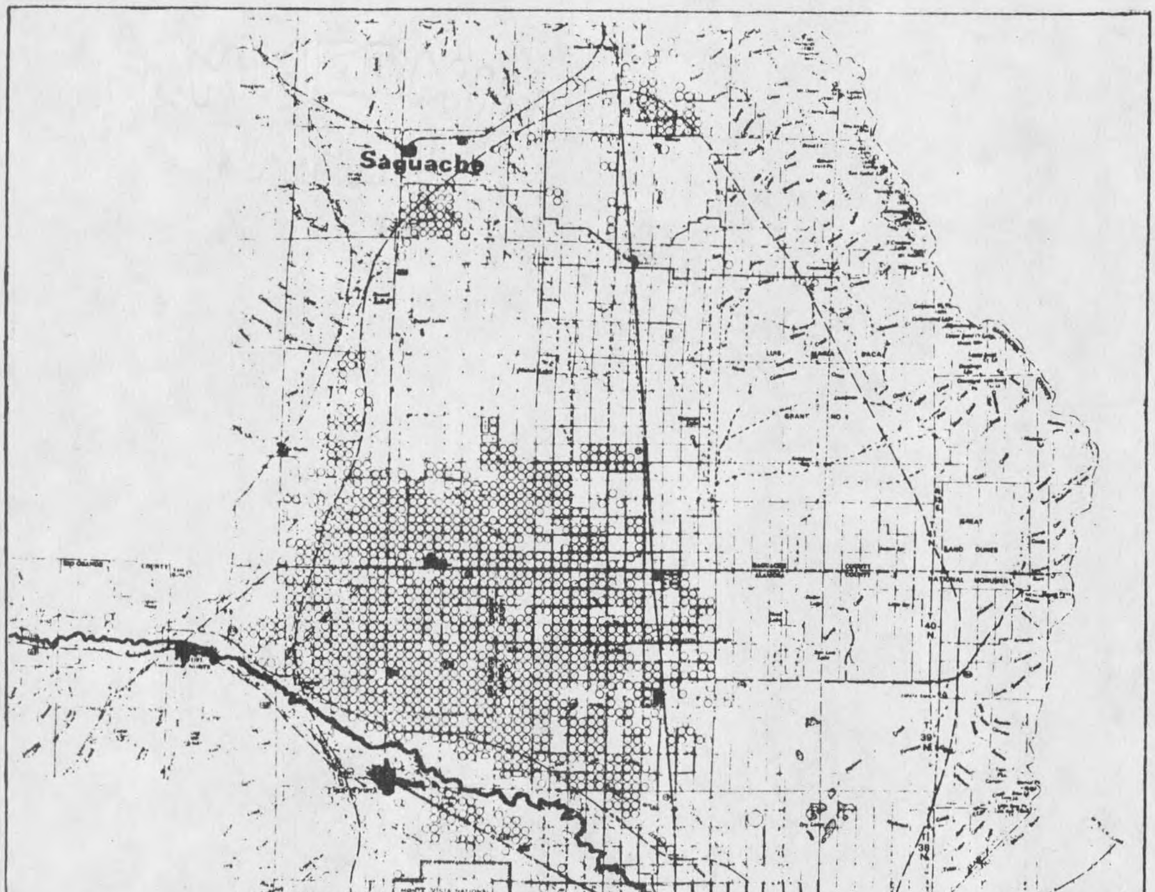

Figure 2. Distribution of 1,724 center pivot irrigation systems as of January 1982. (Courtesy Colorado State University Cooperative Extension Service, Alamosa, CO)

The proliferation of these systems also has changed the face of the valley dramatically. Cottonwood stands throughout the valley are being lost at an alarming rate and the amount of brushland is being reduced. Trees along unused irrigation ditches and now dry stream beds are dying or have died and disappeared, due to lack of water. Other trees and stands have been and are being removed to clear a path for new center pivots. Herbicide and pesticide use is increasing coincident with an advancing monoculture.

Historical Use by Bald Eagles

The earliest documented sighting of a bald eagle in Colorado was on 29 July 1839 in Grand County about 200 km north of the SLV (Marsh 1931). First mention of wintering bald eagles in Colorado concerned sightings on the eastern plains (Cooke 1897). Spanish expeditions to the SLV in the 17th and early 18th centuries and American expeditions in the 19th century made reference to wildlife in the SLV but none mentioned eagles. References by Spanish (Thomas 1932) and American expeditions (Sanford 1933, Jackson 1966) to abundance of fish and waterfowl indicate a food base capable of supporting eagles was present.

Earliest records of bald eagles in the SLV were made by Ryder on 7 April 1949 and Armagest on 19 February 1950 (Ryder 1965). By 1955 bald eagles often were seen in winter and commonly recorded at the Monte Vista and Alamosa National Wildlife Refuges (Ryder 1965, Alamosa NWR narratives 1954-1983). Each winter from 1976 to 1979, personnel from the U. S. Fish and Wildlife Service (USFWS), the National Audubon Society (NAS), and the Colorado Division of Wildlife (CDW) conducted an aerial survey of the SLV for eagles. Random north-south transects were flown over a 10% portion of the valley in January. Bald eagle winter population estimates of 280, 180, 150 and 130 were calculated for the entire valley during 1976-1979 respectively (Craig 1981).

METHODS

Capture

All bald eagles were captured by a modified "Lockhart" method (Miner 1975) which Harmata and Stahlecker (1977) found more successful than cannon nets and bownets. This method, originally developed for capture of golden eagles (Aquila chrysaetos), utilizes leg-hold traps placed around a small animal carcass with a live lure eagle placed nearby. The presence of the live lure also deters non-target birds and mammals from the bait.

Double long spring leg-hold traps, #3 or #3N, were used exclusively. Number 3N traps were preferred since stake down chains are more substantial and less likely to become entangled in the environment and jaws are offset. Each trap was padded with 2x20 cm strips of latigo leather wrapped barber-pole style around each jaw. The leather was secured with vinyl electrical tape, wrapped in a similar manner. Soft padding material such as foam rubber was not used since it allowed an eagle caught by only the talons to escape. Jump traps were not used because these traps grasp the eagle around the leg (tarsus) when sprung. Catching an eagle by the toe is preferable and less injurious. Lockhart (pers. comm.) also found jump traps less efficient for capturing golden eagles. The stake-down chains of 2 traps were wired together to form pairs. Trap springs were not weakened, but new traps were not used. Springs of new traps are substantially stronger than well used traps and are potentially dangerous to eagles.

A pad of 7.6 cm thick fiberglass building insulation was cut to fit under the trigger pan and between the jaws. The pad insured that soil would not fill in under the pan and impede release of the jaws when triggered. Insulation was used rather than traditional pancovers because it saved time in trap placement and allowed for differential trigger pressures. Common ravens (Corvus corax) and black-billed magpies (Pica pica) often are attracted to carcass baits and may walk over the traps many times, gradually depressing the pan and eventually setting off traps equipped with traditional pan covers. Insulation provided sufficient resistance and resilience to return the pan trigger to a pre-set position each time a bird lighter than a raptor depressed it, reducing captures of non-target birds.

Trapping operations during 1977 and 1978 were designed to capture as many bald eagles as possible, regardless of age. In 1980 and 1981 efforts were directed at capturing only adult mated bald eagles. Observations during 1977-78 indicated that a portion of the SLV eagles wintered as mated pairs. Often 2 eagles remained separated from others during the day and were thought not to go to communal roosts at night. Other pairs using communal roosts apparently foraged together during the day but were seldom in association with other eagles.

Trap sites were chosen after at least 1 week of observation each year. Observations revealed specific trees or groves of trees frequented by pairs of bald eagles in the study area. Since sexual dimorphism in bald eagles is manifested in size differences, trap sites were subjectively chosen on the basis of frequency and duration of the presence of 2 adult bald eagles of distinctly dissimilar size.

Most trap sites were in areas unused by livestock and on small mounds that could be observed at least 1 km away. Trap sites were no closer than 50 m from fences or irrigation ditches and as far as possible from shrubs.

In 1981, after 4 adult eagles presumed to be mated and from 4 different pairs were captured, trap sites were placed in areas where eagles congregated, but emphasis remained on capture of adult bald eagles. Less emphasis was placed on capture of mated eagles because time expended on determining trap sites detracted from time spent monitoring previously captured eagles. No trap site was within 3 km of a known roost site.

