1969

Population status of the golden eagle in south-central Montana

Harry V. Reynolds
The University of Montana

POPULATION STATUS OF THE GOLDEN EAGLE IN SOUTH-CENTRAL MONTANA

By

Harry V. Reynolds, III

B. S. University of Montana, 1966

UNIVERSITY OF MONTANA

1969

POPULATION STATUS OF THE GOLDEN EAGLE IN SOUTH-CENTRAL MONTANA

By

Harry V. Reynolds, III

B. S. University of Montana, 1966

Presented in partial fulfillment of the requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1969

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

May 5, 1969
Date

PROJECT FINANCING

Financial support for this project was supplied by U. S. Fish and Wildlife Service Contract No. 10-16-008-718 and by the Montana Cooperative Wildlife Research Unit: U. S. Fish and Wildlife Service, University of Montana, Montana State Fish and Game Department, and Wildlife Management Institute cooperating.

ACKNOWLEDGEMENTS

I am especially indebted to Dr. John Craighead, Leader of the Montana Cooperative Wildlife Research Unit, for incentive, guidance, and advice in all phases of the study. I also wish to thank John Seidensticker for contributing valuable advice and time throughout the study.

I wish to extend thanks to Dr. B. W. O'Gara and Dr. D. A. Jenni for their critical review of the manuscript and to the other members of my committee, Drs. P. L. Wright, S. J. Preece, and C. C. Gordon, for helpful suggestions.

Sincere thanks go to members of the Wildlife Research Unit and to other persons who have given freely of friendship and time throughout the study. Mrs. Alvina Barclay helped with many problems. Mrs. Rae Dabbert typed the final manuscript and Anna Phelps and Pat Embry also helped to type portions of the thesis.

For field assistance and companionship, I thank Derek Craighead, Charlie Craighead, and Jay Sumner.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table		Page

INTRODUCTION

Many species of raptors recently have suffered serious declines in the United States and Europe. In the United States the peregrine falcon (Falco peregrinus), bald eagle (Haliaetus leucocephalus), and golden eagle (Aquila chrysaetos) have been nearly exterminated in much of their former range east of the Mississippi River (Hickey, 1969; Cottam et al., 1961; Arnold, 1954). Breeding success of golden eagles in Britain has decreased (Lockie and Ratcliffe, 1964). These and other declines indicate the need for intensive studies of raptor populations in order to establish population norms and to identify the causes of major declines.

Because of their position at the top of the food chain and their mobility, raptors are likely to obtain heavy loads of persistent toxic chemicals. Contamination of raptor food supplies by pesticides has been blamed for low nesting density and success in bald eagles (Carson, 1962; Cottam, et al., 1961), golden eagles (Lockie and Ratcliffe, 1964), and peregrines (Cramp, 1963; Ratcliffe, 1965a, 1965b; Jefferies and Prestt, 1966). A search of the literature revealed scant information concerning pesticide residue levels in the U. S. golden eagles.

The present investigation is part of a long-term study of the golden eagle in Montana, planned and directed by Dr. John Craighead, Leader of the Montana Cooperative Wildlife Research Unit. Phase 1, conducted by Jerry McGahan (1966, 1967, 1968), treated food habits, quantified estimates of predation, nesting density, productivity, nesting success, and mortality.

In this study I compared data on population density, nesting success, productivity, and food habits that I gathered from 1965 to 1968 with McGahan's data for the period 1962 through 1964. In addition I evaluated environmental changes that occurred and sampled pesticide residue levels in the golden eagle population and some of their prey species. I attempted to evaluate the effects of environmental changes and chlorinated hydrocarbon residue levels on the ecology of an eagle population.

DESCRIPTION OF THE STUDY AREA

Geographic location

The study area was established and described by McGahan (1968). Study Area A is located near Livingston, Montana, in the south-central portion of the state. The 1260 sq. mi. area is 30 miles from north to south and 42 miles from east to west; it includes portions of Park and Sweetgrass Counties. Study Area B, which was studied less intensively than Area A during both phases, includes those portions of Park and Sweetgrass Counties not included in Area A as well as the adjacent counties of Gallatin, Stillwater, and Carbon.

Physiography

Area A is situated where the eastern edge of the Rocky Mountains meet the plains. Elevations vary from 4,000 to 10,000 ft. The Crazy Mountains border the area on the north -- the Bridger and Gallatin Ranges on the west and southwest. The Absoroka Range juts into the southern and southeastern portions of the area. Three river valleys cut through the area: the Yellowstone, Shields, and Boulder. Between the mountains and the river bottoms lies a transitional zone of foothills characterized by ridges, buttes, and breaks.

Climate

Climate in the study areas is milder than in most other sections of Montana. Average temperatures and precipitation for Livingston, Montana, which is near the center of the study area, are presented in Table 1. Average annual precipitation is 13 to 14 in. and during the nesting season, from March to August, temperatures range from - 20° to 100° F.

Table 1. Climatological summary.*

	Average temperature, °F				Total precipitation, In.			
Month	1965	1966	1967	1968	1965	1966	1967	1968
March	22	36	28	38	0.67	0.90	2.21	1.18
April	43	40	39	39	2.22	0.59	1.60	1.77
May	48	55	49	47	2.02	2.83	1.90	3.09
June	58	58	57	57	1.92	1.00	5.30	4.15
July	67	71	67	67	1.69	0.48	2.98	0.41
August	64	65	67	65	2.62	1.42	0.43	1.21

*Data taken at the Livingston FAA Airport in the approximate center of the study area (U.S. Dept. of Comm.; Weather Bureau).

Vegetation

Natural vegetation on the lower elevations between 4,000 and 6,000 ft. includes wheatgrasses (*Agropyron* spp.), fescues (*Festuca* spp.), needlegrasses (*Stipa* spp.), prairie junegrass (*Koeleria cristata*), and wild rye (*Elymus* sp.) which may be found among big sagebrush (*Artemesia tridentata*) and juniper (*Juniperus scopulorum*). In addition, cottonwood (*Populus* spp.), willows (*Salix* spp.), and wildrose (*Rosa* sp.) are often found along creek and river bottoms. Douglas fir (*Pseudotsuga menziesi*), lodgepole pine (*Pinus contorta*), and limber pine (*P. flexilis*) were the most abundant trees found at these elevations.

Between 5,500 to 7,000 ft. characteristic grasses include alpine fescue (*Festuca ovina*), bluegrasses (*Poa* spp.), and hairgrasses (*Deschampsia* spp.). More shrubs are apparent than in the lower elevations, especially nine bark (*Physocarpus* sp.), snowberry (*Symphoricarpos* sp.), and chokecherry (*Prunus virginiana*). Lodgepole pine is more abundant in this zone. Douglas fir and limber pine are still abundant.

Above 7,000 feet, alpine fescues and sedges (*Carex* spp.) are plentiful. Lodgepole pine is the most prevalent tree; Douglas fir and alpine fir (*Abies lasiocarpa*) are also found.

Land Use

The major business in the study area is agriculture. The Bureau of Census (U. S. Dept. of Commerce, 1964) reported that in 1964 Park County ranches supported 60,000 cattle and 35,000 sheep. In that year almost 24,000 lambs were sold. More than half of Area A is under cultivation. Hay, wheat, oats, and barley are the principal crops. According to census figures, there is a trend to consolidate ranches; as a result, there are fewer ranches and farms but those remaining are larger and more intensively managed. Increased use of pesticides has accompanied intensive management.

FOOD HABITS

Methods

Techniques used to determine food habits have been described in detail by Craighead and Craighead (1956) and McGahan (1966). Identifiable remains of prey at eagle eyries were recorded in the field. Unidentifiable remains and regurgitated pellets were collected and later identified by comparing hair and feathers with study skins at the University of Montana. Remains of prey found in nests were recorded and then removed if there was no flesh on the bones. If the prey remains were edible, they were marked (usually by toe-clipping), left in the nest, and removed at a later visit.

Results and Discussion

From 1965 through 1967, 1,009 individual prey items were collected from 39 nests located within Areas A and B (Table 2). Thirty-nine prey species were identified: 15 mammals, 22 birds, and 2 reptiles. Of the total number of prey items identified, 752 (74.5%) were mammals, 253 (24.2%) were birds, and 4 (0.4%) were reptiles.

Prey proportions of 980 food items on the same study areas from 1962 through 1964 (McGahan, 1968) were: 854 (87.0%) mammals, 122 (12.4%) birds, and 4 (0.4%) reptiles. My data show a 12.5% decrease in the number of birds in the diet of nesting eagles. Reptiles percentages remained the same.

Game and domestic species made up 16.7% of the prey found in nests (Table 3). The greatest proportion of this (7.2%) consisted of four species of grouse. The remainder was divided among the following categories: big game, 4.1%; ducks 1.3%; introduced game birds, 3.6%; and

Table 2. Prey found in golden eagle nests, listed in decreasing order of frequency, Areas A and B.

	1965		1966		1967		Total	
Mammals	No.	%	No.	%	No.	%	No.	%
Whitetail Jackrabbit	46	30.7	108	27.2	110	23.8	264	26.2
Cottontail (Desert and Mtn.)	19	12.7	63	15.9	119	27.2	201	19.9
Yellowbelly Marmot	10	6.7	62	15.6	44	9.8	116	11.5
Richardson Ground Squirrel	28	18.7	35	8.8	43	8.7	106	10.5
Mule Deer (35 fawns, 1 yrlg.)	6	4.0	17	4.3	13	2.7	36	3.5
Striped Skunk	0		3	0.8	3	0.7	6	0.6
Longtail Weasel	0		2	0.5	2	0.5	4	0.4
Pronghorn (Fawn)	0		0		4	0.9	4	0.4
Voles (*Microtus* sp.)	0		0		3	0.7	3	0.3
Domestic Cat	0		0		2	0.5	2	0.2
Domestic Sheep (1 lamb, 1 adult)	0		0		2	0.5	2	0.2
Bushytail Woodrat	0		0		1	0.2	1	0.1
Muskrat	1	0.7	0		0		1	0.1
Coyote (pup)	0		1	0.2	0		1	0.1
Black-tailed Prairie Dog	5	3.3	0		0		5	0.5
Birds								
Black-billed Magpie	13	8.7	40	10.1	30	6.6	83	8.2
Grey Partridge	0		6	1.5	21	4.6	27	2.7
Sage Grouse	2	1.3	14	3.5	10	2.1	26	2.6
Blue Grouse	1	0.7	3	0.8	12	2.7	16	1.6
Common Crow	5	3.3	5	1.3	3	0.7	13	1.3
Grouse (Unidentified)	3	2.0	7	1.8	5	1.1	15	1.5
Great Horned Owl	0		6	1.5	4	0.9	10	1.0
Sharp-tailed Grouse	5	3.3	1	0.3	3	0.7	9	0.9
Red-shafted Flicker	0		4	1.0	1	0.2	5	0.5
Ruffed Grouse	1	0.7	3	0.8	1	0.2	5	0.5
Ring-necked Pheasant	1	0.7	5	1.3	5	1.1	11	1.1
Duck (Unidentified)	1	0.7	0		5	1.1	6	0.6
Robin	1	0.7	2	0.5	1	0.2	4	0.4
Passerine (Unidentified)	0		0		3	0.7	3	0.3
Western Meadowlark	0		1	0.2	3	0.7	4	0.4
Great Blue Heron	0		0		2	0.5	2	0.2
Mallard Duck	0		4	1.0	2	0.5	6	0.6
Lewis Woodpecker	0		0		1	0.2	1	0.1
Townsend's Solitaire	0		0		1	0.2	1	0.1
Sparrow Hawk	0		0		1	0.2	1	0.1
Cooper's Hawk	0		0		1	0.2	1	0.1
Common Nighthawk	0		1	0.2	0		1	0.1
Pintail Duck	0		1	0.2	0		1	0.1
Domestic Chicken	1	0.7	0		0		1	0.1
Domestic Pigeon	0		1	0.2	0		1	0.1
Reptiles								
Racer Snake	0		1	0.2	1	0.2	2	0.2
Bull Snake	0		1	0.2	0		1	0.1
Unidentified Snake	1	0.7	0		0		1	0.1
Total	150	100.3	397	100.0	462	99.9	1009	100.1

