Canopy Density Analysis at Goshawk Nesting Territories on the North Kaibab Ranger District, Kaibab National Forest

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Abstract:

We investigated the relationship between goshawk breeding activity and changes in canopy density on the North Kaibab Ranger District of the Kaibab National Forest, Arizona. We compared aerial photographs from 1972 with 1986 and 1989 photographs for areas of 250, 700, 1600 and 2500 acres around nest clusters. We found an almost complete loss of the 60-80% and 80-100% closure classes since 1972. We also found a reduction in the proportion of 40-60% closure class, and an increase in the 20-40% closure class. Due to lesser accuracy of aerial photograph canopy closure determination in mixed conifer forest, only goshawk territories dominated by ponderosa pine forest were analyzed (n = 12). We found that territories still active in 1986 and 1989 had significantly lower proportions of the 20-40% closure class than did inactive territories. We found that active territories had a higher proportion of 40-60% canopy closure classes than did inactive territories. Neither of these differences were evident in 1972 photographs. We also found differences in the proportion of 40-60% as well as 60-80% closure classes near the nests for 1972, with active territories having higher proportions of 60-80% closure classes, and inactive territories having higher proportions of 40-60% closure areas. These results suggest that the relatively closed-canopy, mature forest conditions recognized as critical in goshawk nest stands are also important across wider areas of its home range. Our results indicate that not only are these forest characteristics being lost from the goshawk's home range, but their availability for nest stands is also being reduced. While statistical treatment of this study was compromised by a small sample size, our findings have important implications for management of habitat to maintain a viable northern goshawk population on the North Kaibab Ranger District and similar forest habitat elsewhere.

Introduction

The northern goshawk (*Accipiter gentilis*) inhabits forests and woodlands from sea level to tree line, and is generally associated with dense, mature forest (Bent 1937, Dixon and Dixon 1938, Ligon 1961, Palmer 1988, Johnsgard 1990). Basic ecological requirements of the goshawk that are logically linked to habitat type and structure include thermal microclimates and cover for nesting, habitat for a variety of prey species, and the physical environment to which the goshawk is behaviorally and morphologically adapted for foraging. The goshawk has been characterized as a short-flight, short-sit-and-wait predator (Johnsgard 1990). As such, and with an *Accipiter* hawk's high maneuverability in short bursts of speed, the goshawk is clearly adapted to the complex, closed physical environment of forests, where visibility is limited and this foraging strategy is optimum.

Forests and woodlands are assumed to provide various important attributes of goshawk habitat, and the specific characteristics of forests in turn are respectively important, to varying degrees. Forest structure is measured by several criteria, including species composition, basal area, trees per acre, and canopy closure. These characteristics are related to one another to various degrees, in various situations. Of the above habitat attributes, canopy closure is most readily measured from aerial photographs as well as on the ground. Canopy closure to some degree reflects other structural attributes such as tree density and basal area.

In North America, northern goshawk nest sites are typically found in mature or overmature forest stands characterized in part by higher degrees of canopy closure relative to the wider surroundings (Bent 1937, Henessey 1978, Reynolds *et al.* 1982, Saunders 1982, Marquiss and Newton 1982, Moore and Henny 1983, Mannan and Meslow 1984, Hall 1984, Bloom *et al.* 1985, Crocker-Bedford and Chaney 1988, Palmer 1988, Woodbridge 1988, Anonymous 1989, Hayward and Escano 1989, Patla 1991). Saunders (1982) found a mean of over 76% canopy closure for nest stands, and Hall (1984) found a value of 94% closure. In Arizona, Crocker-Bedford and Chaney (1988) found goshawks preferred stands with greater than 80% canopy closure for nesting. Even where goshawks have been found breeding in atypical habitat, nest sites and the immediate surroundings usually exhibit the best available characteristics of contiguous stands of mature larger trees and fairly closed canopy (Bond 1940, White et al. 1965).

Canopy closure values and other forest attributes over the broader home range of the goshawk are not as well defined as the nest stands. However, where a mosaic or range of forest types and clearings are present, evidence suggests goshawks forage preferentially in the most mature or more heavily wooded forests present (Fisher 1986) and/or prefer woodlands over clearings (Kenward 1982). Crocker-Bedford (1990) provided evidence that mature forest characteristics, over an area much more extensive than the nest stands, are important in maintaining successful breeding sites, and particularly that commercial thinning in home ranges beyond nest stands, degrades goshawk habitat.

