Biology and habitat requirements of the nesting golden eagle in southwestern Montana
by John William Baglien

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
Montana State University

Abstract:
The habitat requirements and biology of the nesting golden eagle (Aquila chrysaetos) in the Madison River Basin of southwestern Montana were studied from 1972-1974. Five, seven and ten golden eagle territories were occupied in 1972, 1973 and 1974 respectively, and production averaged 0.91 fledglings per occupied site. A reproductively healthy, if somewhat depressed, population of golden eagles in the Madison Basin seems indicated, though much of the apparent growth in population must be attributed to the author's increased familiarity with the study area. Mean dates of egg laying and hatch were April 2 and May 15 respectively, though great temporal variations in nesting were noted. Fledging of the eaglets occurred between mid-July, and the first week in August. Lagomorphs and sciurids comprised 81 percent of the prey items noted in golden eagle nests. Chi-square comparisons of the distributions of 47 golden eagle cliff nests, and 799 randomly plotted points, indexing cliff site availability, revealed significant ($p<0.05$) to highly significant ($p<0.01$) selection by eagles for sites having: south or east aspect, less than 200 inches average annual snowfall, lower elevation, and greater availability of sagebrush- grassland hunting areas. Mathematical modeling, a stepwise discriminant function based upon these variables, was attempted and limitations of the function are discussed.

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of

MASTER OF SCIENCE

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Approved:

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Bozeman, Montana

March, 1975

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Date 28 February 1975

ACKNOWLEDGMENT

I wish to express sincere appreciation to the following people for their contributions to this study: Dr. Robert L. Eng, Montana State University, for technical supervision and guidance in the preparation of this manuscript; James D. Stradley for superb flying and knowledge of the area; Drs. Don C. Quimby and Richard Mackie, Montana State University, for critical review of the manuscript; and to family and friends for their encouragement. The Gallatin National Forest, United States Department of Agriculture, financed this project.

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ABSTRACT

The habitat requirements and biology of the nesting golden eagle *(Aquila chrysaetos)* in the Madison River Basin of southwestern Montana were studied from 1972-1974. Five, seven and ten golden eagle territories were occupied in 1972, 1973 and 1974 respectively, and production averaged 0.91 fledglings per occupied site. A reproductively healthy, if somewhat depressed, population of golden eagles in the Madison Basin seems indicated, though much of the apparent growth in population must be attributed to the author's increased familiarity with the study area. Mean dates of egg laying and hatch were April 2 and May 15 respectively, though great temporal variations in nesting were noted. Fledging of the eaglets occurred between mid-July, and the first week in August. Lagomorphs and sciurids comprised 81 percent of the prey items noted in golden eagle nests. Chi-square comparisons of the distributions of 47 golden eagle cliff nests, and 799 randomly plotted points, indexing cliff site availability, revealed significant ($p<0.05$) to highly significant ($p<0.01$) selection by eagles for sites having: south or east aspect, less than 200 inches average annual snowfall, lower elevation, and greater availability of sagebrush-grassland hunting areas. Mathematical modeling, a stepwise discriminant function based upon these variables, was attempted and limitations of the function are discussed.

INTRODUCTION

Occupying positions near the top of trophic pyramids, populations of golden eagles *(Aquila chrysaetos)* are useful indicators of the stability of the habitat in which they live. The golden eagle has nearly disappeared as a breeding raptor from its range east of the Mississippi River, decreasing significantly in annual migratory bird counts over Hawk Mountain, Pennsylvania (Spofford, 1969, 1971). In the west, the golden eagle appears to be maintaining itself (Wrakestraw, 1972; Heugly *In* Snow, 1973) in spite of locally severe persecution arising from controversial allegations of heavy livestock depredations (Spofford, 1969). Chlorinated hydrocarbon pesticides (DDE, DDT, and dieldrin) have been indicted in the declining reproductive success of the golden eagle in Scotland (Lockie *et al.*, 1969; Ratcliffe, 1970), and suggested as a cause of population decline east of the Mississippi (Spofford, 1971). Possible detrimental conflicts with agricultural land-use have been noted by Kochert (1972) in Idaho.

To minimize land-use impacts on populations of these raptors, their habitat needs must be identified. This study, a cooperative venture between the Gallatin National Forest and Montana State University, centered on the habitat requirements of the golden eagle in the Madison Valley, Montana. Incidental data were collected on bald eagles *(Haliaeetus leucocephalus)* and ospreys *(Pandion haliaetus)* (Appendix B).