Table 3. Game and domestic animal remains found among 1,009 prey items in golden eagle nests, 1965-67, Areas A and B.

Big Game	Number	% of total prey
Mule deer (fawn)	36	3.6
Mule deer (yearling)	1	0.1
Pronghorn (fawn)	4	0.4
Subtotal	41	4.1
Game Birds		
Sage grouse	27	2.7
Gray partridge	26	2.6
Blue grouse	16	1.6
Unidentified grouse	15	1.5
Ring-necked pheasant	10	1.0
Sharp-tailed grouse	9	0.9
Ruffed grouse	5	0.5
Mallard	6	0.6
Unidentified duck	6	0.6
Pintail	1	0.1
Subtotal	121	12.1
Domestic Species		
Cat	2	0.2
Sheep (lamb)	1	0.1
Sheep (adult)	1	0.1
Chicken	1	0.1
Subtotal	5	0.5
TOTAL	167	16.7

domestic species, 0.5%. Proportions of game and domestic species in the food habits of eagles changed little from Phase 1 levels. The greatest increase during Phase 2 occurred in the grouse species which, as a whole, increased by 4.2%.

Domestic species were found as prey in eyries during both phases of study. In Phase 1, McGahan (1968) found remains of one lamb in a nest; during Phase 2, I found remains from one lamb and an adult sheep. Lambs have been reported as eagle prey in other studies (Gordon, 1955; Lockie and Stephen, 1959; Lockie, 1964). However, "lamb dumps", sites where ranchers dispose of carcasses, are common throughout the area and are usually accessible to eagles so it is possible that the single lamb found was taken as carrion. It is also probable that the adult sheep was dead when taken.

Food habits were studied more intensively in Area A than in Area B (Table 2, Table 20, Appendix). I collected 771 prey items in Area A and 240 in Area B. During each three-year phase about 700 prey items were found and identified in Area A and food habits are compared for Phase 1 and Phase 2 in Table 4. In 1965-67 there was a decline from 1962-64 levels in the number and percentages of both whitetail jackrabbits (Lepus townsendi) and cottontails (Sylvilagus auduboni and S. nuttalli). An increase was noted in yellowbelly marmots (Marmota flaviventris), Richardson ground squirrels (Citellus richardsoni), and birds (Table 4, Table 21, Appendix).

Lagomorphs declined by 25.8% while other mammals increased 10.8% and birds increased 12.9%. Since raptors usually take prey in proportion to prey population densities (Craighead and Craighead, 1956), this

Table 4. Differences in percent of major prey species found at golden eagle nests during Phases 1 and 2 in Study Area A.

	Phase 1 1962-64		Phase 2 1965-67		Difference*
	No.	%	No.	%	(%)
Whitetail jackrabbits	248	35.3	176	22.8	-12.5
Cottontails (Desert & Mtn.)	241	34.3	162	21.0	-13.3
Yellowbelly marmots	53	7.5	112	14.5	+ 7.0
Richardson ground squirrels	26	3.7	69	9.0	+ 5.3
Black-billed magpie	33	4.7	71	9.2	+ 4.5
Mule deer (fawn)	24	3.4	30	3.9	+ 0.5
Gray partridge	16	2.3	23	3.0	+ 0.7
Blue grouse	15	2.1	15	2.1	0
Other mammals	19	2.7	21	2.7	0
Other birds	24	3.4	91	11.8	+ 8.4
Reptiles	2	0.3	0	0	- 0.3
TOTAL	702	99.7	771	100.0	

shift in food habits indicated a decline in jackrabbit and cottontail numbers which was verified by field observations and by population figures for jackrabbits in Montana during this period. Pacific Hide and Fur, a firm collecting jackrabbits for mink food, processed approximately 88,000 in 1962, 80,000 in 1963, 45,000 in 1964, and only 18,000 in 1965. Because this venture was unprofitable in 1965, it has been discontinued. Although these jackrabbits were taken throughout Montana, a majority were taken within 100 miles of the study area.

An epidemic of tularemia may have been the cause of the widespread decline in rabbits (Jellison, per. comm.). The disease was not reported in rabbits but cases were found in sheep on the edge of the study area and in beaver within the area itself.

Because nestling golden eagles in the study area are dependent on rabbits as a major food source, it would be expected that a severe decline should have some effects on the eagle population.

The production and success of the five individual nests listed in Table 5 illustrate the dependence of some eagles on a food supply of rabbits. Nests #7, 13, and 14 were dependent on rabbits for much of their food supply and were more successful and productive in years of high rabbit population. Two of these nests, #13 and 14, were 0.25 miles distant; hence competition between these pairs would have compounded the effects of low food supply. The other nests did not depend on rabbits to as great a degree and both were highly productive and successful throughout the study.

Reduced rabbit populations would have the greatest effect upon eagles during a time of critical food availability. This period, when food availability is lowest compared to food needs for eagles, is from the beginning of incubation to the time when eaglets are about three weeks old. During this period only one adult hunts while the other bird is at the nest; also, during this part of the year few prey species other than rabbits are available as food. Most incubation occurs during mid-March to mid-May while rodents are still hibernating and young-of-the-year of most prey species are not available. This critical time would have a greater effect on eyries which are located in marginal areas where prey is scarce.

In Scotland, Brown and Watson (1964) studied golden eagle populations in relation to their food supply. They concluded that reductions

Table 5. Success and productivity of five golden eagle nests in relation to the proportion of jackrabbits to total prey items.[1]

Year		1962	1963	1964	1965	1966	1967	1968
Rabbit population levels*		H	H	M-H	VL	L	L-M	L-M
Eyrie No.								
7	Productivity	2_3	2	1_3	U_1	U_2	X	2
	Rabbits/total prey	36/42	30/38	36/41	--	--	--	--
	Percent	86	79	88	--	--	--	--
13	Productivity		2_2	2	X	2	U_2	2
	Rabbits/total prey		15/25	15/63	--	16/33	--	7/8
	Percent		60	87	--	44	--	88
14	Productivity		2	2_2	X	U_1	U_2	1
	Rabbits/total prey		26/32	40/47	--	--	--	3/6
	Percent		81	85	--	--	--	50
5	Productivity	1	2	2	2_2	1	1_2**	2
	Rabbits/total prey		4/10	3/9	0/26	5/20	6/23	4/12
	Percent		40	33	0	25	26	33
18	Productivity		S	2_2	2_2	2	2_2	++
	Rabbits/total prey		1/4	3/10	0/4	3/8	2/5	++
	Percent		25	33	0	38	40	++

* Rabbit population levels were estimated on the basis of percentages of rabbits found in nests, number collected by Pacific Hide and Fur, and field observations. H=high; M= moderate; L=low; VL=very low.

** One of two eggs was taken for pesticide analysis.

1 Productivity and success were shown in the following way: S - successful, no. of young unknown; U - unsuccessful nest; 1, 2 - no. of young fledged; Sub-$_{1, 2, 3}$ - observed number of eggs; x - nest unoccupied.

in food sources did not control the numbers of adult eagles but that breeding success may be related to food potential. In the present study prey was scarce during at least one year; in subsequent years prey populations reached higher levels but did not match 1962-64 levels. The eagle population showed some failure to nest during the year when food was scarce; in later years, when food was still not plentiful but at higher levels than in 1965, nesting productivity was still affected.

POPULATION DYNAMICS

Methods and Techniques

McGahan (1966 and pers. comm. 1965) furnished the locations of many eyries on the study area. In addition to studying these eyries, I searched for new and undiscovered nests and checked alternate sites of the established eyries. Nests were discovered by systematic glassing of cliffs, buttes, timbered ridges, and ravines from vantage points. Several eyries were found after locating perches which were repeatedly used by adult eagles as evidenced by "whitewash"; these perches were often within sight of nests.

Information on nesting success and productivity was obtained during three visits per nest. I made the first nest visit during incubation to count eggs, the second soon after the young hatched, and the third just prior to fledging. At a few inaccessible eyries, or when time did not permit early observations, only fledgling counts were made.

Nesting Population

Craighead and Craighead (1956) found that the number of pairs of nesting raptors in an area remains relatively stable over a period of time. The number of known nesting pairs on Study Area A averaged 18 during the study and ranged from 12 in 1965 to 23 in 1967. The low number of nesting pairs observed in 1965 apparently reflects the failure of some adults to nest and not a reduction in numbers of adults on the study area. The apparent increase in the number of nesting pairs in the last two years of the study might be the result of my discovery of several nests in 1967 which may have been occupied in previous years but not located.

Fifteen percent of the eagle pairs on the study area failed to nest during Phases 1 and 2. I estimated the number of non-nesting pairs during Phase 1 from McGahan's (1966) data by counting those unoccupied nests which were occupied in other years. During Phase 2, I used the same method in conjunction with direct observation of those eagle pairs which were present in the area but did not nest. Estimates of non-breeding pairs may have been high in some cases because alternate nests were not located.

In 1965 there was a sharp increase in the number of pairs that did not nest. This was not observed during any other year of the study. More than half of the birds which nested in 1964 did not re-nest in 1965 but apparently were present in the area. The factors responsible for this change are not exactly known. A decline in the number of rabbits available as prey in 1965 can be correlated with this decline in nesting pairs. If other potential depressant factors such as disturbance by the investigator or adverse influence of pesticides had been responsible for the 1965 decline, they would also have had a depressant effect in other years.

