Reproductive success and post-fledging behavior of red-tailed hawks (Buteo jamiacensis) in the Gallatin Valley, Montana
by Sara Jane Johnson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Zoology
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Abstract:
A study was made on reproductive success and post-fledging behavior of the red-tailed hawk in the Gallatin Valley, Montana, during springs and summers of 1971 and 1972, Non-breeding pairs comprised 11.6 per cent of 146 observed pairs and 53 per cent of the breeding pairs were successful in fledging at least one young.

An average of 2.34 young were fledged per successful nest. Losses in production due to infertility and nestling mortality were 3.7 and 5.9 per cent, respectively. The number of young fledged per total nesting attempts indicated that the observed population was maintaining itself. The highest density of pairs in the study area was one per three square kilometers. Nine territories ranged in size from 2.6 to 4.6 square kilometers. The number of pairs and distribution of territories throughout the study area were similar both years. No mortality was observed during the 30 to 70 days after fledging that young remained with the parent birds. After fledging the young remained within post-nesting areas for an average of 22 days. Upon leaving the post-nesting areas young used all parts of the parental territories and possibly the surrounding areas. Temporary flights into the surrounding areas were made by young from zero to five times, and young were gone from several hours to seven days and traveled maximum distances of 1.6 to 35 kilometers from the parental territories. Three radio-tagged young migrated at known ages of 35 to 70 days after fledging, leaving both the parental territories and the Gallatin Valley on the same days. Within the parental territories young limited most of their hunting activity to one to five well-defined hunting areas. Young gradually increased their hunting efficiency as the post-fledging period progressed by increasing the number of hunting flights, decreasing time intervals between hunting attempts and increasing the areas hunted by using higher perches and quartering over the ground.

Young were fed by the parent birds until at least 34 days after fledging, and young stole food from the parent birds until at least 48 days after fledging. Hunting success of young during the post-fledging period was observed to be low.

Social behavior between sibling young, non-sibling young, parent birds and their young, and non-parental adult birds and young are discussed, and play behavior by young is described.

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Zoology

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ABSTRACT

A study was made on reproductive success and post-fledging behavior of the red-tailed hawk in the Gallatin Valley, Montana, during springs and summers of 1971 and 1972. Non-breeding pairs comprised 11.6 per cent of 146 observed pairs and 53 per cent of the breeding pairs were successful in fledging at least one young. An average of 2.34 young were fledged per successful nest. Losses in production due to infertility and nestling mortality were 3.7 and 5.9 per cent, respectively. The number of young fledged per total nesting attempts indicated that the observed population was maintaining itself. The highest density of pairs in the study area was one per three square kilometers. Nine territories ranged in size from 2.6 to 4.6 square kilometers. The number of pairs and distribution of territories throughout the study area were similar both years.

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Social behavior between sibling young, non-sibling young, parent birds and their young, and non-parental adult birds and young are discussed, and play behavior by young is described.

INTRODUCTION

A study was made on reproductive success and post-fledging behavior of the red-tailed hawk (*Buteo jamaicensis*) in the Gallatin Valley, Gallatin County, Montana, during the springs and summers of 1971 and 1972. Between 1946 and 1970 the reproductive success of various red-tailed hawk populations in the United States has been measured (Fitch, Swenson and Tillotson, 1946; Orians and Kuhlman, 1956; Craighead and Craighead, 1956; and Hagar, 1957). Although these studies have shown that various aspects of reproductive performance such as clutch size and the number of young hatching and surviving to fledging are variable from area to area, no attempts were made to determine if these populations were stable. Recently two studies have been made on the stability of red-tail populations in Alberta (Luttich, Keith and Stephenson, 1971) and south-central Montana (Seidensticker and Reynolds, 1971), and both have indicated the observed populations were declining. Thus an attempt was made to determine if the Gallatin Valley population was declining or at least maintaining itself.

The post-fledging period extends from the time the young leave the nest until they become independent of the adults. For raptors in general, very little research has been done on this period of the bird's life. I know of only three studies where post-fledging

behavior was systematically studied. These include work on the tawny owl (*Strix aluco*) by Southern, *et al.* (1954), the African crowned eagle (*Stephanoaetus coronatus*) by Brown (1966) and the great horned owl (*Bubo virginianus*) by Dunstan (1970). No in-depth studies have been made on the post-fledging period of the red-tailed hawk although observations have been made on a few unmarked individuals during the early part of the post-fledging period by Fitch, *et al.* (1946).

The post-fledging period has been difficult to study because once the young become older and more active they become increasingly difficult to observe. To overcome this problem I used a radio-tagging technique to aid in the location of fledged young. The first reported use of transmitters on raptors was by Southern (1964) on the bald eagle (*Haliaeetus leucocephalus*). By 1972 radios had been used on at least 17 different species of raptors (Dunstan, 1972), including the osprey (*Pandion haliaetus*), the bald eagles, the marsh hawk (*Circus cyaneus*), the sparrow hawk (*Falco sparverius*), and several species of owls, accipiters and buteos. The transmitters used ranged in field life from 31 to 510 days and were placed on birds ranging in average weight from 109 grams for the male sparrow hawk to 6300 grams for the female bald eagle (Brown and Amadon, 1968).

Objectives of the post-fledging study were to determine the length of time the young are dependent upon the adults, length of time the young remain within the parental territory, the manner of termination of the young-parent relationship, movements of the young both inside and outside the parental territories, mortality, social behavior and the development of hunting behavior.

METHODS

Reproduction

Nesting pairs of birds were located in March and April each year by driving section roads and walking to inaccessible areas before the trees leafed out. Observations were begun early in the breeding season to detect all nest failures, as otherwise there would be an apparently higher success of the breeding population and larger number of non-breeding birds than actually occurred. An attempt was made both years to locate the majority of nesting birds in the study area by checking both old and new nest sites and checking some sites several times to locate late nesters. Non-breeding birds were located by searching areas where available nesting sites were not being used.

Once active nest sites were located, they were not visited again until May. Climbing to nests was avoided during the incubation period, due to reported desertions by adults caused by this disturbance (Luttich, Keith and Stephenson, 1971). All active nests were checked twice from May to July, first when the young were one to two weeks old to determine the number of young per nest, and later when the young were five to six weeks old to determine nestling survival. Most nests were checked at close range by climbing the tree. During the second check young were banded with Fish and Wildlife Service bands. Forty-nine young

were banded in 1971 and 70 in 1972. Nests which could not be reached by climbing were also observed to determine if young fledged. Nest locations accessible by road were checked when the young were between six and seven weeks of age to determine dates of fledging.

Color-marking and Radio-tagging

Non-toxic enamel spray paint was used to color-mark young for identification after fledging. The undersurfaces of the wing and tail feathers were marked, with markings on the wings used to denote the nest of origin and markings on the tail to identify the individuals from one nest. A variety of colors and combinations were tested in 1971, and most of the young in nests which were reached by climbing were marked. This was done at the same time they were banded in 1971, but in 1972 young were marked when they were older, at approximately seven weeks when the wing and tail feathers were longer. In 1972 both the total number of nests in which young were marked and the number of colors used were reduced to prevent confusion in identification of marked young. Young in only eight nests were marked and only two colors were used, with the exception of three colors being used to mark four young from one nest.

Both years radio-transmitters were placed on the birds in the field when the young were approximately seven weeks old. The transmitters were held on the bird by a harness. The harness was constructed with 0.3 centimeter polyethylene tubing. The transmitter was carried on the bird's back with the harness running forward forming a loop around the bird's head and then running down the breast and behind each wing. The antenna extended down the bird's back. Dissolvable gut-suture was used to fasten the harness.

In 1971 the radio-tagging was experimental. Transmitters were placed on two fledged young from one nest. These transmitters, built by Coy Miller of Dugway, Utah, had a frequency of 104 megacycles. They weighed 34 and 40 grams including the harness. No adequate receiving system was devised, and the transmitters were used only to determine the effects extra weight and the harness had on the young. No adverse effects were observed during the 53 days both young remained within the parental territory after fledging.

In 1972 10 transmitters were purchased from the AVM Instrument Company of Champaign, Illinois. A 12-channel AVM receiver and an antenna, both portable and easily carried in the field, were rented from William Cochran of Champaign, Illinois.

The four-element yagi antenna was directional and no triangulation was needed to locate birds. The transmitters weighed between 32 and 41 grams, including the harness. They functioned at frequencies between 150.892 and 151.117 megacycles and had an estimated field life of three months. Transmitting distance was approximately 0.4 kilometer from the ground, 1.6 kilometers from a tree, and up to 25 kilometers higher in the air.

These transmitters were placed on 10 young from seven nests. Three territories had two radio-tagged young, and four had a single radio-tagged young. The locations of these territories are given in Figure 1. Two radio-tagged young from one nest died from entanglement of the harness on a branch and a fence, and the radios were then placed on two young from another nest. These were the only observed mortalities resulting from the radio-tag.

Observations of Post-fledging Behavior

In 1971, color-marked young from eight nests were observed until the young became too active to be easily located, and then only young from three nests were observed to the end of the post-fledging period. In 1972 all radio-tagged young were observed until they either migrated out of the valley or were lost due to unknown causes. Untagged nestmates were occasionally

located. The seven territories containing the radio-tagged young were observed on a three-day cycle. The first day was spent completely at one territory, number 34, to obtain detailed data on behavior. All 10 radio-tagged young were located three times daily on the second and third days of the cycle to obtain data on movements and length of time the young remained within the parental territory. Distance covered to check all seven territories once was approximately 40 kilometers. The pattern of observation frequently broke down later in the post-fledging period when individual radio-tagged young were followed for extensive periods of time.

