STUDY PLAN

DATE: 15 March 1999

TITLE: The use of remote cameras to investigate diet, prey delivery, and behavior of nesting northern goshawks ***(Accipiter gentilis)*** in east-central Arizona.

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PROBLEM ANALYSIS AND STUDY DEVELOPMENT

The northern goshawk (*Accipiter gentilis*) is a top predator in forest ecosystems, largest of the 3 North American accipiters, and nests in mature coniferous, deciduous, or mixed-pine forests (Squires and Reynolds 1997). Over the last two decades there has been growing concern over the persistence of goshawk populations (USFWS 1998). Probable causes of decline have been linked to habitat alterations that include timber harvesting, fire suppression, and grazing, which have changed the structure of forests, including a reduction in the abundance of large diameter trees while a concurrent increase in the density of smaller diameter trees (Moir and Dieterich 1988). The goshawk is afforded special status in Arizona and was recently evaluated for listing under the federal Endangered Species Act (AGFD 1996, USFWS 1998). In 1992, the U. S. Forest Service developed management guidelines that are currently being implemented across the southwestern United States (Reynolds et al. 1992).

Northern goshawks are generalists that prey on a variety of small to medium-sized birds and mammals. Some important prey species in the Southwest include eastern cottontail *(Sylvilagus floridanus)*, Stellar's jay *(Cyanocitta stelleri)*, northern flicker *(Colates auratus)*, and Abert's squirrel *(Sciurus aberti)* (Kennedy 1990, Reynolds et al. 1992, Mannan and Boal 1994). Diets of goshawks in various forest cover types, response of goshawk populations to fluctuations in prey abundance, and the habitat relationships of prey are poorly known (Reynolds et al. 1992).

In 1993, the Arizona Game and Fish Department initiated a study to examine population biology of northern goshawks on the Apache-Sitgreaves National Forest in east-central Arizona (Ingraldi and MacVean 1994). This demography study focused on determining nesting status within 44 historical territories, capturing and banding adult and juvenile goshawks, investigating dispersal rates of juveniles, and calculating nest productivity of all territories (Ingraldi 1999). Specific territories within the study have shown consistently high productivity, while other territories have shown consistently low productivity. These differences in productivity may be linked to prey availability or habitat quality (Ingraldi 1999). A technical steering committee was assembled in 1998 to discuss future research plans for the northern goshawk on the Apache-Sitgreaves forest. The committee listed prey composition and delivery rates by adults to nestling goshawks as a priority for future research. Thus, the purpose of this study is to compare diet between traditionally high and low productive nest sites using remote cameras near active northern goshawk nests.

LITERATURE REVIEW

Northern Goshawk Diet Studies

Habitat alterations have had a considerable effect on goshawk nesting and foraging habitat. In addition to habitat loss, goshawk declines could be related to decreases in prey populations

(Reynolds et al. 1992). Schnell (1958) suggested that foraging rates of goshawks were controlled by prey abundance rather than food requirements because nestling food consumption did not correspond with increased prey delivery. In addition, Wikman and Linden (1981) observed that even when suitable nesting habitat was available, goshawk and brood size numbers declined in response to a corresponding decrease in their principal prey species. If goshawk declines are in response to prey fluctuations, then forest management should feature managing for prey habitat (Reynolds et al. 1992).

Studying raptor diets allows better understanding of raptor niches and can provide information on prey distribution and abundance (Marti 1987). Studies of goshawk diet over its boreal and temperate forests range throughout the Holarctic include Widén (1987) in Europe and Reynolds and Meslow (1984) and Boal and Mannan (1994) in North America. Most diet studies conclude that goshawks are opportunistic foragers whose diet reflect the prey species available to them (Widén 1987, Kennedy 1990, DeStefano and McCloskey 1997).

The management recommendations for the northern goshawk recognize 14 prey species of importance to the goshawk in the Southwest. Goshawk diet studies in the Southwest are limited to 3 studies in Arizona and New Mexico (Kennedy 1991, Boal and Mannan 1994, Reynolds et al. 1994). In all 3 of these studies, mammals represent over half of the goshawk diet. On the North Kaibab Ranger District, Arizona, Boal and Mannan (1994) found that mammals constituted 76% of goshawk diet, while birds accounted for 24% of the observed prey. In addition, mammals comprised 94% of the total biomass consumed, with cottontail rabbits making up the greatest proportion. Reynolds et al. (1992) reported 62% mammals and 38% birds by number, and 84% mammals and 16% birds by biomass on the Kaibab National Forest. Likewise, in the Jemez Mountains, New Mexico, Kennedy (1991) observed that similar proportions of prey items contributed to goshawk diet.