The goshawk's apparent preference for woodland over clearings, and for the more mature of available forest types likely reflects the superior availability of the important habitat attributes discussed above (nest sites, prey habitat, foraging habitat). Canopy closure, by reflecting density and continuity of forest conditions, thus provides one measure of goshawk habitat suitability. Alteration of important habitat characteristics, including reduction in canopy closure, may reduce numbers and availability of goshawk prey species such as Abert's squirrels (Patton *et al.* 1985), red squirrels (Sullivan and Moses 1986) and forest dwelling birds (Mannan and Siegel 1988). Forest thinning may also allow raptor species better adapted to more open forest conditions to outcompete and even prey upon goshawks in degraded goshawk habitat (Moore and Henny 1983). The appearance of other raptors or ravens nesting in abandoned goshawk nests has been documented on the North Kaibab Ranger District (Zinn and Tibbitts 1990). The probability that breeding northern goshawks will occupy a territory and produce young is therefore likely to be directly and indirectly affected by changes in critical forest attributes, including canopy closure and other attributes reflected by canopy closure.

A locally dense goshawk population has been documented and monitored from the mid-1970s through 1991 on the Kaibab National Forest, North Kaibab Ranger District (NKRD) (Luckett 1977, Crocker-Bedford and Chaney 1988, Tibbitts *et al.* 1988, Tibbitts and Zinn 1989, Crocker-Bedford 1990, Zinn and Tibbitts 1990). Declines in size and reproductive success of this population since intensive postwar timber harvest began have been hypothesized and described (Crocker-Bedford 1990, Zinn and Tibbitts 1990).

In 1990, the Arizona Game and Fish Department (AGFD) analyzed forest canopy closure around goshawk nest clusters on the NKRD, in cooperation with the Kaibab National Forest (KNF). We sought to elucidate any correlation between changes in canopy density and goshawk population trends. We analyzed canopy density, as measured by percent canopy closure, at 21 goshawk nesting territories on the NKRD. We compared changes in canopy density recorded on aerial photographs with changes in goshawk nesting success documented in AGFD's continuing monitoring program, also done in cooperation with the KNF.

Methods

We grouped NKRD goshawk nests into hypothetical nesting territories based on historical occupancy and nest proximity. We defined a nesting territory as a cluster of nests within 0.5 mile of a common center, with no more than one nest active per year. Most NKRD nest territories exist as discrete clusters of two to four nests within 100 meters of one another. We sought to compare canopy closure changes in territories active in both 1972 and 1989 with those active in 1972 but inactive by 1990. Definitions of "active" and "inactive" follow Postupalsky (1974); "active" being a nest (or territory) occupied by goshawks with the reproductive effort achieving at least the production of eggs. Goshawk territories defined on the NKRD are presented in Appendix A.

We selected territories for canopy closure determination based on 2 criteria:

1. Territories must have had reliable reproductive data obtainable from past nest records, and the territory must have been active at least one breeding season prior to 1988.

2. Territories must have had 1972 aerial photographs available.

Within the constraints listed above, we chose two groups of territories. One group included territories which had been active prior to 1988 and were active at least one breeding season since 1988. This group contained territories 2, 3, 4, 15, 19, 20, 22, 34, 46 and 50. We analyzed photos from 1972 and 1989 for this group. The other group of territories had been active prior to 1988, but had remained inactive since 1988. 1972 and 1989 photos were used for territories 1, 10, 36, 37, and 51. The 1989 overflights of the NKRD was the most recent prior to this study but did not photograph the entire District, necessitating the use of 1986 photos for territories 12, 33, 38, 47, 53 and 54 within this second group. None of those territories for which 1986 photos were used were active after 1986, therefore any habitat change relevant to its breeding status should have been recorded during the 1986 overflight.

We assembled aerial photographs to encompass 2500 acres centered on each nest cluster. Nest cluster locations were transferred to mylar from 7.5 minute U.S. Geological Survey (USGS) topographic maps with nest locations marked on them. Concentric circular areas of 250, 700, and 1600 acres were nested within the 2500 acre area and all four were traced on the mylar. If the nest trees were spaced more than 0.25 miles apart, the 250 acre area was centered on the nest tree active for that year's photo. The 700, 1600, and 2500 acre areas were centered on the nest stand. Obvious roads were traced to facilitate positioning of photos.

In order to decrease subjective classification errors, one person outlined areas of generally uniform canopy density and vegetative characteristics on the mylar, down to a minimum patch size of ten acres. Areas smaller than ten acres were grouped with the adjacent area of closest canopy and/or vegetative characteristics. This same person used a crown density scale produced by Forest Survey-Central States Forest Experimental Station to place each area in one of 5 canopy closure classes: 0-20%, 20-40%, 40-60%, 60-80%, 80-100%. Approximately 30% of each area was sampled and compared to representative grid densities prior to categorization. If the average density for one area was between classes, then the area was place in the higher canopy class. Therefore, an area averaging 20% canopy closure would be placed in the 20%-40% class rather than the 0%-20% class. We measured the area of each outlined canopy density class using a planimeter (Numonics Corporation electronic graphics calculator). We present a summary of results for canopy closure estimates of greater than or equal to 40% canopy closure the all acreage classes examined in Figures 1-4.

