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NESTING ACTIVITY TIME BUDGETS  
OF BALD EAGLES IN SOUTHEAST ALASKA

by

Steven L. Cain

B.A., Humboldt State University, 1979

Presented in partial fulfillment of the requirements

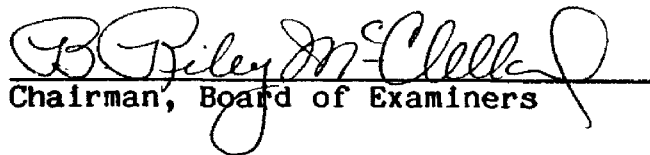
for the degree of

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1985

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Chairman, Board of Examiners

  
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## ABSTRACT

Cain, Steven L., M.S., Spring 1985

Wildlife Biology

Nesting activity time budgets of bald eagles in southeast Alaska  
(47 pp.)

Director: B. Riley McClelland *BRM*

Time budgets for adult bald eagle (Haliaeetus leucocephalus) activities at nests were documented from mid-incubation to fledging at one nest and from hatching to fledging at two nests. Timelapse cameras were used to monitor nests. Eagles incubated for 94% (range 89-100) of daylight hours; the male incubated 42% (range 22-68) of the time and the female incubated for 52% (range 30-74). Total incubation time was positively correlated with wind velocity and negatively correlated with with daily high temperature. The primary brooding period lasted for 50 days. Total brooding time averaged 79% of each day 1-10 days after hatching and declined to 6% of each day 41-50 days after hatching. Total brooding time consisted of 29% male brooding and 71% female brooding. Total brooding time was negatively correlated with daily high temperature at all nests; negative correlations with percent sunshine and positive correlations with wind velocity and precipitation were found at exposed nests. The proportion of male incubating and brooding decreased during periods of cold, wet, windy, and cloudy weather. The majority of prey item deliveries were performed by the female at two nests and by the male at one nest. The average number of prey deliveries per day did not vary with the age or number of young in the nest, and prey deliveries decreased with increases in precipitation. Females fed young for 81-91% of all feedings; the number of daily feedings increased with the number of young in the nest. Possible sources of time budget variation between nests included nest exposure to weather, variable hatching dates, the number of young in the nest, and individual differences of parental care. Comparisons with other raptors showed that male and female bald eagles share the nesting duties to a greater extent than many birds of prey.

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## INTRODUCTION

Few studies have documented detailed observations of nesting bald eagles (Haliaeetus leucocephalus). Herrick (1924a, 1924b, 1932, 1933) provided in-depth accounts of bald eagle nesting activities, but most of his observations included little quantified data. Sprunt et al. (1973) considered Herrick's work a monumental contribution but added that many gaps still existed. Brief accounts of nesting behavior were also presented by Broley (1952). More recently, time budgets and nesting behavior of captive breeding eagles were studied by Gerrard et al. (1979).

Detailed and quantified accounts of the nesting activities of other raptors include studies of captive and wild golden eagles (Aquila chryseatos) in Montana (Ellis 1979, Craighead 1980), peregrine falcons (Falco peregrinus) in Alaska (Enderson et al. 1972), ospreys (Pandion haliaeetus) in California and Nova Scotia (Levenson 1979, Jamieson et al. 1982), and gyrfalcons (Falco rusticolus) in Greenland (Jenkins 1978). The lack of detailed behavioral studies on bald eagles is partly a result of characteristics that make them difficult to study. Because bald eagles are only slightly sexually dimorphic, distinguishing between the sexes in the field is impossible in many cases. And because they are shy, bald eagles are difficult to trap and equally difficult to observe at close range without disturbance. With the exception of the Alaska Peninsula and Aleutian Island populations (Hehnke 1973, Sherrod

et al. 1976), bald eagle nests are usually located near the tops of the tallest trees in a stand (Anthony et al. 1982); this can further complicate observation efforts.

With increasing interest in captive breeding, nest fostering, and translocation programs aimed at supplementing depleted or declining wild populations, there is a need for a more complete understanding of the nesting behavior of wild bald eagles. Detailed accounts of nesting time budgets are needed to develop criteria for bald eagle management in areas where the potential for human disturbance is of concern. In this paper I report on the time budgets of nesting bald eagles from mid-incubation to fledging at one nest and from hatching to fledging at 2 additional nests. My objectives were to document the amount of time adults spent at incubating, brooding, and feeding at the nest, with specific emphasis on: the division of these activities between the male and female, temporal changes in time budgets, and the effects of several environmental parameters on nesting time budgets.

## STUDY AREA

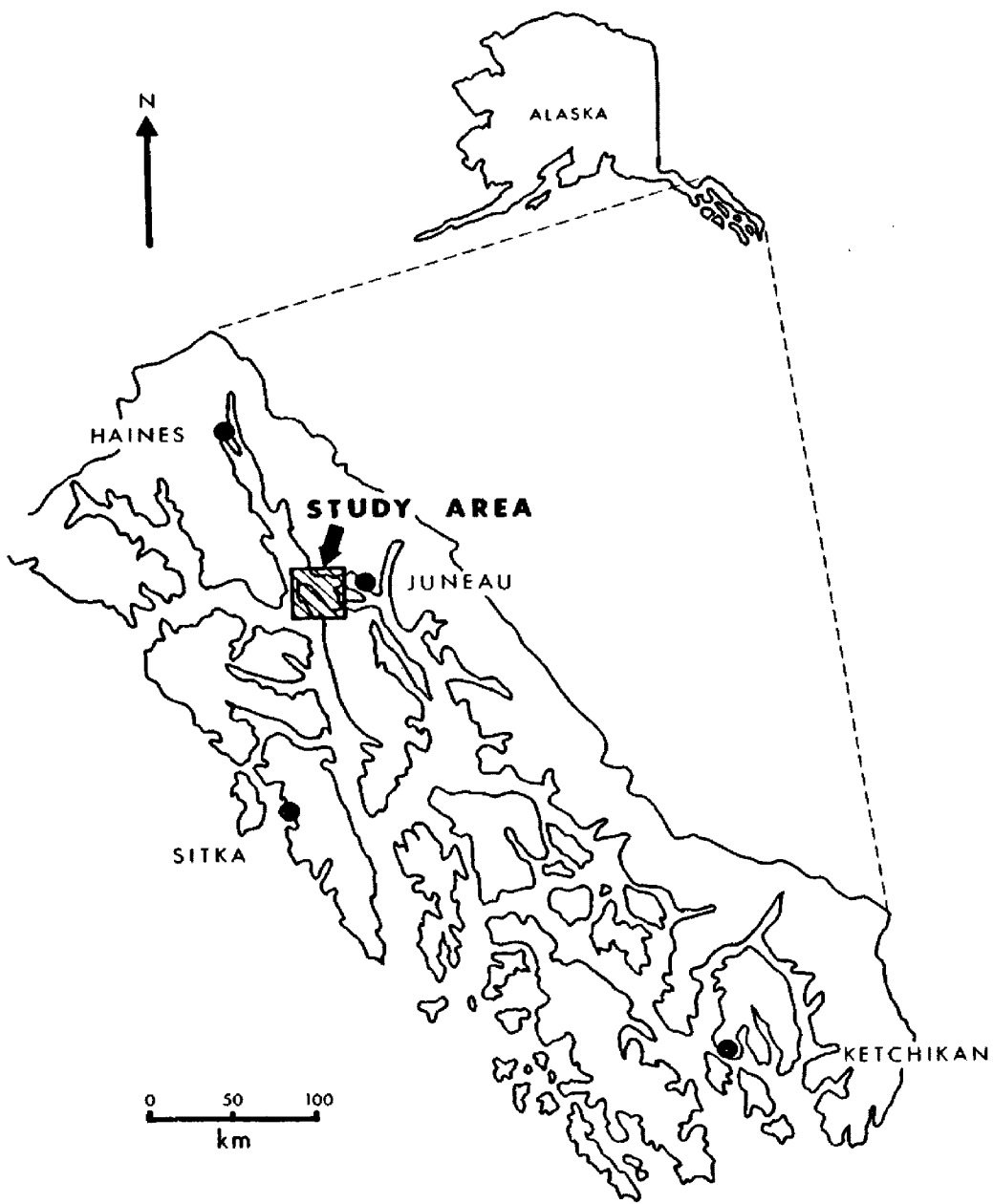
Southeast Alaska is an area of mountainous islands, inland-sea channels, bays, and fjords, the products of a mainland coast carved by glaciers (Fig. 1). The numerous Islands range in size from several thousand square kilometers to small islets only a few meters across. Topography ranges from flat muskeg and forested areas, to broad river valleys, steep cliffs, and glacier-covered mountains. Generally, island

topography is more rugged in the northern, geologically young reaches of the panhandle. Together, the mainland and islands contain 24,000 km of coastline. Shoreline vegetation consists primarily of closed conifer forests of Sitka spruce (Picea sitchensis) and western hemlock (Tsuga heterophylla) (Viereck and Dyrness 1980) with open areas of lodgepole pine (Pinus contorta) and muskeg interspersed. The weather is typically maritime, damp and mild. At the study area near Juneau (Fig. 1), precipitation averages 230 cm annually, varying locally due to the effects of high mountains. The average temperature in January is -1 C, and the average temperature in July is 15 C. Extreme temperatures during the 1984 nesting season (April-August) were -2 C on 25 April and 26 C on 6 July.

Abundant nesting habitat in southeast Alaska supports the largest breeding population of bald eagles in the United States (Sprunt et al. 1973). Population surveys in 1967 and 1977 indicated approximately 7,300 adult (white-headed) birds (King et al. 1972, Hodges et al. 1979) and over 8,000 adults in 1982 (Hodges, unpublished data). Nests are usually located in dominant or co-dominant trees of coastal old-growth stands within 0.5 km of the shoreline. The average DBH of 3,850 nest trees is 110 cm; Sitka spruce is the most important nest tree species (75%), followed by western hemlock (19%) (Hodges and Robards 1981).