DESCRIPTION OF THE STUDY AREA

The study area encompasses approximately 674 square kilometers in the southeastern half of the Gallatin Valley, and ranges in elevation from 1289 to 1634 meters. This area extends from the Bridger Mountain Range at the east end of the valley to the dry hilly terrain west of Manhattan. The southern and northern boundaries are the Gallatin Mountain Range and the Horseshoe Hills. The towns and cities of Bozeman, Belgrade, Manhattan, Church Hill and Amsterdam are located within the study area. The terrain varies from generally flat on the valley floor, to gently rolling along the foothills. The area is predominantly open, with most trees occurring along natural and artificial waterways. The black cottonwood (*Populus trichocarpa*) is the dominant tree, with quaking aspen (*Populus tremuloides*) and willow (*Salix sp.*) occurring with less frequency. The land is used for both grazing and agriculture, with the main crops being forage and small grains.

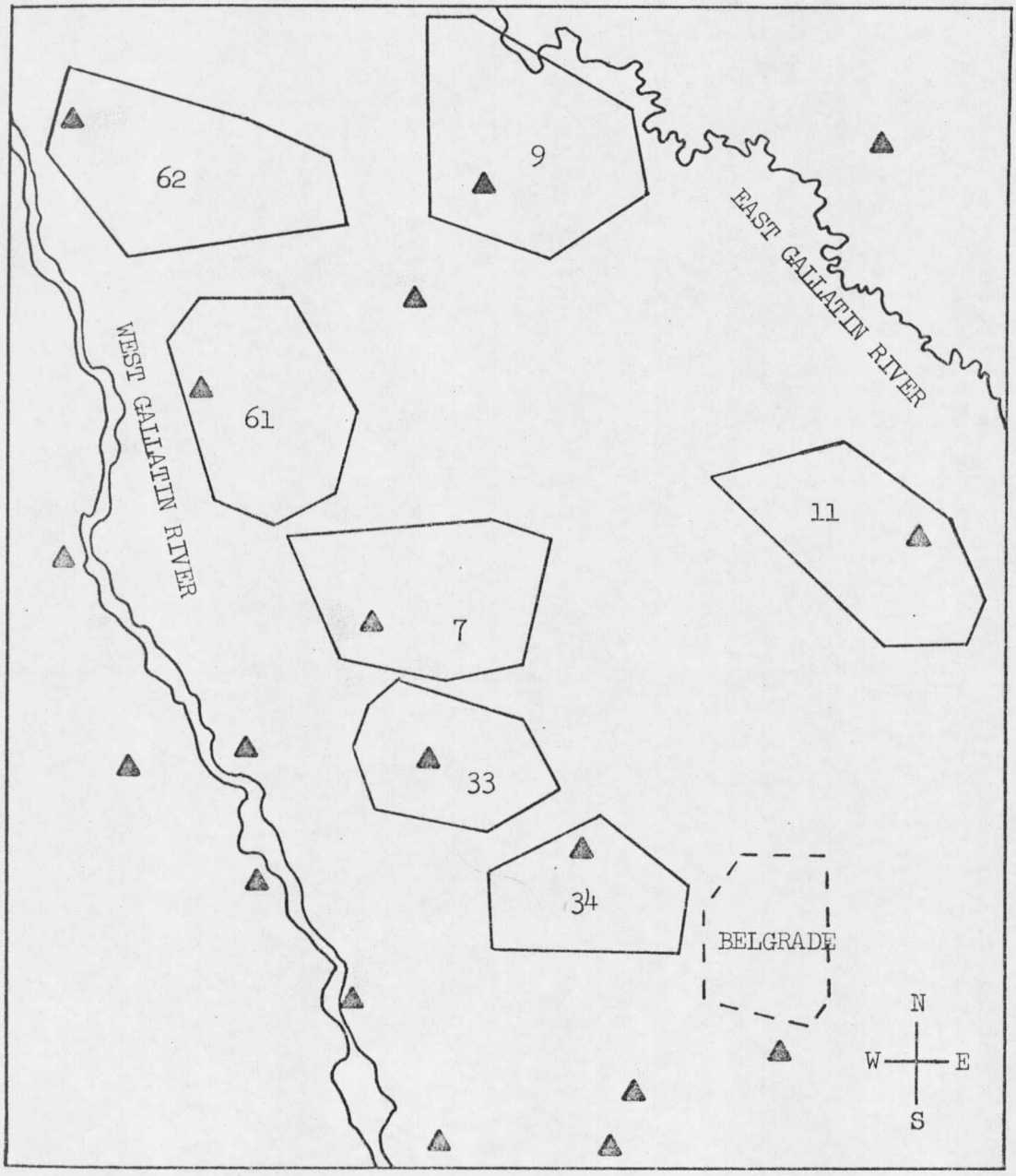


Figure 1. Location and approximate area of seven territories containing radio-tagged young in 1972. The territory number was used to identify the young from each territory.

REPRODUCTION

Reproductive Chronology

The migrant red-tailed hawk population begins returning to the Gallatin Valley as early as the first week in March. Both single and paired birds were observed building nests as early as the second week in March. Late nesters may begin nest construction a month later than early nesters. The amount of time from initiation of nest building activity to egg-laying in five known cases was 22, 27, 27, 29 and 29 days. The shortest period occurred in the case of a pair of late nesters. Laying dates were determined by back-dating 32 days from the time the young were estimated to hatch. Thirty-two days is the estimated incubation period for the red-tail (Hardy, 1939 and Bent, 1937). In 1971 laying dates ranged from 14 April to 6 May, with a peak from 16 April to 26 April. Hatching dates ranged from 16 May to 7 June. The young fledged from 30 June to 22 July. In 1972 laying dates ranged from 4 April to 6 May with a peak occurring between 11 and 21 April. Hatching dates ranged from 6 May to 7 June. The young fledged from 20 June to 22 July. Thus birds began laying 10 days earlier in 1972 as compared to 1971. The range for egg-laying was 22 days in 1971 and 32 days in 1972. For both years the latest laying date was the same, and during each there was a 10-day peak of egg-laying.

Density of Pairs and Stability in Territory Distribution

The approximate location of summer territories of paired red-tails in the study area during 1971 and 1972 are mapped in Figure 2. Sixty-nine pairs were located in 1971 and 77 in 1972. A minimal estimate of density in the Gallatin Valley was approximately one pair per eight square kilometers during both years. The greatest density of pairs during both years occurred along the West Gallatin River and was approximately one pair per three square kilometers. The highest reported density of red-tails was one pair per 1.3 square kilometers in California (Fitch, Swenson and Tillotson, 1946). The estimated sizes of nine summer territories ranged from 2.6 to 4.6 square kilometers. The smallest territory occurred in a predominately grazing area (87 per cent grazing) while the largest occurred in a predominately agricultural area (57 per cent cropland).

Stability of both distribution and number of nesting territories has been reported to be characteristic for red-tail and other raptor populations. Luttich, *et al.* (1970) reported that the red-tail pairs were approximately stationary in number during a three-year study made in Alberta. Hagar (1957) noted a tendency for the same nesting territories to be occupied by red-tails in consecutive years. Craighead and Craighead (1956) found that over a six-year period the number and distribution of all nesting raptors in the study area, including the red-tail, showed little important change,