The wariness of adult bald eagles dictated that all traps be set in darkness. Sets were usually made in the evening between 1700 and 0000 hrs for trapping eagles the following day. Trap setting at this time insured that eagles were either at communal roosts out of sight or were unable to associate bait carcasses with humans. Because wind greatly increased the lift capacity of an eagle, no sets were left operational in winds over 20 km/hr.

Previous trapping operations in the SLV (1977-78) indicated that golden eagle lure birds often discouraged extremely wary adult bald eagles from visiting a bait. Therefore, trap sets without lure birds were used most often. However, an immature bald eagle or an immature golden eagle also were used to determine the best lure for attracting and capturing immature and adult eagles of either species. The lure birds were transported in a large wooden box designed and built specifically for that purpose. At trap sets where lure birds were used, sets were made just prior to sunrise or during early morning to reduce the possibility of lure birds being injured or harrassed by great horned owls (Bubo virginianus), coyotes (Canis latrans), bobcats (Lynx rufus), striped skunks (Mephitis mephitis), or feral and domestic dogs (Canis familiaris) during the night.

Snow cover was removed from the trap site. Absence of snow cover possibly helped alert foraging eagles to the presence of a carcass. The carcass of a jackrabbit (Lepus spp.) was placed on its side on the ground. Four traps (2 pairs) were set and 1 each placed close to head, back, tail, and belly of the rabbit. The bait was then removed and depressions for all traps and chains were excavated. Before placing, each trap was set and sprung 10 times to eliminate any rust or metal burrs on the jaws that would impede quick and complete closure. Insulation pads were placed under the pan triggers and the triggers set so that maximum pressure was needed to spring the traps. The traps were then placed in position (Fig. 3) and completely but lightly covered with fine soil, often brought to the site in buckets. Trap chains were not staked down nor run under the bait carcass position. Snow was not used to help conceal traps. Snow would melt and refreeze, fouling the traps. To prevent fouling of the traps by an eagle dragging the bait over the set, the rabbit was secured with binding wire attached to the heads of the 60d spikes driven into the ground near the head and pelvic region. The securing wire was concealed within the fur. To simulate a raptor kill, fur was plucked from the thoracic region of the rabbit and allowed to drift away with the wind, and the carcass opened to expose blood and viscera. Human urine was liberally deposited around the trap site in order to repel carnivorous mammals.

If a lure eagle was used, a 45 cm government trap stake was driven into the ground about 1.5 m (Fig. 4) from the bait leaving about 5 cm exposed. The leash of the lure eagle was secured with a falconer's knot under the top washer of the stake and the stake driven completely into the ground. The lure eagle was presented with just enough food for satiation just prior to leaving the site. Feeding prevented repeated attempts by the lure eagle to obtain the bait while presenting an additional incentive to foraging eagles since feeding eagles attract other eagles (Knight and Knight 1983). Traps were checked in daylight every 30 minutes or watched continuously.

Handling and Marking

Eagles captured in leg traps were approached with slow deliberate steps. Most eagles attempted to escape, dragging the traps 10 to 30 m, then remained motionless with wings outstretched (Fig. 5). The untrapped leg was secured first, and the trap removed. Eagles were restrained by both tarsi and either cradled in 1 arm or "slung" over a shoulder with head upright and above the trapper's head, while being transported to the processing site. If not processed immediately, eagles were wrapped in a field jacket and transported in a prone position to prevent respiratory distress.

All eagles were processed by at least 2 persons. Eagles were placed in a supine position on the tail gate of a pickup truck, feet

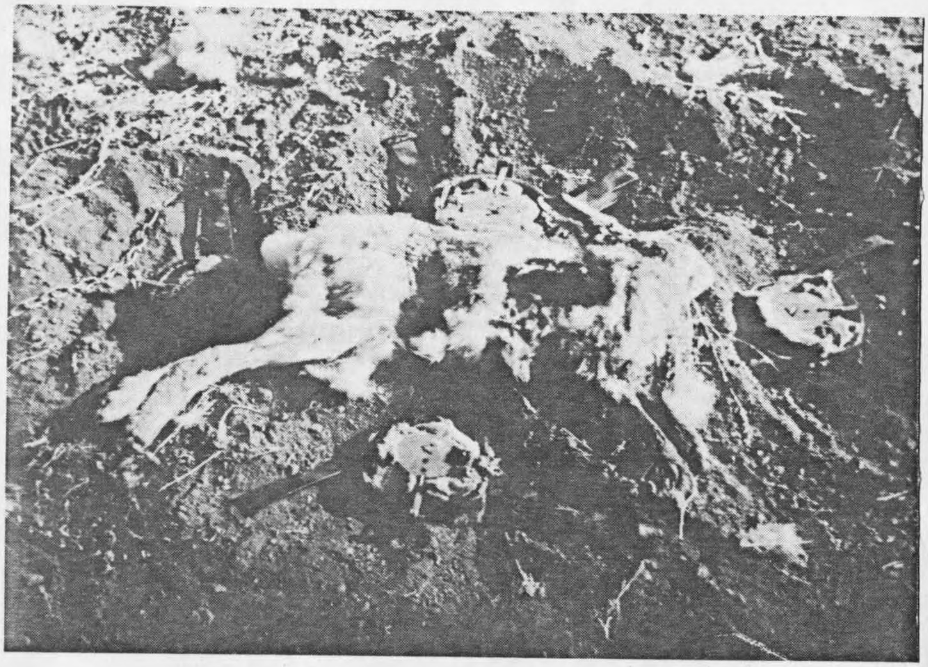

Figure 3. Placement of leg traps around jackrabbit carcass for capture of eagles. Traps were then covered with fine soil for concealment.

Figure 4. Trap site with bald eagle lure. Lure bird was placed no closer than 1.5 m to the bait. Flat open areas were preferred.

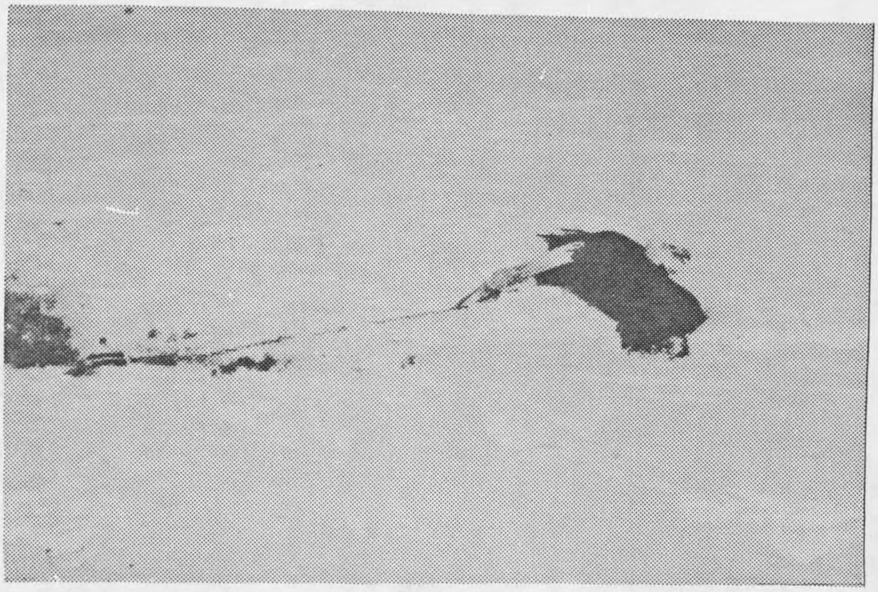

Figure 5. Adult bald eagle captured by the modified Lockhart technique.

restrained, and head covered. No hoods, foot bags, trusses, harnesses, or tape were used to restrain captured eagles.

All adult eagles were radio-tagged with Telonics 1B5 configuration transmitters mounted proximo-ventrally on the tail. Transmitter frequencies were between 148.500 and 148.950 Megahertz (MHz) with a pulse rate of 60 beats per minute and an associated life expectancy of 5+ months. Dimensions of transmitters were 4.1 x 2.4 x 2.0 cm. The length of the flexible whip antenna was 43.2 cm. A 7.2 x 1.8 cm tab with eight, 3 millimeter (mm) diameter holes was mounted on the transmitter to facilitate attachment to the center 2 rectrices. Complete transmitter packages (transmitter, antenna, mounting tab) weighed 50 to 57 grams (g).

After each adult eagle was banded, weighed, and measured, it was placed in a supine position with the head covered by a jacket, and isopropyl alcohol applied liberally to the undertail coverts. The alcohol matted the feathers permitting unobstructed access to the ventral calamus and rachis of the central rectrices (Fig. 6). The transmitter package was placed in position approximately 5 to 10 mm from the skin of the feather follicle and suturing points were marked on the feather shafts. The transmitter was removed and holes drilled laterally in the calamus and rachis with a 1 mm drill bit.