Methods to Access Diets in Raptors

Raptors do not fully digest prey items. Undigested remnants of bones, feathers, and keratinous material of prey are regurgitated, usually daily, in a pellet form. Pellets can provide both qualitative and quantitative diet information (Marti 1987). Errington (1932) suggested that pellet analysis is most reliable for owls because little if any bone digestion occurs. The pellet method can be an accurate technique for studying diet for species that swallow their prey whole, but for raptors that eat large prey or are insectivorous, the pellet method is equivocal (Marti 1987). Raptors that eat large prey break bone material into small fragments that are not easily identified. The pellet method is not reliable for insectivorous raptors, which often swallow their prey whole, because chitinous material is usually broken down into pieces too small to identify.

An invasive way to investigate diet of raptors is the stomach content method. Measuring stomach contents is done in two ways: opening the stomachs and crops of dead raptors and identifying what is present (Storer 1966), and squeezing the crop out of live nestlings to identify what is inside (Errington 1932). Unless a researcher has access to a number of dead raptors, or has experience with crop squeezing, the stomach content method is too invasive (Marti 1987).

Several studies have used collections of uneaten prey remains as a successful tool to identify diet components (MacLaren et al. 1988, Steenhof and Kochert 1988). Accipiters regularly remove pelage and plumage from prey in nesting and plucking areas, which can be used for identification (Reynolds and Meslow 1984, Boal and Mannan 1994). Limitations to this method include scavengers eating remains before the researchers can obtain them, disturbance in the nesting area while collecting, and miscounting prey items due to unidentifiable remnants.

Direct raptor observation is a good way to investigate diet because disturbance is minimal.

Direct observation can be achieved by setting up a blind over several days within the nesting area, or the use of high powered spotting scopes. Grubb (1995) used spotting scopes, 300-500 m from nests, to observe bald eagles (*Haliaeetus leucocephalus*) and was able to identify 1,471 out of 1,814 prey items to Class. This method of quantifying diet, while more reliable than other methods, is labor intensive, requires dawn to dusk observations, and is difficult for cavity-nesting species.

A more recent technology for studying diet involves putting remote cameras near active raptor nests. There are 2 basic types of camera devices: those that document real time digital video and those that take time lapse or triggered photographs. Advantages of video surveillance are that it does not require handling of individuals, it facilitates real-time behavioral analysis, and it operates remotely with minimal impact (Delaney 1999). Kucera and Barrett (1993) used trigger cameras that took photographs when an infared beam was broken by animal movement. They successfully photographed 32 species of mammals, 16 species of birds, and 1 amphibian, and 90% of all frames were clear. Researchers have also used solar powered remote cameras to investigate diet and behavior at raptor nests. This video provides clear detail ranging from nestling's feathers, small insects moving in the nest bowl, and whiskers of catfish brought back to the osprey nest (Kristan et al. 1996). Limitations to camera methods of assessing diet include relatively high cost and mechanical problems, such as low resolution (Marti 1987).

RESEARCH OBJECTIVES

My objectives are to: (1) identify and quantify prey items, delivery rates, and biomass of prey brought to nests by adult goshawks; (2) compare delivery rates, biomass, and diversity of prey between historical low and high productive nest sites; (3) assess relationships between prey remains, collected beneath and within nests, and prey delivered to nests as observed from video footage; and (4) quantify sex-specific feeding behavior of nestlings.

APPROACH

Objective 1: To identify and quantify prey items, delivery rates, and diversity of prey brought to nests by adult goshawks.

Procedure 1.1 – Selection of study area and nests to monitor.

The Apache-Sitgreaves Forest is located on the Mogollon Plateau in east-central Arizona and is about 330,300 ha (Fig. 1). Elevation ranges from 1768 to 2417 m (5800-7930 ft). Located on the southern boundary of the study area is the Mogollon Rim, a large escarpment stretching east across central Arizona and into New Mexico. The study area is bounded to the north by the forest boundary, to the west by Leonard Canyon, and to the east by the Springerville Ranger District boundary on the Apache National Forest. A wide variety of vegetation communities occur within the study area (Brown 1982). The Mogollon Rim edge has deep drainages with mixed-conifer communities of Douglass-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), aspen (*Populus tremuloides*), ponderosa pine (*Pinus ponderosa*), New Mexico Locust (*Robinia neomexicana*),and Gambel oak (*Quercus gambelii*). Ridgetops are commonly dominated by ponderosa pine forest. Elevation decreases going north, and ponderosa pine/juniper-pinyon forest transitions to pinyon-juniper woodland, which is dominated by alligator juniper (*Juniper deppeana*), Utah juniper (*J. osteosperma*), and Rocky Mountain pinyon pine (*Pinus edulis*). As elevation continues to decrease, a grassland community develops with blue grama (*Bouteloua gracilis*), sand dropseed (*Sprobus crytandrus*), and fourwing saltbush (*Atriplex canescens*).