Field investigations were conducted on a full time basis from June 12 to September 1, 1972 and from June 11 to September 1, 1973. Aerial surveys were conducted as time and weather permitted during the winter and spring of 1973 and 1974. Production data for 1974 were obtained by a mid-summer aerial survey of occupied nests located during the course of spring flights.

DESCRIPTION OF AREA

Geography and Physiography

The study area included that portion of the Madison River Basin of southwestern Montana lying between Ennis Lake and the boundary of Yellowstone National Park, Wyoming (44°32'N latitude, 111°7'W longitude). The Madison River arises in Yellowstone Park, transects the Madison Range as it flows west and north through Hebgen and Quake Lakes, the Madison Valley, Ennis Lake, the Beartrap Canyon, and the lower Madison Valley. South Meadow Creek, Ennis Lake, and St. Joe Creek formed the northern boundary of the study area, and the Yellowstone Park line a portion of the eastern boundary. Divides of the Madison River drainage formed the remaining boundaries.

The study area is conveniently divided into two sections for the purposes of description, and data analysis. The Hebgen Lake Basin, under jurisdiction of the Hebgen Ranger District of the Gallatin National Forest, extends from the Park boundary to the outlet of Quake Lake. The basin is dominated by Hebgen Lake at 6500 feet, and includes numerous surrounding peaks ranging from 9-10,000 feet in elevation. The Madison Valley, under jurisdiction of the Madison Ranger District of the Beaverhead National Forest, is bisected for most of its length by the Madison River. Elevation varies from 4815 feet (Ennis) to 6195 feet (Quake Lake outlet) along the valley floor. The Madison Range east of the river includes numerous peaks above 10,000 feet; Hilgaard Peak is the highest at 11,316. The Gravelly Range, west of the river, has numerous ridges above 9,000 feet; Black Butte is the highest at 10,545.

Geology

Precambrian metamorphics (gneiss and related rocks), overlain by strata of Paleozoic, Mesozoic and Cretaceous sediments, were variously and complexly folded, faulted and eroded in the building of the Madison Basin area (Montagne, pers. comm.). Compressional folding and overthrust faulting pushed up the Spanish Peaks and much of the Madison Range over 50 million years ago, while downfolding the Gravelly Range area. More recent tensional faulting dropped the Madison Valley and Hebgen areas to form the present basin. Simultaneous uplifting of the mountain ranges increased elevational differentials.

The Madison River developed upon this system, and alternately eroded or deposited, depending on climatic and geologic influences. The course of the river has been juggled by faulting, and the river has been forced to overtop numerous barriers.

Glaciers have from time to time filled portions of the Hebgen basin, and capped the local mountain ranges. Glaciation and erosion have etched out, in bold relief, cliffs of the more resistant limestones and sandstones, and, locally, cliffs of volcanic intrusives and metamorphics.

Climate

The climate of the Madison Valley is characterized by warm, dry summers, and long cold winters. The average January and July temperatures at Ennis are 21.8 and 64.6 F. respectively. The growing season averages 101 days, and freezing temperatures are noted as late as mid-June, and as early as the first week in September. Annual precipitation averages 10.57 inches at Ennis, with the major peak in precipitation occurring in May and June, and a minor peak in September (U. S. Dept. Com., National Oceanic and Atm. Admin., 1973; Water Resources Division, 1972?).

The Hebgen Basin is cooler and more moist than the Madison Valley. Average January and July temperatures are 10.7 and 59.6 F. respectively at West Yellowstone, and 10.4 and 61.3 at Hebgen Dam. Annual precipitation averages 21.22 inches at West Yellowstone, and 25.84 inches at Hebgen Dam (U. S. Dept. Com., National Oceanic and Atm. Admin., 1972). The average growing season is 62 days at Hebgen Dam (U. S. Dept. Com., Weather Bureau, 1960).

The mountainous areas are much colder, and receive from 30 to 80 inches of precipitation annually; much of it in the form of snow (200 to 400+ inches of snow annually). Snow in the highest elevations often stays until mid-July, and the freeze-free season averages less than 30 days (Caprio, 1965).

Vegetation

Payne (1973) mapped four basic vegetative subtypes for the Madison Basin area. Two forest subtypes, subalpine, and lodgepole pine *(Pinus contorta)*--Douglas fir *(Pseudotsuga menziesii)*, dominate the rough mountainous regions. The foothill sagebrush *(Artemisia* spp.*)* subtype occupies most of the Madison Valley, but is interrupted by extensive areas (not mapped) closely resembling Payne's foothill grassland subtype. These areas are typified by fescues *(Festuca* spp.*)*, wheatgrasses *(Agropyron* spp.*)*, needlegrasses *(Stipa* spp.*)* and wildrye *(Elymus* spp.*)*. For the purposes of this study, foothill sagebrush and foothill grassland are considered together as "sagebrush-grassland". The fourth subtype, intermountain valley grassland and meadow, is limited to the valley bottom near Ennis.