**Figure 1. Southeast Alaska study area.**



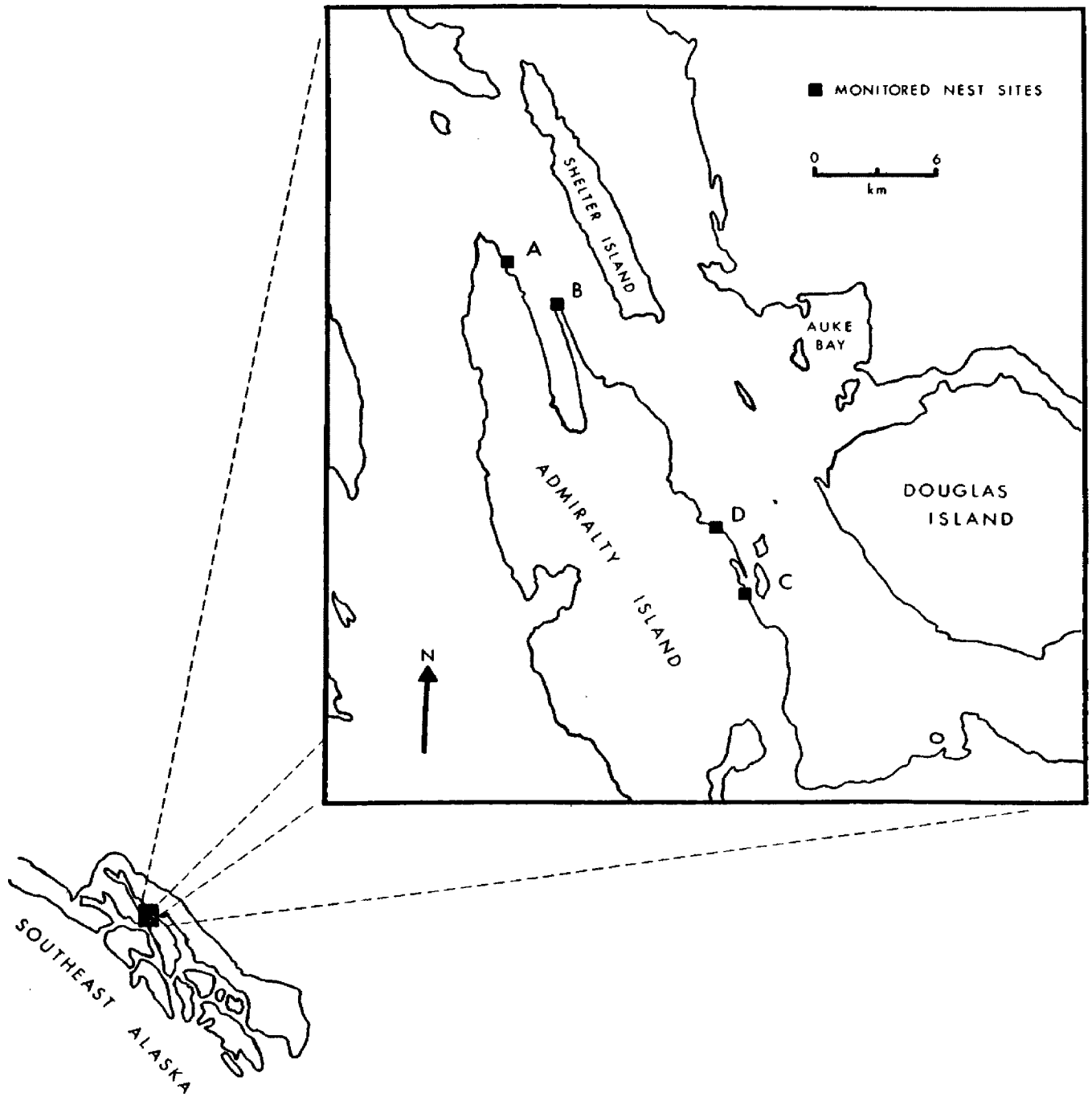


Monitored nests were located on the northern tip of Admiralty Island, approximately 32 km west of Juneau (Fig. 2). One of the 3 largest islands in southeast Alaska, Admiralty is 160 km long and up to 48 km wide, with elevations that exceed 1200 m. Almost the entire island remains in a pristine state. The average nest density along the 1400 km of coastline on the island is 1 nest per 1.6 km (Robards and King 1966), the densest concentration of nesting eagles known in the region. Approximately 30-40% of these nests are productive each nesting season (Robards and King 1966, Hodges 1982).

#### METHODS

Nests were monitored with remote, time-lapse camera units. Each unit consisted of a Minolta XL-601 super 8 movie camera, an intervalometer, a photocell, and a battery pack. The intervalometer and photocell circuits were similar to those described by Diem et al. (1977). Six-volt battery packs consisting of four C-size alkaline batteries powered the intervalometers, and cameras were powered by two AA-size alkaline batteries. Each camera unit was housed in a 50 caliber ammunition box with a hole cut for the camera lens. A 5 cm long, 9 cm diameter plastic lens hood, attached and sealed to the camera housing, provided the lens with adequate protection against the elements. To muffle the sound of the camera shutter release, the inside of the housing was lined with polyurethane foam. All components of the system were mounted on the inside of the housing lid so that they could be

**Figure 2. Study area showing monitored nest sites.**



easily serviced by simply opening the box. The camera units proved to be reliable; all operated flawlessly for the duration of the study.

Time-lapse films record activities at pre-selected moments in time, a sampling technique known as instantaneous sampling (Altmann 1973). Instantaneous sampling is well suited for sampling activity states such as incubating and brooding, but it is inefficient for sampling brief events such as vocalizing and defecating. It is particularly well suited for studying the amount of time an individual devotes to various activities (i.e. time budgets). Intervalometers were set to take single-frame exposures every 90 seconds. This sample interval was short enough to record the desired information, and long enough to ensure I could return to change each roll of film before it was completely exposed. With photocells that turned the system off at night, a standard 15 m roll of super eight film lasted 4-6 days.

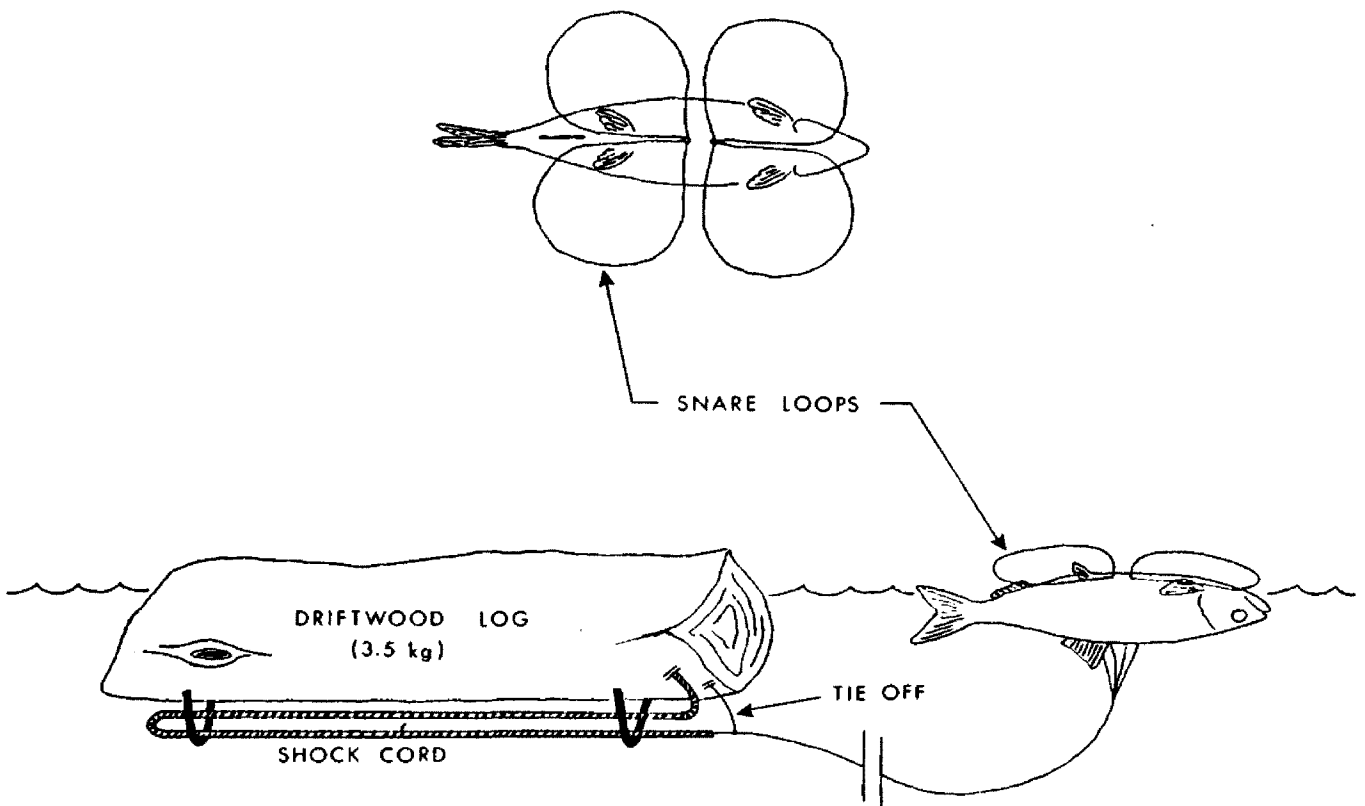
Occupied nests were located during the last week in May by cruising the shoreline in a small boat. A helicopter survey also helped locate nests, particularly those that were not visible from the water. Nests to be monitored were selected from the occupied sites based on nest tree and adjacent tree characteristics. To accommodate camera monitoring, the height of adjacent trees had to exceed the height of the nest. At least 4 m of trunk or branch structure extending above the nest platform was required for nest trees. With this combination, the nest could be monitored from an adjacent tree initially while the nesting pair became

accustomed to the presence of the camera and to regular maintenance visits; later, the camera could be transferred to the nest tree for more detailed monitoring.