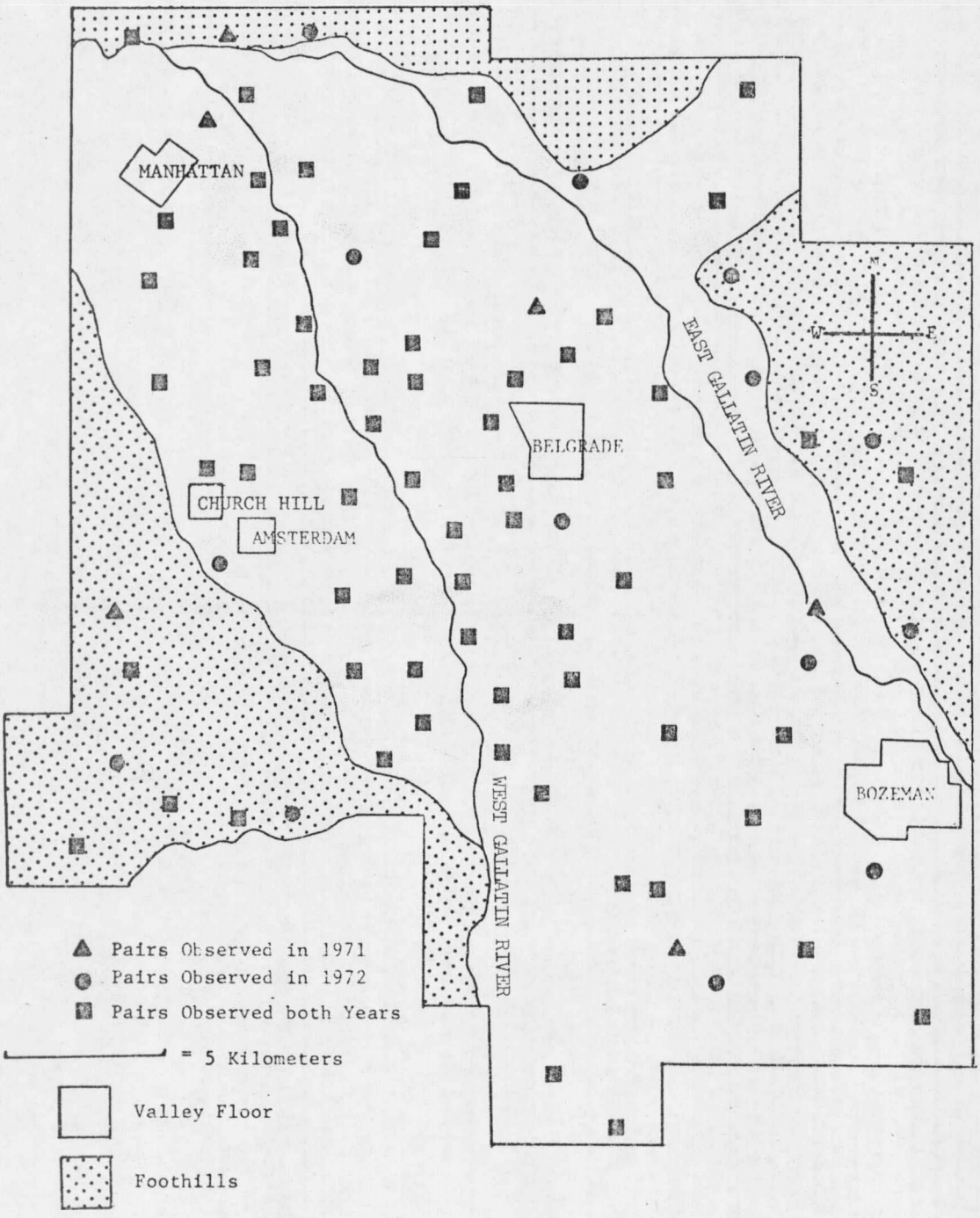


Figure 2. Approximate location in the study area of territories occupied by pairs of red-tailed hawks in 1971 and 1972.

and all raptor species studied exhibited a strong tendency to re-occupy nesting territories in consecutive years. Southern and Lowe (1968) found that once tawny owls possessed a nesting territory, they sometimes held it up to 10 consecutive years.

Evidence that occupied nesting territories were both similar in number and distribution both years of my study was obtained from comparisons of the locations of nest sites and territories used in both 1971 and 1972. Although six territories occupied by pairs in 1971 may not have been occupied in 1972, the remaining 63 territories occupied in 1971 were also occupied in 1972. Of 14 new territories discovered in 1972, 13 were located by extending the study area. Only one of these was known to be non-existent in 1971.

Forty-six of the 63 territories occupied by pairs both years contained nesting birds both years. In 24 of these territories the same nest was used both years. The remaining 22 territories had different nests used in 1971 and 1972. In 11 of these territories the approximate boundaries were determined in 1971, and the 1972 nests were located within these boundaries. For the other 11 territories in which the approximate boundaries of the 1971 nesting territory had not been determined, the distance of the 1972 nests from the 1971 nests ranged from 0.4 to 1.2 kilometers, and averaged 0.7 kilometers. Thus these nests were within or at least close to the nesting territories used in 1971. The other 17 territories known to

be occupied in both 1971 and 1972 contained non-breeding birds one or both years or contained pairs for which breeding activity was not determined. The approximate locations of these territories was similar both years.

Nest Sites

Data were recorded for 95 different nest sites within the study area. Ninety-two nests were constructed in trees (92.4 per cent in black cottonwoods and 7.6 per cent in quaking aspen). Size of tree stands in which nests were located ranged from stands approximately 1.6 kilometers in diameter to solitary trees. Heights of nests within the trees ranged from 4.6 to 23 meters. Sixty-six per cent of the nests in trees were constructed along the central axis of the tree and 34 per cent lateral to the main axis. Twenty-four per cent of the tree nests were built in dead trees or unshaded areas within trees. Three nests were located on cliffs. Red-tails have also been reported to nest on cliffs in Colorado (Olendorff, 1973).

Reproductive Success of the Total Observed Pairs

There were 137 pairs of red-tails for which sufficient observations were made during 1971 and 1972 to classify breeding activity (Table 1). Approximately half of the total observed pairs were successful in fledging at least one young. Causes of failure of the remaining pairs to fledge young were due to pairs not attempting to

TABLE 1. REPRODUCTIVE SUCCESS IN HATCHING AND FLEDGING YOUNG OF 137 PAIRS OF KNOWN BREEDING ACTIVITY.

	1971		1972		Average per cent
	Number	Per cent	Number	Per cent	
Pairs which did not attempt to breed	6	9.4	10	13.7	11.6
Pairs which failed in the nesting attempt prior to or shortly after hatching young	21	32.8	22	30.1	31.5
Pairs which failed in the nesting attempt between hatching and fledging of young	3	4.7	2	2.7	3.7
Pairs which fledged at least one young	34	53.2	39	53.4	53.3
Total number of pairs for which breeding activity was determined	64		73		

TABLE 2. REPRODUCTIVE SUCCESS IN HATCHING AND FLEDGING YOUNG OF 129 BREEDING PAIRS

	1971		1972	
	Per cent	Number	Per cent	Number
Breeding pairs which hatched young	63.9	37	65.1	41
Breeding pairs which fledged young	58.6	34	61.9	39
Breeding pairs which failed between hatching and fledging of young	5.3	3	3.2	2

breed or failing in the nesting attempt sometime prior to fledging of young. Number of non-breeding pairs of the total observed pairs fell within the 11 to 26 per cent range observed in other populations (Table 4).

Reproductive Success of the Breeding Pairs

Data on the reproductive success of the breeding pairs in hatching and fledging young are given in Table 2. During 1971 and 1972, only about 60 per cent of the breeding pairs were successful in fledging at least one young. Most nest failures occurred prior to hatching of young.

TABLE 3. PRODUCTION OF BREEDING PAIRS WHICH HATCHED AND FLEDGED YOUNG. Losses in production due to infertility and nestling mortality are included.

	1971		1972	
Average number of eggs/nest	2.27		2.79	
Average number of hatched young/nest	2.16		2.72	
Per cent loss of young due to infertility		4.8		2.5
Average number of fledged young/nest	2.15		2.52	
Per cent mortality of young from hatching to fledging		4.6		7.1

Data on production of eggs and young by breeding pairs are given in Table 3. There was a 23 per cent increase in the number of eggs laid in 1972 as compared to 1971, due to an increase in the number of clutches containing four eggs and a decrease in the number of clutches containing a single egg. Per cent of nests containing one, two, three and four eggs were 16, 35, 46 and 3 in 1971 and 5, 32, 42 and 21 in 1972. Little difference was noted in average clutch size and average number of hatched young per nest during both years. There was a 17 per cent increase in the number of young fledged per nest in 1972

as compared to 1971, due to a higher average clutch size and a lower percentage of unhatched eggs of the total laid. However, the increase in the production of eggs in 1972 was partially offset by an increased nestling mortality that year as compared to 1971. Most mortality of nestlings was due to complete failure of the nest rather than death of single young within a nest. Seventy-one of 73 nests fledged the same number of young that were hatched. In a single nest one of two young disappeared due to unknown causes, and one young in a nest of four may not have fledged due to possible desertion by the parent birds. This young was almost three weeks behind in development as compared to the three nestmates. In south-central Montana (Seidensticker and Reynolds, 1971) 14 per cent of the total nests observed had losses of at least one nestling per nest. Mortality of individual young from a nest has also been reported but not measured in other areas (Fitch, Swenson and Tillotson, 1946; Hagar, 1957; Craighead and Craighead, 1956; and Orians and Kuhlman, 1956).

Data on the reproductive success of the total observed population and the production of the pairs hatching and fledging young for seven other areas in the United States and Canada are given in Table 4. The average results on reproductive success and production for both years on the Gallatin Valley population are included. Only three of the seven other areas reported maximum clutch sizes of four eggs. The number of hatched young per nest for the Gallatin Valley population

TABLE 4. REPRODUCTIVE SUCCESS OF THE GALLATIN VALLEY AND SEVEN OTHER RED-TAILED HAWK POPULATIONS IN THE UNITED STATES AND CANADA.

	Gallatin Valley, Montana	South-central Montana[1]	Alberta[2]	Wisconsin[3]	New York[4]	California[5]	Michigan[6]	Wyoming[7]
Per cent of the population breeding	88.4	-----	86.0	90.0	74.0	-----	-----	-----
Per cent of the breeding population which hatched young	64.5	-----	74.0	74.0	59.0	83.0	-----	-----
Per cent of the breeding population which fledged young	60.0	50.0	-----	-----	-----	-----	-----	-----
Maximum clutch size	4	4	4	---	3	3	3	4
Average clutch size	2.53	2.9	2.1	---	---	2.0	2.2	2.3
Average number of hatched young/nest	2.44	2.6	1.9	---	---	---	---	---
Per cent infertility of eggs	3.7	5.7	4.0	-----	-----	-----	-----	9.0
Average number of young fledged per successful nest	2.34	1.7	1.4	1.9	1.9	1.4	---	1.7-1.9
Per cent mortality of nestlings	5.9	35.0	27.0	-----	-----	-----	-----	19.0

[1] Seidensticker and Reynolds, 1970
[2] Luttich, Keith and Stephanson, 1971
[3] Orians and Kuhlman, 1956
[4] Hagar, 1957
[5] Fitch, Swenson and Tillotson, 1946
[6] Craighead and Craighead, 1956
[7] Craighead and Craighead, 1956

during 1972 (2.72) was higher than for any other area. The average number of young fledged per successful nest was also higher in the Gallatin Valley than for other areas. The average nestling mortality for the Gallatin Valley population was considerably lower than that reported for any other red-tail population.