Mylar overlays and data sheets were labeled as follows: territory number, photo year, photo scale. Photograph information was also included as: flight line : photo #. For example, 1:12000 scale 1989 photographs #1 and #2 from flight line 6, territory 5 would be listed as 5.1989.12000. 689:1,2. This was done in order to facilitate a repetition of the analysis.

To validate the estimates, we ground-checked canopy closure values for 12 of the 21 NKRD goshawk territories analyzed in the photo interpretation. We first relocated the areas delineated on the mylar overlays on 7.5' topographic maps. We then "road-surveyed" these areas for obvious timber cuts that had occurred after the latest photographs were taken, which would change an area's canopy density category designation. We did not ground-check areas which appeared to have been harvested after the 1986 or 1989 photos had been taken.

We sampled territories in both mixed-conifer forest and ponderosa pine dominated forest with representative areas in each of the five canopy closure classes. The majority of aerial photo estimates fell into the 40%-60% canopy class, therefore a corresponding majority of densiometer transects were also in this class. Within each territory, we sampled the nest stand and areas well away from the nest stand (approximately 0.5 mile to 1.5 miles away).

We ground-checked canopy density by walking transects and measuring closure values with a spherical densiometer. Transects were randomly selected to the extent practicable. We chose areas that we could locate on topographic maps and the ground to assure sampling the selected category of canopy closure, and then determined transect direction randomly by coin toss. Transects were 100 meters in length with point readings taken at 10 meter intervals. Point readings were the mean of densiometer readings in the four cardinal directions. Where deciduous species contributed to the canopy, we estimated closure as the perimeter of the observed crown; all deciduous species had lost their leaves at the time of this measurement. This was a problem mostly in mixed conifer forest. The role of saplings in the canopy closure estimates was not corrected for; saplings inflate the closure by showing up on the densiometer but functionally representing understory or mid-story foliage. We attempted to correct for this but found methods too subjective and time consuming. We wrote a brief description of vegetative and topographic features of areas, noting areas in which the number of saplings and deciduous trees presented problems. We present data collected during ground verification in Appendix C.

The mean of the 10 point readings and the standard error of the mean were calculated for each transect and are presented in Tables 1 - 5. The data were separated into one of the five tables based on its proximity to a known goshawk nest and the broad vegetative type of the area. We present the ground verification results for 3 canopy closure classes (20%-40%, 40%-60%, and 60%-80%) in Figures 5 - 7. All the above raw data has been supplied to the KNF and Kaibab Forest Products Company.

Results and Discussion

Our comparison of 1972 canopy density estimates with 1986 or 1989 estimates revealed that changes in canopy closure, and therefore forest structure, have taken place on the NKRD at locations evaluated in this study (Figure 8). A near total loss of the 60-80% and 80%-100% canopy closure classes has occurred since 1972. The 40-60% closure class has also been drastically reduced. The forest of the NKRD is now much younger, and more open as measured by canopy closure, than it was in 1972.

Our ground verification showed that aerial photograph canopy closure measurement was most accurate in forest dominated by ponderosa pine (Tables 1 and 2, Figures 5 and 6). Mean ground-measured closure was 28% for the 20-40% cover class (n = 6, standard error = 3.9) and 51% for the 40-60% cover class (n = 5, standard error = 2.8). Our single ground verification of the 60-80% class measured 43% closure. We feel that this reading is an anomaly because this was an area with a dense middle canopy of pinyon, juniper and Gambel's oak, i.e. not ponderosa pine, as well as being on a slope of a steep canyon. The rarity of existing areas of 60-80% canopy closure as determined from photo analysis made further ground verification difficult.

We found aerial photograph closure measurements to be less accurate in mixed conifer forests (Table 3 and 4, Figures 5 and 6). Mean ground measured closure was 42% for the 20-40% class (n = 1) and 61% for the 40%-60% class (n = 5, standard error = 6.1). Mean ground measured closure for the 60-80% class was 72% (n = 2, standard error = 4.5).