The drill and drill bit were fashioned from a tip cleaning tool for an oxy-acetelene gas welding unit. The tip cleaning bits were sharpened on a grinder and the brace permitted easy penetration of the feather shaft.

Vetafil, a veterinary suture material, was used to secure the transmitter to the feather shafts (Fig. 6). One side of the transmitter package was sutured tightly at 4 points to 1 feather shaft. Suture points on the other shaft were loosely tied to permit at least 1.5 cm spreading of the tail feather at the most distal suturing point (Fig. 7). The whip antenna was sutured at 2 points along the feather shaft to which the transmitter package was tightly sutured, and tied at least once distally where the shaft was too narrow to permit drilling. The antenna was allowed to protrude 20 to 25 cm beyond the tip of the tail. Each fastening point was individually tied and knots secured with a cyano-acrylic glue.

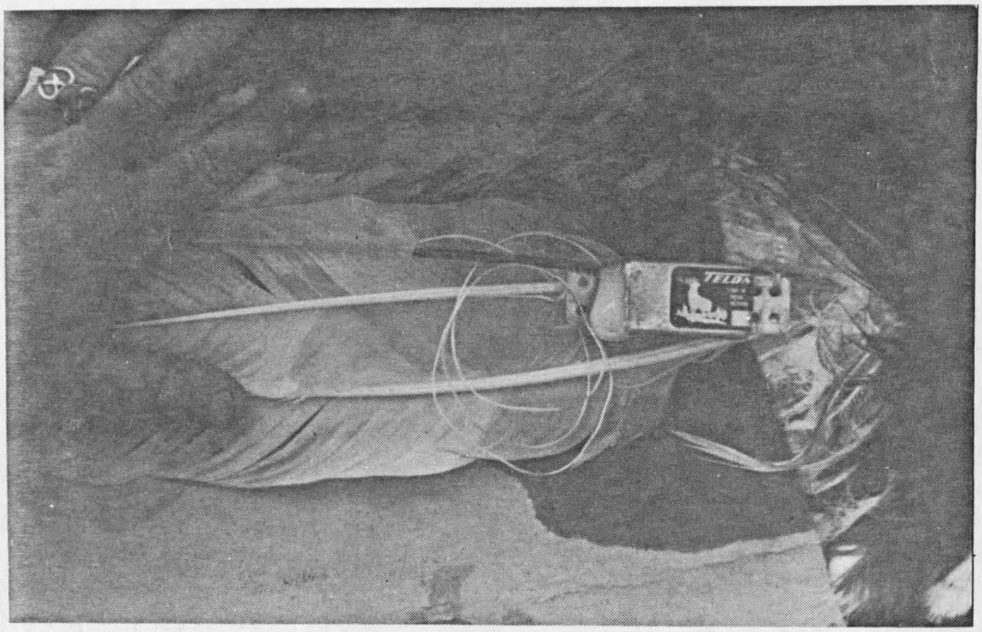

Figure 6. Radio transmitter mounting procedure on proximal ventral tail of adult bald eagle ½ complete. Note alcohol-soaked feathers permitting unobstructed access to the base of the tail.

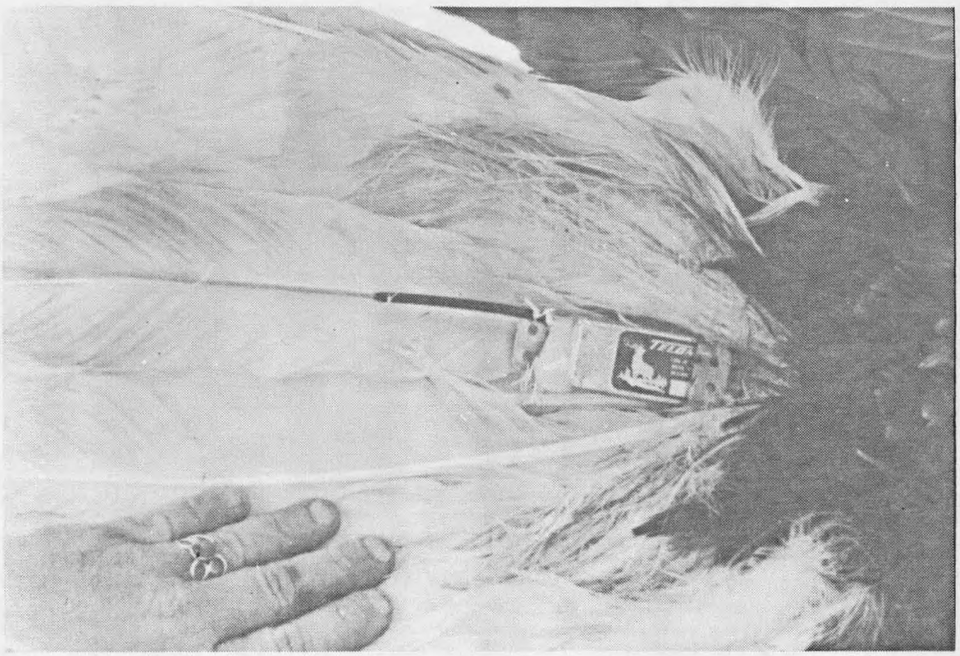

Figure 7. Completed attachment of radio transmitter to adult bald eagle tail. Note loose suture on distal left central rachis (bottom left) to permit spreading of tail.

All captured eagles were released between 0.8 and 1.6 km from the capture site. Frequently eagles returned to and continued using a perch adjacent to the trap site.

Monitoring

On the wintering ground, instrumented eagles were monitored throughout the day from a vehicle and on foot. Each tracker was equipped with a Telonics receiver (TR-1 10 channel or TR-2 programmable), an omni-directional antenna and either a Telonics 2 element "H" yagi, 3 element or 7 element High Gain yagi antenna. Large size and relatively sedentary activities of bald eagles allowed visual tracking by 1 observer per eagle rather than by triangulation as required for tracking small, highly mobile species such as prairie falcons (<u>Falco mexicanus</u>) (Harmata et al. 1979). The monitoring strategy was to locate the eagle via telemetry in the morning and maintain visual contact throughout the day. Telemetry also assisted in following eagles' extended flights within their home ranges when visual contact was lost. Signal characteristics permitted interpretation of movements and activity when eagles were out of sight.

Eagle activities were observed and recorded in a narrative style in a notebook as suggested by Hall and Kelson (1959), while flight paths and perches were drawn with grease pencil on an acetate covered U.S.D.I., Bureau of Land Management, San Luis Resource Area (SLRA) map, ca. 1976, 1.2 cm = 1.6 km. Movements were transferred to tracing paper overlays at the end of the day and stored for analysis. All tracings of daily movements were subsequently overlayed on a base SLRA map and only areas actually covered by eagles were included in the home range polygons.

Attempts to follow a statistically valid monitoring regimen failed. Logistical problems and inadequate funding dictated expedient choice of the eagle to be followed each day. Consequently, most time was expended monitoring eagles judged to be mated and with ranges closest to field quarters.

Mated Status, Plumage, and Morphology

An eagle's mated status was determined by considering proximity to and time spent feeding, perching, and roosting with another eagle of distinctly dissimilar size both before and after capture, observed copulation, or association with an active nesting grounds. Remnants of a brood patch observed at time of capture assisted in determination of status. Sex was determined initially in the field by size and ultimately by measurements.

Plumage characteristics and morphology of each captured eagle were described and measured. Data were collected to: (1) use in the development of techniques to quickly age and sex bald eagles in hand under field conditions, (2) create an aging protocol to be used by observers censusing eagles during aerial surveys, (3) help determine latitudinal origin of eagles by specific measurements, and (4) determine the relationship of wing loading (Brown and Amadon 1968), aspect ratio, and tail/wing ratio (Brown 1976) to migration mechanics and activity patterns.

An aging protocol was determined from general trends of iris and mandible coloration and feather length, wear, and replacement noted on all captured birds. These trends were verified by (1) observing plumages, iris and mandible color on nestling and fledgling eagles during summer banding in the Greater Yellowstone Ecosystem (GYE), (2) inspecting plumages of 3 subadult bald eagles retrapped 1 and 2 years after initial capture as 0.5 year (yr)-old birds in the SLV, (3) observing plumages of colormarked eagles up to 6 years after being marked as 0.5 yr-old birds, and (4) inspecting plumage characteristics of 2 bald eagles banded as nestlings in the GYE and recovered 2.5 and 3.5 years later.