Distribution and Occupancy of Eyries

Distribution: The distribution and occupancy of eyries during Phase 2 is presented in Figure 1.

McGahan (1968) found maximum and minimum distances between nests of 10.5 miles and 1.0 miles during 1963-64. I found no difference in these figures in 1965-68.

The average density of known nesting pairs on Study Area A was one pair per 70.8 square miles from 1963 through 1967. During McGahan's study (1966) the density of nesting pairs remained relatively stable: 17 pairs were located in 1963 and 19 pairs in 1964; densities were one pair/74.2 sq. mi, and one pair/66.3 sq. mi. However, the average density of known nesting pairs in Area A fluctuated greatly in Phase 2. In comparison to the earlier figures the same area supported 12 pairs in 1965, 18 in 1966, and 23 in 1967 for average densities of one pair/105.0 sq. mi., 70.0 sq. mi., and 54.8 sq. mi. respectively.

Changes in density of known nesting pairs were evident in the Boulder River Valley, which drains approximately 20% of Study Area A (Table 6). In 1963, 1964, and 1965, four nesting pairs were found in this area for a density of one pair/63.0 sq. mi. each year. In 1966, the density was one pair/42.0 sq. mi. In 1967, with 10 nesting pairs the density was one pair/25.2 sq. mi., the highest recorded density for any portion of the study area.

Other investigators have found higher densities than those calculated for Area A. In Scotland, Lockie (1964) found the average density of 13 pairs to be one pair/22.1 sq. mi. In the same country, Watson (1957) found 14 pairs to have an average density of one pair/15.7 sq. mi.

One hunting range used by golden eagles was mapped. In late June and early July of 1965, I observed the hunting area of pair #5 from dawn until dark for 10 days. Although the eagles spent much of their time in 13 sq. mi., the total area used by this pair was 32 sq. mi.

Table 6. Nesting densities in two portions of Area A.

	Boulder River Valley (252 sq. mi.)		Rest of Area A (1008 sq. mi.)		Total Area A (1260 sq. mi.)	
	Pairs	Density	Pairs	Density	Pairs	Density
1963 (McGahan, 1966)	4	63.0	13	77.5	17	74.2
1964 (McGahan, 1966)	4	63.0	15	67.2	19	66.3
1965	4	63.0	8	126.0	12	105.0
1966	6	42.0	12	84.0	18	70.0
1967	10	25.2	13	76.2	23	54.8

Density = One pair/______ sq. mi.

The total land area used by golden eagles has been mapped in two other studies conducted in the U. S. In Colorado the average area per pair was 36 sq. mi. (Arnold 1964). Dixon (1937) found the areas used by 27 golden eagle pairs in California ranged from 19 to 59 sq. mi. (average 36 sq. mi.). He observed that those eagles hunting over land planted to crops had large ranges, presumably due to lower food availability.

The distribution and density of eagles on different portions of Area A was probably due to food availability. Raptors hunting over intensively cultivated or relatively barren land require larger areas to capture the same amount of prey than raptors hunting over areas where prey is more abundant.

Occupancy: An eyrie was considered occupied if an eagle pair made an attempt to nest as indicated by direct observation or field signs. The number of nests which were occupied varied from 12 in 1965 to 23 in 1967 (average 18).

Changes in population levels may be caused if paired eagles do not nest annually. Watson (1957) watched five pairs for 13 years in Scotland, and found that each pair failed to breed at least once during the period. Spofford (1964) reported that it was unusual for breeding pairs to nest every year in the U. S.

In the present study, nesting attempts have been sporadic -- some nests are occupied yearly, others only occasionally. Three of nine nests under observation from 1962-68 were occupied for all seven years (Table 7). Other nests showed at least one year of non-nesting.

Table 7. Number of years that 31 nests were occupied compared with the number of years these nests were under observation, Area A, 1962-68.

Years under observation	Number of years nests were occupied while under observation							Total nests
	7	6	5	4	3	2	1	
7	3	2	1	1	1	1	1	9
6		1	3	1	1	2	--	8
5			1	1	1	--	--	3
4				3	--	--	1	4
3					1	--	--	1
2						4	2	6
Total nests	3	3	5	6	4	7	3	31

Nesting density figures may have been affected by eagles using alternate eyries which were not found by the investigator. Eagles often build alternate eyries; McGahan (1966) found one nest with seven alternates. Thirty-one paired eagles and their nests were under observation on Area A in Phase 2. Eighteen of these had from one to three alternate nests; 13 pairs had no known alternate nests. Thirty alternate nests were often repaired and/or lined yearly and sometimes used. When a regularly used nest was unoccupied during a year, an intensive search was made for alternate nests. In at least three instances no alternate nests were found for unoccupied nesting sites until the second or third nesting season after the search began.

Changes in nesting density and occupancy may be partially due to mortality of adult birds in wintering areas. Band returns from McGahan's (1966) study indicated that sub-adult eagles from the Livingston area migrate as far as Texas. Adult birds have been observed on the study area during most of the year, and at least some adult birds were residents of the area.

Poisoning of golden eagles in their wintering areas could cause changes in occupancy of nests. According to Ward and Spencer (1947), 1080-poisoned baits theoretically can kill golden eagles only in high (5 mg/kg) dosages, but other investigators (Rudd, 1966; Rudd and Genelly, 1957; Robinson, 1953) reported that eagles were killed at coyote bait stations. The 1080-poisoning of adult birds with coyote baits, which were common in the study area, may have caused some mortalities. Two ranchers volunteered information that "government hunters" had approached them to ask permission to place 1080-treated coyote baits on their land. Both ranchers stated that eagles frequented their land prior to placing of poison baits, but not afterwards. Baits were placed near one nest which was successful for two years prior to setting of poison baits, but eagles have not been observed in the area since.

Poisoning or other winter mortality may remove some adults from the breeding population but breeding density and occupancy have remained relatively stable except for 1965.

Disturbance by the investigator did not generally affect occupancy of nests. Data in Table 8 indicate that 68% of all nests have either been occupied every year since discovery or every year except one. Also, 85% of all nests visited were occupied the following year in all years except 1964 when the percent was 56. It was during the winter of 1964-65 that the rabbit population suffered a severe decline, and the high percentage of non-occupancy in 1965 may be due to a decline in food availability.

Nesting Success

A nesting effort was considered successful if one or more eaglets fledged. Of the 109 known nesting efforts in Area A, 83 or 76.1% were successful during 1963-68. An additional 14.7% of the nesting efforts were not successful as a result of natural causes -- eaglets which were found dead below nests, eggs that failed to hatch, or eaglets that disappeared from the nest. Half of the remaining 10 unsuccessful nesting efforts (9.2%) were due to human disturbance. The other five were thought to have resulted from human disturbance but evidence was not conclusive.

Nesting success during 1965-68 declined from 1963-64 levels (Table 9). The average nesting success for the two-year period of Phase 1 was 91.7% (McGahan, 1966); for the first two years of Phase 2 it was 76.7%, a 15% decline. During the next two-year period, nesting success dropped to 62.8%. The average nesting success of

Table 8. History of occupancy and fledging success of 31 golden eagle eyries, Area A.

	Phase 1		Phase 2					
Nest	1963	1964	1965	1966	1967	1968	Fledglings produced	No. fledged/ occupancy
1	U	S	X	X	X	X	1	0.33
2	S	(U)	(S)	(S)	(S)	(U)	5	0.71
3	X	X	X	X	U	U	0	0
4	S	S	U	(S)	S	S	8	1.14
5	S	S	S	S	S	S	11	1.56
6	S	(S)	(S)	(S)	(S)	(X)	7	1.16
7	S	S	(U)	U	X	S	7	1.16
8	S	S	X	(S)	U	S	5	1.00
9	X	X	S	X	S	S	6	1.50
10	S	S	-	(S)	(U)	-	4	1.00
11	U	S	X	S	X	U	2	0.50
12	S	S	X	X	X	X	3	1.50
13	S	(S)	X	(S)	U	(S)	8	1.60
14	S	S	X	(U)	U	(S)	5	1.00
15	S	S	U	S	U	U	2+	0.40
16	S	S	S	X?	(U)	U	2+	0.50
17	S	X	X	X	S	(?)	1+	1.00
18	S	(S)	S	(S)	S	-	8+	2.00
19	S	S	X	(S)	(S)	-	6	1.50
20	X	S	X	X	X	U	1	0.50
21		S	X	X	X	-	2	2.00
22		S	X	(S)	X	U	3	1.00
23			S	U	S	S	5	1.25
24			S	U	S	S	5	1.25
25			S	S	X	X	2	1.00
26				S	S	(U)	1+	0.50
27					S	S	3	1.50
28					S	S	2	1.00
29					S	X	1	1.00
30					S	X	1	1.00
31					S	U	1	0.50
Tot. Occ. Nests	17	19	12	18	23	20	118	

<u>Designations</u> S = successful nesting attempt; U = unsuccessful nesting attempt; X = unoccupied; () = nested in alternate nest; - = not determined

NOTE: Identify of pairs of eagles using alternate nest sites could generally be determined by behavior traits, defense of former nest sites, specific plumage characteristics, and their spatial distribution in relation to other pairs of eagles.

During their first year of observations, nests #15, 16, 17, 18, and 26 were successful but the number of young fledged was not known. Thus, these five nesting efforts were not included in calculation of number of young produced or number fledged/occupancy.

Table 9. Nesting success of golden eagles, Area A, 1963-68.

	Phase 1		Phase 2			
	1963	1964	1965	1966	1967	1968
Successful nests/ nesting attempts	15/17	18/19	9/12	14/18	16/23	11/20
% nesting success	88.2	94.7	75.0	77.8	69.6	55.0

five eagle pairs in Scotland was 66% over a 13-year period (Watson, 1957).

Histories of occupancy and fledging success, Table 7, showed that some nests, such as #5 and 18, were occupied yearly, were successful, and produced a high number of fledglings; others in the same study area were generally unsuccessful and fledged few eaglets. Continued occupancy was not necessarily correlated with success.

During Phase 2 the population was dependent on certain individual pairs for production of young (Table 8). Pairs with low or marginal success may have needed more favorable conditions than prevailed in order to fledge young.

Human disturbance was the direct cause of one nesting failure each year from 1963 to 1966; during 1967 and 1968, two and four failures respectively were attributed to man.

Even if all study-connected mortalities were credited as successful, the Phase 2 success levels would be at least 10% lower than Phase 1.

Natural causes of nest failure exerted a greater influence than did human disturbance. In the two years during Phase 1, there was 1 nest failure attributed to natural causes; in Phase 2, there was a total of 15 in four years--2, 3, 5, and 5 respectively, This decrease in nesting success may be due to one or more factors such as severe climatic conditions, variation in availability of prey, or the influences of pesticides.