Stability of the Gallatin Valley Population

According to a study made by Henny and Wight (1970) red-tail populations in the United States and Canada must fledge between 1.33 and 1.38 young per nesting attempt to maintain a stable population. The Gallatin Valley population fledged 1.26 young in 1971 and 1.49 young in 1972 per total nesting attempt, giving an average of 1.38 young produced for both years. As this figure is at the top of the range given by Henny and Wight (1970) the Gallatin Valley population is apparently at least maintaining itself. This conclusion supports Henny and Wight's (1970) and Spofford's (1969) ideas that the red-tailed hawk is maintaining itself in the United States and Canada.

A recent study done in south-central Montana on the stability of the red-tail population there indicated the population was declining (Seidensticker and Reynolds, 1971). The 0.9 young fledged per total nesting attempts for the observed population was considerably lower than the number given by Henny and Wight (1970) as

necessary to maintain a stable population. If one were to compare equal numbers of breeding birds in the two populations the Gallatin Valley population would have a 76 per cent greater production of young. The production of the total population could not be compared as Seidensticker and Reynolds (1971) did not compute the number of non-breeding pairs in the population. The greater production of the Gallatin Valley breeding population as compared to the south-central Montana breeding population was due to 10 per cent more pairs fledging young and 38 per cent more young fledged per successful nest. Although the actual number of young hatched per nest was seven per cent greater in the south-central Montana population as compared to the Gallatin Valley population the mortality rate was 29 per cent greater from hatching to fledging.

A red-tail population in Alberta was also found to be declining on the basis of a life table constructed from banding returns (Luttich, Keith and Stephenson, 1971). However, the authors stated this conclusion was questionable due to a probable overestimation of first-year mortality of red-tails. Comparison of production of the Alberta red-tail population to the Gallatin Valley population was not possible as Luttich, *et al.* (1970) did not give the per cent of breeding pairs which were successful in fledging young.

POST-FLEDGING BEHAVIOR

The young red-tails gradually increased the amount of time spent out of the nest and in the branches of the nest tree until they finally left the nest tree. The first flight from the nest tree was considered to be the beginning of the post-fledging period. The post-fledging period was divided into an inactive and an active phase, based on the range of movements of the fledged young within the parental territory. The inactive phase which began after fledging of the young was termed the post-nesting period.

Length of Time Young Remained with Parents

Observations were made on 26 fledged young in 10 territories during the two summers to determine the length of time the young remained associated with the parent birds. The age in days after fledging the young left the parental territories permanently is referred to as departure age. Departure age was determined for 23 young, nine of which carried radios. Departure age for 14 untagged young was recorded as the last date these young were observed within the parental territories. Accurate departure dates for the nine radio-tagged young were determined. A single untagged nestmate in each of three territories was observed only until the radio-tagged nestmate left the parental territory.

TABLE 5. AGE AFTER FLEDGING WHEN YOUNG WERE LAST OBSERVED WITHIN THE PARENTAL TERRITORIES.

Nest	Year observed	Number of young in nest	Days after fledging when young were last observed within the parental territories			
			1st	2nd	3rd	4th
61	1972	4	39r	41	42	70r
7	1971	3	53	53	53	
34	1971	3	31	42	42	
7	1972	3	30r	38	63r	
34	1972	3	46	46	51r	
11	1971	2	33	47		
9	1972	2	31r	31*		
11	1972	2	42r	43*		
33	1972	2	34r	35*		
32	1972	2	38	51r		

r Radio-tagged
* After this date no further observations were made.

The results for ages of departure are given in Table 5. All 26 young remained associated with the parent birds for at least 30 days after fledging. There was a 40-day range in departure age for the young, from 30 to 70 days after fledging. The average length of time each radio-tagged young was associated with the parent birds was 46 days after fledging. This extended period of association of young with the parent birds after fledging has also been observed for other raptor species. Fledged young have been observed within the parental territory up to two months for osprey (Brown and Amadon, 1968),

two and a half to three months for tawny owls (Southern, Vaughan and Muir, 1954), five months for great horned owls (Dunstan, 1970) and 11 to 11.5 months for African crowned eagles (Brown, 1966).

Range in departure ages of nestmates was almost as great as the range for young from different nests. Some nestmates left on the same day while others left at intervals up to 33 days. There were three departure patterns for young from a single nest. In one territory three young all left within several days of each other. In three territories containing two, two and three young, respectively, departure dates were staggered with at least a week's interval between each departure. In each of three remaining territories containing three, three and four young the departure date of one young differed considerably from departure dates of remaining nestmates. The number of young remaining in different territories at similar times during the summer was also variable. The first departure of young from one territory was 30 days after fledging and 53 days in another. All nestmates were known to have left one territory by 42 days after fledging and not until 70 days in another.

Mortality

Mortality has been reported to be quite high during the first year of life for various species of raptors. Several first-year mortality estimates on raptors include 80 per cent for the prairie falcon (*Falco mexicanus*) (Brown and Amadon, 1968), 60 per cent for

TABLE 6. DAYS AFTER FLEDGING DURING WHICH NO MORTALITY WAS OBSERVED. Observations were made on 41 young from 16 territories.

Nest	Year observed	Number of young in the nest	Length of time after fledging during which no mortality was observed for all young from each nest
61	1972	4	41
7	1971	3	53
34	1971	3	33
7	1972	3	32
34	1972	3	47
11	1971	2	33
9	1972	2	31
11	1972	2	42
33	1972	2	34
62	1972	2	39[1]
24	1971	3	23[1]
26	1971	3	27[1]
15	1971	3	25[1]
8	1972	2	18[1]
25	1971	2	26[1]
36	1971	2	25[1]

[1] Observations were discontinued at that date.

the osprey (Brown and Amadon, 1968), 57 per cent for the common buzzard (*Buteo buteo*) (Olsson, 1958) and 46 per cent for the great horned owl (Steward, 1969). Henny and Wight (1970) estimated first year mortality to be 62 per cent for the red-tailed hawk, but this figure included fledgling mortality. Mortality of red-tailed hawks after fledging to one year of age was estimated by Luttich, *et al.* (1970) to

be 54 per cent. Although the actual age of young when this high mortality occurs has not been determined, my results indicate that mortality is insignificant during the post-fledging period for the red-tailed hawk.

No deaths of fledged young were observed. Data were recorded on the periods of time for which all young in each of 16 territories were observed and thus known to be alive (Table 6). As disappearance of young from the parental territory was not necessarily due to mortality, the recorded period of zero mortality was actually a minimal estimate. The shortest recorded period of zero mortality was 18 days after fledging for one of six nests in which observations were discontinued while all young were still present within the parental territory. For the remaining 26 young in 10 territories, the shortest observed period of zero mortality was 31 days after fledging, and the longest was 53 days after fledging. Thus mortality was zero for at least the first month after fledging for all 26 young and appeared to be negligible until the end of the post-fledging period. This conclusion is supported by the fact that none of the nine radio-tagged young in 1972 were found dead within the parental territories. One band return in 1971 was from a young outside of the parental territory. Support for these results is also obtained from other studies on post-fledging mortality. Fledged tawny owls had a mortality rate of only three per cent during a two and a half to

three month period they spent within the parental territory (Southern, Vaughan and Muir, 1954). Enderson (1964) felt that a large percentage of fledged prairie falcons survived at least until their first winter based on observations of a high proportion of young in the early winter populations. Brown (1966) reported that 100 per cent of the observed fledged African crowned eagles were reared to independence.

If mortality is low during the post-fledging period, then it must increase after the young have become independent, assuming the estimates of Luttich, *et al.* (1971) and Henny and Wight (1970) were correct. Brown and Amadon (1968) stated that the time of greatest mortality of fledged young raptors was probably the period immediately after independence. Southern, *et al.* (1954) found that mortality of fledged tawny owls was high immediately after independence.

The Post-nesting Period

The length of the post-nesting period was determined for young in 12 territories and ranged from 18 to 25 days after fledging. The average length was 22 days. The young remained within what was termed the post-nesting area throughout the post-nesting period. The post-nesting area generally consisted of trees surrounding the nest but in several cases it consisted of another clump of trees or row of telephone poles at a distance from the nest. In the latter type of post-nesting area the young never used the nest after fledging. When the post-nesting area consisted of several trees surrounding

the nest tree the young used the nest almost daily throughout the post-nesting period. In post-nesting areas which contained many trees the young usually did not return to the nest for approximately a week but they would then use the nest intermittently up to at least 12 days after fledging.

Sizes of post-nesting areas in eight territories ranged from a single row of trees 0.1 kilometer in length up to 19 hectares. In two other territories the young ranged over 61 and 122 hectares, respectively, during a 22-day period after fledging, and no definite post-nesting period could be recorded. The size of the post-nesting area appeared to be influenced by its location within the parental territory. The movements of the young were oriented toward the directions in which the adults approached with food, so post-nesting areas were larger when centrally rather than laterally located. In centrally located post-nesting areas the adults returned from more directions than they did in laterally located post-nesting areas.

Movements and Flight Behavior - Most observations on the movements of fledged young within the post-nesting area were made on three young in territory 34 during 1972. The post-nesting period of these young lasted 23 days. The post-nesting area extended over 17 hectares and included five separate clumps of trees,

TABLE 7. RANGE OF MOVEMENTS OF THREE YOUNG IN TERRITORY 34 THROUGHOUT THE POST-NESTING AREA DURING THE 23-DAY POST-NESTING PERIOD IN 1972.