During the 1999 breeding season we will begin monitoring 44 historical territories on the Apache-Sitgreaves forest to determine nesting status. Active nests are described as those nests in which at least one egg is laid. Twelve nests will be selected and ranked by investigating historical productivity of all territories that have been active for ≥3 years (Fig. 2). The 6 nests that have had the most young per active nest will be considered "high" historical nests. Likewise, the 6 nests that have had the lowest number of young per active nest will be considered the "low" historical nests.

Procedure 1.2 – Camera installation.

Twelve (6 "high" and 6 "low") nest trees will be climbed when the young are >7 days old, and we will use remote cameras to monitor these nests. Portable electronic color board cameras, with 3.6mm lenses and audio capability, will be housed in black heavy-gauge plastic bins with a transparent cover (Delaney et al. 1999). We will mount cameras at a distance slightly above the nests (about 1 m) as to not disturb nesting activities. Cameras will be positioned at an angle such that resulting film will enable us to see all nestlings and their relative heights to one another. We will connect a power line and coaxial video cable to a VHS recorder, located at the base of the tree, and powered by 2 12 volt, 33 amp-hour rechargeable marine batteries. We will film at 5 frames/sec, which will generate 2 full days of coverage on an 8 hour tape. Six nests sites will be recorded for 2 consecutive days followed by a 2-day off period in which to charge batteries. During this time, the VHS recorders will be moved at night to the other 6 nests to continue filming. Rotational recording will continue until the young have fledged, which should yield about 18 days of film per nest.

Procedure 1.3 – Identify and quantify prey from video.

We will quantify prey numbers and identify prey species by viewing video from all prey deliveries. However, the probability of identifying prey species is not always equal if the prey is plucked, decapitated, or skinned before delivery to the nest, or if the item is partially consumed by the adult before delivery (Boal and Mannan 1994). Unidentifiable prey will be categorized into 1 of 5 categories: large or small mammal, large or small bird, or lizard. These size classes will be developed by comparing identifiable prey item size from the video.

Procedure 1.4 – Calculation of delivery rates and prey biomass.

We will use descriptive statistics to summarize prey composition data into total number of prey items, total number by species, and lumped prey class categories (birds, mammals, lizard, unidentified). Prey delivery rates will be expressed as the mean number of prey items/hour and the mean number of prey items/day for each nest.

Biomass of prey will be estimated by multiplying the number of individuals of each prey species by the mean weight of the prey. Biomass will be depicted as the proportion of the unit (species or class) contributed to the total mass consumed. Mean weights of prey will be obtained from the literature (Steenhof 1983, Dunning 1984), and, if possible, weights from locally obtained specimens will provide more accurate estimates of dietary biomass. Total biomass per day will be depicted by species and by class (birds, mammals, and unidentified) for all nests.

Objective 2: To compare delivery rates, biomass, and diversity of prey between historical nest sites of low and high productivity.

Prey item data from Procedure 1.4 will be used to compare prey delivery rates and biomass between historical nest sites of low and high productivity. We will test the null hypothesis (H_{01}) that there will be no significant difference between biomass, prey delivery rates, or prey diversity at nests of traditionally high and low production.

Procedure 2.1 – Comparison of delivery rates, biomass, and diversity.

Diversity can be expressed as evenness (numbers of prey) and richness (how uniformly represented the various kinds of prey) (Marti 1987). A raptor diet exhibiting high diversity represents a broad food niche. Conversely, a raptor diet demonstrating low diversity represents a narrow food niche. Measuring dietary breadth is a way of measuring diversity.

We will use Levin's equation to calculate dietary breadth of all high and low nests (Krebs 1989), and Mann-Whitney U tests with a Bonferroni correction factor (Zar 1984) to compare total biomass per day by species and class, prey delivery rates, and prey diversity between the 2 nest categories (low and high). All statistical tests will be considered significant at an alpha level of $P \leq 0.05$.