To differentiate between the sexes, one of the eagles at each monitored nest site was captured and marked. The capture system consisted of snares fixed on a floating herring (Clupea pallasii) that was attached by monofilament and shock-cord to a floating, driftwood log (Fig. 3). To ensure floatation, the herring's gut cavity was emptied and then fitted with a piece of styrofoam. The snare consisted of four separate slip-knot loops of 14 kg monofilament arranged in the plane of the water's surface. The ends of the loops ran through two holes in the ventral surface of the herring, through the styrofoam in the gut cavity, and finally through the dorsal surface of the fish. There, the ends of the loops were first tied together and then were tied to the line (18 kg monofilament) and shock-cord connected to the floating log.

When set for capture, the shock cord was concealed by coiling it on the undersurface of log. The shock-cord was also temporarily tied off by a 3-5 cm length of 4.5 kg monofilament that secured the connecting line directly to the log. After a strike, the tie off caused an abrupt tightening of the line and an instantaneous closing of the snare loops as the eagle attempted to fly away with the herring. The tie off would then break, and, as the shock-cord stretched out, the weight of the log would slowly force the eagle into the water. Without the breakaway tie

**Figure 3. Snare system used to capture bald eagles.**





off line, eagles appeared to feel the resistance of the shock-cord and would evade capture by dropping the herring before the snare loops had closed.

Eagles selected for capture were usually perched near the nest in a lookout or hunting position while their mate attended the nest. The snare was placed approximately 100 m offshore at an angle that would allow wind or tidal currents to move the bait toward the target bird. Observations took place from a distance of approximately 1 km. Observing from greater distances was usually unnecessary because eagles in the study area were accustomed to the regular presence of fishing boats. The birds' reactions to the bait varied depending on hunger, visibility, and the presence of other scavengers, such as other eagles, gulls, and terns. Good visibility or the presence of scavengers often resulted in the bird taking the bait immediately. Poor visibility, the lack of competition with other scavengers, and possibly the lack of hunger all caused longer reaction times, occasionally allowing the snare to drift out of the area. In this case, replacing the snare progressively closer to the bird usually resulted in a strike. Once caught, the bird floated in the water with its wings outstretched and its head well above the surface of the water, occasionally swimming toward the shore or flying short distances before being pulled back into the water by the weight of the log. The bird then could be slowly approached, carefully pulled into the boat, and secured with a hood, talon bag, and wing wrapping.

This capture method proved to be effective and safe. Fifty percent of strikes resulted in successful captures (N=14). The action of the shock-cord combined with the log dragging across the water caused a smooth, harmless descent of the bird into the water. Only one minor injury was observed: a snare loop caused a small cut on the toe of one bird.

Captured eagles were marked by dyeing an off-white, 6 cm patch on the primary coverts near the carpal joint of each folded wing. This gave a perched bird the appearance of having white shoulder caps. The dye used was a human-hair dye (Lady Clairol Ultra Blue); application procedures followed recommendations given by Ellis and Ellis (1975). The dye immediately produced an orange color on the dark-brown feathers, which turned to a very light off-white color within a week. This proved to be an easily applied, effective, and non-permanent method of marking. Throughout the nesting season the mark was readily identifiable, and dyed feathers appeared to remain undamaged.

The dyeing procedure required a 15 minute waiting period between applying and rinsing off the solution; this time was used for measuring, banding, and taking blood samples. Measurements taken were those necessary for sex discrimination in the field (Bortolotti 1984). Blood samples were taken from the brachial vein with a 10cc syringe and a 21 ga X 1 in needle. Longer needles were awkward to use, and smaller diameter needles often clogged. The entire procedure of marking,

measuring, banding, and blood sampling could be completed in 25 minutes. Blood samples were centrifuged and frozen; testosterone analyses of these samples, performed by the Western Montana Clinic, aided sex discrimination of the marked birds.

After eagles were marked, cameras were placed in adjacent trees 10-30 m from the nest tree. Trees were climbed using tree climbing spurs, ropes, and rappeling equipment. The camera units were attached to a large branch or the trunk of each tree with steel pipe and floor flanges. The mounting system included two adjustable 90 degree bends to allow precise positioning of the camera. Cameras were focused on the nest bowl only; therefore, activities away from the nest were not recorded.

After initial installation of the cameras, film and batteries were changed at 4-6 day intervals, depending on daylength. Camera units were moved into the nest trees and mounted 3-4 m above the nest platform when eaglets were 25-30 days old. At this age the eaglets could thermoregulate, and were not in danger of exposure if the adults were absent from the nest for a long period of time.

Films were analysed with a Timelapse analysing projector. Data from the films were entered into a computer as the films were observed using a FORTRAN computer program that allowed the observer to input only the variable(s) that changed for each line of data written; variables that remained the same were automatically duplicated from line to line.

A line of data was input only when one or more variables changed value from frame to frame. Frame numbers recorded represented the time of day for which each data line was written. Activity states were assumed to last for 90 seconds for each frame on which they were observed. Weather data were taken from the National Oceanic and Atmospheric Administration weather station at the Juneau Munciple Airport, approximately 13 km from the center of the study area.

## RESULTS

### Disturbance

Peliminary time-lapse studies in 1983 indicated that the reaction of nesting eagles to monitoring cameras was variable, but that most eagles were extremely sensitive to intrusion during incubation and for the first one or two weeks after hatching. Three occupied nests were abandoned as a result of camera placement at nest sites during this time. At two nests, cameras were placed in the nest tree approximately 4 m above the nest. One of these nests was in the later stages of incubation; the other nest contained two eaglets 1-3 days old. At the third nest, a camera was placed in an adjacent tree approximately 10 m from the nest. This nest contained two eaglets that were 4-6 days old.

Adults remained attentive to nests at 4 other sites monitored in 1983. At three of these nests, cameras were installed when eaglets were 3-4 weeks old (two cameras in nest trees, one in an adjacent tree). A

fourth camera was placed in an adjacent tree approximately 20 m from a nest containing two eaglets 5-7 days old. Adjacent tree cameras were eventually transferred to the nest trees, and all four nests were monitored until after the eaglets in each nest had fledged.

Regardless of the variability observed in the adult eagles' reactions, this information indicated a risk of nest abandonment involved with monitoring nests during the early stages of the nesting cycle. Therefore, in 1984 an effort was made to habituate eagles to the investigator's regular visits to the nest prior to installing any monitoring equipment. This was accomplished by making several passes in front of the nest by boat, then walking on the beach near the nest, and finally walking around the base of the nest tree. These activities were carried out progressively over a period of one week. During each of these visits the same boat and clothing were used by the same personnel.

After habituation periods, cameras were placed in adjacent trees at 4 nest sites. Three of these 4 nests, 2 with eggs and 1 with newly-hatched young at the time of camera installation, were monitored until after a total of 4 young had fledged (Table 1). The fourth nest failed shortly after camera monitoring commenced. Adults did not return to this nest for 54 hours after the camera was installed; this period of exposure probably caused mortality of the single egg present. After returning, the pair incubated inconsistently for 11 days, spending an average of 75% (female 43%, male 34%) of each day at the nest. The nest

**Table 1. Camera dates and nest productivity in 1984.**

	<b>Nest A</b>	<b>Nest B</b>	<b>Nest C</b>
<b>Date Camera Installed</b>	5-23	5-18	5-16
<b>Eggs Laid</b>	2	2	3
<b>Eggs Hatched</b>	2	2	3
<b>Date 1st Egg Hatched</b>	5-23	6-3	5-17
<b>Young Fledged</b>	2	1	1
<b>Date Young Fledged</b>	8-10 8-15	8-24	8-11
<b>Date Camera Removed</b>	8-26	8-26	8-24
<b>Camera Days Lost</b>	0	9	4

was finally abandoned after a film change on the thirteenth day after the camera was installed. Four hours after the film change, a common raven (Corvus corax) arrived at the nest and depredated the egg.

Monitoring the nest for 8 days following abandonment revealed some additional activity. Two species of scavengers were seen at the nest; Steller's jays (Cyanocitta stelleri) were seen 7 times and a northwestern crow (Corvus caurinus) was seen once. Scavengers were usually in the nest cup, probably picking at egg remains. The female eagle also returned for 32 minutes on the seventh day after abandonment. During this time she removed an egg shell from the nest cup, and then assumed an incubating position for about 10 minutes before departing. After the camera was removed, the pair was observed in the vicinity of the nest for most of the nesting season.

The eagles' reactions to the placement of cameras at the other 3 nests were variable. Generally, the birds left the nest as the climber ascended the tree. Circling overhead and vocalizing characterized their behavior while the climber was mounting the camera. Aggressive dives were made occasionally, some to within 1 m of the climber, but the eagles never made physical contact with the climber. The length of time it took for a bird to return to the nest after the camera was installed varied from nest to nest (Table 2). At nest A the female was back on the nest while I was still mounting the camera less than 30 m away. At nest C, the female returned to the nest a few minutes after I descended

the camera tree. The birds at nest B were much more reluctant to return to the nest. The male finally returned nearly 2.5 hours after the camera was installed.

Nest absence periods and frequency of the first adult to return to the nest after camera maintenance visits exhibited a similar pattern of variability (Table 2). Absence periods for nests A and C were similar; however, average nest absence periods for nest B were greater. Because of great variability, only nests B and C had nest absence periods that were significantly different ( $P < 0.05$ ). Frequencies of the first adult to return at nest B also differed from the other nests by having the male return more often than the female.