A deviation from the accuracy of the aerial photo estimates in ponderosa pine is noted in the nest stand (Table 2, Figures 5 and 6: note that PIPO means ponderosa pine). There, a mean of 66% (n=6, standard error = 3.3) was found for areas classified as 40-60% closure. We also found ground-measured canopy closures to be higher within the nest stand than the surrounding forest for mixed-conifer territories (Tables 3 and 4, Figure 6). This error probably arises from a limitation in our methodology in the photo analysis, where stands of less than 10 acres were not distinguishable from surrounding classes. This means that a goshawk nest stand in a small patch of relatively dense forest would not be differentiated from the less dense forest surrounding it if the small patch was less than 10 acres in size. Crocker-Bedford and Chaney (1988) determined that average canopy closure estimates for nest stands were 18% higher than average estimates for control sites. This implies that either goshawks nest preferentially in stands with denser overstories, or that nest-stand canopy density is greater than the overall forest now because they are relict stands, where timber activities around the nest tree are curtailed by forest plan standards and guidelines.

Because the estimates of canopy closure were considerably more accurate in ponderosa pine forest, we examined changes in canopy density and nesting success for that forest type. The active territory group contained territories 3, 5 15, 19, 20, 22 and 34. The inactive territory group contained territories 10, 12, 33, 47 and 54. Our initial analysis of the data involved taking the arithmetic mean of the number of acres within each canopy class for the active and inactive territories for each of the 250, 700, 1600 and 2500 acre areas. This resulted in a frequency distribution of the average number of acres within the inactive and active groups for each canopy closure class. We performed a Chi-Square test of goodness of fit (Pearson statistic) on the frequency distributions, with a null hypothesis that the distribution of acres within each canopy closure class was equal between the active and inactive territories. We were able to reject the null hypothesis ($p << .0001$) in all cases.

We followed the Chi-Square test of goodness of fit with a series of Mann-Whitney U-tests to elucidate where the differences within the distributions were. The null hypothesis was that the number of acres within each canopy closure class within each circular area was equal between active and inactive territories ($p < 0.05$). Therefore, for each of the 250, 700, 1600 and 2500 acre areas, we performed a U-test between active and inactive territories within each canopy closure class (Table 6). We also performed U-tests on the number of acres within each area which had a canopy closure of greater than 40% (Table 7). P values less than or equal to 0.10 ($p \geq 0.10$) have notations in the table explaining directionality of the differences. We can draw some interesting conclusions despite small sample sizes ($n = 12$).

We found that in 1986/1989, inactive territories had significantly higher proportions of 20-40% canopy closure class than did active territories. Active territories had higher proportions of 40-60% canopy cover in 1986/1989 photos, within the 1600 and 2500 acre areas than did inactive territories at the $p = 0.09$ level (Table 6). These findings suggest that the loss of acreage within the 40-60% canopy class is correlated with goshawk territories becoming inactive.

The importance of canopy closure to continued goshawk breeding success is revealed in Table 7. Territories that were active since 1988 had significantly greater acreage in the 40% or greater catagory for the 250, 1600 and 2500 acre areas. Analysis of the 700 acre area yielded $p = 0.06$, which is close, but not at the $p<.05$ significance level. The directionality for this area also mirrors that of the other three acreage areas. Unfortunately, the analysis was not performed on 60% or greater canopy closure because of small sample size, but suggests that increasing percentages of canopy closures less than 40% is correlated with goshawk territories becoming inactive.

Another finding of this study is discernable in the 1972 data for the 250 acre areas around the nest stands. Territories which would later become inactive had higher proportions of the 40-60% canopy closure class ($p = 0.10$) and lower proportions of the 60-80% canopy closure class ($p = 0.10$) than did territories which would remain active. This suggests that the territories which would later become inactive were either marginal for successful goshawk breeding or were becoming degraded as long ago as 1972. This raises the question of site-fidelity: long-lived territorial animals such as goshawk pairs may continue to use an area which has deteriorated to the point that a new goshawk pair would not use it. By 1986 and 1989, the forest had lost most of its large areas of 60-80% canopy cover. The 1972 territories which would later become inactive had much greater amounts of 60-80% canopy cover than do the territories which are presently active. This may suggest that we are currently observing a site-fidelity effect with the North Kaibab goshawks, that pairs are continuing to attempt to breed in spite of deteriorating habitat.

When examining all 21 goshawk territories for which canopy density measurements were completed, we found no statistically significant difference between canopy closure at territories that were active in the last 3 years and territories that were not active in the last 3 years (Mann-Whitney U test, $p < 0.05$). Our inability to find statistical significance is not surprising in light of the following observations:

1. Uncertainty exists regarding the exact breeding status of some of the territories in mixed conifer forest. Searches for alternate nests in mixed conifer are more difficult, thus increasing the probability of classing a territory as inactive when it was in fact active. For territories in which only a single nest tree is known or searches for active alternate nests were performed by a single surveyor, our confidence in inactive designation is decreased.