Dates	Range of movements of the three young
July 6 - July 10	One dead tree clump
July 11 - July 20	Three dead tree clumps
July 21 - July 23	All five tree clumps
July 24 - July 28	All five tree clumps and 150 meters in pasture

three which were almost completely dead, and a neighboring grazed pasture. The tree clumps were between 24 and 72 meters in length and extended in a row 30 meters from an interstate highway. The distance between clumps was 12, 38, 113 and 90 meters. During the post-nesting period there was a gradual increase of the total area used by the three young (Table 7). The area used increased from one to all five tree clumps and ultimately extended 150 meters into the pasture. The young were not observed using the pasture until near the end of the post-nesting period, but at that time each used it an average of seven hours in one day (Table 8). The young also extended movements up to 0.14 kilometer out from the initial post-nesting area to use neighboring haystacks, fencelines and telephone poles in four of five other territories.

TABLE 8. CHANGES IN THE USE OF THE POST-NESTING AREA BY THREE YOUNG IN TERRITORY 34 DURING A 23-DAY POST-NESTING PERIOD IN 1972.

Date young observed	Age of young in days after fledging	Time span the three young were observed	Total flights the three young made to the ground	Maximum time any young remained on the ground at one time	Total time all three young spent on the ground	Total number of times all three young used fence posts for perches	Total number of flights by all three young between clumps of trees	Total number of flights by all three young between trees and pasture	Total time spent by all three young in the pasture
July 8	3	11:30 a.m. to 9:30 p.m.	4	3 minutes	10 minutes	0	2	0	0 hours
July 11	6	9:00 a.m. to 8:30 p.m.	0	0 minutes	0 minutes	0	10	0	0 hours
July 14	9	10:07 a.m. to 8:43 p.m.	1	1 minute	1 minute	0	13	0	0 hours
July 18	13	9:30 a.m. to 8:10 p.m.	9	18 minutes	69 minutes	1	35	0	0 hours
July 21	16	9:25 a.m. to 8:05 p.m.	12	15 minutes	73 minutes	1	66	0	0 hours
July 24	19	11:30 a.m. to 8:03 p.m.	6	16 minutes	----------[1]	6	25	0	0 hours
July 28	23	11:00 a.m. to 8:23 p.m.	23	80 minutes	313 minutes	27	16	18	21 hours

[1] Time the young spent on the ground was not accurately measured this date.

Increase in area utilized by the three young in territory 34 as the post-nesting period progressed was accompanied by an increase in flight activity, use of fence posts for perching and the use of the ground (Table 8). The total number of flights all young made between three clumps increased from two flights at three days after fledging up to 66 flights at 16 days after fledging. The number of flights between clumps of trees decreased toward the end of the post-nesting period when the young were using the pasture. Use of fence posts as perches increased from the first observed use 13 days after fledging to the end of the post-nesting period.

Flights made to the ground during the first week after fledging appeared to be accidental as the number of times young were observed on the ground was less at six and nine days than at three days after fledging. From 13 to 23 days after fledging the number of flights to the ground made by all three young increased from nine to 23. The total time spent on the ground by all young increased from 69 to 313 minutes and the maximum time spent on the ground by any young at one time increased from 18 to 80 minutes from 13 to 23 days after fledging.

Vocalization - Young were observed giving two types of calls throughout the post-fledging period. There was no difference in vocal behavior between the post-nesting period and the remaining post-fledging period. The calls were the typical adult scream and food

cries (Brown and Amadon, 1968). Food cries were given frequently every day throughout the post-fledging period and their frequency increased when the parent birds were present. Young also gave food cries to non-parental adults. Young were observed giving food cries when being mobbed by small birds. Use of the adult scream by the young was infrequent throughout the post-fledging period.

Hunting Behavior - The fledged red-tails were not required to hunt for themselves during the post-nesting period as the parent birds supplied them with food. Young were observed making attempts to catch unidentified invertebrates, but it was not known to what extent these invertebrates supplemented the food brought by the parent birds. Other raptor species have also been reported to feed their young for an extended period after fledging. Southern, *et al.* (1954) found that tawny owls fed their young from two and a half to three months after fledging, Dunstan (1970) found that great horned owls fed their young for three or more months after fledging, and Brown (1966) observed African crowned eagles feeding their young 11 to 11.5 months after fledging. As flight quills of raptors are not fully developed at fledging age (Brown and Amadon, 1968, and Bond, 1942), Bond (1942) felt that raptors feed their young for an extended period after fledging until feather development is complete. His conclusions were based on the lack of fault bars in

flight quills in 90 per cent of the young goshawk (*Accipiter gentilis*) specimens he examined. Presence of fault bars would indicate a period of starvation during the 23 to 28 days of feather development after fledging.

Presence of Adults in the Post-nesting Area - In territory 34 the female did no hunting until late in the post-nesting period. Any food she brought to the young she had previously taken from the male. The first week of the post-nesting period she spent most of the day with the young, just leaving for short periods of usually less than 10 minutes. As the post-nesting period progressed she spent less and less time with the young, and by the last several days of this period she was observed in the post-nesting area only several hours a day. The male was present in the post-nesting area only when he brought food or defended the young when I approached the post-nesting area. When I visited other post-nesting areas one bird was present or close by and usually a second approached from a distance.

Feeding Behavior - The young in territory 34 were fed individually by the female up to a week after fledging. Although these young would take food from the adults at that age the female often took food back in order to feed them herself. By the second week of the post-nesting period young were more aggressive and would strike at any bird, either another young or an adult, which approached them

when they were eating. The time required for the young to approach adults which brought food decreased from several minutes during the first week to an immediate approach in the second week after fledging. At this time young also began approaching the adults even when they did not have food. The adults remained perched when the young landed beside them to take food during the first week after fledging but in the second week after fledging they began leaving the perch to avoid the approaching young. The food was left on the perch, and it often dropped before the young grabbed it. Until at least 10 days after fledging these young made no attempts at retrieving food. By 13 days after fledging they waited up to 20 and 30 minutes before attempting to find the food and were not always successful. By 15 days after fledging they were making immediate and successful retrieves and were also finding old previously dropped food. Of the parent birds only the female was observed retrieving dropped food, and at these times she then ate it herself.

Once the young were feeding themselves, distribution of food was very competitive. The first young to reach the adult which had food got it, and often this was the young which had been the longest without feeding. The young were not usually observed taking food from each other until the young which was eating became partially satiated. During fights over food both young would pull at the food with their feet. Up to the 18th day after fledging the adults were

observed bringing food to the young as often as four times daily. During the last several days of the post-nesting period no such observations were made.

Social and Play Behavior - The young in all observed post-nesting areas remained together throughout the post-nesting period even when they were initially scattered up to 0.8 kilometer after leaving the nest. Young in territory 34 used the same areas within the post-nesting area at similar times in the day and at similar times throughout the post-nesting period. They were observed following each other from tree clump to tree clump and to the ground.

Beach (1945) stated that there is no one criterion that can be applied to describe play behavior. Cade (1953) summarized Beach's description of play behavior as having the following characteristics: Play is assumed to carry an emotional element of pleasure, it is characteristic of young animals, there is no relatively immediate result which affects the continued existence of the individual or the species, and it appears to be youthful attempts at adult activities. The play behavior observed by fledged red-tails was similar to that described for young golden eagles (Herrick, 1924) goshawks (Bond, 1942) and various species of falcons (Cade, 1953). Play behavior of raptors seems to involve two forms: playful hunting of inanimate objects and attacks on live animals in a sportive manner with no apparent attempt to kill(Cade, 1953).

Play behavior was only occasionally observed by the young in territory 34 during the first week after fledging. At this time the young bit and struck at branches and carried branches around in their beaks. When the young began using the ground their play behavior became more variable. They would spend over an hour at one time playing on the ground. They attacked various inanimate objects by running at them with their heads held low and their wings outstretched and then striking, pouncing upon and/or beating their wings at the prey object. Pounces often continued as several bounds into the air with the prey object being held in the feet. During bounds into the air the young often turned and came down facing another direction. They also would make sharp reversing turns to strike at real or imaginary objects while running over the ground, and they would use their beaks to toss objects into the air. They then would attack the object before or shortly after it landed back on the ground.

Playing was both an individual and a social activity. All three young often played with the same objects at one time. By the second week of the post-nesting period they also made dives upon each other in the air or dived from the air on another young which was on the ground. They would also rush at each other with outstretched wings on the ground.

Behavior of Young after the Post-nesting Period

Movements and Flight Behavior within the Parental Territory - At the end of the post-nesting period movements of the young extended out from the post-nesting area into all parts of the parental territory and also to areas outside the parental territory. Movements within the parental territory were recorded for eight young which remained within the parental territory from 42 to 70 days after fledging: one young in two territories in 1972 and one young in three territories in both 1971 and 1972.

No data were obtained on hunting behavior of the young outside the parental territory. Within the parental territory all observed young limited most of their hunting activity to small areas. Of a total of 20 hunting areas used by the eight young within the eight parental territories, seven were oriented along rows of telephone poles, with the young using an estimated length of 0.3 to 0.9 kilometer of the rows. Six hunting areas were oriented along fence rows, with the young using an estimated length of 0.3 to 0.8 kilometer of the rows. The remaining seven hunting areas were larger and included use of a variety of perches, such as posts, poles, bushes, trees and old junk piles. Five measured areas ranged from 12 to 63 hectares with an average size of 22 hectares. The presence of small localized areas within a territory which were more consistently hunted than other areas was also reported by

Craighead and Criaghead (1956) for various species of raptors, including the red-tail.

The number of hunting areas per territory and the amount of use each received was calculated for all eight territories in which young were observed (Table 9). The number of hunting areas used within one territory varied from three to five. Zero to 10.5 per cent of the locations of young were in areas other than well-defined hunting areas, and the inconsistent patterns of use were such as to prohibit recognition of specific hunting areas. Some hunting areas were used throughout the post-fledging period, whereas others were used only for a single period of several days.