#### Incubation

Fifteen days of incubation activities were recorded at nest B. Total incubation time averaged 94% (range 89-100%) of each day, with the female incubating 52% (range 30-74%) of the time and the male 42% (range 22-68%) (Fig. 4). Daily fluctuations in total incubation time were positively correlated with average wind velocities and negatively correlated with maximum daily temperatures ( $p < 0.05$ ). Correlations with precipitation and the percentage of the day that was sunny were also evident, but these were not statistically significant. The percent of the day adults incubated on film change days was days; therefore, only non-maintenance days were included in incubation



Table 2. Nest absence periods of adults and frequency that each sex returned following camera installation and maintenance visits.

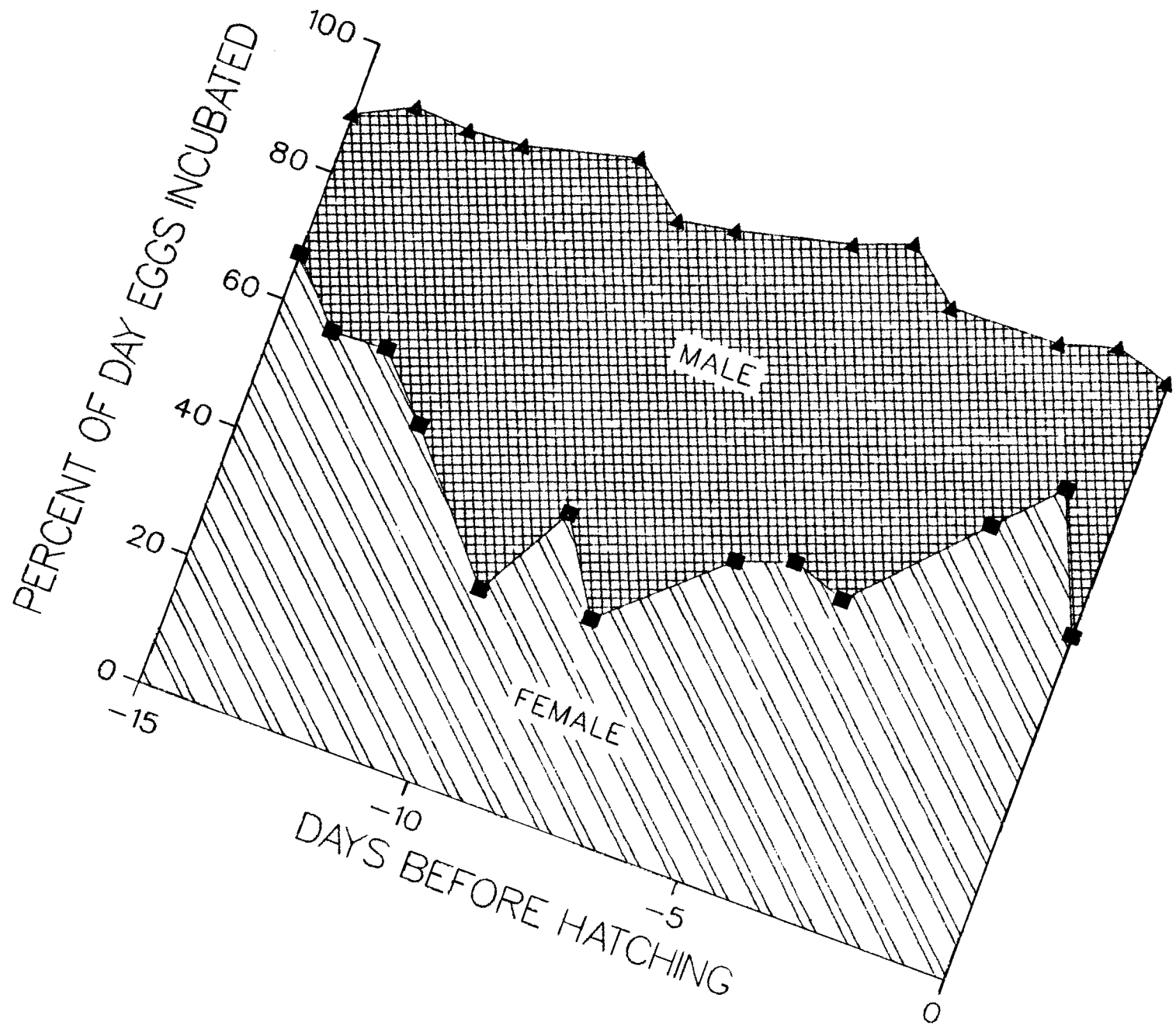
Nest	Nest Absence Periods (minutes)		Frequency of 1st Adult to Return (%)	
	day camera installed	mean of visits hatching - young 3 weeks old (range)	male	female
A	0	26 (0-119)	17	83
B	140	62 (23-228)	83	17
C	24	29 (21-33)	0	100
MEAN	55	41 (0-228)	62.5	37.5

analyses.

Fluctuations in total incubation time division between the male and female also seemed to be influenced by weather patterns. The proportion of female incubation increased on cold, wet, and windy days whereas the proportion of male incubation increased on warm, dry and calm days. For example, during a storm on the second day before hatching (Fig. 4) the maximum temperature was 8.3 C, the average wind velocity was 32 kph, 1.9 cm of rain fell, and 0% of the day was sunny. These values, all extremes for the 15 day period that incubation was monitored, coincided with the maximum percent female incubation during the same period. In contrast, the maximum percent male incubation, 11 days before hatching, coincided with a maximum temperature of 18.9 C, an average wind velocity of 13 kph, no rainfall, and 75% sunshine. Other incubation extremes for each sex seemed to follow similar fluctuations in weather, although correlations with individual weather variables were not statistically significant.

Daily routines consisted of several alternating male and female incubation bouts. The number of incubation bouts per day averaged 3.1 (range 2-5) for the male and 4.5 (range 3-10) for the female. Average incubation bout duration was 164 (range 76-273) minutes for the male and 144 (range 82-261) minutes for the female. Incubating birds frequently picked at moss and dry grass in the nest, often pulling it toward them to maintain and re-shape the nest cup. Egg turning postures, the eagle

**Figure 4. Percent daily incubation by the male and female. Missing data points occur on camera maintenance days.**



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bent over with its beak touching the egg, were observed an average of 4.2 (range 0-11) times daily; male and female rates were approximately equal. Because of the interval between film frames, many of these events may not been recorded on the films however. No prey deliveries or feedings occurred at the nest until four days prior to hatching. During the 4 days prior to hatching, the female delivered at least two prey items; the male fed once, and the female fed four times. Vocalizing just prior to nest exchanges was observed several times, both from the films and while in the field. Usually the the incubating bird initiated the exchange by calling to its mate, and then, after several vocal exchanges, the birds switched positions. Periods when both birds were at the nest usually occurred during nest exchanges, but these periods were brief and accounted for less than 1% (range 0-1.5%) of each day. The nest was left unattended for an average of less than 4% (range <1-21%) of each day. Field observations indicated that at least one bird was perched within 50 m of and in clear view of the nest during most unattentive periods.

### Brooding

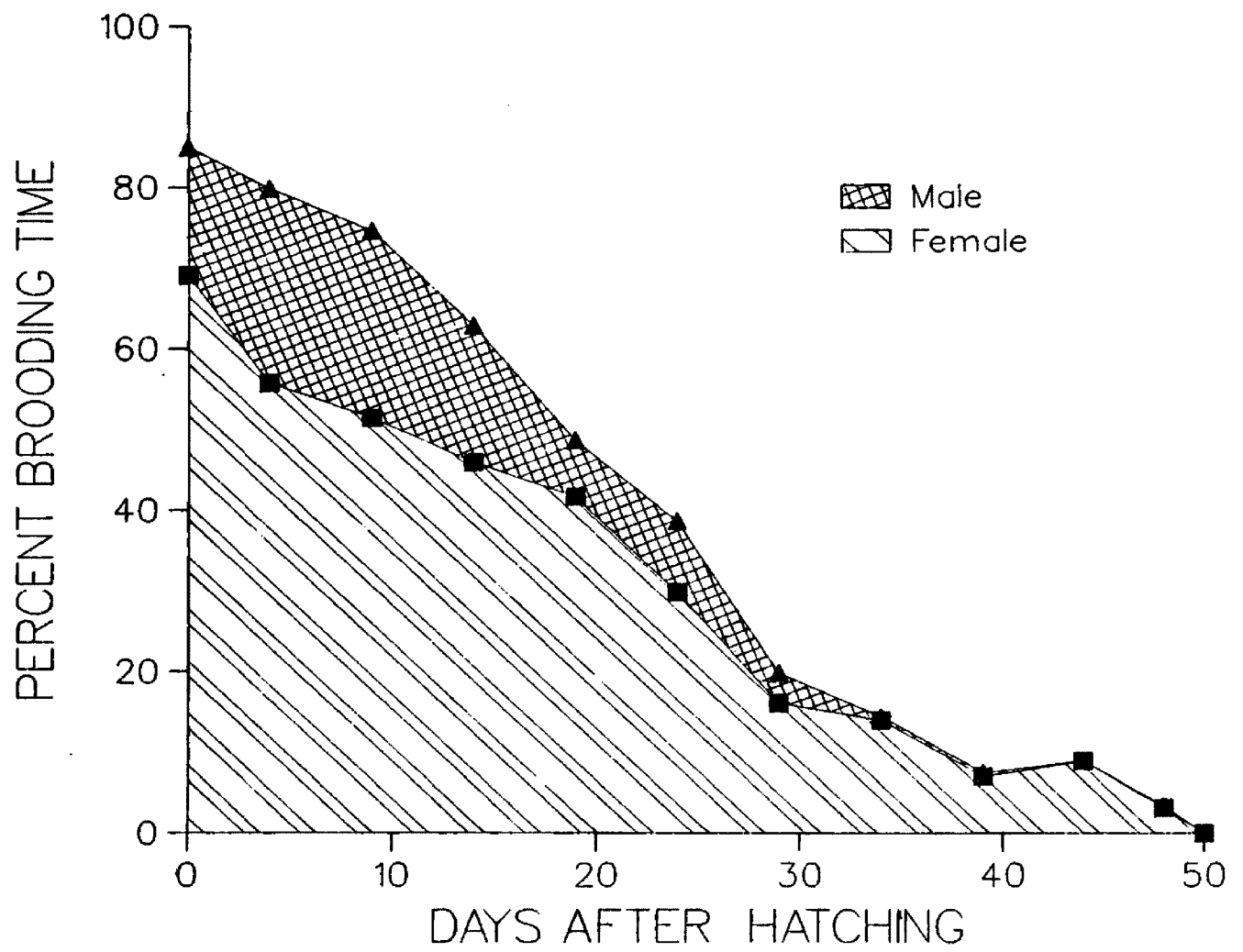
Total brooding time averaged 79% of each day during the first 10 days after hatching and tapered off gradually to approximately 6% by 41-50 days after hatching (Fig. 5). Total brooding time consisted of an average of 29% male brooding and 71% female brooding. The most rapid decline in total brooding time, between 25-30 days after hatching,