The transition between sagebrush-grassland, and lodgepole pine-Douglas fir forest is not sharply defined in the Madison Basin. The sagebrush-grassland locally tops the Gravelly Range, and extends high into portions of the Madison Range.

Land Use

Ranching is the dominant land use of the Madison Valley. Logging is a major land use in the Hebgen Basin, and is significant in portions of the Madison Valley. Recreation is an important and growing land use throughout the Madison Basin area.

METHODS

Survey

A concerted effort was directed towards locating all eagle and osprey nests (active or inactive) within the study area. Seventy-three hours of aerial survey were complemented by directed search from the ground.

Excellent aerial coverage was provided by repeated, low level (less than 200 feet) flights in a Piper "Super Cub" (PA 18 150). This plane has been noted for its efficiency in locating golden eagle nests (Hickmann, 1972).

Two types of flight patterns were employed in the survey. Extensive flights, directed toward a more general eagle-osprey distributional survey, attempted to cover much or all of the study area in a single flight. These flights followed general preselected contours (e.g. 6500 feet) for golden eagles, and water courses for bald eagles and ospreys. However, deviations from this pattern were frequently made to check areas of reported activity, or sites that appeared promising. Intensive flights, directed primarily toward locating golden eagle nests, consisted of flying "S"-shaped patterns along all cliffs between the valley floor and the divide, with each turn of the "S" placing the pilot and observer two to three hundred feet higher along the same series of cliffs. A tabular summary of the flights is presented in Appendix A, Table 8.

Search from the ground began with query of local ranchers for information on raptor activity, and permission to trespass. Subsequently, many miles of highway, and back-country roads and trails were either driven or hiked, with frequent stops to search cliffs and slopes with a binocular and a spotting scope.

Search from the ground was intensified in areas of reported or observed eagle or osprey activity, and in areas where vagaries of wind or terrain precluded adequate aerial search. Some exceptionally remote areas (notably the Hilgaard high country and upper West Fork) where satisfactory aerial survey failed to locate eagles or nests were not searched from the ground.

Nesting Biology

Golden eagle nests were distinguished from other raptor nests by specific raptor associations, size, construction, and location.

Of the major raptors reported (Skaar, 1969), or observed to nest within the Madison Valley study area, only the bald eagle and osprey build tree nests substantial enough to be confused with golden eagle tree nests (Headstrom, 1951). Osprey nests were distinguished from eagle nests by their characteristic position in the extreme tops of the nest tree (Mathisen, 1968), and remaining eagle nests were separated by the specific associations of bald or golden eagles.

Among other raptors which consistently or occasionally utilize cliff nest sites, falcons either make simple scrapes or acquire sites of other species (Olendorff, 1971), great horned owls *(Bubo virginianus)* almost never build their own nests, and red-tailed hawks *(Buteo jamaicensis)* may either build or acquire (Bent, 1937, 1938). Ravens *(Corvus corax)* may also utilize cliffs as nest sites (Bent, 1946); red-tailed hawk and raven nests tend to be substantially smaller (15-30" vs 30-60+") than golden eagle nests (Headstrom, 1951). However, some unusually large hawk or raven nests may have been mistaken for small golden eagle nests. Error resulting from misidentification of nests is believed to be minimal, involving possibly three which were included with golden eagles.

Nest status was assigned as suggested by Postupalski (1974). A nest was classified as occupied when at least one of the following activity patterns was observed during a given breeding season:

a) young were raised;
b) eggs were laid;
c) one adult observed sitting low in the nest, presumably incubating;
d) two adults present at or near a nest, regardless of whether or not it had been repaired during the season under consideration, provided there is no reason to suspect that this pair had already been counted elsewhere;
e) one adult and one bird in immature plumage at or near a nest, if mating behavior was observed;
f) a recently repaired nest with fresh sticks or boughs on top, and/or droppings or molted feathers on its rim or underneath.

A successful nest was a nest fledging at least one young. Nests were assigned supernumerary status only if adults from an occupied site were observed to use the nest, or green boughs indicated that the nest was being actively maintained. Nests thought to be within an occupied territory, though not showing sign of recent use or repair, were assigned the status of possibly supernumerary. Inactive nests were those which could not be associated with any breeding pair, and usually showed advanced stages of decay.