Culmen length and tarsal width were measured with calipers. All other linear measurements were taken with a carpenter's rule. Tarsal width was measured at the narrowest point of the right tarsometatarsus, anterio-posteriorly. Wing span was taken by slowly stretching the right wing of the eagle to its fullest extent without hyper-extending. The measurement was taken from the tip of the longest primary remige to the keel bone. Wing chord measurements were standard, but primary remiges were flat rather than relaxed. Tail length was measured dorsally from the uropygial gland to the tip of the longest central rectrix.

Wing and tail areas were obtained by tracing the outline on brown wrapping paper, tacked to a 61 x 122 x 23 cm sheet of plywood. A falconer's "rufter" hood was used during the procedure but not secured by pulling the braces. The wing was not forcibly depressed but held firmly against the paper so the outline could be traced while the wing retained its natural curvature. Primary and secondary feathers were not spread but allowed to lie naturally against the paper (Fig. 8). The tail was traced in a similar manner, but feathers were spread in an approximate 90° arc by grasping the base of each outermost rectrix (Fig. 9).

The outlines of wing and tail tracings were electronically digitized (x-y coordinates coded to the points) on a digitizing tablet of a Hewelett-Packard 9640A mini-computer (H-P 9640A) running on the RTE-III operating system. Wing and tail areas were calculated by GSA2D subprogram of the GEOSCAN System (Lonner and Pexton 1983). Wing loading was determined by weight to wing area ratios. Length and width measurements were secured from wing tracings to determine aspect ratio. Tail/wing ratios were calculated for all eagles using wing span and tail X 2 length variables.

Morphological measurements of all bald eagles captured in the SLV were analyzed. The main purpose of analyses was to categorize each bird into 1 of 2 classes, male or female. Classification was based on variables defined as: WEIGHT, TAIL LENGTH, WING CHORD, WING SPAN, TARSAL WIDTH, and CULMEN LENGTH. Age was classified only as adult or immature, and determined by obvious plumage characteristics. Five birds, all males, were positively sexed either by necropsy (n = 3) or by position during copulation; their sex was included in the analyses as justification for groupings.

Initially, 2-way stepwise discriminate analysis (Program 7M, Dixon 1981) was run by a Honeywell Level-66 mainframe computer running on Honeywell's CP6 (HW-CP6) operating system at Montana State University.

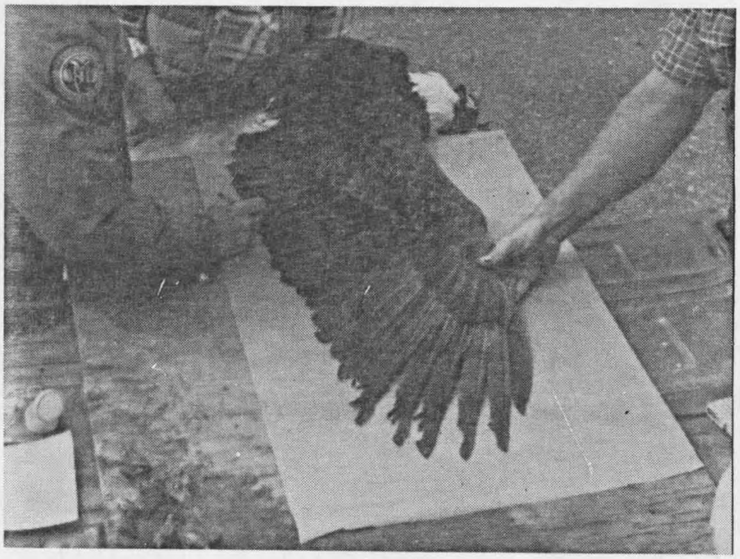

Figure 8. Procedure for tracing wing area of bald eagles.

Figure 9. Procedure for tracing tail area of bald eagles.

This analysis was used to determine whether variables measured had sufficient discriminating power to distinguish among known adult and immature eagles.

Probabilities of the analysis used was assumed to be 50/50. The analysis generates a canonical correlation valve, which is roughly equivalent to an R^2, and indicates how closely the data fit the descriminate function. The resultant classification function can be used to predict group memberships, i.e. age class of eagles, for which only measurements are available.

A second computer analysis used relied on a "K-means clustering algorithm" (Dixon 1981) or pseudo-nearest neighbor approach of BMDP Program KM to determine if there were 4 natural, biological groupings within the data, and ultimately to determine the variables which distinguished sex. Three approaches were taken:

(1) Look for 4 groupings with no pregroupings, using all data.

(2) Look for 4 groups, but specifying the first level of grouping with the AGE variable (adult/immature). This approach used measurements of all eagles, but initiated with AGE groupings and split each of those groups into 2 or more.

(3) Look for 2 groupings but using only adult eagles and repeated using only immature eagles.

Using the 4 groupings determined by K-means clustering algorithm, 2-way stepwise discriminate analyses were run to determine which variables discriminated most between genders for both age classes (adult, immature). Classification functions using these variables were then derived to be used as a technique to sex eagles of both age classes by measurements.

A dimorphism index was calculated by the method used by Storer (1966) and Snyder and Wiley (1976) using (1) all variables plus flight related statistics, (2) only variables used by Storer (1966), and (3) only flight related statistics. Indices were calculated between males and females and adults and immatures. For age class indices, adults were treated as males and immatures as females and the sign of values ignored during calculations.

Winter Ecology

Home Range and Movements

All continuous observations of radio-tagged adult bald eagles in 1980 and 1981 were converted to discrete location points. Daily movement tracings were sequentially overlayed on a base map and all perches and flight paths electronically digitized (x-y coordinates coded to points) on a digitizing tablet of an H-P 9640A. Points were digitized at 1 minute (min) intervals along flight paths. Eagles commonly sat on 1 perch for many hours, therefore a location was digitized once for every 5 min of consecutive time at a single perch. Single locations were also digitized.

All digitized points were displayed on a Tektronics 4014-1 graphics terminal that produced a copy. Seasonal home range boundaries were drawn by connecting all peripheral points in a manner suggested by Macdonald et al. (1980), while attempting to include only areas visited or flown over by eagles.

Flight paths from perch to perch (including perch to ground or roost and vice-versa) were drawn and measured on SLRA maps; flight durations were timed by chronograph. Characteristics of non-direct flights varied among individuals but generally were greater than 2 min and were considered soaring flights. Soaring flights were also most often characterized by circling while ascending or at constant altitude.

Home range areas were calculated by GSA2D subprogram of the GEOSCAN system on the H-P 9640A. One-way and 2-way analyses of variance (ANOVA) were used to compare mean home range size among various groupings based on year, sex, and mated status. A Newman-Keuls procedure (Snedecor and Cochran 1972) was used to indicate where differences were.

Activity

When eagles are perched, activities such as hunting, loafing, and sleeping must be subjectively assessed. Activity was, therefore, defined as the percentage of total monitoring time an eagle was engaged in flight, or spent on the ground, or both. Time spent on the ground was considered active time since most eagles observed on the ground were either actively feeding or perched near other feeding eagles, presumably waiting for a feeding opportunity at a carcass. If not feeding or waiting, eagles on the ground were walking near or approaching a food source.

Since eagles are strictly diurnal, activity for individual eagles was derived by dividing the monitoring day into standard hourly intervals from 0600 hrs to 1900 hrs MST and calculating the percent of time active for all monitoring days for each eagle. Activity (A) for interval (x) was calculated by dividing the total minutes active (t_a) during interval (x), by total min of monitoring (t_m) during interval (x), multiplied by 100. Therefore, $A_{(x)} = t_{ax}/t_{mx}$ (100). Percent activity in each hour period was averaged to obtain total percent activity for specific groups of eagles (i.e. males, females, mated).

Student's t-tests were used to compare mean activity level between various groupings based on gender and year. One-way ANOVA's were used to compare mean activity between and among months (January, February, March) for males, females, and all eagles for both years. A Scheffe procedure (Snedecor and Cochran 1972) was employed to determine which months were different.

A Winter Severity Index (Picton and Knight 1971) correlated monthly activity for all eagles with meteorological conditions. Local Climatological Data Monthly Summary Sheets containing data recorded at Alamosa, CO (Fig. 1) were obtained from the National Oceanic and Atmospheric Administration (NOAA), Asheville, NC 28801. Average temperature was chosen as an indicator of severity. Stalmaster (1981) determined that the lower critical temperature for captive bald eagles was 10.6°C. Therefore, a temperature of 10°C was chosen as a transition point for the Winter Severity Index. Average wind velocity during daylight hours was chosen as a multiplier of low temperature effects. However, since Steenhof (1983) found the highest portion of eagles foraging during winds 15-20 km/hr, these average wind velocities were considered to ameliorate low temperature effects. Velocities <15 and >20 km/hr compounded low temperature effects.