Objective 3: To assess relationships between prey remains, collected beneath and within nests, and prey delivered to nests as observed from video footage.

Procedure 3.1 – Collection of prey remains.

We will collect prey remains from beneath nests and in plucking areas every 2 days while the cameras are recording. In addition, prey remains will be collected from within the nest bowl when we climb trees. Remains will be packaged and labeled with nest site names. All remains will be reconstructed by locating remiges, rectrices, and bills of birds, and fur, skull parts, and feet of mammals. This procedure minimizes the risk of overcounting the number of individuals of each species (Reynolds and Meslow 1984).

Procedure 3.2 – Analyze prey remains data.

We will use a Pearson's and Spearman's Rank correlations (Zar 1984) to determine if significant relationships exist between prey remains data from Procedure 3.1 and prey delivery video data from Procedure 1.3. We will perform linear regression on significant variables ($P \leq 0.05$) to establish a prey index.

Objective 4: To quantify sex-specific feeding behavior of nestlings

Procedure 4.1 – Color marking and sexing of the nestlings.

To collect behavioral data, we must recognize individual nestlings in the video. Upon climbing of the nest tree to affix cameras (Procedure 1.2), all nestlings will be individually marked with colored dye on top of their heads. In addition, each nestling will be banded with a same color plastic band so that when down is molted the individual will still be identifiable (e.g., a nestling with a green head would receive a green band). Nests with only one nestling will not be used for behavioral studies. At 22-24 days of age, we will climb nest trees and use tarsus measurements to identify the sex of nestlings (Ingraldi 1999). At this time we will be able to match the individual's color (head or band) with their corresponding sexual identification, and remove leg bands.

Procedure 4.2 – Behavioral analysis.

It is widely known that the females of most raptor species are larger than the males. Thus, we hypothesize that female nestlings will consume more food than male nestlings. The null hypothesis (H_{02}) is that female and male nestlings consume the same amount of food (i.e., no difference).

Methodology for behavioral analysis will follow Teather (1992). For each feeding, we will rank each nestling's behavior in 3 ways: (1) sequence of begging initiation, (2) relative height of the nestling just before the adult offers food, and (3) the lateral distance from the nestling's bill to the parent. Each food bite taken will be averaged per nestling per nest. We will use a Wilcoxan paired *t*-test to compare possible sex-related differences using behavioral means from male and female nestlings (Zar 1984). Statistical tests will be considered significant at the $P \leq 0.05$ level.

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Figure 1. Prey deliveries and nestling behavior at the nest of northern goshawks will be monitored with remote cameras on the Apache-Sitgreaves National Forest in central Arizona.

Figure 2. Number of northern goshawk nestlings at nests on the Apache-Sitgreaves National Forest in central Arizona.

Figure 1.