Productivity

Three measures of production by nesting eagles were recorded: (1) number of eggs laid, (2) number of young hatched, and (3) number of eaglets fledged. All three indices of production were observed during the 1967 nesting season. Egg counts, but not hatch counts, were made in 1964 and 1965. Each year from 1963 through 1968 the number of eaglets fledged were observed.

Clutch size: Fifty clutches were counted. Twenty clutches were counted in 1964 and 1965 by McGahan (1968), and I counted 30 from 1966 through 1968. One-egg clutches represented 2%, two-egg clutches 90%, and three-egg clutches 8%.

Clutch sizes from seven different studies are compared in Table 10. The average clutch size of 2.0 eggs per nest found in this study may be a minimum figure. Because laying of multiple egg clutches may take place over a three to six day period, data on clutch counts which I made during early incubation may have biased the smaller clutch sizes.

Differences in clutch size between the two phases of this study were not great. During the entire study there were five observed departures from 2.0 eggs per clutch. Clutches of three eggs were observed in three nests during 1964 and one nest in 1968; a single one-egg clutch was found in 1965.

Hatching success: Hatching success was determined by visiting eyries within five days after eaglets hatched. Hatching success was

Table 10. Comparison of clutch sizes from different areas.

Area and investigator	Number of clutches in sample	Percent of different clutch sizes		
		1 egg	2 eggs	3 eggs
California (Dixon, 1937)	Unknown	10	80	10
California (Hanna, 1930)	Unknown	35	60	5
California (Slevin, 1929)	21	19	67	14
Scotland (Gordon, 1927)	82	18	72	10
Colorado (Jollie, 1943)	5	20	80	0
Montana (McGahan, 1968)	20	5	80	15
Montana (Present Study)	30	0	97	3

estimated to be at least 85% during Phase 2. Hatching success was observed at 14 nests during 1967. In these nests, 24 (86%) of 28 eggs hatched (1.71 eaglets per nest). If the established 2-egg clutch size is projected for all nesting efforts during Phase 2 and the number of young hatched is determined by subtracting unhatched eggs from laid eggs, 127 (87%) of 146 eggs hatched. Because the number of unhatched eggs was not recorded for Phase 1, I did not estimate hatching success for that period.

The number of unhatched eggs found in nests provides a good estimate of hatching success. Unhatched eagle eggs usually remain unbroken from 4 to 6 weeks after incubation ceases. The four eggs which failed to hatch in 1967 were collected 2 to 6 weeks after the adults abandoned the nests and were still whole at the time of collection. Most of the eggs that failed to hatch were probably found.

The literature includes little information about hatching success. McGahan (1968) and Wellein and Ray (1964) calculated the minimum number of young hatched by adding the number of young fledged to the number of known nestling mortalities. This method does not take into account the proportion of young which may hatch and then disappear.

Eight of 24 nestlings disappeared from eyries in 1967 and were presumed dead, 5 other nestlings were found dead on nests, and 11 eaglets fledged. Thus 37.5% of the young disappeared from these nests.

Fledging success: One hundred twelve young eagles fledged during 1963-68 or an average of 1.11 eaglets per occupied nest (Table 11). Occupied nests included both those that were successful and those that were not. Fledging success from successful nests only averaged 1.43.

Pairs associated with 10 nests produced most of the fledglings during the study periods (1962-68). These 10 pairs accounted for 37% of all nesting attempts and 60% of the young fledged (Table 8). The young fledged from these nests averaged 1.51 per nesting effort.

In the southern Rocky Mountains, Wellein and Ray (1964) reported 1.51 fledged eaglets per nesting attempt from 23 nests. In Scotland, Watson (1957) observed that eagle pairs from 5 nests produced an average of 0.8 young per pair over a 13-year period.

Other investigators have reported mean fledgling production only from successful eyries. In Scotland, Brown and Watson (1964) recorded

1.2 eaglets per nest from 97 successful eyries and Sandeman (1957) recorded 1.4 fledged from 19 eyries.

During Phase 2 I found the average number of young fledged per nesting effort declined steadily. The average number of eaglets fledged dropped from 1.36 in 1963-64 to 1.11 in 1965-66 and to 0.95 in 1967-68 (Table 11). During Phase 1, McGahan (1966) recorded 32 nesting efforts resulting in 43 fledged eaglets. During the next four years my data showed that 68 nesting efforts yielded only 67 fledglings, a drop of 37.6%.

Three factors could have caused this downward trend: (1) influence of pesticides, (2) influence of the investigator, or (3) fluctuations in the availability of food. The influence of pesticides can be discounted because there was not an increase in kinds or amounts of pesticides applied to the area in 1965 (the first year of the decline).

Human influence accounted for a 9% decrease in young fledged during Phase 2. This parameter includes three unhatched eggs and three eaglets taken for pesticide analysis. Even if these mortalities were counted as fledged eaglets, the number of young fledged per nesting during Phase 2 would still have been 16% below Phase 1.

Lack (1966) and Brown and Watson (1964) suggest food as a possible factor limiting breeding success or young fledged per eyrie. It is probable that changes in availability of food, specifically population declines of jackrabbits and cottontails, were responsible for the fledgling decline during my study. Food availability and its relation to golden eagle population dynamics are discussed in more

Table 11. Summary of young fledged per occupied nest*, Area A, 1963-68.

	Phase 1**			Phase 2						6-year Avg.
	1963	1964	2-year Avg.	1965	1966	2-year Avg.	1967	1968	2-year Avg.	
Nesting efforts	13	19	16.0	12	17	14.5	20	20	20.0	16.8
Young fledged	19	23	21.0	13	18	15.5	19	19	19.0	18.7
Average fledged/nest	1.46	1.26	1.34	1.08	1.06	1.07	0.95	0.95	0.95	1.11

*Note: The number of young fledged for these nests is accurate; however, nesting efforts or young fledged from nests which were used experimentally or not located until after the young had fledged were not included.

**Date of Phase 1 after McGahan, 1966.

detail in a later section.

Mortality

From 1962 to 1968, 52 golden eagles were found dead (Data from 1962-64, McGahan, 1968). Nestlings accounted for 76.5% of these; juveniles, 7.8%; adults, 5.9%; and those of unknown age, 9.8%. Because of their wide-ranging habits, immature and adult mortalities are less apparent than nestling mortalities and are probably more prevalent than the data suggest (McGahan, 1966). Brown and Watson (1964) estimated that 75% of young golden eagles may die before reaching sexual maturity, which for golden eagles is about 4 years (Jollie, 1947).

From 1962-64, McGahan (1966) found 22 dead golden eagles: 14 nestlings, 2 juveniles, 2 adults, and 4 of unknown age. Of the 14 nestling mortalities, 11 were found in Area A. Six of these 11 were caused by man, 1 by the investigator. Causes of death for the other five eaglets were unknown (Area A nestling mortalities are included in Table 12).

Thirty mortalities were recorded in Phase 2: 25 nestlings, 1 four-month old juvenile, 1 ten-month-old juvenile, 2 adults, and 1 of unknown age. Of the 25 nestling mortalities (Table 12), three were a direct result of the study. Of the remaining 22, 1 was killed by its nest-mate, 2 were taken from the nest by an unknown person, and the causes of death for the other 19 were unknown. Seven were found dead in or below their nests, but the other 12 disappeared. The largest number of mortalities was recorded in 1967, primarily because nests were kept under closer surveillance from hatching to

Table 12. Summary of known nestling mortalities and eggs failing to hatch, Area A.

Year	Known nestling mortalities	Unhatched eggs
1962	2	?
1963	3	0
1964	6	?
1965	4	2
1966	2	3[1]
1967	17	6[1]
1968	2	7
Total	37	18

[1] One egg each from two-egg clutches of three pairs were taken for pesticide analysis. One was taken in 1966; two in 1967.

fledging.

In Table 13 the changes in nestling numbers between hatching and fledging are reviewed. If the observed clutch size from 50 known-size clutches is projected for all clutches except when otherwise known (i.e. the single 1-egg clutch and three 3-egg clutches) and the established hatching success applied, the number of eggs hatched can be estimated. Of the eaglets hatched 24.9% could not be accounted for and were presumed dead (range 37.5% to 10.0%). The low figure was observed during 1967, when I was in the field during the entire nesting season, and, as a result, recorded mortalities of young eagles which otherwise would have disappeared from the nest. The figure is higher in other years when observations did not begin until June.

Table 13. Summary of fate of nestlings*, Area A.

	1963** No.	1963** %	1964** No.	1964** %	1965 No.	1965 %	1966 No.	1966 %	1967 No.	1967 %	1968 No.	1968 %
Eggs hatched	26		40		21		32		40		34	
Nestlings found dead	3	11.5	4	10.0	2	9.5	2	6.3	17	42.5	4	11.8
Nestlings that fledged (observed)	19	73.4	23	57.5	13	61.9	18	56.3	19	47.5	19	55.9
Nestlings unaccounted for and presumed dead	4	15.3	13	32.5	6	28.6	12	37.5	4	10.0	11	32.4

* The number of eggs laid were projected from clutch sizes calculated from 50 clutch counts; the number of eggs hatched was determined by subtracting the unhatched eggs from the projected clutch size of 2.0 eggs/nest. For additional information on hatching success see page 23.

**Date from McGahan, 1966

Because 74% of the mortalities occurred within the first month after hatching (Table 14), many deaths were missed if the nests were not visited until later in the nesting season.

The number of eggs which failed to hatch was not recorded during Phase 1.

In Phase 2, 18 eggs did not hatch on Area A (Table 12). Three of these were taken from incubating eagles and were presumed to be viable. Three eggs were found under an adult which died on the nest. Only one of the remaining 15 eggs in Area A was found in a successful nest; all others had been abandoned. It was not known what proportion of the eggs which were abandoned were infertile, but at least some were fertile and contained well developed embryos.

Table 14. Ages at death for 12 eaglets that died in 1967, Area A.

Age (days)	1 - 10	11 - 20	21 - 30	31 - 40
Number	7	1	1	3
Percent	58	8	8	25

SURVEY OF PESTICIDES

Because there is evidence that pesticides in the environment influence raptor population dynamics (Carson, 1962; Lockie and Ratcliffe, 1964; Rudd, 1966; Hickey, 1969), this factor was examined in detail. A survey was conducted to determine what pesticide residues were present in: (1) major prey species of golden eagles; (2) the tissues of golden eagles; and (3) the eggs of golden eagles.

Methods and techniques

Four major prey items were analyzed: whitetail jackrabbits, desert and mountain cottontails, yellowbelly marmots, and Richardson ground squirrels. These prey species constituted 67.1% of 1,009 prey items collected at eagle nests during 1965-67. Collectively, they represented approximately 72% of the food biomass of the nesting eagles.