coincided with the eaglet's second-down stage and a greater ability to thermoregulate. Total brooding time fell to less than 3% 51-60 days after hatching and to less than 1% 61-70 days after hatching. No broodings were recorded after the 71st day after hatching. Data were not recorded for 4 days between 17-21 days after hatching at nest C and for a total of 9 days between 53-57 and between 72-78 days after hatching at nest B. Brooding time budgets were not significantly different on camera maintenance days; therefore, these were included in analyses.

Brooding times varied with changes in several weather variables. Significant negative correlations were found between total brooding time and daily high temperature at all nests (2 nests  $p < 0.001$ , 1 nest  $p < 0.08$ ). Total brooding time was also positively correlated with average wind velocity at the more exposed nests, A and C ( $p < 0.01$ ). Significant positive correlations with daily precipitation ( $p < 0.005$ ) and negative correlations with percent sunshine ( $p < 0.01$ ) were found at nest A as well. With few nearby trees and very little overhead tree canopy, this nest was by far the most exposed to the elements.

Similar to incubation time budgets, females tended to brood more during periods of severe weather. Female percent brooding was negatively correlated with daily high temperature at all nests ( $p < 0.05$ ); at the more exposed nests A and C, correlations with female brooding time were positive for average wind velocity ( $p < 0.001$ ) and

**Figure 5. Percent daily brooding by the male and female. Data points represent five day interval averages.**





negative for percent daily sunshine ( $p < 0.005$ ). Male brooding response to daily high temperature at nests A and B was similar to female responses with negative correlations ( $p < 0.05$ ). The response of male brooding to changing weather was often exactly opposite to female response, however, indicating a tendency for the female to brood during periods of unfavorable weather. At nest C for example, significant reversed relationships existed for all 4 weather variables (Fig. 6). Male and female brooding times at nest A also had opposite relationships for percent sunshine ( $p < 0.05$ ). Correlations with wind at nest A and precipitation at nests A and B also indicated opposite relationships but were not statistically significant.

Significant variations in total percent of the day brooded and male and female brooding times between nests was primarily confined to the first 30 days after hatching (Table 3). Total brooding time at nest C was significantly greater than total brooding time at nest A 11-20 days after hatching ( $p < 0.001$ ) and significantly greater than total brooding time at nests A and B 21-30 days after hatching ( $p < 0.01$ ). Male and female proportions of the total brooding time were significantly different at each nest ( $p < 0.05$ ) throughout the brooding period. Males brooded an average of 16% of the total brooding time at nest A, 28% at nest C, and 42% at nest B. Corresponding female contributions to total brooding time averaged 84% at nest A, 72% at nest C, and 58% at nest C. Periods when both the male and female were present at the nest averaged less than 1% of the total time each day.

**Figure 6. The influence of weather variables on brooding at nest C.**

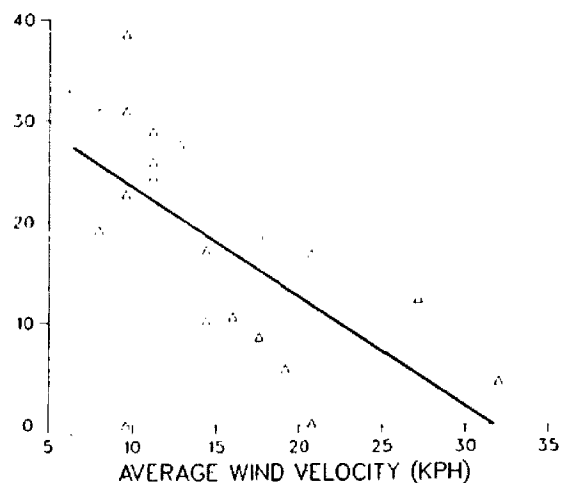
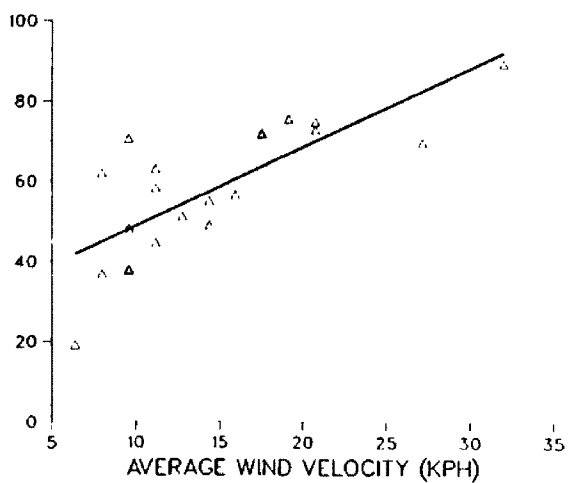
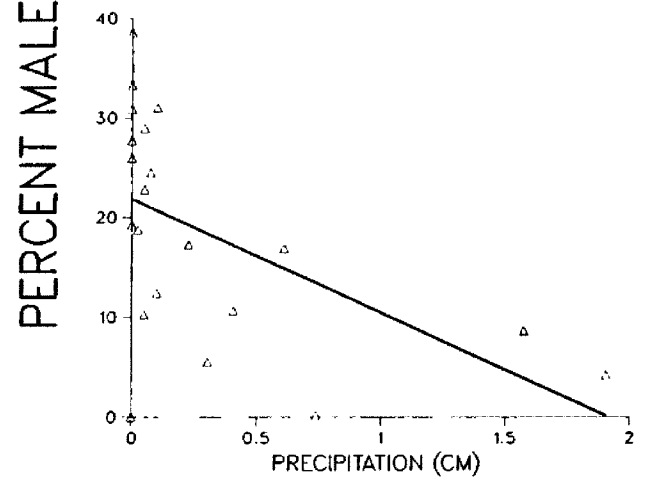
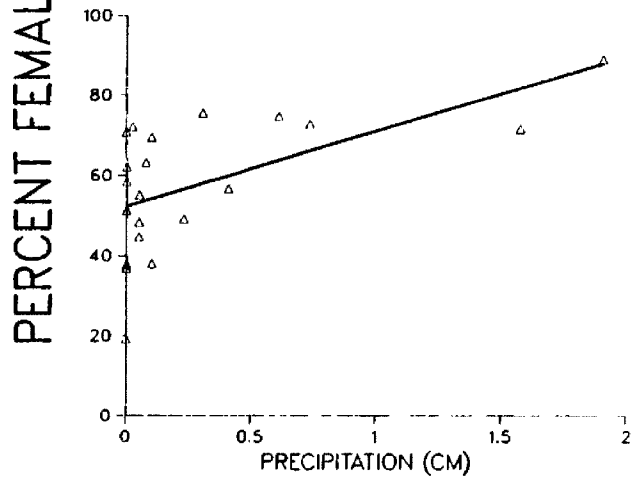
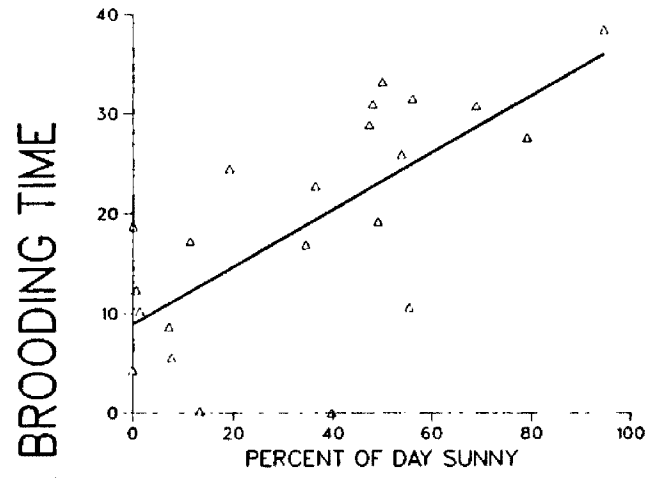
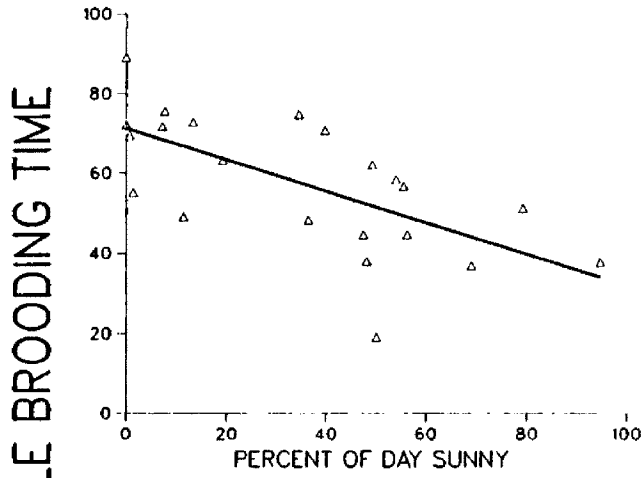
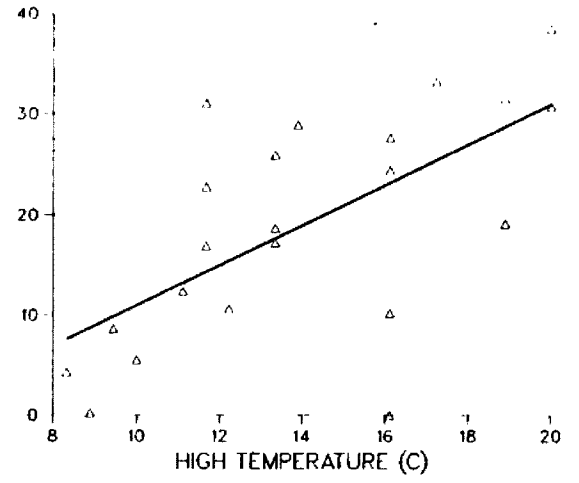
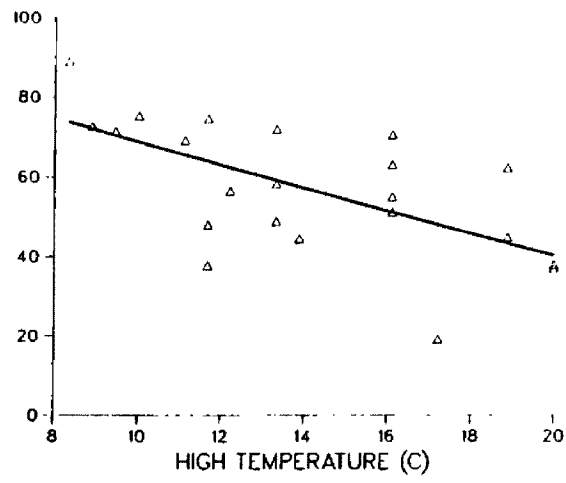