Initiation of nesting within the study area was approximated by extensive type aerial survey flights. All active golden eagle nests were visited at seven to ten day intervals during the field season to record the development of the young, activity of the adults, and prey remains observed in the nest or vicinity. Development of the young in 1973 and 1974 was recorded on 35mm Kodachrome or Ektachrome slides. Care was taken to limit the exposure of the young. Nests were not closely approached as eaglets neared flight stage to avoid forcing premature fledging.

Shortly after the young had fledged in 1973, I rapelled into all five successful nests, and collected prey remains and castings. On June 4, 1974, I rappelled into five of ten active nests, noted prey items and recorded the stage of the young. Prey items collected were identified to genera by comparison to study skins and skeletons in the Montana State University Vertebrate Museum. Most probable species of these prey items were established by reference to Hoffman and Pattie (1968) and Hoffman *et al.* (1969).

Seasonal nest histories were estimated by back-calculation. The ages of eaglets observed in this study were determined by comparison to pictures and descriptions of known age young (Sumner, 1925). These ages, and the dates of observations, provided the dates of hatch. Egg laying and nest initiation were calculated from incubation and life history data summarized in Bent (1937) and Snow (1973). Calculated nest histories were cross-checked against survey data.

Habitat Requirements

All nests found in 1972 and 1973 were visited at least once, and data on location, aspect, slope, and general cover type associations were recorded. These data suggested that selection for certain environmental factors restricted the distribution of golden eagle nests, and provided a basis for the hypothesis that such factors are sufficiently limiting to provide a useful descriptive model of golden eagle nesting habitat. This hypothesis was tested, in part, by the null: there is no significant difference between the distribution of cliff nests, and the distribution of available cliff nest sites. Discriminant function analysis completed the evaluation of the hypothesis. Test of the hypothesis was limited to the Madison Valley portion of the study area, which contained 51 of the 53 nests located.

Cliffs of the Madison Valley were not randomly distributed, relative to the hypothesized habitat requirements, so an index of availability of "potential" cliff nest sites was obtained by plotting 803 random points on cliffs identified on aerial photos (1:62,500). These points were plotted by positioning a dot grid (1 dot = 10 acres) over cliffs on the photos. The maximum number of points were placed on any cliff or series of cliffs, provided that one point was placed directly over a nest, if present. The following data were taken for all points plotted, referencing the aerial photos, Soil Conservation Service snow survey maps, and topographic maps:

1) site status; nest present, or not
2) aspect; north, east, south or west
3) elevation; to nearest 500 feet
4) average annual snowfall; less than 200", from 200-300", from 300-400", or more than 400"
5) acreage of sagebrush-grassland cover type within 1/4 mile;
    a) total acreage
    b) acreage not obstructed by a ridge exceeding 1,000 feet above the site
    c) acreage below a line defining 200" or more of average annual snowfall
    d) acreage as limited by both b) and c)
6) acreage of sagebrush-grassland within 1/2 mile; a) to d) as in 5)
7) acreage of sagebrush-grassland within 1 mile; a) to d) as in 5)

8) acreage of sagebrush-grassland within 2 miles; a) to d) as in 5)

The distributions of golden eagle nests, and the randomly plotted points representing "potential" sites were compared, relative to the above data, using two-way chi-square tests (Snedecor and Cochran, 1967) and stepwise discriminant function analysis (Dixon, 1973).

Stepwise discriminant function analysis classifies sites by comparing the habitat characteristics of unclassified sites to those of sites already classified, utilizing the variables which describe the characteristics in order of decreasing significance to the function. An "F" of 3.5, approximating a p-value of 0.05 for the degrees of freedom expected was assigned as the level of inclusion or deletion for the variables. The initial groups from which the function was built were established by placing the 47 known cliff nest sites in one group, and 98 sites having no sagebrush-grassland within 2 miles below a line defining 200 inches average annual snowfall into the second, "unused", group. The function was refined by placing initially unclassified sites into the appropriate group, based upon posterior probabilities of 0.995 or greater of belonging to one group or the other. The function was then simplified by using only the statistically and biologically most significant variables, and refined again from the original groups. Data appropriate to the simplified function were taken from an independent sample in the Yellowstone Valley, and the function was tested against these data.