During the 1967 field season, 9 tissue samples from jackrabbits and 10 from the other three items of prey were collected at eagle nests. Another eight tissue samples were collected from free-roaming jackrabbits for comparison with the analyses obtained from those collected at nest sites.

Tissue samples were taken from red-tailed hawks (Buteo jamaicensis) as well as from golden eagles. Golden eagles and red-tailed hawks prey on some of the same animals so they would be exposed to roughly the same pesticide concentrations. Using the hawks allowed a greater sample size and a better indication of pesticide levels on the area while minimizing the number of eagles that had to be shot.

Twelve nestling eagles were analyzed; of these, seven samples were collected by taking fat biopsies from live birds and five included pectoral muscles from birds found dead in nests. Two samples of pectoral muscles were taken from fledgling eagles that were sacrificed; another muscle sample was taken from an adult found dead near a highway. Ten tissue samples were taken from red-tailed hawks; five were of adipose tissue taken by the biopsy technique; five were pectoral muscle tissue from two dead birds, two sacrificed birds, and one fledgling that was shot. One muscle sample was also taken from an adult great horned owl (Bubo virginianus).

The biopsy technique, developed by Seidensticker (1968), involved making a 2 cm incision along the posterior mid-line of the keel and removing adipose tissue with a forceps and scalpel. The tissue was then put in a small, glass, screw-cap vial and frozen within two hours after removal.

Nineteen raptor eggs were collected and analyzed. Three were taken from golden eagles; two were from red-tailed hawks; and three were from great-horned owls. The remaining eleven eggs were found in abandoned nests: seven eagles; three red-tailed hawks; and one prairie falcon (Falco mexicanus).

All tissue and egg samples were frozen in vials or double plastic sacks soon after collection and kept frozen until analyzed. Analyses were conducted for chlorinated hydrocarbons and were performed by the Wisconsin Alumni Research Foundation, Madison, Wisconsin, using gas chromatography. (See appendix for details.)

Study area levels

Levels of chlorinated hydrocarbon pesticides (DDT, dieldrin, heptachlor, and chlordane) applied to the area are not known.

Information from different sources concerning pesticides applied to agricultural land were contradictory. The study area included one-third of Park County. In 1967 one merchant in this county sold enough pesticides to spray 26,000 acres to ranchers who applied their own spray. Several other merchants in the county also sell pesticides and three aerial spray companies serve the area. In spite of these facts, the county extension agent (pers. comm.) estimated that only 27,000 acres were sprayed in Park County.

Prey residue levels

The major chlorinated hydrocarbon pesticides used within the last five years were dieldrin and chlordane; others marketed in the area included DDT, aldrin, lindane toxaphene, and heptachlor. The metabolites of these pesticides which were found were: DDD (TDE), and DDE from DDT; dieldrin from dieldrin and aldrin; and heptachlor epoxide from heptachlor. Heptachlor epoxide is also one of the metabolites of chlordane (Menzie, 1968).

Table 15 summarizes the results obtained from 48 specimens of the major prey of nesting golden eagles in the primary study area. Total mean residues from prey found at nests calculated at a wet weight basis, ranged from 0.053 ppm in cottontails to 0.102 ppm in jackrabbits. All prey items except one jackrabbit showed dieldrin residues, and none of the prey analyzed contained heptachlor epoxide. The mean amount of extractable lipids in the tissue sample varied from 0.27 to

Table 15. Pesticide residues in prey found in golden eagle nests, Area A, 1967.

Species	No.	Lipid as % of wet wt.		DDE ppm wet wt.		TDE[1] ppm wet wt.		DDT ppm wet wt.		Dieldrin ppm wet wt.		Total ppm wet wt.	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Yellowbelly Marmots	10	1.95	0.43-2.51	0.023	0.033-0.02	0.018	0-0.020	0.016	0-0.020	0.008	0-0.02	0.065	0.020-0.073
Richardson Ground Squirrel	10	8.38	0.27-55.2	0.038	0.020-0.061	0.021	0.020-0.030	0.016	0-0.032	0	--	0.075	0.040-0.112
Cottontails (Desert & Mtn.)	10	1.00	0.31-4.81	0.024	0.020-0.041	0.021	0.020-0.029	0.008	0-0.020	0	--	0.053	0.040-0.069
Cottontails* (Desert & Mtn.)	1	5.59	--	0.020	--	0.020	--	0.020	--	0	--	0.060	--
Whitetail Jackrabbit	9	0.72	0.31-1.30	0.025	0-0.032	0.022	0-0.030	0.035	0-0.16	0.002	0-0.02	0.102	0-0.21
Whitetail Jackrabbit*	8	0.94	0.37-3.30	0.018	0.01-0.02	0.017	0.01-0.02	0.007	0-0.02	0.001	0-0.01	0.036	0.020-0.061

*These prey species were either shot or picked up as road kills.

[1]TDE is the same residue as DDD.

55.2 percent (wet weight).

Raptor levels

All pesticide levels analyzed in raptors' tissues and eggs were relatively low. The chlorinated hydrocarbon residues detected in eggs and tissues of golden eagles and other raptors are presented in Table 16. All the eagle samples included DDT or its metabolites and dieldrin, but heptachlor epoxide was missing in nestling fat and pectoral muscle. The highest total residues were found in the adipose tissue of a nestling.

Concentration ratios of mean prey residue levels compared to mean levels in eggs ranged from 1:5 to 1:18. When comparing prey with juvenal muscle (including both nestlings and fledglings), the ratio ranged from 1:3 to 1:84. Only tissue from one adult was measured; residues detected were lower than those found in the same tissue of juvenile birds.

Tissue biopsies which were taken from golden eagles and red-tailed hawks contained mostly sub-cutaneous adipose tissue. Since chlorinated hydrocarbon residues are fat soluble and concentrate in fat, these residues are much higher in adipose tissue than in other body tissues. For this reason, fat biopsies may be a valuable tool to determine presence of pesticide residues but cannot be used to determine critical levels.

Residue levels in golden eagle eggs, nestlings, and adults.

Table 17 shows the mean pesticide residues found in eagles, their eggs, and young in 1966-67. The total residues in this present study were lower than one part per million, wet weight, with the exception

Table 16. Pesticide residues in raptor tissues and eggs, 1967.*

Golden Eagle	No.	Lipid as % of wet wt.		DDE ppm wet wt.		TDE ppm wet wt.		DDT ppm wet wt.		Dieldrin ppm wet wt.		HE. ppm wet wt.		Total ppm wet wt.	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Adult muscle 1966	1	--	--	0.23	--	0.071	--	0.058	--	0.19	--	0.051	--	0.60	--
Fledgling muscle	2	1.43	1.42-1.45	0.45	0.20-0.70	0.27	0.13 0.42	0.043	0.025-0.062	0.017	0.017-0.017	0.042	0.010-0.075	0.88	0.42-1.24
Nestling fat (biopsy)	7	14.31	2.00-34.8	4.30	0.29-10.7	0.68	0-3.85	0.24	0-3.50	0.21	0.10-0.45	0	--	5.47	0.69-18.4
Nestling muscle[1]	5	1.60	0.34-2.87	0.15	0.038-0.42	0.032	0.02-0.04	0.034	0-0.11	0.041	0.020-0.10	0	--	0.26	0.108-0.48
Viable eggs	3	--	--	0.35	0.18-0.50	0.021	0.010-0.038	0.029	0.012-0.053	0.096	0.060-0.15	0.069	0.060-0.078	0.565	0.365-0.739
Non-viable eggs	4	--	--	0.35	0.13-0.57	0.015	0.010-0.020	0.013	0.010-0.023	0.25	0.081-0.38	0.057	0.046-0.080	0.726	0.364-0.846
Non-viable eggs 1966	3	--	--	0.23	0.09-0.31	0.007	0-0.01	0.003	0-0.01	0.15	0.02-0.24	0.16	0.08-0.20	0.54	0.19-0.74
Red-tailed Hawks															
Fledgling muscle[2]	1	1.41	--	1.25	--	0.020	--	0.080	--	0.16	--	0	--	1.51	--
Nestling muscle (biopsy)	4	3.59	1.66-7.52	3.93	1.27-6.87	0.75	0.20-1.10	0.77	0.20-1.30	0.50	0.10-1.40	0	--	5.95	2.97-10.37
Eggs, viable	2	--	--	0.92	0.24-1.60	0.034	0.028-0.040	0.053	0.047-0.060	0.30	0.16-0.44	0.16	0.09-0.24	0.97	0.73-2.22
Eggs, non-viable	3	--	--	4.19	1.08-10.3	0.218	0.035-0.58	0.263	0.013-0.75	0.39	0.23-0.63	0.51	0.34-0.80	5.56	1.82-13.06
Great Horned Owl															
Adult muscle	1	--	--	7.33	--	0.62	--	1.24	--	0.15	--	0.19	--	8.54	--
Eggs, viable	3	--	--	0.74	0.36-1.13	0.34	0.012-0.075	0.020	0.015-0.025	0.16	0.11-0.24	0.045	0.020-0.23	1.00	0.72 1.58
Prairie Falcon															
Egg, non-viable	1	--	--	2.35	--	0.010	--	0.040	--	0.23	--	0.70	--	3.33	--

* All samples were collected in 1967 unless marked otherwise.

[1] The five nestling golden eagle muscle samples were taken from birds that died on the nest.

[2] Shot with .222 magnum rifle

Table 17. Mean pesticide residues* found in golden eagle eggs, young and adults. 1966-67. Areas A and B.

Tissue	Source	No. Samples	Year	DDE ppm	TDE ppm	DDT ppm	HE ppm	Dieldrin ppm	Total ppm
1	eggs	3	1966	0.23	0.03	0.003	0.16	0.15	0.573
1	eggs	4	1967	0.35	0.020	0.017	0.078	0.33	0.795
2	eggs	3	1967	0.35	0.021	0.029	0.069	0.096	0.565
Fat	nestlings	7	1967	2.87	0.74	0.27	0.19	0.01	4.08
Breast	adult	1	1966	0.23	0.071	0.058	0.051	0.19	0.60

* All residues measured as ppm wet weight. Heptachlor epoxide is abbreviated as HE.

1. Blended dead embryo and egg contents.
2. Blended viable embryo and egg contents.

of nestling birds. Nestling bird levels were also low because samples were collected from adipose tissue, a place where chlorinated hydrocarbons accumulate. Dieldrin levels were highest in unhatched eggs of 1967 but were still below the one ppm level which Lockie and Ratcliffe (1964) set as causing infertility or egg breakage by adult golden eagles in Scotland.