Table 3. Ten day interval averages for brooding time in percent of daylight hours, ranges in parentheses.

Days After Hatching	Nest A	Nest B	Nest C	Mean
<b>1-10</b>				
Male	15 (1-31)	33 (17-63)	23 (12-32)	23 (1-50)
Female	69 (50-86)	41 (16-50)	58 (38-74)	56 (17-86)
Total	84 (74-95)	73 (51-85)	80 (66-91)	79 (51-95)
<b>11-20</b>				
Male	3 (0-9)	27 (7-58)	11 (<1-28)	14 (0-58)
Female	36 (9-60)	29 (10-50)	66 (42-89)	41 (9-89)
Total	39 (19-65)	56 (17-85)	78 (67-93)	55 (17-93)
<b>21-30</b>				
Male	<1 (0-6)	2 (0-13)	14 (0-39)	6 (0-39)
Female	25 (0-55)	12 (0-39)	43 (10-70)	26 (0-71)
Total	25 (0-60)	14 (<1-52)	57 (18-76)	36 (0-76)
<b>31-40</b>				
Male	0	<1 (0-2)	3 (0-19)	1 (0-19)
Female	14 (0-50)	7 (0-39)	11 (2-27)	11 (0-50)
Total	14 (0-50)	7 (0-39)	14 (2-35)	12 (0-50)
<b>41-50</b>				
Male	<1 (0-2)	0	0	<1 (0-2)
Female	5 (0-28)	7 (0-34)	6 (0-21)	6 (0-34)
Total	5 (0-28)	7 (0-34)	6 (0-21)	6 (0-34)

During the brooding period, a total of 3 eaglets died at nests B and C. At nest B, the second egg hatched on 5 June, two days after the first egg had hatched. Both eaglets were observed erect and being fed by the adults on 6 June, but later in the day the newly hatched eaglet died and the adult female removed it from the nest cup. On 7 June, the male removed the carcass from the nest when departing from a brooding session. Three eaglets had hatched by 22 May at nest C, and by 25 May 2 eaglets were much larger than the third. Three eaglets were last seen in the nest on 29 May just prior to an intense storm with rain, wind, and cold temperatures that lasted for 3 days. Two eaglets were last seen on 2 June, before 4 filming days were lost between 3 and 7 June. By 7 June only one eaglet remained.

#### Prey Deliveries

While cameras were mounted in adjacent trees, the angle of view precluded confirming prey deliveries to the nest. Often an adult eagle or the thick layers of moss and grass in the nest bowl obstructed the view so that it was difficult to tell when prey items were delivered. And since eagles often left prey items in the nest for long periods, feedings were not indicative of new prey items. Therefore, prey delivery analyses were confined to the period when cameras were mounted in nest trees, which was from 30 days after hatching to fledging. This angle of view allowed positive confirmation of nearly all prey deliveries.

The average number of prey deliveries per day and the percentage of male and female deliveries varied from nest to nest (Table 4). More prey items were brought to nest C per day than to either nest A ( $p = 0.06$ ) or nest B ( $p < 0.005$ ); the number of deliveries to nests A and B were similar however. The percentage of deliveries made by the male and female were similar at nests A and C where females delivered the majority of prey items; at nest B the male delivered more prey items. Occasions when a prey item was delivered between frames and the adult eagle was not seen were of similar proportions at all nests. These events became more common as the adults spent less time at the nest and the eaglets gradually began feeding themselves.

The number of prey items delivered fluctuated from day to day but showed no consistent trends. Fluctuations probably were related to hunting success, and to the size of prey caught. Hunting success may have been influenced by daily precipitation. The number of prey items delivered per day at nests A and B showed significant decreases with increases in the amount of daily rainfall (nest A  $p = 0.063$ , nest B  $p < 0.05$ ).

### Feedings

Feedings were recorded in two categories: 1) Eaglet Feedings (adults feeding eaglets), and 2) Adult Feedings. Because of the interval between film frames, determining which of these was occurring was difficult. Therefore, Eaglet Feedings was recorded for any feeding bout

Table 4. Average number of prey deliveries per day during the period of 30-80 days after hatching for each nest, ranges in parentheses.

	Nest A	Nest B	Nest C
Prey Deliveries Per Day	2.7 (0-8)	2.3 (0-6)	3.6 (0-11)
% Male Deliveries	21 (0-100)	40 (0-100)	15 (0-100)
% Female Deliveries	48 (0-100)	26 (0-100)	46 (0-100)
% Unknown Deliveries	31 (0-100)	34 (0-100)	39 (0-100)

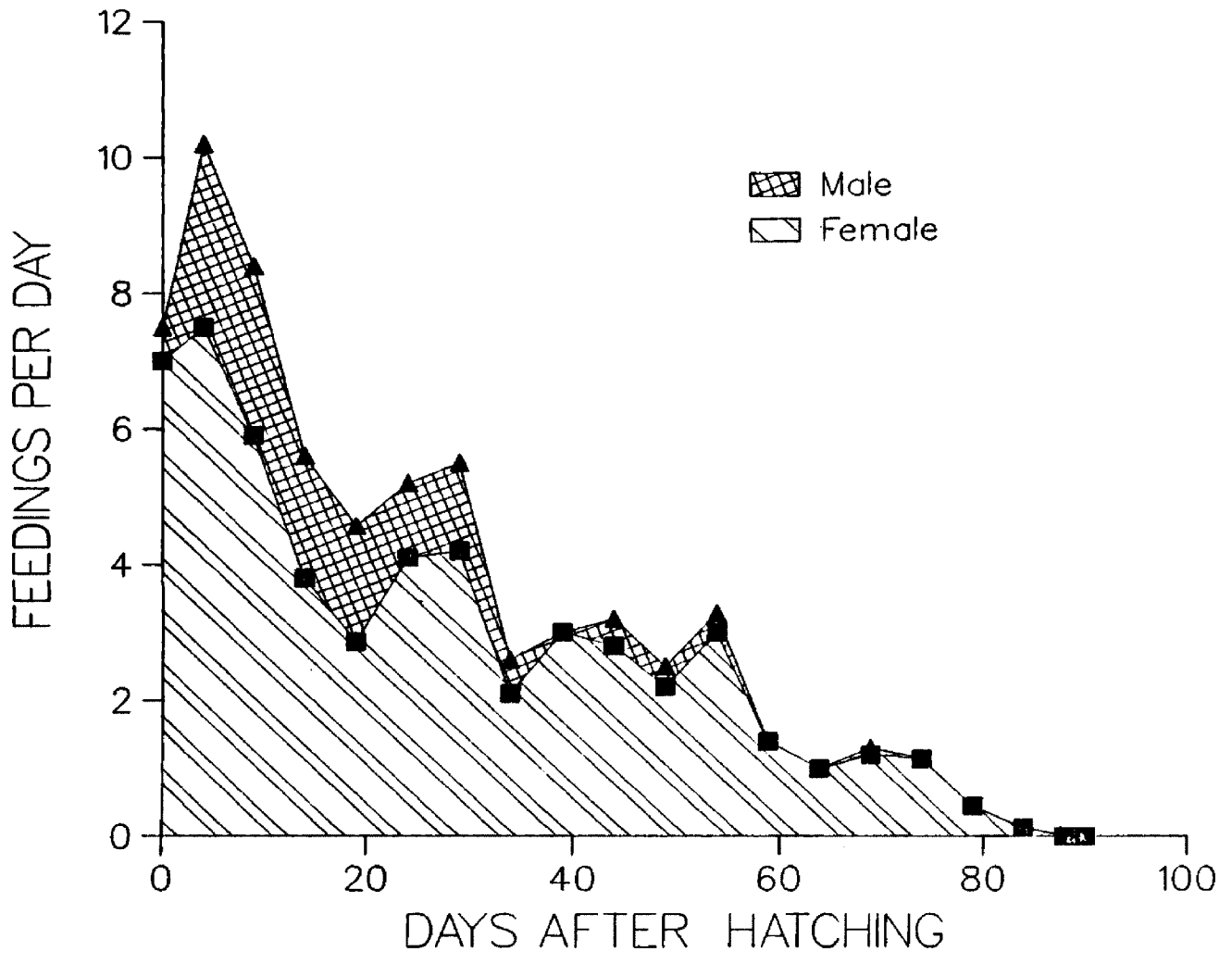
in which an eaglet was in a feeding position: head and neck erect, close to and facing the feeding adult. Feeding bouts that occurred with an eaglet not in a feeding position were recorded as Adult Feedings. It is likely that adults occasionally fed during Eaglet Feeding bouts however; therefore, the number and duration of Eaglet Feedings was probably overestimated and the number and duration of Adult Feedings underestimated.