In territory 34 the young used one hunting area almost exclusively (over 80 per cent of the total use) throughout the summer each year. Use of hunting areas by the remaining six observed young was spread more evenly with no one area receiving more than 60 per cent of the total use (Table 9). In territory 61 the young used five hunting areas in sequence, and it used each area for eight, six, four, five and five days, respectively.

Use of hunting areas within the parental territories was compared between years for three territories, 7, 34 and 11. In territory seven one hunting area which received 47.4 per cent of the total hunting use in 1971 (Table 9) was changed from a grazed area to a grain field in 1972. This area received no use in 1972, and the number of hunting

TABLE 9. USE OF HUNTING AREAS BY EIGHT YOUNG WITHIN PARENTAL TERRITORIES. The number of each hunting area identifies the same area used both years within a given parental territory.

ID of young[1]	Year	Days after fledging each young remained within the parental territory	Number of times each young was located after the post-nesting period	Per cent of total locations each young was found within each hunting area					Scattered locations[2] of young (per cent)
				1	2	3	4	5	
34[g]	1971	43	36	82.1	12.2	5.7			
34[r]	1972	51	90	93.8	5.1	1.1			
11[g]	1971	47	52	56.4	25.6	7.7	10.3		
11[b]	1972	42	37	60.0	25.0	10.0	5.0		
7[g]	1971	53	38	47.4	18.4	13.2	10.5	0.0	10.5
7[o]	1972	63	49	0.0	0.0	40.8	34.7	23.2	1.3
62	1972	51	50	58.0	30.0	12.0			
61[o]	1972	70	64	21.9	20.3	20.3	17.2	12.6	7.8

[1] Number designates territory in which each young was fledged.
[2] Per cent of total locations where young were found outside the well-defined hunting areas.

TABLE 10. COMPARISON OF USE OF HUNTING AREAS BY YOUNG IN TERRITORY 11 DURING 1971 AND 1972.

Order in which areas were used	Age in days after fledging when young used each hunting area	
	1971 (11^{a} young)	1972 (11b young)
Area 1	21 - 25	22 - 28
Area 1 and 2	26 - 32	29 - 34
Area 1, 3 and 4	34 - 47	35 - 42

areas within the territory decreased from four in 1971 to three in 1972. Despite the lack of other changes in the territories only two hunting areas were used both in 1971 and 1972. This decrease in hunting areas resulted in a reduced range of movements of the young within the parental territory in 1972 as compared to 1971. The maximum range between areas utilized by the young within the parental territory throughout the post-fledging period decreased from 2.73 kilometers in 1971 to 1.01 kilometers in 1972. The locations of young outside the hunting areas decreased from 10.5 per cent of the total locations in 1971 to 1.3 in 1972. In territory 11, the young during both years used similar hunting areas at similar ages throughout the post-fledging period (Table 10).

Young were commonly observed soaring after the post-nesting period within the parental territory between 9:30 a.m. to 5:00 p.m. The

young in territory 34 in 1972 made 89 per cent of their soaring flights within the parental territory between 11:00 a.m. and 1:00 p.m. The average measured soaring time for these young during 18 flights within the parental territory was 13 minutes and ranged from less than one to almost 60 minutes. The maximum observed number of soaring flights per day by any of these young was three. They were observed soaring almost every day except when it was raining. Several radio-tagged young were never observed soaring even though all young except those in territory 34 in 1972 were checked an equal number of times daily.

Movements and Flight beyond the Parental Territory - Data on post-fledging movements of young beyond parental territories during the time they remained associated with the parents are given in Table 11. The number of flights made between the parental territories and surrounding areas was variable. Three of the nine radio-tagged young ($r7^{b}$, $r61^{g}$ and r 62) had no movement out from the parental territories until permanent departure from 30 to 51 days after fledging. Three other young (r9, r33 and $r61^{o}$) left and returned to the parental territories only once before permanent departures at ages ranging from 31 to 70 days after fledging. The remaining three radio-tagged young ($r11^{b}$, $r7^{o}$ and r34) left and returned to the parental territories four to five times before permanent departures at

TABLE 11. MOVEMENTS OF RADIO-TAGGED YOUNG OUTSIDE THE PARENTAL TERRITORIES. Movements of untagged young which were occasionally observed away from the parental territory are included. Ages are in days after fledging.

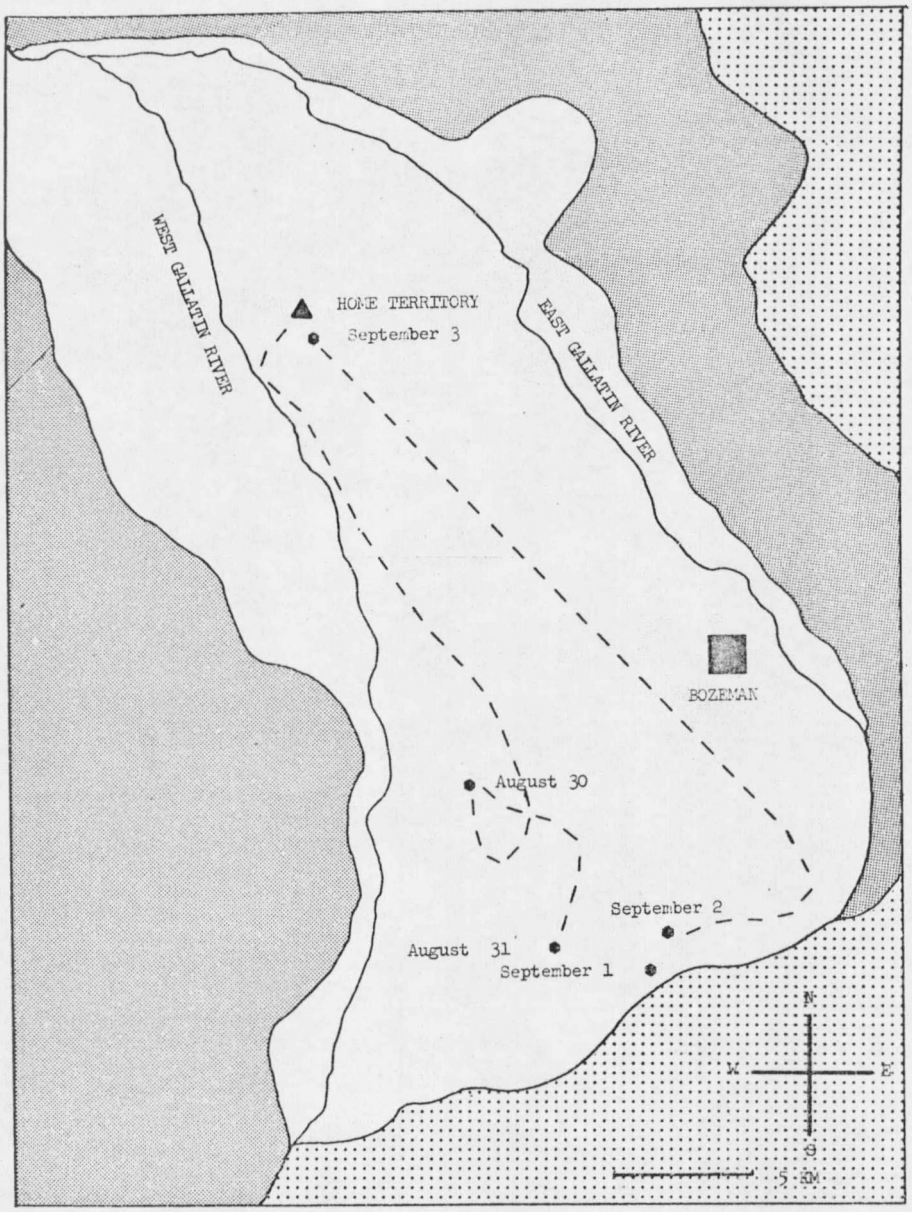
Young (ID)	Age left	Distance & Direction	Age returned	Age left	Distance & Direction	Age returned	Age left	Distance & Direction	Age returned	Age left	Distance & Direction	Age returned	Age left	Distance & Direction	Age returned	Age left	Distance & Direction
r34	35	1.6 KM SW	36	38	1.6 KM SW	39	39	1.6 KM SW	40	45	1.6 KM SW	45	49	1.6 KM SW	49	51	*
r11[b]	34	2.4 KM SE, SW	34	36	7.2 KM NW	36	37	7.2 KM[1] NW		40	8.0 KM S	40	42	*			
r7[o]	26	3.2 KM SE	27	51	1.9 KM SW	52	55	1.9 KM SW	56	57	27 KM S, SW	61	*				
r61[o]	59	35 KM S, SE	66	70	MIG SE												
r62	51	MIG SE															
r33	32	1.6 KM S	33	34	MIG SE												
r61[g]	39	0.8 KM S	*														
r9	28	---	29	31	*												
r7[b]	30	6.4 KM E	*														
11[o]	39	5.6 KM SW	39														
7[nc]	28	3.2 KM SE	29														
11	53	5.4 KM SW	*														

[1] Unknown whether radio ceased functioning or young left parental territory at this age.

r = Radio-tagged
KM = Kilometers
* = No subsequent observations were made
MIG = Young migrated out of the Gallatin Valley
--- = Location outside the parental territory not observed

42 to 61 days after fledging. Apparently the length of time a young bird remains associated with the parent birds does not determine the amount of movement of this young bird between the parental territory and the surrounding areas.