Eagle Responses to Human Activity

Data on behavioral responses of bald eagles to human activity were collected during the winter and spring of 1981. Any human activity that caused a bald eagle to flush from a perch was defined as a disturbance.

Human activity and bald eagle responses were documented throughout the SLV. Human activity beyond 760 m from the affected eagle was not recorded due to the possibility that the factor actually causing the behavioral response may have been undetected by the observer. Parameters of human activity that were considered important were recorded on a data form (Appendix, Fig. 64). An observation was composed of the type of response of 1 bald eagle to human activity within 760 m. Eagles in their first year (0.5 yr-olds) were referred to as juveniles, 1.5 through 3.5 yr-olds were grouped as subadults and 4.5 yr-olds and older birds recorded as adults. Volume of sound was used as the criterion for classifying the intensity of human activity. The volume at the site of the eagle was subjectively determined. A Rangematic, Mark V, optical range finder was initially used to increase field personnel's ability to estimate distance. Weather conditions were those on site at the time of observation. Other variables are explained on the data form (Appendix, Fig. 64).

Response was treated as the dependent variable and all others were treated as independent variables. Data were mostly categorical, therefore, frequency and crosstabulation (contingency) tables were used in data analysis. Tables were constructed on the HW CP-6 computer using the Statistical Package for Social Sciences (SPSS) subprogram

CROSSTABS (Nie et al. 1975) to search for possible relationships between response and each independent variable. Variables were subsequently recoded and those showing no relationships were dropped.

Stepwise multiple regression with dummy coding of variables using the SPSS REGRESSION subprogram was performed to identify important sets of independent variables. The dependent variable, response, was coded as only presence or absence of response to human activity. A log linear, multiway frequency model (BMDP Program 4F; Dixon 1981) was used to confirm relationships between independent variables and their effect on response.

Habitat Selection

Habitat selection by bald eagles in the SLV was assessed by comparing used perch/habitat relationships to habitat relationships of points of nonuse. "Habitat types" were mostly vegetative associations, but also included roads, cities, plant and soil associations, rivers, etc. GEOSCAN (Lonner and Pexton 1983), a computer based system that correlates animal locations with geographic/habitat data was used to quantify perch/habitat relationships. Discriminate analyses were run to determine the most important variables that distinguished between observed (used) and expected (nonused) perch locations.

Only a portion of the SLV was used for analysis of habitat selection by GEOSCAN. This area contained all bald eagle locations but size was determined primarily by scale of available land use and terrain maps in conjunction with size of the digitizing tablet.

Habitat types within the study area were digitized on a H-P 9640A tablet and fell into 3 groupings: points, lines, and areas. Although GEOSCAN has the capacity to use a fourth variable, topography or uniform grid, the SLV is flat and topography was not included in the analysis. Natural plant community associations and agricultural land use (areas) were digitized from U.S. Dept. of Agriculture, Soil Conservation Service Land Use and Natural Plant Communities, 1:126,270 maps of each county. Roads, creeks, rivers (lines), houses (points), and cities (areas) were digitized from SLRA maps.

Most eagles observed perched on the ground were either feeding or waiting for a feeding opportunity; therefore, it was assumed that ground perches represented habitat in which eagles actually foraged. However, it was unknown if eagles selected tree perches in foraging areas. Tree perches may have simply represented adequate secure substrate for perching high, thereby permitting eagles with their superior visual acuity to scan foraging habitats well removed from the perch. To test this association, tree and ground perches were analyzed separately.

Input data for used ground and tree perches to be related to habitat feature data were derived from digitzed perch locations on daily movement overlays (see Home Range and Movements: 30). Nonused locations were generated from digitized points systematically distributed throughout the study area to adequately sample all available habitats.

All locations of used perches and nonused locations were input to the GEOSCAN system based in a Digital Equipment Corporation (DEC) VAX 11/780 mini-computer. GEOSCAN can build a circular area with a scanning radius of any size dependent on the user's choice, around each used and nonused location (Fig. 10). A scanning radius was selected and GEOSCAN computed the following on command:

1) Minimum distance point to point (MDPP): the distance between a location and the nearest point (i.e. house) within the entire study area.

2) Minimum distance point to line (MDPL): the distance between a location and the nearest line within the entire study area for each line category (i.e. river, road).

3) Habitat area (A2D): the total area of each habitat type (i.e. city, cropland) contained within the scan area around each location.

4) Total edge of a habitat type (EDGE): the total linear measure (km/km^2) of the edge of a habitat type area contained within the scan area around a location.

5) Total expressions of a habitat type (EXP): the number of non-coterminous expressions of a single habitat type contained within the scan area around each location.

GEOSCAN output was transferred to HW-CP6 for analysis. A 2-way discriminate analysis (BMDP program P7M; Dixon 1981) was used to rank variables (MDPP, MDPL, A2D, EDGE, EXP for each habitat type) relative to their ability to distinguish between used and nonused perch locations. Therefore, habitat variables which discriminate well in predicting perch locations used by bald eagles were considered selected for or against by bald eagles depending on the relative value.

In these analyses, variables entered the stepwise procedure if the F statistic was above 1.0. *A priori* classification was 50/50,

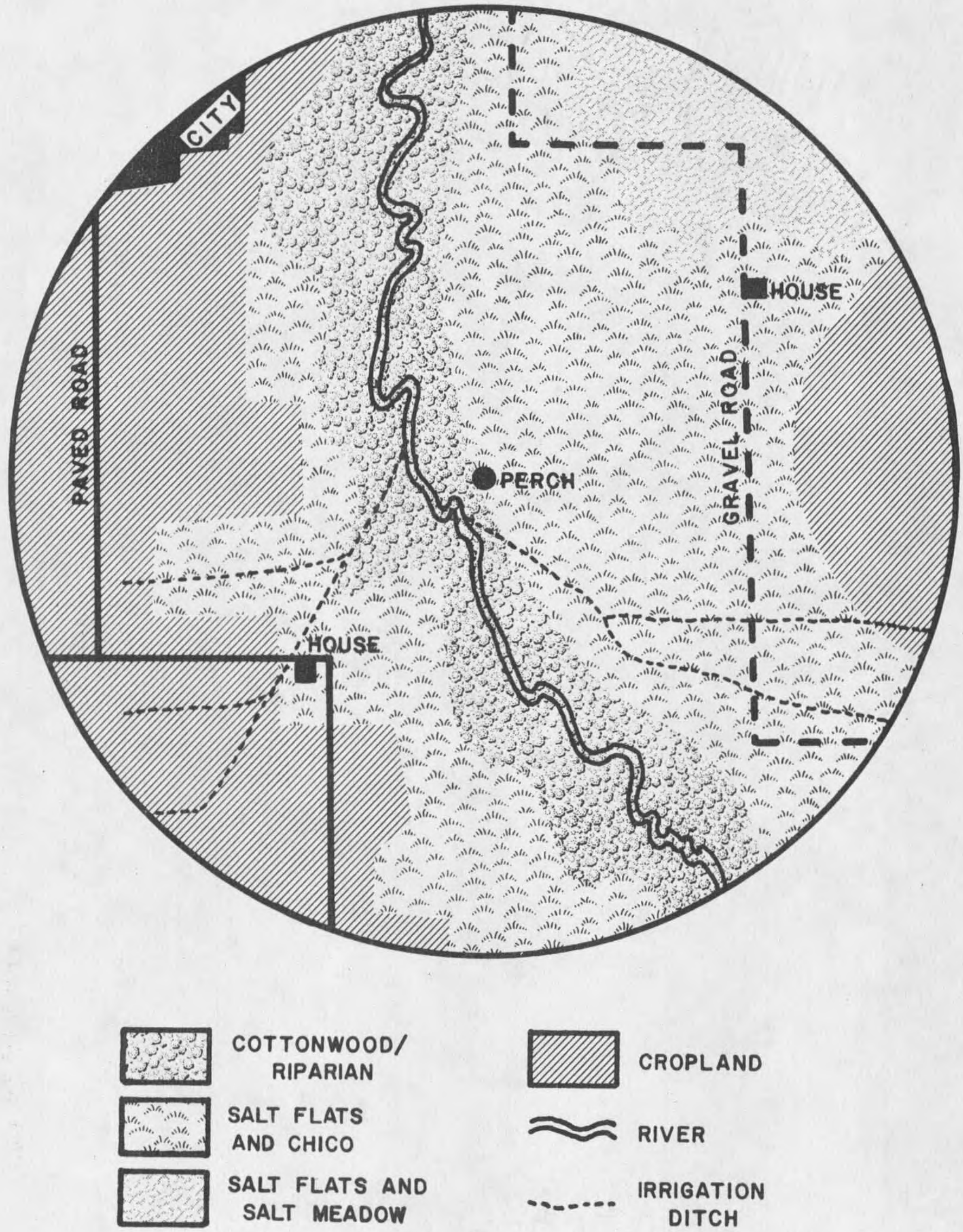

Figure 10. Scanning circle around a hypothetical perch location used by bald eagles.

since no quantified information concerning the probability of use of a site was available.