POSSIBLE CAUSES OF CHANGES IN POPULATION CHARACTERISTICS

The changes in nesting population, distribution, and occupancy of eyries, nesting success, and productivity were probably due to a number of environmental factors or to the influence of the investigator. Environmental factors which could cause changes in golden eagle population dynamics included the influences of prey availability, pesticide contamination of the environment, climate, and land use changes. Disturbance by the investigator included visiting nests from the pre-incubation period to after fledging, removing an egg from each of three nests, and causing the death of three young.

Environmental factors

Variation in availability of prey: Food availability has long been recognized as a population regulating mechanism. Within the last 15 years Southern (1954), Lack (1966), and Pitelka et al. (1955a, 1955b) have discussed this phenomenon in raptors. As the present study progressed, it became increasingly apparent that variation in prey population numbers was probably an important factor in golden eagle population dynamics on the study area.

Craighead and Craighead (1956), studying raptor-prey relationships, concluded that "a nesting raptor population takes its prey in proportion to the prey population densities". Prey items found in eagle nests during 1962-64 showed considerable variation from those found in 1965-67 (Table 4). Numbers of rabbits, both whitetail jackrabbits and cottontails (desert and mountain), dropped from 69.6% of total prey in 1962-64 to 43.8% in 1965-67, a loss of 25.8%. Yellowbelly marmots, Richardson ground squirrels, black-billed magpies, and grouse made up most of the deficit. The shift in food habits from rabbits to other prey sources indicated a drop in jackrabbit and cottontail numbers.

Lack (1966) suggested four ways in which a raptor population could compensate when its major food source suffers a sharp decline: (1) migration; (2) failure to breed; (3) enlarged territories, thus theoretically enabling a pair to have access to more prey; and (4) lower production of eggs and young.

It was not known whether any eagles left the study area. Failure to breed probably did occur on the area, especially in 1965. Eagles were seen near many of the known eyries which were not occupied. It was not known if these were non-nesting eagles or if they nested in alternate eyries not located by the investigator.

Except for 1965 and 1966 the total number of eagles on the area was nearly constant (Table 18). This table does not include non-nesting pairs seen in the area because such information was not available for Phase 1. However, from 1965-67 four pairs were thought to be non-nesting each year; not enough time was spent on the area in 1968 to determine non-nesting. The total number of eagles on the study area was static except in 1965 when the rabbit population declined. The successful to unsuccessful ratios for 1967-68 indicate that when high numbers of adult birds were present and rabbits were not abundant there were many unsuccessful nesting efforts and low numbers of young fledged per nest.

The expected reaction of an eagle population to severe decline in prey abundance would be failure to nest if the eagles did not migrate. At slightly higher prey densities they would nest with low rates of

Table 18. Number of eagles in summer population, 1963-68, Area A.

Year	Ratio of successful to unsuccessful nesting pairs	Young fledged	Total
1963 (McGahan, 1966)	15/2	26*	60
1964 (McGahan, 1966)	18/1	24	62
1965	9/3	13	37
1966	14/4	19*	55
1967	16/7	18	64
1968	12/8	19	59
Mean	14.0/4.2	20.0	56.2
Range	9-18/1-8	13-26	37-64

* For nests known to be successful but observed after young had fledged; the number of young was interpolated by applying production rates from all other successful nests during that year. Adjusted figures included seven young from four nests in 1963, and one eaglet from one nest in 1966.

nesting density, success, and productivity. Table 19 outlines the relationships of the abundance of rabbits to the number of nesting pairs and to the number of young fledged by those pairs. Rabbits were at a population high in 1963; the number of nesting pairs known in Area A was 17 (two more nests were found the next year) and the number of young fledged per occupied nest was high. The percent of rabbits taken in 1964 was only slightly higher than in 1965; the number of nesting pairs was 19 and production was still at a fairly high level. In 1965 rabbits declined severely; at least seven pairs of eagles did not nest

Table 19. Rabbits as percent of total prey compared to the number of nesting pairs and the young fledged per nesting effort.

	1963	1964	1965	1966	1967	1968*
Rabbits - & of total prey	71.9	68.2	37.8	37.9	50.0	55.0
Pairs nesting	17	19	12	18	23	20
No. fledged/ nesting pair	1.46	1.26	1.08	1.13	0.95	0.95

* In 1968 only a minimum time was spent on the study area. Food habits were determined from 54 prey items collected from 10 nests. Four eagle nests located in hard-to-reach areas were not examined so it is not known whether these pairs nested.

---

and productivity fell to 1.08 young fledged per nest. In 1966 rabbits found at nests were still in lower proportion than in 1962-64; however, as many eagles nested as in previous years but they fledged proportionately fewer young. During 1967 and 1968 rabbits were regaining earlier densities and the number of nesting pairs surpassed previous levels. However, since rabbits were still not numerous, the increased number of nesting pairs may have competed for existing rabbits and thus the number of fledglings per nest was even lower than before. It was not known whether all eagles in this study maintained mutually exclusive hunting ranges. Another factor which was at least partly responsible for the decline in productivity in 1967-68 was human disturbance; if this factor was not present, the number fledged per occupied nest would have approached the 1965-66 level.

Influence of Pesticide Residues: Chlorinated hydrocarbon residues found in the major prey of golden eagles were low, the highest mean being 0.10 ppm wet weight. Most residues detected were metabolites of DDT; small amounts of dieldrin were found.

Nine muscle samples of whitetail jackrabbits were taken from eagle nests and another seven which were shot and one which was taken as a road kill served as controls. An analysis of variance was calculated for the two groups and they were found to be significantly different at the 95% level. The control jackrabbits had lower levels of pesticides with mean total residues of 0.102 ppm as compared to 0.36 ppm for those from nests. This indicates that jackrabbits with higher pesticide residue levels are more susceptible to predation than those with low levels. Changes in the learning ability of mice fed pesticides in their diet have been reported by Shellhammer (1961). Changes in behavioral patterns which might increase the vulnerability of the rabbits may result from sublethal residues of chlorinated hydrocarbons.

Residues in the eggs were low in golden eagles but were higher in great horned owls, red-tailed hawks, and prairie falcons. This may be explained in two ways: (1) adult eagles in the area are probably not migratory while the latter two species are, thus enabling them to pick up higher residues in other more highly contaminated areas (great horned owls are probably not migratory so differences are primarily due to the second explanation) or (2) the prey of eagles and the other raptors differ sufficiently with the latter taking more highly contaminated prey. Both factors probably contribute to the differences in contamination.

Residues were more concentrated in eggs than in prey species but the ratios found in this study were lower than those found in Alaskan peregrine eggs when compared to their prey (Cade, et al., 1968).

The chlorinated hydrocarbon residues detected in eggs in this study were lower than levels which were thought to have been responsible for a decline of breeding success of golden eagles in Scotland (Lockie and Ratcliffe, 1964). In the Scottish study, dieldrin in excess of 1 ppm was thought to be correlated with infertile eggs or egg breakage by adults. In the present study, viable eggs of raptors had less total mean residues than non-viable eggs but the sample size was so small that no conclusions could be reached.

Residues from juvenile birds were taken from live nestlings (by biopsy) and from fledglings and nestlings which had died in nests. Birds that died in nests had lower levels than live birds which were biopsied, indicating that none of these nestling mortalities were pesticide-caused. Concentrations of pesticides were approximately similar in eggs and juvenile birds.

The golden eagle population in the primary study area is a healthy, reproductively active one. Pesticides, including DDT, chlordane, dieldrin, and heptachlor have been applied to land in the study area and later ingested and retained by lagomorphs and rodents. When golden eagles prey on these animals the residues are further concentrated in the eagles' tissues. Apparently at the present time, concentrations of pesticide residues are not high enough to adversely affect the population. However, knowledge concerning pesticide residue levels in a healthy golden eagle population may provide a basis for further study of the effects of pesticides on the reproductive biology and behavior of this bird.

Climate

Climatic changes from nesting season to nesting season were slight on the study area (Table 1). Any population changes in eagle numbers, nesting density, nesting success, or productivity which were caused by unusually prolonged cold waves or snow storms would exert pressure only during the year of their occurrence. Golden eagles are adapted to withstand extreme climatic conditions; nests have been located at 10,000 ft elevation (Wellein and Ray, 1964), and within 100 miles of the Arctic Circle (Hobbie and Cade, 1962). Climatic changes probably had little effect on this population of eagles.

Land use

Changes in land use usually occur over a long period of time and show their effects gradually. According to Bureau of the Census figures (1964), there is a trend to consolidate farms; as a result there are fewer farms but those remaining are larger, more intensively managed, and utilize greater amounts of pesticides. Changes in land use could not account for any sharp changes in golden eagle productivity, nesting success, or nesting density but increased use of pesticides could account for such changes.

Influence of the investigator

Disturbance of nesting golden eagles by the investigator is difficult to define and more difficult to assess. The nesting cycle can be broken down into four portions which are progressively less sensitive to disturbance: (1) pre-incubation, when eagles may line several nests, select one, and lay eggs; (2) incubation, lasting about 41 days (observation at nest #16); (3) the first three weeks after hatching when at least one of the parent birds stays near the nest; and (4) the remaining seven or eight weeks before fledging when the adults visit the nest infrequently. An effort was made to minimize disturbance throughout the entire nesting cycle.

During the pre-incubation period nests were observed only from a distance of at least one-quarter mile. While eagles were incubating, my visits to make egg counts were short. Approaches to the nests were made carefully and out of sight of the parent bird so it would not flush until I was close by, thus minimizing the time adults were away from the nest. Except during 1967, investigations did not begin until mid-June when the eagles were 4 to 6 weeks old. At this stage chances for abandonment by adults were minimal.

Hancock (1966), in a two-year study of the bald eagle, claimed that close observation of nests from a helicopter and banding of nestling birds during one year caused a decline in production of fledglings and changes in nest site selection during the following year. In another bald eagle study, Mathisen (1968) categorized the degree of isolation and possible human disturbance of 140 nests and found no differences in occupancy or productivity among the categories. In the present study banding or repeated visits to nests did not influence occupancy or productivity.

The study was most intensive in 1967. If disturbance by the investigator was a causal factor in the decline, it would have had its greatest effect in that year. In 1967, 11 nests were selected for detailed study to be visited every three days during the nestling period; 6 of these nests were unsuccessful. Two unsuccessful nests, each with one egg and one young, were abandoned after a five-day cold wave with intermittent snow storms. These two nests had been visited only once, six weeks earlier. One of these nests had been observed daily the previous year with no adverse effects. In the remaining unsuccessful nests, one eaglet was found dead below its nest; another was found dead in a nest with a full crop and no visible marks on its body. A fifth unsuccessful nest was attributed directly to the study when a young eagle was fed pesticides and died. In the last unsuccessful nests two young died of unknown causes, possibly because of abandonment by adults. However, disturbance was probably not the cause because in an earlier year an amateur photographer placed a swinging blind 20 feet from the same nest and the adults still raised one young.