The young predominantly left the parental territories around noon while they returned at various times throughout the day. Of 22 recorded movements of young from the parental territories only two were in a northerly direction (Table 11). There were 16 known temporary movements of young from the parental territories. Fourteen of these movements were of short duration (less than one to two days), and the young remained within 7.2 kilometers of the parental territories. The average distance traveled from the parental territories during these 14 departures was 3.0 kilometers. Two young ($r7^{o}$ and $r61^{o}$) were gone five and seven days, respectively, at one time and traveled a maximum distance of 27 and 35 kilometers from the parental territories (Figures 3 and 4). Time intervals between all departures of young from the parental territories ranged from zero to five days and average 2.25 days. There was a tendency for young to return to an area outside the parental territory where they had been previously. One young (r34) returned to a 53 hectare area each of five times it temporarily left the parental territory. One young ($r11^{b}$) used a specific area outside the parental territory two of four times it temporarily left, and one young ($r7^{o}$) used a



— — —Movement of bird.
● Location the bird discontinued movement for that day.

Valley Floor

Foothills

Mountain Ranges

Figure 3. Movements of young (7°) during five days it remained away from the parental territory (30 August to 3 September, 1972).

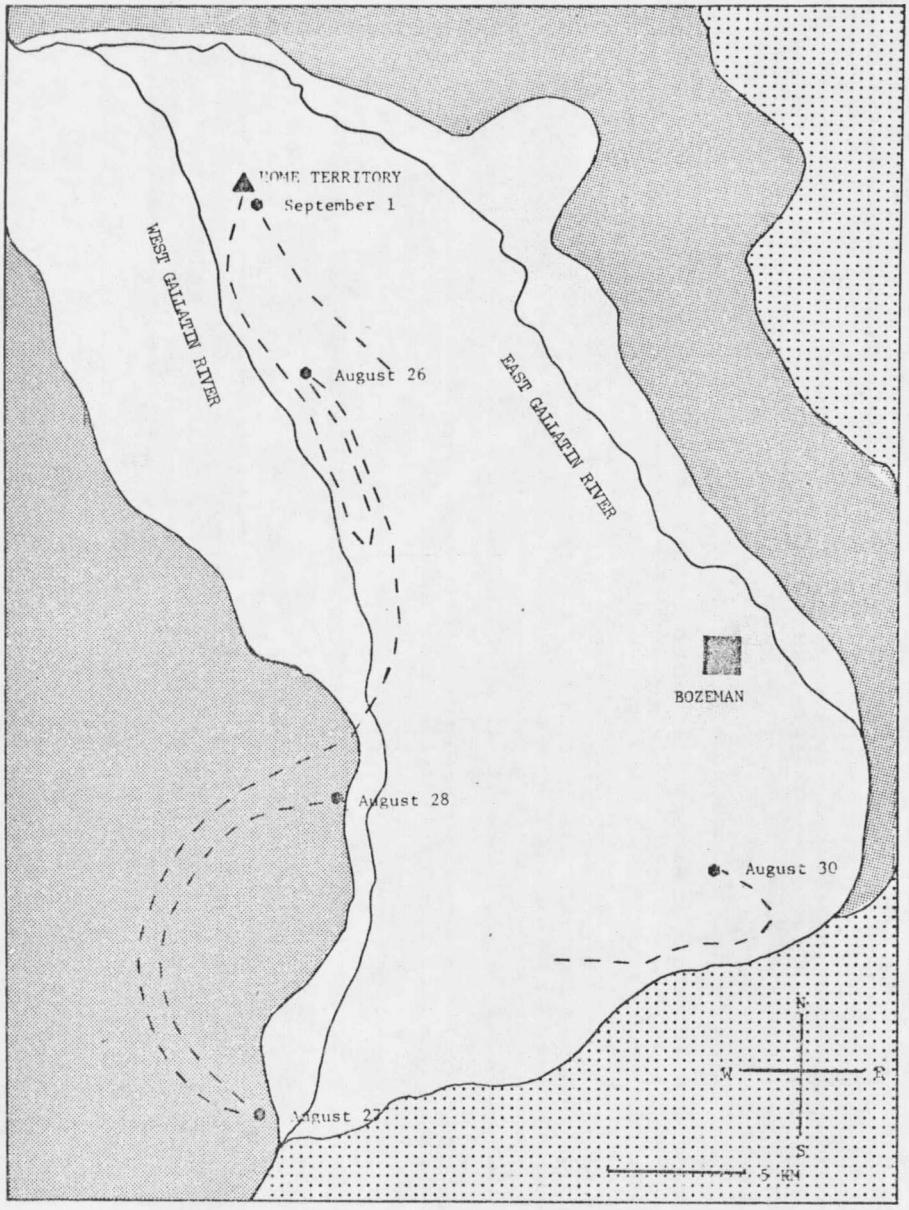


Figure 4. Movements of young (61^{O}) during the seven days it remained away from the parental territory (26 August to 1 September, 1972).

specific area outside the parental territory three of four times it left temporarily. (One observed flight to this specific area was made during a longer flight from the parental territory.)

Soaring was the predominate means of flight for young moving back and forth from the parental territories. During the 14 flights less than 7.2 kilometers from the parental territories the total soaring time per day and in some cases per single flight ranged from less than one up to five hours. The young either soared to an area and then went down or soared continually until they returned to the parental territories. The two young which left the parental territories for longer periods spent time soaring four of five and six of seven days. They soared an average of 3.7 hours per day and up to five hours per single flight. Maximum distance traveled per single flight was approximately 35 kilometers and the maximum distance traveled per hour was approximately 14.5 kilometers. The greatest distances traveled occurred during flights away from and returning to the parental territories. Movements during the intervening days spent outside the parental territories were more localized. One young ($r7^{o}$) spent three days after initially leaving the parental territory within only several sections of land at the southeast end of the valley. On two of these days it spent a total of 8.4 hours soaring and traveled only 2.8 kilometers from its initial location.

Only three radio-tagged young ($r61^{o}$, r33 and r62) were followed in migration flights out of the Gallatin Valley. The young migrated from 34 to 70 days after fledging, a 36-day range in age (Table 11). The experiences of these three young away from the parental territories prior to migration was also variable. All three young left both the parental territories and the Gallatin Valley on the same day. However, three young ($r7^{b}$, 11 and $r61^{g}$) were located within 6.4 kilometers of the parental territories a day after they had left permanently and groups of young fledged red-tails (six or more) had been observed hunting together in small areas for several days at one time. Thus, rather than migrating directly from the valley after permanent departure from the parental territories, some young remain within the valley for an undetermined period of time prior to migration.

All three radio-tagged young followed during migration from the Gallatin Valley made direct soaring flights from the parental territories to cross the south end of the Bridger Mountain Range. One young traveled 24 kilometers in two hours and a second young traveled 37 kilometers in four hours. All three soared in a southeasterly direction during the migration flights from the valley. The migration direction of young red-tails fledged in Alberta was also southeast (Austing, 1964). All 20 band returns of young red-tails banded in Alberta were recovered southeast of

there, some as far as the Gulf Coast. The winter range of the red-tail extends as far as northern Nicaragua (Brown and Amadon, 1968). No band recoveries from outside the Gallatin Valley have been obtained for red-tails banded during my study.

Hunting Behavior - The development of hunting behavior during the latter part of the post-fledging period is discussed from two aspects: description of changes in behavior of young during hunting activity and observed hunting success. Changes in hunting behavior were analyzed from 11 recorded hunting periods (periods when the young were observed to begin hunting actively and then later to become inactive) for three young in three territories (Table 12). Ages of these young when their hunting activity was observed ranged from 30 to 49 days after fledging. The percentage of the total flights made which were hunting attempts during each hunting period averaged 32.6 per cent for young during 30 to 37 days after fledging and 77.6 per cent for these young during 43 to 49 days after fledging. Hunting attempts are described either as flights made by the young to the ground or low quartering flights over the ground. The average time interval between all flights during the hunting periods was approximately eight minutes during both age spans. The average length of time between hunting attempts was 24.4 minutes for the 30-37 day age span and 10.4 minutes for the 43-49 day age span. The

TABLE 12. BEHAVIOR OF THREE YOUNG DURING 11 RECORDED HUNTING PERIODS.

ID of young	Age in days after fledging	Length of hunting period (hours)	Total number of flights made while hunting	Number of hunting attempts made	Per cent of hunting attempts made of the total flights	Average length of time between all flights (minutes)	Average length of time between hunting attempts (minutes)
7°	30	2.0	13	2	15.4	0.2	60.0
34	31	1.43	6	3	50.0	24.3	28.5
34	31	0.97	14	3	21.4	4.1	19.3
34	34	0.33	6	2	33.3	3.2	10.0
11g	36	0.37	12	5	42.0	1.8	4.4
34	37	3.21	24	8	33.3	8.0	24.1
34	43	2.25	10	9	90.0	13.5	15.0
34	45	0.8	8	5	62.5	6.0	9.6
34	45	1.02	7	6	85.7	8.7	6.1
11g	48	0.91	6	3	50.0	9.2	18.3
7°	49	0.25	5	5	100.0	3.0	3.0

TABLE 13. BEHAVIOR DURING HUNTING ATTEMPTS OF THE RADIO-TAGGED YOUNG IN TERRITORY 34 DURING 1972.

Age of young in days after fledging	Time span young observed	Number of observed hunting attempts	Type of flight used during hunting attempt		
			Post to ground	Pole to ground	Quartering over ground from poles
31	10.5 hours	6	5	1	0
34	11.0 hours	3	3	0	0
37	3.2 hours	5	2	2	1
45	7.8 hours	11	0	3	8

type of flight used during hunting attempts was adequately observed for only one young bird (Table 13). There was an increase both in use of higher perches (telephone poles as opposed to fence posts) and quartering flights by the young through the post-fledging period. The young gradually increased their hunting efficiency by increasing the number of hunting flights relative to the total flights made during the hunting periods and by decreasing the time interval between each hunting attempt. Young bird number 34 was also increasing the area over which it was searching for prey by using higher perches and quartering over the ground rather than remaining perched.