Habitat Use

Home range and frequency of tree perch use (F_p) data were used to illustrate relative area use by adult bald eagles in the SLV. Data from movements of 3 males (2 in 1980 and 1 in 1981) and 1 female in 1981, each monitored over 190 hours and presumed to be mated, were selected for analysis.

SYMAP program (Harvard Univ. 1971a) based in the HW-CP6 was used to compile X-Y-Z coordinate data for SYMVU graphical display program (Harvard Univ. 1971b) also based in HW-CP6. SYMVU using SYMAP output, produced 3 dimensional displays on a Calcomp plotter.

X-Y coordinate input for SYMAP included home range boundary coordinates and coordinates of tree perch sites. Z-coordinates were F_p. F_p was not weighted for time spent on the perch. If an eagle used a perch 3 times for 5 minutes each time, then $F_p = 3$. If an eagle used a perch once for 5 hr, then $F_p = 1$.

Roost Site Determination and Description

Ten active and 2 potential roost sites were identified in the SLV by Harmata and Stahlecker (1977). A roost site is defined here as an area containing trees in which bald eagles perch for the duration of at least 1 night.

Spatial limits of a "site" were often intuitive but usually consisted of areas no larger than 5 ha. During 1978, 1980, and 1981 radio-telemetry studies of adult bald eagles confirmed use of some of these sites, eliminated consideration of others and discovered additional ones. Other sites were found by incidental observations coincident with radio-tracking.

Counts of eagles flying to known roosts were conducted periodically over 3 winters. The site chosen for counting each night was dependent on proximity of the nearest site at the end of each day's activities and logistical considerations. Sampling counts were not systematic nor random and known high use sites were counted more often. Counting periods normally began ½ hour before sunset and continued until ½ hour after sunset.

Roost sites containing an average of 10 or more eagles per night and/or sites used more than 5 nights by radio-tagged eagles were classified as major roosts. Trees containing approximately 30 to 50% of roosting eagles at a site were considered primary roost trees (Fig. 11).

To assess physical characteristics of roost sites, 25 parameters categorized into 4 groups were measured at 6 major roosts (Table 1). Three of the groups were physical/vegetative parameters. The remaining group was related to human disturbance. Disturbance variables measured distance between sites and the continuous presence (city) or intermittent presence (road) of human activity.

Area of the stand containing the roost site, direction of optimal view (degree of maximum line of sight distance), degrees of view (width) and distance to potential disturbances were measured on U.S. Geological Survey (USGS) county maps, 2 cm = 1 km scale and USGS 7' quad maps. Tree density was estimated by the point-centered quarter method (Mueller-Dombois and Ellenberg 1974); the primary roost tree

Figure 11. Major winter roost site and primary roost tree (arrow), used by bald eagles along the Rio Grande River, San Luis Valley, CO.

was the center point. Distances on site were measured by a Rangematic Mark V optical range finder and tree heights determined by distance, inclinometer and sine function analysis. Diameter at breast height (dbh) was measured with a dbh tape. Other variables were recorded on site.

Roost Site Suitability

A "suitable" roost site was assumed to be one which was actually used by any number of eagles for at least 1 night. Chi-square analysis was used to test for differences in distribution of roost sites within the study area. In an attempt to determine the importance of selected variables in determining roost site "suitability" the null hypothesis

Table 1. Group variables measured at bald eagle roost sites, San Luis Valley, CO.

Group							
Habitat		Tree Stand		1° Roost Tree		Disturbance	
Rubric	Variable	Rubric	Variable	Rubric	Variable	Rubric	Variable
HGS	Surrounding habitat[1]	SA*	Area (hectares)	TC	Condition[4]	DOD*	Distance to nearest occupied dwelling (km)
HNB*	Distance to vegetative break	SD*	Density 100/m^2	TH*	Height (m)	DDD	Direction to nearest occupied dwelling
HBB	Habitat beyond break[2]	SS	Side of stand roost situated[3]	TT	Trunk type	DCR*	Distance to nearest county road (km)
HPW	Prevailing wind directions[3]	SH*	$\bar{x}$ height of trees in stand	TD*	Dbh		
SINU*	Sinuosity (km of river within 0.8 km of site)	SN*	# roost trees in stand	TW*	Distance to H_2O(m)	DRD	Direction to nearest county road
				TV	Side of tree used[3]	DVT*	Distance to nearest vehicle trail (km)
				TV	Direction of optimal view degrees	DTD	Direction to nearest vehicle trail
				TM	Maximum view angle (degrees)	CITY*	Distance to nearest urban area (km)

*Continuous Variable

[1] 0 = Upland
1 = Riparian

[2] 0 = Slough
1 = Cultivated field
2 = River
3 = Brushland
4 = Grassland

[3] 0 = N
1 = NE
2 = E
3 = SE
4 = S
5 = SW
6 = W
7 = NW
8 = All
9 = Center

[4] 0 = Dead
1 = Decadent
2 = Live

that bald eagles randomly select roost sites along the timbered corridor of the river was tested. However, time and lack of funds prevented on site measurements of the same variables at nonused sites as at used sites. Therefore, USGS 7' quad maps were used to randomly select nonused sites along the 2 major rivers in the SLV. Fifteen nonused sites were selected on the Rio Grande River and 6 on the Conejos River.

A corridor was drawn on the maps along the timbered portions of the Conejos and Rio Grande Rivers. The corridor was 1.6 km wide; 0.8 km perpendicular from the center of the main channel of the river. Segments of river were selected by random numbers generator; limits represented the range of section numbers contained in the river corridor on each 7' quad map. When a section number was chosen by random numbers generator all stands (timbered areas as shown on the map) contained in that section were numbered and 1 stand chosen by random numbers generator. As most known roost sites were at the periphery of a stand, the site within the selected stand was chosen by randomly selecting a degree between 1 and 360.

Six parameters (3 physical and 3 disturbance) for used and nonused sites were measured on the map. Stand area (SA) was measured by polar compensating planimeter. River sinuosity (SINU) was defined as the total length in kilometers of all river channels and sloughs within a 0.8 km radius of the site and was determined by map wheel measure. Site distance from water (TW) was also measured. Disturbance related variables were distance to nearest occupied dwelling (DOD), distance to nearest county road (DCR) and distance to the nearest incorporated city (CITY).

Non-parametric Kruskal-Wallis tests incorporated the 6 variables SA, SINU, DOD, DCR, TW, CITY, to test for differences between used sites on the Rio Grande River and the Conejos River and between used and nonused sites on each river to determine if rivers should be analyzed collectively or separately.

A 2-way discriminate analysis (BMDP program P7M, Dixon 1981) was used to rank variables relative to their ability to distinguish between used and nonused roost sites. In these analyses, variables entered if the F statistic was above 0.99. Although there are intuitive reasons to classify certain sites in use or nonuse categories, probability cannot be determined unless based on original case memberships. A priori classification was therefore 50/50. Variables which discriminated well in predicting use of known roost sites can be used to predict the likelihood of areas of unknown use to be used or not. The values of the discriminating variables may help in management schemes designed to create suitable roost sites.

An initial analysis was performed using 6 continuous variables (SA, SINU, DOD, DCR, TW and CITY) measured at used and nonused sites on both the Rio Grande and Conejos Rivers combined. Subsequent runs analyzed each river independently and used the variables determined to be most discriminating for 1 river as a model to classify cases on the other river.

Roost Site Preference

Roost sites that supported more eagles were considered "preferred". Preference may not be due just to 1 variable but a combination of the

25 measured at each known site (Table 1). However, with data available for only 6 roost sites it is not possible to find statistically significant multiple correlations of more than 2 variables. Hence, roost site preference was examined through simple comparisons of eagle counts (mean number of eagles for all counts at each roost site) vs each individual variable.