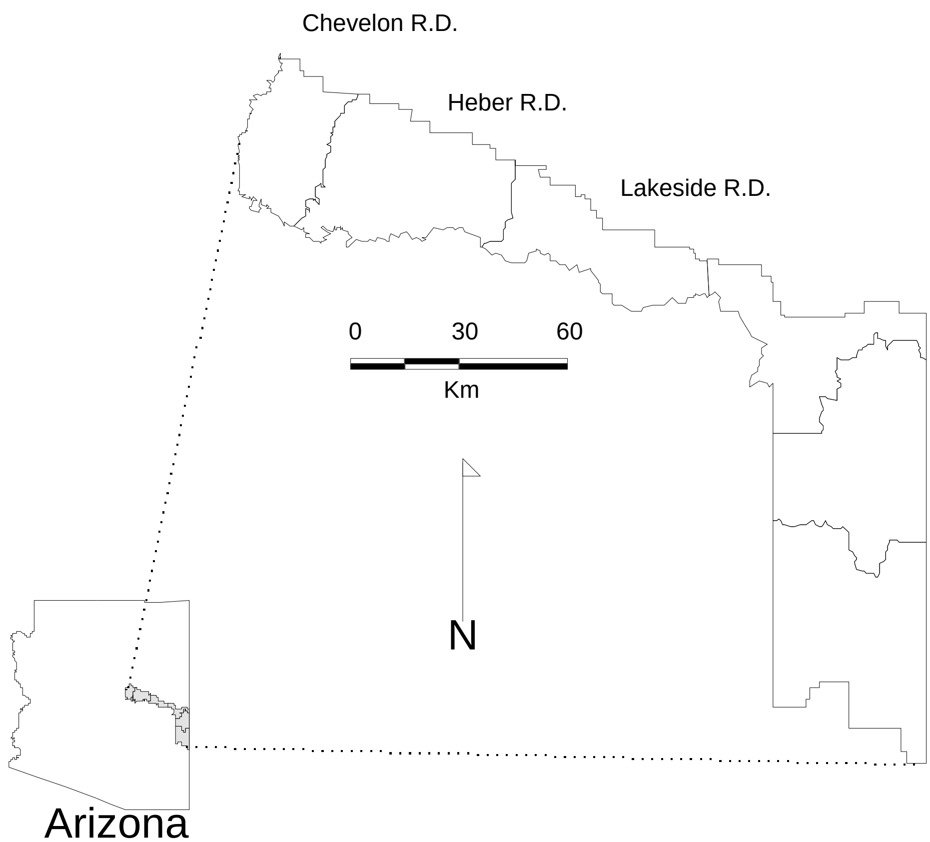
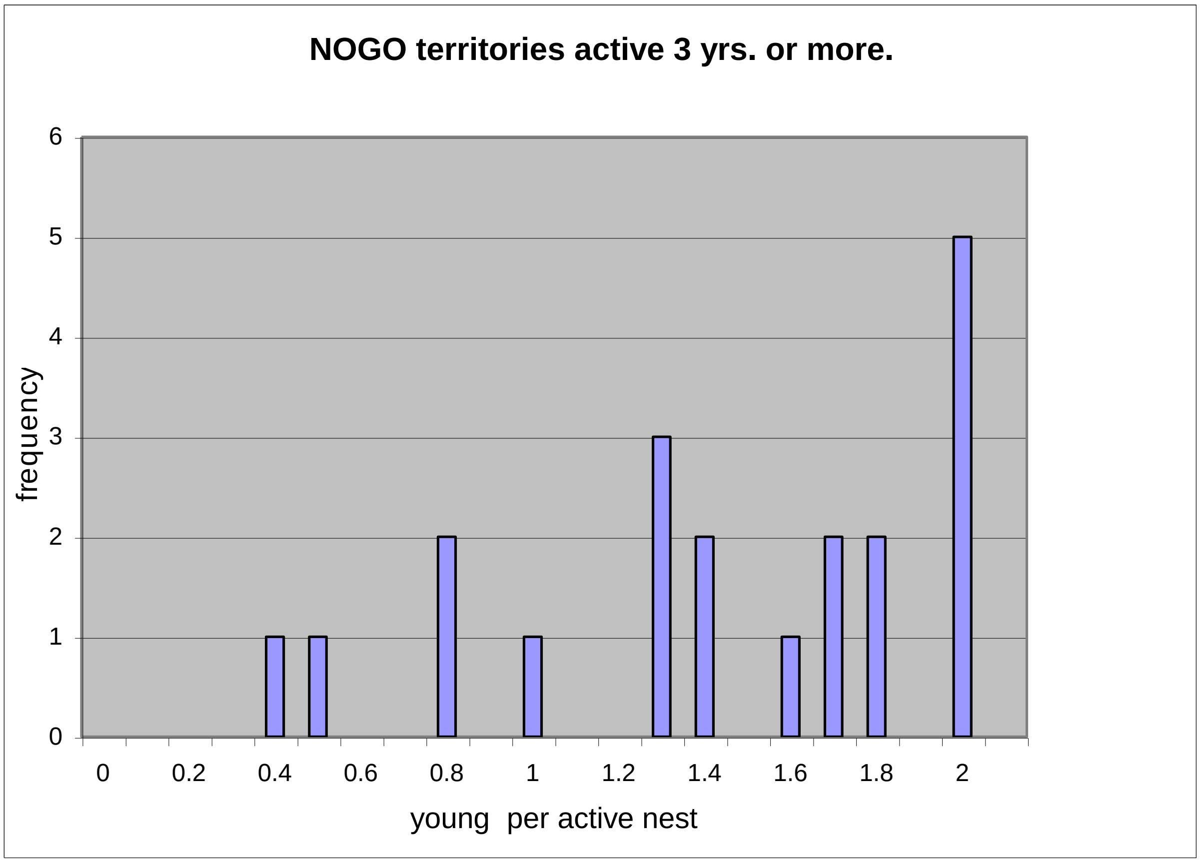


Figure 2.


NOGO territories active 3 yrs. or more.
frequency
0
1
2
3
4
5
6
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
young per active nest