If development of hunting behavior by the young is a gradual process, the young should not be required to become immediately self-sufficient at the end of the post-nesting period, even though they

appear capable of moving around actively within the parental territory. This assumption is supported by observations of adults bringing food to young up to 34 days after fledging, an average of 12 days after the termination of the post-nesting period, and by the low observed hunting success of the young for several weeks after the post-nesting period. During the two-year study only five successful hunting attempts by young (four of known age) were observed in which the young caught small mammals rather than invertebrates. Eighteen observations of adults catching prey were made even though adults were only accidentally observed. The earliest known age a young was observed making a small-mammal kill was 39 days after fledging. The other three known ages of young when successful kills of small mammals were made were 47, 52 and 55 days after fledging. Fitch, *et al.* (1946) reported a young red-tail killing a small mammal no later than 39 days after fledging.

The young appear to rely at least partially upon stolen food for several weeks after the post-nesting period. Young were observed stealing food from the parent birds 17 times within the parental territories up to 48 days after fledging. In 12 cases the young were hunting in the same hunting area the adult was using and approached the parent bird when it made a kill. In five cases the young made direct flights as far as 0.9 kilometer to approach a parent bird which had made a kill. There appeared to be no apparent decrease in the

tendency of young to steal food from the parent birds as the post-fledging period progressed, as five observations of young stealing food occurred between 20 and 28 days after fledging, six occurred between 31 and 40 days after fledging and six occurred between 43 and 48 days after fledging. The parent birds appeared to tolerate the stealing of food by the young for several weeks after the post-nesting period, as they would leave the food on the perch when the young approached. Several weeks after termination of the post-nesting period the parent birds became more resistant to piracy by their young and tried to retain food by avoiding the approaching young. Young were also observed stealing food from unrelated young and adults, usually by waiting until the other bird was through eating. Stealing of food may be how young which leave the parental territory shortly after the termination of the post-nesting period are able to survive until they develop hunting skills.

The conclusion that young red-tails learn to hunt gradually is supported by studies done on other raptor species. Brown (1966) stated that young African crowned eagles kill for themselves long before the end of the post-fledging period, but only to supplement the food brought to them by the adults. Dunstan (1970) found that young great horned owls did not become independent of the adults until up to four months after fledging although they were making successful kills during the third month after fledging.

Figure 5 depicts the time of day the young were observed hunting. The greatest activity occurred between 9:00 a.m. and noon and between 5:00 and 8:00 p.m. Observations were made between 30 July and 24 August.

Play and Social Behavior - Play behavior between sibling young was similar to that described for the post-nesting period, except for the stooping behavior which occurred during soaring. When soaring, both sibling and non-sibling young would stoop on each other at distances of 25 meters or more. The stooping young dropped straight down with its wings outstretched and rigid, making several sharp turns per second to the left and right. The young which was being stooped upon also dropped in this manner. Stooping adults folded their wings and dropped without the series of turns.

Four types of social interactions were observed: between sibling young, between young and the parent birds, between non-sibling young and between non-parental adults and young. There was a tendency for sibling young to remain together throughout the latter part of the post-fledging period. Table 14 contains data on the percentage of total sightings in which eight young were observed with a sibling. All sightings were made within the parental territory during the period when at least two sibling young were associated with the parent birds. The percentage of total sightings during which young

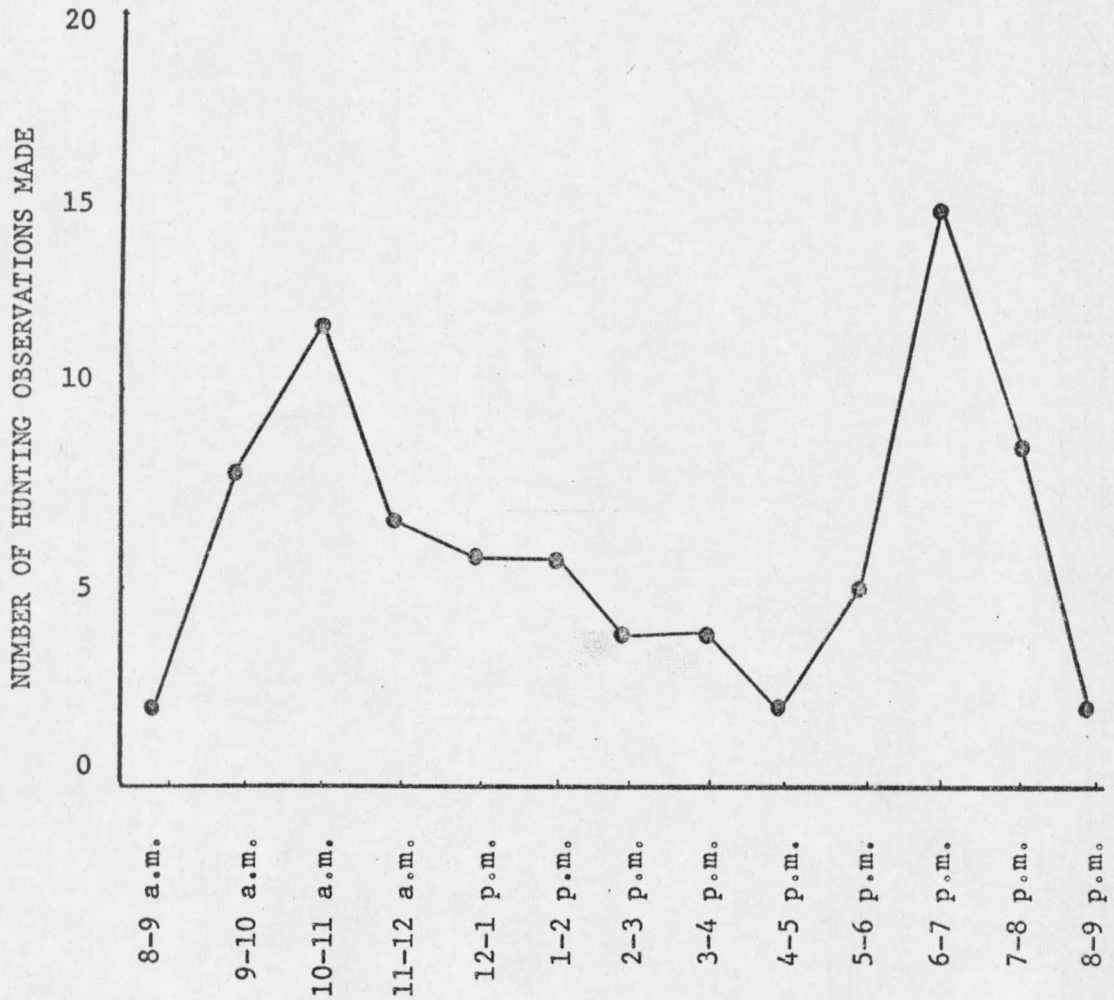


Figure 5. Time of day young were observed hunting. Observations were made between the dates of 30 July and 24 August.

TABLE 14. PERCENTAGE OF TOTAL SIGHTINGS THE YOUNG WERE OBSERVED WITH A NESTMATE. All observations were made within the parental territories after the post-nesting period.

ID of young	Year	Number of young within parental territory	Length of time in days after fledging when at least two nestmates were associated with parents	Number of sightings of observed young	Percentage of sightings observed young was with a nestmate
7[g]	1971	3	53	54	41
34[g]	1971	3	46	31	71
11[b]	1972	2	42	37	49
61[o]	1972	4	42	43	88
61[g]	1972	4	39	37	85
62	1972	2	38	33	55
7[o]	1972	3	37	23	61
11[g]	1971	2	33	21	52

were located with a sibling ranged from 41 to 88 per cent and averaged 63 per cent. Sibling young were also observed hunting and moving together within the parental territories.

The parent birds appeared to tolerate their young within the territory at any time during the post-fledging period, and all young which were observed at the time they left the parental territories did so voluntarily. One parent bird was observed striking and pursuing its young after this young had repeatedly approached the adult. These observations indicate that the young rather than the parent birds terminated the post-fledging period. Brown (1966) states that the young African crowned eagle terminates the post-fledging period by gradually becoming indifferent to the adults. Dunstan (1970) never observed any young great horned owls being driven from the parental territories by the adults.

Aggressive interactions between non-sibling young were observed twice, once when a young within the parental territory attacked a non-sibling young which had wandered into the territory, and once when a young outside its parental territory attacked a non-sibling young. However, many more non-aggressive than aggressive interactions were observed between non-sibling young, and it appeared that non-sibling young were attracted to each other. Young within the parental territory were frequently approached by wandering young, radio-tagged young outside the parental territory were

frequently observed soaring and perching with other young, and groups of six or more young were observed soaring and hunting together.

It appeared that adults which had not successfully fledged young during the summer were less aggressive to wandering young than adults which had fledged young. Adults which had not fledged young appeared non-aggressive toward wandering young as groups of young were observed hunting within their territories and single young were observed soaring with these adults. The young would soar directly above and behind the adult, and the adult would drop its legs. This behavior is similar to a form of courtship behavior described for red-tails by Fitch, *et al.* (1946). Wandering young which entered territories occupied by adults which had successfully fledged young that summer were almost always attacked by these adults, although the adults were not always able to drive the young from their territory.

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