The five intensively studied nests that were successful in 1967 were visited 26, 24, 17, 15, and 10 times. All were occupied again in 1968.

During Phase 2, the only mortalities directly attributed to the study were the deaths of three young and the taking of three supposedly-viable eggs. This influence did not greatly affect the eagle population. In 1968, data were collected during one visit each to 27 of the 31 known occupied nests. If disturbance was a major factor in fledgling production and nesting success decline, such minimal disturbance should have raised both of these parameters of population condition in 1968, a year of low fledgling numbers and nest success.

A decline in prey abundance caused a drop in the eagle's nesting success and the number of young fledged. As rabbits approach earlier population numbers, the eagles will probably regain earlier levels of nesting success and production of fledglings. Human disturbance, chlorinated hydrocarbon residues, climate, and changes in land use practices may have had slight influences on population levels and reproductive success during this study.

SUMMARY

1. The second phase of a long-term investigation of nesting golden eagle population dynamics was conducted from 1965 to 1968 in a 1,260 sq. mi. area of south-central Montana.

2. From 1965 to 1967, 1,009 individual prey items were identified during 247 visits to 38 nests. Mammalian prey comprised 74.5% of the total number in the sample. Lagomorphs accounted for 45.1% of the prey collected; whitetail jackrabbits were the most numerous prey (26.2%) and cottontails (desert and mountain) were second most numerous (19.9%). Birds comprised 25.1% of the total prey sample; black-billed magpies (8.2%) and grey partridges (2.7%) were the most prevalent species. Domestic species--two cats, a chicken, a lamb, and an adult sheep--accounted for 0.5% of the total sample.

3. During 1965-67, jackrabbits and cottontails declined from 1963-64 population levels, probably due to an epidemic of tularemia. Proportions of rabbits found in golden eagle nests during Phase 2 dropped by 25% from Phase 1 levels. Pacific Hide and Fur, a firm collecting jackrabbits for mink food, collected 70% fewer jackrabbits in 1965 than the average for 1962-64.

4. The eagle population of 20-23 pairs remained relatively stable; however, during 1965 the proportion of non-nesting pairs increased.

5. Nesting density approximately doubled in the Boulder River Valley during Phase 2 of the study. This change was probably related to changes in prey availability during 1965-67.

6. Nesting success was 15% lower in Phase 2 (26%) than in Phase

1 (91.7%).

7. The average clutch size was two eggs (50 clutches, 20 from McGahan, 1968, and 30 from the present study). Only five clutches varied from this figure--one 1-egg clutch and four 3-egg clutches.

8. The average number of eaglets fledged from 1963-68 was 1.11. Fledging success was 37.6% less in Phase 2 than in Phase 1.

9. Approximately 193 young hatched, but only 111 fledged (42.5% nestling mortality). Observed mortalities accounted for the fate of 16.6% of the hatched young; however, an additional 25.9% apparently hatched and then disappeared from their nests.

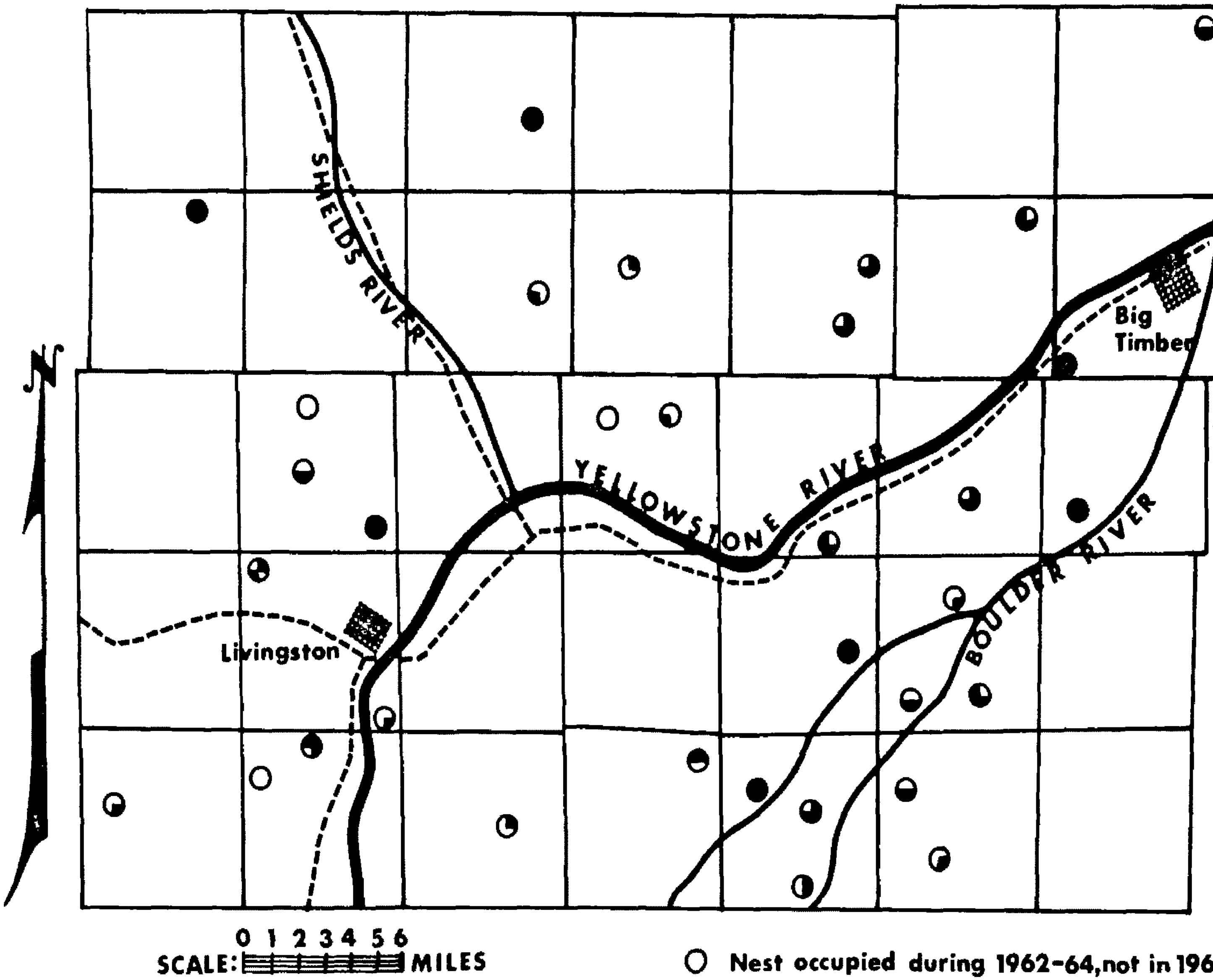
10. A survey was conducted to determine whether pesticides had any effects on the productivity and nesting habits of the golden eagle population. Chlorinated hydrocarbon residue analysis of golden eagle eggs, young, and adults as well as the eagles' major prey species indicated that pesticide levels on the study area were low. At these low levels, influences of pesticides on the eagle population were probably minimal. However, because of the accumulative nature of persistent pesticides, their effects may not have immediate impact on this population.

11. The amounts of pesticide residues were significantly higher in nine jackrabbits taken as prey by eagles than in seven jackrabbits which were shot and one which was killed by a car.

12. Disturbance by the investigator influenced eagle population dynamics very little. Human disturbance was most evident in 1967-68 but the greatest proportion of the decline during the study was due to other factors.

13. A reduction in numbers of jackrabbits and cottontails, the golden eagle's major food source, was the primary cause of the decline in the eagle population from Phase 1 to Phase 2. Many pairs failed to nest when rabbits were at their lowest numbers. When lagomorph populations were recovering, eagles nested but had low nesting success and fledged few young. Environmental factors other than food availability--pesticide contamination, climate, and land use changes--may influence golden eagle population dynamics but in this study their effects on the population appeared negligible.

Figure 1. Distribution and occupancy, golden eagle nests, Area A, 1965-68.



Nest occupied during 1962-64, not in 1965-68

Nest occupied in 1965

Nest occupied in 1966

Nest occupied in 1967

Nest occupied in 1968

Nests occupied for more than one year are shown as combinations of the above

LITERATURE CITED

Arnold, L. W. 1954. The golden eagle and its economic status. U. S. Fish and Wildl. Serv., Circular No. 27. 35 p.

Brown, L. H. and A. Watson. 1964. The golden eagle in relation to its food supply. Ibis 106:78-100.

Cade, T. J., C. M. White, and J. R. Hough. 1968. Peregrines and pesticides in Alaska. Condor 70:170-178.

Carson, R. L. 1962. Silent spring. Houghton Mifflin Co., Boston, Mass. 367 p.

Cottam, C., D. A. Murno, R. H. Pough, H. A. Hockbaum, R. A. McCabe, and I. N. Gabrielson. 1961. Report to the American Ornithologist's Union by the committee on bird protection. Auk 79:463-478.

Craighead, J. J. and F. C. Craighead, Jr. 1956. Hawks, owls, and wildlife. Stackpole Co., Harrisburg, Pa. 433 p.

Cramp, S. 1963. Toxic chemicals and birds of prey. Brit. Birds 56:124-139.

Dixon, J. B. 1937. The golden eagle in San Diego County, California. Condor 39:49-56.

Gordon, S. K. 1955. The golden eagle: king of birds. Citadel, New York. 246 p.

Hancock, D. 1966. David Hancock reports on the bald eagle research project. Can. Audubon 28(1):88-92.

Hanna, W. C. 1930. Notes on the golden eagle in southern California. Condor 32:121-123.

Hickey, J. J. (ed.). 1969. Peregrine falcon populations; their biology and decline. Univ. Wisconsin, Press, Madison. 596 p.

Hobbie, J. E. and T. J. Cade. 1962. Observations on the breeding of golden eagles at Lake Peters in northern Alaska. Condor 64:235-237.

Jefferies, D. J. and I. Prestt. 1966. Post-mortems of peregrines and lanners with particular reference to organochlorine residues, Brit. Birds 59:49-64.

Jollie, M. 1947. Plumage changes in the golden eagle. Auk 64:549-576.

Lack, D. 1966. Population studies of birds. Oxford Univ. Press, London. 341 p.

Lockie, J. D. 1964. The breeding density of the golden eagle and fox in relation to food supply in Wester Ross, Scotland. Scot. Nat. 71:67-77.

_____________ and D. A. Ratcliffe. 1964. Insecticides and Scottish golden eagles. Brit. Birds 57:89-102

_____________ and D. Stephen. 1959. Eagles, lambs, and land management on Lewis. J. of Animal Ecol. 28:43-50.

Mathisen, J. E. 1968. Effects of human disturbance of bald eagles. J. Wildl. Mgmt. 32(1):1-6.