RESULTS

Nests and Population

Fifty-three nests were located within the study area; twelve were initially located in 1972, thirty-one in 1973, and ten in 1974. Thirty-eight nests were located by aerial survey, and fifteen by search from the ground. Aerial survey proved to be a highly effective tool in locating golden eagle nests, particularly after experience was gained in spotting nests. All nests were eventually observed from the air, and, due to lack of adequate vantage from the ground, aerial survey proved to be the only means by which to check the productivity status of many nests. However, the necessity of complementary search from the ground was amply demonstrated by the difficulty found in the aerial observation of several nests.

Sixteen nest territories were occupied at least once during the three seasons of study (Appendix A, Table 9). Only six (38%) of these territories included nests which could positively be identified as supernumerary. If nest sites classified as possibly supernumerary are also included, then 9 of 16 (56%) of the territories included supernumerary nests. McGahan (1968) reported that 20 or 36 territories (56%) included supernumerary nests, Camenzind (1969) 11 of 21 territories (52%), while Kochert (1972) reported that all territories in the Snake River Canyon area included supernumerary nests. The utilization of supernumerary nests may be an index of site availability. Criteria for assigning supernumerary status are often not mentioned, and the assumption that unutilized nests represent supernumerary nests may fail to adequately account for historical nesting distributions.

Six mature pairs, two lone adults, four immatures, and three fledgling golden eagles were identified within the study area in 1972; seven mature pairs, two lone adults, eight immatures, and eight fledglings in 1973; and eleven mature pairs, three lone adults, one immature, and nine fledglings in 1974. These yearly totals represent minimum population estimates, in that they consider as separate individuals only those eagles differentiated by nesting activity, time-space distribution, or field marks (immature). Much of this apparent increase in population is attributed to increasing familiarity with the study area, but some real growth seems indicated by changes in nesting distributions and densities.

Five of the six mature pairs identified in 1972 were believed to have occupied nest territories. The sixth pair frequented a "territory" though no nest could be located. Six mature pairs and one lone adult occupied nests in 1973. One of these nests was a new site located in an area which had been frequented by a single immature bird during the previous season. Three sites had been previously undiscovered. Eleven mature pairs occupied territories in 1974. One pair was seen in the "territory" which had been frequented in 1972, five pairs occupied previously undiscovered nests, and two pairs occupied sites which had been known inactive in 1973.

Productivity of the Madison Basin golden eagles averaged 1.54 young per successful nest, and 0.91 young per occupied nest (Table 1). The number of young produced per occupied site is recommended by Postupalski (1974) as the most reliable comparison of productivity among major raptor populations. This measure of productivity was 0.84 fledglings per occupied nest in Utah (Camenzind, 1969), 1.32 and 0.95 fledglings in Montana (McGahan, 1968; Reynolds, 1969), 0.97 fledglings in Colorado (Olendorff, 1973), and 1.18 fledglings in Idaho (Kochert, 1972). The comparable productivity of the Madison Basin golden eagles suggests that the population is healthy and reproductively active.

TABLE 1. PRODUCTIVITY OF THE MADISON BASIN GOLDEN EAGLES.

Year	Young Fledged/Occupied Nest
1972	3 / 5 = 0.6
1973	8 / 7 = 1.1
1974	9 /10 = 0.9
Total	20/22 = 0.91

The density of nesting, calculated as the area of a circle having a radius of the average minimum distance between occupied eyries (Kochert, 1972), was one pair per 243 square miles in 1972, one pair per 167 square miles in 1973, and one pair per 92 square miles in 1974. The nesting density found in 1974 approaches the density of one pair per 70.8 square miles found by McGahan (1968), and Reynolds (1969) for the Yellowstone-Shields River area of Montana, though it is far below the one pair per 28.3 square miles reported by Kochert (1972) for the Snake River, Idaho area.

The distribution of inactive nests relative to occupied territories (Fig. 1) suggests that the population of eagles in the Madison may be depressed from 29 to 57 percent from recent historical levels, depending on the degree of territoriality which is assumed for the eagles. If 28 territories are assumed (a population depressed 57%), the resulting nesting density of one pair per 45 square miles seems unreasonably high for this area. Reynolds (1969) noted that in 1965 the nesting density of eagles in the Shields-Yellowstone area fell to one pair per 105 square miles in response to lowered prey availability. If 17 territories are assumed (a population depressed 29%), a nesting density of one pair per 80 square miles results. However, several of the "potential" territories are on the periphery of the present golden eagle range within the Madison Basin, and may have been established at a time when prey availability and/or territorial behavior encouraged pairs to attempt nesting in more "marginal" areas. These potential territories also include one nest whose identity as an eagle nest may be questionable.

Chronology of Nesting

The initiation of nesting activities by golden eagles in the Madison Basin probably begins in late February or March. The