Eaglet feedings at nests containing one eaglet (B and C) averaged 8.6 per day 1-10 days after hatching and declined gradually to 1.9 feedings per day 71-80 days after hatching. Male participation in eaglet feedings declined from 22% of all feedings 1-10 days after hatching to no feedings 71-80 days after hatching (Fig. 7). Eaglet feedings at nest A, which contained 2 eaglets, averaged 12 per day 1-10 days after hatching and declined to 2.8 per day 71-80 days after hatching. At this nest the male fed eaglets 30% of the time 1-10 days after hatching and 16% of the time 71-80 days after hatching (Fig. 8). Adults continued to feed eaglets until they fledged, but no post-fledging feedings were observed at the nest during a total of 28 days of post-fledging monitoring at all 3 nests.

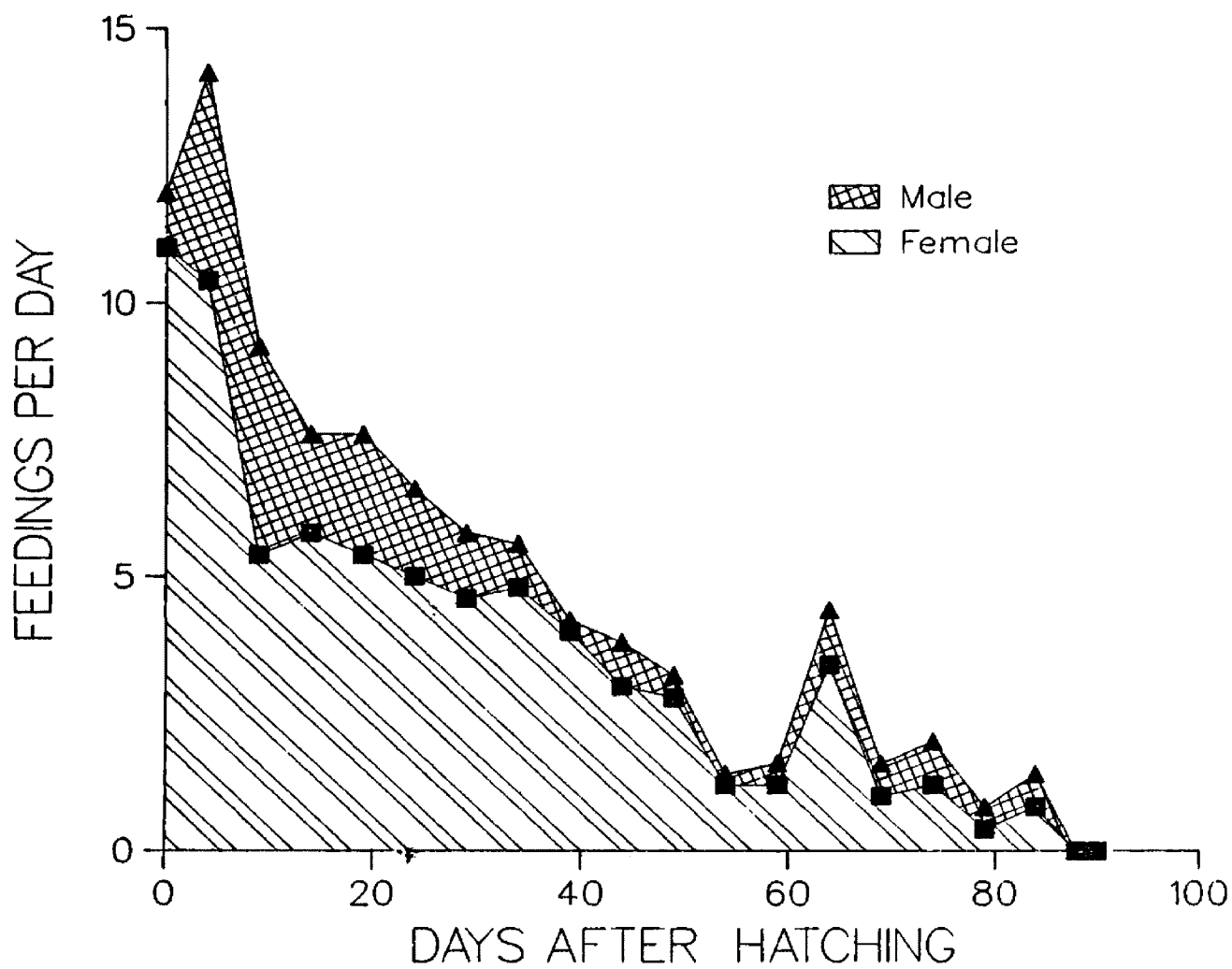
Differences in Eaglet Feeding strategies occurred primarily between nests that contained 1 young and nests that contained 2 young (Table 5). Total Eaglet Feedings per day were significantly greater at nest A than at nest B or C ( $p < 0.05$ ). Eaglet Feeding bout duration was similar for



**Figure 7. Average number of daily Eaglet Feedings for two nests that contained one eaglet each (nests B and C). Data points represent five day interval averages.**



**Figure 8.** Number of daily Eaglet Feedings at a nest that contained two eaglets (nest A). Data points represent five day interval averages.



females at all nests, but male feeding bout duration was longer at nest A than at nest B ( $p < 0.05$ ) or nest C ( $p < 0.001$ ). The proportion of male and female Eaglet Feedings did not seem to be related to the number of young in the nest however. The proportion of female Eaglet Feedings was similar at nests A and B but significantly greater at nest C ( $p < 0.01$ ). Daily high temperature was the only weather variable found to have any significant effect on aspects of Eaglet Feedings; total Eaglet Feedings per day showed a significant decrease with increasing daily high temperatures at all nests ( $p < 0.001$ ).

Adult Feedings at the nest usually occurred immediately after an eaglet feeding bout when the eaglet became satiated. Occasionally an adult would arrive at the nest with a prey item and feed while the eaglet, apparently not hungry, remained in a non-feeding position. Adult Feeding rates were similar at all three nests, but varied with the stage of the nesting cycle. During the brooding period, 1-50 days after hatching, male and female Adult Feeding rates were approximately equal. Males averaged 0.42 (range 0-6) Adult Feedings per day, and females averaged 0.44 per day. Average Adult Feeding bout duration was 4.0 (range 1.5-23.5) minutes for males and 3.0 (range 1.5-13.5) minutes for females. After the brooding period, male Adult Feeding rates decreased while female rates increased slightly. Adult Feedings declined to 0.11 (range 0-2) per day for males and rose to 0.58 (range 0-5) per day for females. Adult Feeding bout duration remained similar at 4.2 (range 1.5-9.0) minutes for males and 3.1 (range 1.5-9.8) for females.

**Table 5. Average daily number, percent male and female, and male and female bout duration for Eaglet Feedings during the period of 1-80 days after hatching for each nest, ranges in parentheses.**

	Nest A	Nest B	Nest C
<b>Feedings Per Day</b>	5.9 (1-17)	4.7 (1-19)	4.3 (1-15)
<b>% Male Feedings</b>	19 (0-57)	19 (0-67)	9 (0-50)
<b>% Female Feedings</b>	81 (43-100)	81 (33-100)	91 (50-100)
<b>Male Feeding Duration (min)</b>	5.8 (0-38)	3.3 (0-33)	2.9 (0-23)
<b>Female Feeding Duration (min)</b>	7.9 (0-21)	6.9 (0-23)	7.5 (0-22)

## DISCUSSION

### Disturbance

Previous studies have noted little if any disturbance to eagles from activities such as road traffic adjacent to nest trees, nearby timber cutting and military target practice, and visits to active nests for the banding of eaglets (Broley 1947, Mathisen 1968, Grier 1969). Timelapse studies of other nesting raptors have also indicated very little disturbance caused by the mounting and presence of cameras as close as 1.5 m from the eyrie (Enderson et al. 1972, Jenkins 1978). However, nest abandonment that occurred during this study, 3 during preliminary investigations and 1 in 1984, indicate that some nesting bald eagles are extremely sensitive to human intrusion. Furthermore, the results indicate that installing cameras at bald eagle nests may be risking investigator-induced nest failure.

Efforts to habituate eagles to the investigator's presence and mounting cameras in adjacent trees initially were effective at reducing nest abandonment. Although it seems likely that the failure of nest D was a direct result of monitoring activities in 1984, the possibility that incubation patterns were inconsistent prior to installing the camera may be considered. I have no evidence to support or refute this idea. However, the overall productivity and nest success rate of the 4 nests monitored in 1984 was not significantly different from productivity and nest success rates in undisturbed areas of Alaska

(Sprunt et al. 1973, Hodges 1982).

The differences observed in nest absence periods and sex of the first adult to return following camera maintenance visits are probably best explained by individual differences in the nesting pairs, although some variation may be a result of differences in previous close association with humans. The amount of association with humans, based on nest visibility and proximity of the nest to boat traffic, was greatest at nest A and least at nest C. However, nest B was monitored during preliminary investigations in 1983; therefore, previous exposure to humans was probably greatest at this nest. If nest absence periods are used as a relative measure of disturbance, and if we assume that the birds monitored at nest B were the same in both years, the data suggest that this nesting pair became increasingly disturbed by monitoring in successive years, rather than becoming habituated and consequently less disturbed.