McGahan, J. 1966. Ecology of the golden eagle. M.A. Thesis, Univ. of Mont., Missoula. 78 p.

___________ 1967. Quantified estimates of predation by a golden eagle population. J. Wildl. Mgmt. 31:469-471.

___________ 1968. Ecology of the golden eagle. Auk 85:1-12.

Menzie, C. M. 1966. Metabolism of pesticides. U. S. Fish and Wildl. Serv. Spec. Sci. Rept. Wildl. 43:274.

Pitelka, F. A., P. Q. Tomich, and G. W. Treichel. 1955a. Ecological relations of jaegers and owls as lemming predators near Barrow, Alaska. Ecol. Monogr. 25:85-177.

_____________ 1955b. Breeding behavior of jaegers and owls near Barrow, Alaska. Condor 57:3-18.

Ratcliffe, D. A. 1963. The status of the peregrine in Great Britain. Bird Study 10:56-90.

_______________ 1965a. The peregrine situation in Great Britain 1963-1964. Bird Study 12:66-82.

_______________ 1965b. Organochlorine residues in some raptor and corvid eggs from northern Britain. Brit. Birds 58:65-81.

Robinson, W. B. 1940. Thallium and compound 1080 impregnated stations in coyote control. J. Wildl. Mgmt. 12(3):279-295.

Rudd, R. L. 1964. Pesticides and the living landscape. Univ. Wisc. Press, Madison. 320 p.

___________ and R. E. Genelly. 1956. Pesticides: their use and toxicity in relation to wildlife. Calif. Dept. Fish and Game, Game Bull. No. 7. 209 p.

Sanders, A. A. 1921. A distributional list of the birds of Montana. Pacific Coast Avif. 14:1-44.

Seidensticker, J. C., IV. 1968. Response of juvenile raptors to DDT in the diet. M.S. Thesis, Univ. of Mont., Missoula. 74 p.

Shellhammer, H. S. 1961. An ethological and neurochemical analysis of facilitation in wild mice. Univ. Calif. Davis. Doctoral thesis in R. L. Rudd. 1966. Pesticides and the living landscape. Univ. Wisc. Press, Madison, Wisc. 319 p.

Slevin, J. R. 1929. A contribution to our knowledge of the nesting habits of the golden eagle. Proc. Calif. Acad. Sci. 18(3):45-71.

Southern, H. N. 1959. Mortality and population control. Ibis 101: 429-436.

Spofford, W. R. 1964. Golden eagle in the Trans-Pecos and Edwards Plateau of Texas. Audubon Conserv. Rep. No. 1 47 p.

Ward, J. C. and D. A. Spencer. 1947. Notes on the pharmacology of sodium fluoroacetate--compound 1080. J. Amer. Pharm. Assoc. 36(2):59-62.

Watson, A. 1957. The breeding success of golden eagles in the north-east highlands. Scot. Nat. 69:153-169.

U.S. Department of Commerce, Bureau of the Census. 1966. 1964 United States census of agriculture : Park Co., Mont. Series AC 64-pl. 6 p.

__________, Weather Bureau. 1965-1968. Climatological Summaries: Mont. Vol. 68-71.

APPENDIX

Table 20. Food habits of nesting golden eagles listed in order of decreasing frequency, Area A.

Mammals	1965 No.	Per-cent	1966 No.	Per-cent	1967 No.	Per-cent	Total No.	Per-cent
Whitetail Jackrabbit	32	26.9	70	26.1	74	19.4	176	22.9
Cottontail (Desert and Mountain)	13	10.9	32	11.9	117	30.6	162	21.1
Yellowbelly Marmot	9	7.6	59	22.0	41	10.7	109	14.2
Richardson Ground Squirrel	28	23.5	16	6.0	25	6.5	69	9.0
Mule Deer (Fawn)	6	5.0	13	4.9	11	2.9	30	3.9
Mule Deer (Yearling)	0		0		1	0.3	1	0.1
Striped Skunk	0		2	0.7	3	0.8	5	0.7
Longtail Weasel	0		2	0.7	2	0.5	4	0.5
Voles (*Microtus Sp.*)	0		0		3	0.8	3	0.4
Domestic Cat	0		0		2	0.5	2	0.3
Pronghorn (Fawn)	0		0		1	0.3	1	0.1
Domestic Sheep (Lamb)	0		0		1	0.3	1	0.1
Domestic Sheep (Adult)	0		0		1	0.3	1	0.1
Bushytail Woodrat	0		0		1	0.3	1	0.1
Muskrat	1	0.8	0		0		1	0.1
Coyote (Pup)	0		1	0.4	0		1	0.1
Birds								
Black-billed Magpie	12	10.1	30	11.2	29	7.9	71	9.2
Grey Partridge	0		5	1.9	19	5.0	24	3.1
Sage Grouse	2	1.7	11	4.1	5	1.3	18	2.3
Blue Grouse	1	0.8	2	0.7	12	3.1	15	2.0
Common Crow	5	4.2	5	1.9	2	0.5	12	1.6
Unidentified Grouse	3	2.5	5	1.9	2	0.5	10	1.3
Great Horned Owl	0		4	1.5	4	1.0	8	1.0
Sharp-tailed Grouse	4	3.4	0		3	0.8	7	0.9
Red-shafted Flicker	1	0.8	3	1.1	1	0.3	5	0.7
Ruffed Grouse	1	0.8	3	1.1	1	0.3	5	0.7
Ring-necked Pheasant	0		0		4	1.0	4	0.5
Unidentified Duck	1	0.8	0		3	0.8	4	0.5
Robin	0		2	0.7	1	0.3	3	0.4
Unidentified Passerine	0		0		3	0.8	3	0.4
Western Meadowlark	0		0		2	0.5	2	0.3
Mallard	0		2	0.7	1	0.3	3	0.4
Great Blue Heron	0		0		2	0.5	2	0.3
Lewis' Woodpecker	0		0		1	0.3	1	0.1
Townsend's Solitaire	0		0		1	0.3	1	0.1
Sparrow Hawk	0		0		1	0.3	1	0.1
Cooper's Hawk	0		0		1	0.3	1	0.1
Common Nighthawk	0		1	0.4	0		1	0.1
Reptiles								
Racer Snake	0		0		1	0.3	1	0.1
Total	119	99.8	268	99.9	382	100.3	769	99.9

Table 21. Food habits of nesting golden eagles, listed in order of decreasing frequency, Area A.

	1962-64		1965-67	
Mammals	No.	Percent	No.	Percent
Whitetail Jackrabbit	248	35.3	176	22.9
Cottontail (Desert and Mountain)	241	34.3	162	21.1
Yellowbelly Marmot	53	7.3	109	14.2
Richardson Ground Squirrel	26	3.7	69	9.0
Mule Deer (Fawn)	24	3.4	30	3.9
Mule Deer (Yearling)	0		1	0.1
Striped Skunk	1	0.1	5	0.7
Longtail Weasel	8	1.1	4	0.5
Voles	6	0.9	3	0.4
Domestic Cat	0		2	0.3
Pronghorn (Fawn)	1	0.1	1	0.1
Domestic Sheep (Lamb)	0		1	0.1
Domestic Sheep (Adult)	0		1	0.1
Bushytail Woodrat	1	0.1	1	0.1
Muskrat	0		1	0.1
Coyote (Pup)	0		1	0.1
Blacktail Prairie Dog	1	0.1	0	
Porcupine	1	0.1	0	
Birds				
Black-billed Magpie	33	4.7	71	9.2
Grey Partridge	16	2.3	24	3.1
Sage Grouse	7	1.0	18	2.3
Blue Grouse	15	2.1	15	2.0
Common Crow	0		12	1.6
Unidentified Grouse	0		10	1.3
Great Horned Owl	5	0.7	8	1.0
Sharp-tailed Grouse	1	0.1	7	0.9
Red-shafted Flicker	1	0.1	5	0.7
Ruffed Grouse	0		5	0.7
Ring-necked Pheasant	4	0.6	4	0.5
Unidentified Duck	0		4	0.5
Robin	0		3	0.4
Unidentified Passerine	0		3	0.4
Western Meadowlark	0		2	0.3
Great Blue Heron	0		2	0.3
Mallard Duck	0		3	0.4
Lewis Woodpecker	0		1	0.1
Townsend's Solitaire	0		1	0.1
Sparrow Hawk	1	0.1	1	0.1
Cooper's Hawk	0		1	0.1
Common Nighthawk	0		1	0.1
Short-eared Owl	2	0.3	0	
Marsh Hawk	1	0.1	0	
Hawk Nestling	1	0.1	0	
Reptiles				
Blue Racer Snake	0		1	0.1
Prairie Rattlesnake	1	0.1	0	
Unidentified Snake	1	0.1	0	
Total	702	99.4	769	99.9

ANALYTICAL METHODOLOGY

All chemical determinations reported in this study were made by the Wisconsin Alumni Research Foundation. The following description of procedures was provided by the Chemical Department (in litt.):

"Sample preparation:

"Total weights are originally taken on all samples. The samples are then weighed into tared beakers. If the total weight is less than 20 gm the entire sample is used. If the total weight is greater than 20 gm the sample is homogenized and a 20 gm portion taken for analysis. The beakers and samples are dried in an air oven at 40-45°C for 36-48 hours. The beakers are weighed and the percent moisture determined.

"The samples are then ground with sodium sulfate and transferred to extraction thimbles. The thimbles are placed in the Soxhlet apparatus and extracted with a mixture of 70 ml ethyl ether and 170 pet. ether for 8 hours. After extraction the ethers are removed from the erlenmyer flasks by evaporation on a steam bath. The fat is dissolved in pet. ether and transferred to a volumetric flask. After making to volume, one half of the solution is pipetted into a tared beaker. The solvent is removed on a steam bath and the beaker dried in an air oven at 40-45°C for three hours. The beaker is reweighed and the percent of fat calculated.

"The remaining solvent in the volumetric flask is washed onto a florisil column. Pesticides are eluted from the column with 5%-95% (ethyl ether-pet. ether) and 15%-85% (ethyl ether - pet. ether) solutions. The respective solutions are taken to near dryness on a steam bath and then transferred to a volumetric flask. After making to volume, a known volume of each is injected into the gas chromatagraph.

"Instrumental Conditions

"Barber-Colman Pesticide Analyzer, Model 5360 equipped with a Sr-90 electron capture dector.

Column - $\frac{1}{4}$" Pyrex. 5% DC200 on Chromport XXX

Column Temperature - 182°C

Injector temperature - 235°C

Detector temperature - 240°C

Gas - Nitrogen, flow rate 100cc/min."