In an attempt to explain why eagles preferred 1 roost site over another, Spearman and Kendall correlations (non-parametric) were employed (Snedecor and Cochran 1972). Levels of $P \leq 0.10$ were accepted as significant on all statistical tests.

Food Habits

Precise documentation of bald eagle food habits in the SLV became of secondary importance during the study due to its potential conflict with the primary objective of documenting movements and activity of radio-tagged eagles. This conflict arose primarily as a result of the high disturbance potential associated with collection and/or identification of food remains near perching, roosting, or feeding eagles. Often, approaching a feeding eagle close enough to determine the taxonomic category of the food item resulted in the eagle flushing and leaving the area. Conversely, waiting until an eagle or group of eagles finished feeding often resulted in no remains left to identify. Collection of food remains under roost and perch sites was difficult due to the almost continuous presence of eagles at some sites. Therefore, to partially determine food habits, remains were collected under heavily used roosts and perches only when eagles were absent, a strategy which precluded a systematic sampling regimen. These data were supplemented by collection of debris under some perches at locations where eagles fed and evidence remained and by witnessing eagle kills.

Indigestible material regurgitated periodically by eagles, hereafter referred to as castings, were collected, bagged, identified, and dated by site for later analysis. Only complete castings were analyzed. Great horned owls used the same perches as eagles but the occasional owl pellets (casting) were easily identified by their osseous remains and appearance. Contents of castings were identified generally only to taxonomic class, but where obvious, to genus and species. One casting was considered to represent 1 individual unless 2 classes were represented. Where castings and numerous remains were found, the minimum number of recognizable prey individuals (Alt 1980) were identified. One casting plus 2 (or 1) posterior extremity plus 2 (or 1) anterior extremity represented 1 individual.

Perch Structures

Perch structures designed for use by bald eagles as day perches were constructed and placed (Fig. 12). Nonserviceable lodgepole pine (<u>Pinus contorta</u>) or cedar (<u>Libocedrus</u> spp.) electrical transmission poles, 10.7 and 12 m long were obtained from San Luis Valley Rural Electrification Association (REA). Previous observations in the SLV indicated that bald eagles seldom used man-made structures higher than fence posts for perches, so cottonwood branches 2.5 to 4.5 m long with basal diameters of 2.5 to 7 cm were used to make structures appear more "natural." An appropriate sized hole was drilled in the pole in

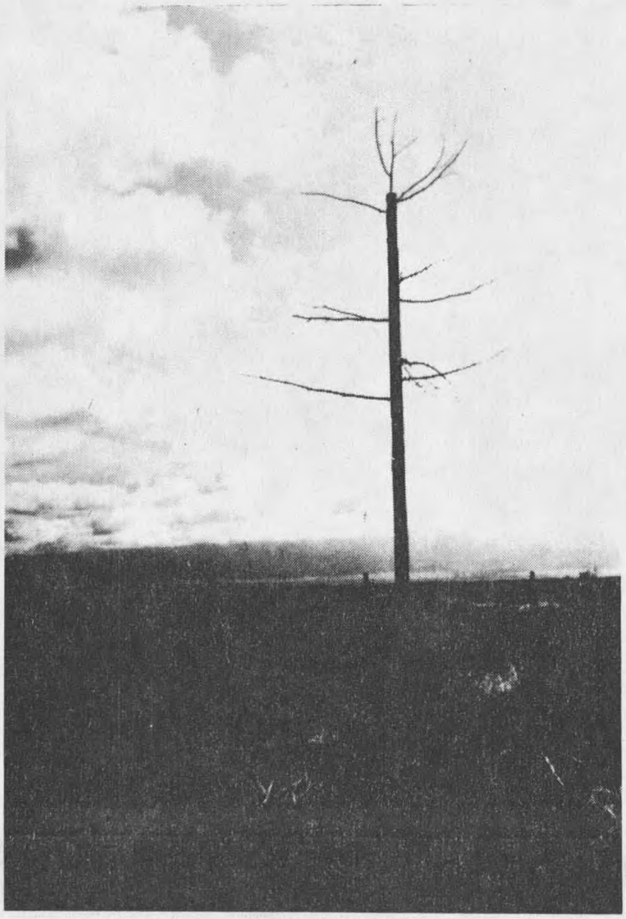

Figure 12. Perch structure for bald eagles placed in the San Luis Valley, CO, May 1981.

10 positions. Each branch and hole set was individually marked, for later assembly on site. Perches were constructed and placed between mid-April and mid-May, 1981, after bald eagles migrated north, in order to avoid their associating perches with human activity. The top 2 tiers of branches were fitted in their respective holes and secured with 16d nails. The ground hole was drilled by augur and the

pole placed in with a hoist (hoist and augur on REA vehicle). The branches of the third tier were then secured by climbing the pole.

Location of Perches. Perches were located at sites in the following priority:

(1) Sites where trees which received high eagle use had been removed. High use was subjectively determined as at least 1 eagle present during 90% of observations at that site.

(2) Sites where the food base (sheep carcasses and jackrabbits) was high and disturbance potential was low, but where no perches previously existed.

(3) Sites where trees that received moderate eagle use had been removed and disturbance was high.

Public Information Programs

Attempts to inform the public to the value of eagles, their problems, and potential solutions were made. During 1980, extended conversations with landowners whose property bald eagles frequented expended considerable time. In 1981 a poster and a flyer (Appendix, Fig. 65 and 66) were placed in agricultural supply stores where many valley farmers and ranchers congregated. Several articles in valley newspapers were published along with 1 in a major Denver newspaper.

A local public affairs radio station carried brief announcements describing the SLV bald eagle population and the study. Presentations were also made at the local Audubon chapter meetings and 3 valley schools.

Migration

Factors Associated with Initiation of Migration

Climatological data associated with days and hours that bald eagles left the SLV on northward migration were analyzed by stepwise discriminate analysis. Climatological data recorded at Alamosa, CO were obtained from NOAA, Monthly Summary Sheets. Data for days that eagles left the SLV were compared to data for randomly selected days between 1 January and 15 April 1980 and 1981 that they did not. Variables selected for comparing days were maximum temperature (MAXT), average temperature (AVGT), range of temperature (RANGE), percent of sky clear (PCTCLR), average wind speed (WINDSPD), and average wind direction (WINDIR). Climatological data recorded during the hour period closest to the time an eagle left on migration were compared to data recorded during daylight hour periods of the same day. Since eagles seldom flew subsequent to 1700 hrs, only 3 hour periods were included in the analysis; 0800, 1100, and 1400 hrs. Variables selected for hour comparisons were temperature (TEMP), WINDIR, WINDSP, PCTCLR, visability (VIS), and hour (HOUR).

Migration Tracking

Migrating eagles were followed primarily by vehicle. The receiving antenna was mounted on an external traversing mount, allowing for directional tracking while the vehicle was moving. Occasionally, when contact with the migrating eagle was lost, an aerial search was implemented. The antenna was taped to the wing strut (high wing) (Fig. 13) or step (low wing) of the aircraft and the area surveyed in transect style with intermittent lazy circles at high altitude. Frequencies were scanned to search for the missing eagle and others. When contact was regained and the eagle's status discerned as stationary, vehicle tracking resumed.

Figure 13. Telemetry receiving antenna position on high wing aircraft. Antenna was mounted for reception of signal from front of aircraft.

RESULTS

Capture

The average time required to set traps at 1 site was 20 minutes. Total trap sets, inclusive days, and eagles captured are shown in Table 2.

Table 2. Trap days and total wintering eagles captured, San Luis Valley, CO.

			Eagles Captured				
			Golden Eagles		Bald Eagles		
Year	Trap days[a]	Days of Trapping	Adult	Immature	Adult	Immature	Total
1980	32	9	2	-	4	4	10
1981	80	25	2	14	12	15	43
Subtotal			4	14	16	19	
Total	112	34	18		35		53

[a]A trap-day is any number of traps around 1 bait presented for any part of 1 day.

Sixteen adult bald eagles were target birds. In addition to eagles 5 ferruginous hawks (Buteo regalis), 3 red-tailed hawks (Buteo jamaicensis), 2 ravens, and 1 rough-legged hawk (Buteo lagopus) were captured, banded, and released. Two other rough-legged hawks were captured and released but not banded.

Table 3 illustrates trap success for bald eagles each winter of trapping and total success for both years combined. Trap success was greater in 1981 for all categories. Traps placed about 100 m away from heavily used perches of target eagles were generally more successful. Traps placed directly under a perch were usually unsuccessful even though adult eagles sat for hours watching the bait. When the bait was placed farther away, eagles seemed more likely to fly to the site to investigate the bait and then seemed more likely to take it.