### Incubation

Much of the time budget data presented in this paper represent the first ever collected for bald eagles, and therefore few comparable data are available for comparison. This is especially true for the incubating and brooding periods of the nesting cycle. Unfortunately, relevant studies are confined to observations on captive bald eagles (Gerrard et al. 1979), observations that include little quantification (Herrick 1933) and observations on other species of raptors, both



captive and wild (Enderson et al. 1972, Jenkins 1978, Ellis 1979, Levenson 1979, Craighead 1980, Jamieson et al. 1982). Comparisons with these studies do point out important differences and similarities in time budget strategies, however.

Results that indicated incubation routines of alternating male and female bouts accompanied by vocalizations during nest exchanges were also observed by Herrick (1933). However, most of the time Herrick was unable to distinguish between sexes and time budgets were not quantified. During 55.5 hours of mid-incubation observation on a pair of captive bald eagles, Gerrard et al. (1979) also noted alternating male and female incubation bouts. Data presented for the following incubation comparisons with captive breeding eagles are taken from their study. Total incubation time per day was greater in captive (98%) than in wild (94%) eagles; female participation was also greater in captive (71%) than in wild (55%) birds. Captive eagles spent more time on the nest together (3.7% of the day compared to <1%) and had shorter average incubation bout durations (84 compared to 155 minutes). Egg turning events, important to prevent egg membranes from sticking together (Newton 1979), were performed more often by captive eagles (1/hr) than by wild eagles (1/4.3 hr).

Comparing time budgets from captive and wild birds should be done with caution because the radical difference in the environments undoubtedly accounts for many of the discrepancies observed. The lack

of a hunting demand on the captive eagles may have been responsible for shorter incubation bout durations and the greater periods of time the male and female spent on the nest together. With little time devoted to feeding, captive birds may initiate nest exchanges more often, rather than having to wait until the absent bird had hunted, fed, and returned to the nest as in the case of wild eagles.

The difference in male and female incubating proportions is probably related to individual differences in the nesting pairs. The male at nest B contributed more time to nearly all activities than either of the males at the other two nest sites monitored during this study. Craighead (1980) observed similar variation between nesting pairs of captive golden eagles. The discrepancy observed in egg turning rates was probably due to the timelapse sampling bias and to the difference in stage of incubation. Egg turning is believed to be more important during the early stages of incubation (Newton 1980); therefore, egg turning rate may gradually decline as the embryo develops.

Results of this study indicate that bald eagles are similar to other species of raptors in that the male contributes a substantial amount of time to incubation. The proportion of incubation performed by the male at nest B (45%) can be compared to male incubation proportions of 36% in golden eagles (Craighead 1980), 29-39% in peregrine falcons (Enderson et al. 1972), and 27% in ospreys (Levenson 1979). The

frequent nest raking by incubating birds observed during this study has also been observed in raptors elsewhere (Enderson et al. 1972, Jenkins 1978, Ellis 1979, Gerrard 1979, Craighead 1980) and seems to be common in birds of prey in general. Ellis (1979) suggested that nest raking served to better isolate the nest cup from cold drafts.

## Brooding

The primary brooding period for bald eagles apparently lasts for 50 days, beginning with the day of hatching, with the most rapid descent of the brooding curve coinciding with the completion of the eaglet's second stage of down plumage, approximately 4 weeks after hatching (Fig. 5). Brooding also took place during the first 50 days after hatching at golden eagle nests in Montana (Ellis 1979). The brooding curve for golden eagles was also sigmoid, but the most rapid descent of the curve occurred 20 days after hatching, five days after the golden eaglets completed their second down stage.

However, the participation of the male and female in brooding was found to be very different in bald eagles when compared to golden eagles and many other raptors. Female bald eagles brooded for 71% of the total daily brooding time in my study. In contrast, average female brooding proportions for other raptors were nearly 100% for golden eagles (Ellis 1979), 99% for peregrine falcons (Enderson et al. 1972), 95-100% for ospreys (Levenson 1979, Jamieson et al. 1982), and 87% for gyrfalcons (Jenkins 1978).

## Prey Deliveries

The proportion of male and female prey deliveries in the above named species also diverges from that found in bald eagles. In each of the other raptor species, the male provides the prey for the female and the young throughout most of the nestling period so that the female is able to devote nearly all of her time to brooding and feeding the nestlings (Enderson et al. 1972, Jenkins 1978, Levenson 1979, Craighead 1980, Jamieson et al. 1982). Male bald eagles delivered proportionately fewer prey items: less than 50% of the total prey items at nests A and C, and 60% of the total prey items at nest B. Comparable male and female prey delivery ratios for bald eagles were observed by Herrick (1924) and Ofelt (1975).

The average number of prey deliveries per day, which ranged from 2.3-3.6 at the 3 nests, were similar to prey delivery rates of 2.5 and 4.0 per day at 2 nests observed by Herrick (1924). Prey delivery rate during my study was highest at a nest that contained 1 eaglet, and significantly lower at the 2 other nests, one of which contained 2 young. Thus prey delivery rates did not increase with the number of young in the nest. Prey delivery rates also remained stable throughout the nesting season. Similarly, Stinson (1978) found that neither age or number of unfledged young affected the rate of fish delivery at osprey nests. Comparing prey delivery rates between nests may not be meaningful without accompanying estimates of prey biomass however; high

prey delivery rates may be a result of the adults securing consistently smaller prey. This may be especially true where prey habitat varies considerably between nests, which was the case in this study. Nest C, which had the highest prey delivery rate, was adjacent to a large tidal flat area that may have contained smaller prey species unavailable to the birds at nests A and B, where tidal flats did not exist.

The decreased rate of prey deliveries with increasing precipitation at nests A and B was probably related to poor visibility during rainy periods. Grubb (1977) found that cloud cover and disturbed water surfaces both significantly decreased capture success of ospreys.

### Feedings

The number of Eaglet Feedings per day, characterized by a rapid increase during the first 5 or 6 days after hatching and then a gradual decline through the nestling period (Figs. 7 and 8), was very similar to feeding patterns observed in golden eagles (Ellis 1979). The participation of males in Eaglet Feedings was greater in bald eagles than in golden eagles and several other raptors however. Male golden eagles, ospreys, peregrine falcons, and gyrfalcons all play an insignificant role in feeding their young; the female feeds the young nearly 100% of the time. Although Eaglet Feedings were dominated by the female more consistently than any other nesting activity recorded in my study, male Eaglet Feedings were significant ranging from 9-19% of all Eaglet Feedings at the 3 nests.

Eaglet Feedings differed significantly at the nest that contained 2 young, both in absolute number of feedings and in feeding effort of the male (Table 5). Eagles at this nest dealt with the greater demand imposed by 2 eaglets by feeding more often and by the male feeding for longer duration at each feeding bout. Enderson et al. (1972) found similar correlations between the number of feedings per day and the number of young in peregrine falcon nests.

#### Effects of Weather on Nesting Activities

Significant correlations between eagle activities and several weather variables indicated that eagle behavior was modified in response to fluctuating environmental parameters. Significant relationships between percent of the day eggs were incubated, average wind velocity, and daily high temperature agree with weather-influenced incubation patterns observed in captive eagles. Gerrard et al. (1979) found that captive breeding eagles left eggs exposed significantly longer during periods of relatively high temperature and low wind velocity.

Correlations with weather and percent brooding time indicated that nest site characteristics may have had a considerable influence on the amount of time spent protecting the young from the elements. Birds at all three nests brooded significantly less as temperatures increased. The eagles at nests A and C, which were not protected from prevailing southeast winds, also brooded significantly more during periods of high wind. Brooding time showed additional correlations with daily

precipitation and percent sunshine at nest A, the most exposed of the three nests. Brooding time was also correlated with wind chill values at golden eagle nests (Ellis 1979) and mean daily temperatures at peregrine falcon nests (Enderson et al. 1972). Jenkins (1978) noted that brooding was influenced by weather extremes in general at gyrfalcon nests.

Correlations that showed opposite responses of the male and female to weather extremes, such as those observed at nest C (Fig. 4), indicate that the male and female may shift brooding proportions in response to changing environmental parameters. The direction of the relationships also indicate that a premium is placed on having the female brood during periods of wet, cold, and windy weather with little sunshine. Although correlations were not statistically significant, similar patterns observed in incubating eagles at nest B suggest these shifts may be important during incubation as well. Jamieson et al. (1982) similarly found that male ospreys incubated significantly less during periods of rain. The reason for this may be that, because of her slightly larger body size and greater ability to retain heat, the female eagle is a more effective incubator and brooder. Perhaps of more importance is the difference in size of the brood patch on the male and female. The brood patch on the female at nest C was a large, oval patch of bare skin on the breast that measured approximately 16 X 9 cm. Brood patches on males at nests A, B, and D were less than half that size. Thus the combination of a larger body size and larger brood patch would enable

the female to transfer heat to the eggs and young more effectively and for longer durations.

A greater ability of the female to provide heat to nestlings may be partly responsible for the significant differences observed in the proportion of male and female brooding at each nest. At nest B, where the proportion of male brooding was greatest (42%), eaglets were the last to hatch among the three nests. Consequently, the average high temperature was significantly greater during the brooding period at this nest than at either of the other two nests ( $p < 0.05$ ) Nest B was also the most protected nest and consequently the least affected by wind and rain. Thus the greater proportion of male brooding at this nest may have been due to a lower heat demand by the growing eaglet. Mean high temperatures were not significantly different at nests A and C. But nest A contained two young, which would place a greater demand for warming ability on the brooding adults. The combination of an early hatching date and the brooding demands of 2 young may explain why the proportion of male brooding was smallest (16%) at this nest.

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