Table 3. Trap success for wintering eagles in the San Luis Valley, CO.

Year	Sets[a] per Capture: Bald Eagle	Sets[a] per Capture: Target Adult Bald Eagle	Days[c] per Capture: Bald Eagle	Days[c] per Capture: Target Adult Bald Eagle
1980	4.0 (25)[b]	8.0 (13)	1.12	2.25
1981	2.96 (34)	6.66 (15)	0.92	0.48
Mean	3.2 (31)	7.0 (14)	0.1	2.31

[a]1 set is any number of traps around 1 bait presented for any part of 1 day
[b]Percentage of trap sets that actually caught eagles are given in parenthesis.
[c]Any portion of 1 day where at least 1 set was placed.

Golden eagle and bald eagle lure birds were used at 10 sets in 1981. Seven immature golden eagles and 1 adult bald eagle were captured at sets with lure eagles. Success per set was greater with a golden eagle lure but the only target eagle (adult bald eagle) captured was at a trap set with a bald eagle lure (Table 4).

Trap success using a lure bird was lower than at sets without a lure bird (Table 5). Traps with a lure bird were more successful at capturing immature golden eagles (70%) than sets without a lure bird

Table 4. Numbers of eagles captured and success of trapping technique with 2 species of lure eagles, San Luis Valley, CO, winter 1981.

Lure species	Sets	Days	Species Captured: Golden Eagle Adult	Species Captured: Golden Eagle Immature	Species Captured: Bald Eagle Adult	Species Captured: Bald Eagle Immature	Trap Success as Sets per capture[a]: Eagle	Trap Success as Sets per capture[a]: Bald Eagle
Golden Eagle	3	3		3			1.0 (100)	-
Bald Eagle	7	7		4	1		1.4 (71)	7.0 (14)
Total	10	10		7	1	mean	1.25 (80)	10 (10)

[a]Percent of trap sets that actually caught eagles are given in parenthesis

(12%). No set with a lure bird caught an adult golden eagle (Table 4); sets without lure birds caught 4 (Table 2). Trap sets with a lure eagle were less successful at capturing both adult and immature bald eagles than those without (Table 5).

Table 5. Trap success of sets with and without a lure eagle, San Luis Valley, CO, winter 1981.

Trap Set Type	# Sets	# Eagles Captured	Sets Per Capture Eagle[a]	Bald Eagle[b]	Adult Bald Eagle
With lure	10	8	1.25 (80)[c]	10 (10)	10 (10)
Without lure	112	45	2.48 (40)	3.29 (30)	7 (14)

[a]Both species
[b]Both age classes
[c]Percent of trap sets that actually caught eagles are in parentheses.

Population Estimate

An estimate of the SLV bald eagle winter population in 1981 was calculated by a Lincoln index (Giles 1971) $N = m(n)/R$, where m = number of eagles banded to January 28, n = number of trap sets after January 28, and R = number of eagles recaptured January 28 - March 18. Population estimate was 170 bald eagles.

Few of the assumptions implicit in the Lincoln index were met. However, empirical data, i.e. survey flights and incidental observations, indicated the estimate was quite accurate, especially when viewed in the context of earlier estimates based on statistically valid sampling (p. 14).

Marking and Monitoring

Fifteen adult bald eagles were radio-tagged between 18 January 1980 and 18 March 1981. Monitoring data, mated status, sex, and age are shown in Table 6. Three eagles were tracked less than 10 hrs; 5 were tracked between 10 and 100 hrs; 3 were tracked between 100 and 200 hrs; and 3 were tracked over 200 hrs.

Age Determination

Age Class Determination by Measurement

Sixty-nine eagles were measured in the SLV between January 1977 and April 1981. Since data were incomplete for 17, only 52 birds were included in stepwise discriminate analysis to determine if measurements could be used in separating adults from immatures. Using a significance level of P = 0.05 (F-to-enter = 4.0), only 2 variables could be used to classify age--TAIL LENGTH and CULMEN LENGTH since correct classification was low (82%, Table 7). Reducing the significance level to P = 0.1 (F-to-enter = 2.7), WING CHORD entered the function, with an overall classification rate of 90.4%. By reducing the F-to-enter to 1.0 (P = 0.5), no additional variables entered into the discriminate function and classification percentage was unchanged. Finally, using all variables (F-to-enter = 0.01, P>0.5) a lower classification (88.5%) was obtained (Table 7). Therefore, the strongest discriminating variables to distinguish age class (adult vs immature) were TAIL LENGTH (TL), CULMEN LENGTH (CL) and WING CHORD (WC) with a 90.4% reliability. The respective classification coefficients for use in classification

Table 6. Monitoring data, mated status, and emmigration date of radio-tagged adult bald eagles, San Luis Valley, CO, winter 1980-81.

Eagle #	Date Captured	Sex	Age	Hours Monitored	Inclusive Days	Mated Status	Date Left SLV
80-1	01-27-80	M	7	158	27	Mated	03-08-81
80-2	01-23-80	M	8	204	39	Unmated	03-21-80
80-3	01-18-80	F	6	118	23	U[a]	03-21-80
80-4	01-23-80	M	6	209	41	Mated	03-22/24-80
81-1	03-18-81	M	10	0.5	1	U[b]	unknown
81-2	02-05-81	F	8	6.5	1	U[b]	02-06-81
81-3	01-07-81	F	7	40	4	Unmated	02-11-81
81-4	01-09-81	M	5	57	8	Unmated	02-20-81
81-5	01-09-81	F	6	205	36	Mated	03-27-81
81-6	01-15-81	F	6	27.2	8	Unmated	03-25-81
81-7A	01-10-81	F	8	0.1	1	U[a]	unknown
81-7B	03-18-81	F	7	30	6	Mated	04-01-81
81-8	01-11-81	M	4	193	22	Mated	03-27-81
81-9	01-17-81	F	8	43.5	5	Mated	01-24-81
81-10	03-15-81	M	6	10	1	U[b]	03-21-81[b]

[a]Uncertain but brood patch present.
[b]Undocumented due to insufficient monitoring time.

Table 7. Classification results of a stepwise discriminate analysis to determine discriminating variables to separate immature vs adult bald eagles by measurement at 3 levels of significance (F-to-enter levels).

Classification	F = 4.0[a]			F = 2.7[b]			F = .01[c]		
	Immature	Adult	% Cor.	Immature	Adult	% Cor.	Immature	Adult	% Cor.
Immature	21	4	84	23	2	92	23	2	92
Adult	5	22	81	3	24	88.9	4	23	85.2
			$\bar{x}$ = 82.7			$\bar{x}$ = 90.4			$\bar{x}$ = 88.5
Discriminating variables entered	CULMEN LENGTH, TAIL LENGTH			CULMEN LENGTH, TAIL LENGTH, WING CHORD			CULMEN LENGTH, TAIL LENGTH, WING CHORD		

[a]P value = 0.05.
[b]P value = 0.10
[c]P value > 0.5.

functions to determine age by measurement are shown in Table 8. Form of the function to determine age group is: $CS_1 = C_{i1}(TL) + C_{i2}(WC) + C_{i3}(CL) + K_i$

Table 8. Discriminating variables and coefficient values for classiication functions to be used in determining age class of bald eagles. Classification equation with the highest score determines age class.

Discriminating Variable	Coefficient Immature Equation $(C_I)^1$	Coefficient Adult Equation $(C_A)^1$
TAIL LENGTH (TL)	2.55748	-.32513
WING CHORD (WC)	37.05921	35.69942
CULMEN LENGTH (CL)	-1.85846	-1.09278
CONSTANT (K)	-414.19687	-385.06964

[1]Form of the equations are: $CS_{I/A} = C_{I/A}(TL) + C_{I/A}(WC) + C_{I/A}(CL) + K_{I/A}$

Aging by Plumage, Eye, and Beak Coloration

Photographs and notes on plumage of 69 adult and immature bald eagles captured in the SLV during winter revealed a general trend in plumage, iris, mandible, and cere coloration change with chronological age. Plumage conditions useful for aging bald eagles at a distance are presented in Figures 14-17.

Eagles exhibiting plumages most similar to those seen on nestling and fledgling eagles during summer banding in the Greater Yellowstone Ecosystem, were judged to be 0.5 yr-old birds (Fig. 14). Plumage differences between late nestling eaglets and 0.5 yr-old birds were primarily in wear and fading. Iris color of 0.5 yr-olds and late nestlings was the same. Remiges obviously were all of the same generation. Upper mandible and cere were totally black. Appendix Figures