2. Our ground verification results indicate that in mixed-conifer forests, canopy density estimates from aerial photographs were less accurate than in ponderosa pine forests. (Figures 6,7 and 8). The mean measured closure outside the nest stand was 42% for the 20%-40% closure class, and 61% for the 40%-60% closure class (Table 3). However, mean measured closure for the 60%-80% closure class (two transects) was 72%. Within the nest stand, aerial photographs underestimated canopy closure, here with a greater error than for mixed-conifer outside the nest stand. Mean measured density for the 40% to 60% closure class was 75%.

Conclusion and Recommendations

This study has demonstrated a correlation between decreasing canopy closure and nesting failure. We believe the correlation is weakly defined chiefly as a result of the small sample size available, which was the result of very limited project funding. Another aerial photo analysis should be performed, analyzing all territories for which we have reliable reproductive histories and using 1991 aerial photographs. Kennedy (1989) determined that male northern goshawks forage over an average of 5200 acres on a harvested forest in New Mexico. Reynolds (1979) estimated 6000 acres for foraging male goshawks. Based on this information, an area of 6000 acres around each nest cluster should be analyzed. Although goshawk nesting data prior to 1972 is virtually nonexistent for the NKRD, pre-1972 aerial photographs should be examined. This will contribute to a better understanding of the overall changes in forest structure and composition that have resulted from increasingly intensive management for commodities production. The forest structure of the NKRD, at least attributes reflected by canopy density, has been drastically altered and continues to undergo change from timber harvest. The six territories for which we used 1986 photographs as the most recent photographs under-represent the habitat alteration to date, because considerable harvest has taken place in the 5 years since 1986.

This study addressed the effects of alteration of wide areas of habitat surrounding goshawk nests. Statistical proof of a correlation between habitat changes and reproductive success is difficult because of the small sample size available. However, the results of this study have disturbing implications on a more coarse but tangible level. The virtual elimination of forest with greater than 60% canopy closure, and the marked reduction of areas in the 40%-60% closure classes, raises the question of availability of basic nest site requirements. As discussed above, current nest stands are protected from harvest by forest plan standards and guidelines. However, as the remainder of the forest is harvested, availability of potential nest stands with high (≥60%) canopy closure is severely reduced. Undiscovered nest stands may be degraded beyond utility by goshawks. Further, important alternate nest stands will cease to be functional after being opened up. The remaining, protected nest stands are rapidly becoming the only forest stands exhibiting nest stand characteristics. These stands are, as any, susceptible to loss by natural events like fire and blowdown. If these stands are lost and no suitable, high canopy closure replacement stands are available, this and other nesting populations may be in jeopardy.

Further exacerbating the above problems of goshawk ecology are observations (Moore and Henney 1983) that in more open, harvested forests, goshawks could be out-competed or preyed upon by species adapted to open conditions, e.g. red-tailed hawks and great-horned owls. Such predation or competition has been documented on the NKRD (Zinn and Tibbitts 1990) and elsewhere (Schuster 1977). The goshawk is recognized as being fairly general in its use of prey, and use of a wide variety of avian and mammalian species has been documented on the NKRD (Tibbitts and Zinn 1989, Mannan and Boal 1990, Mannan and Boal 1991). While it is valuable to consider availability of potential prey items in managing for goshawks, it must be remembered that availability should be defined as not only numerical availability, but ecological availability. As discussed above, the goshawk is adapted to foraging in a complex structural environment. Large numerical presence of potential prey in more open forest conditions may not be truly available to the goshawk, especially when predators adapted to those open conditions are sympatric with goshawks.

The results of this analysis have disturbing implications for the future of the NKRD goshawk population, as well as the status of goshawks elsewhere in the Southwest where comparable changes in forest structure are taking place. Solace should not be taken in the fact that goshawks continue to breed on the North Kaibab at higher densities than they do in any other known area in the lower 48 states. It is possible that when currently breeding adults begin to leave the breeding population a serious decline will occur in the number of breeding pairs on the North Kaibab. If the data from 1972 are any indication, we expect this decline to occur within the next 10 to 20 years unless current forestry management practices are significantly changed.

Further efforts need to be directed toward defining goshawk home range sizes, preferred habitats or forest attributes within that home range, prey use, demographics, and tolerance of goshawks for coexisting with commodities production on forest lands. Crocker-Bedford (1990) provides the only published, statistical analysis of the effectiveness of various habitat-management areas. His results cast doubt on the effectiveness of current management policies, and clearly indicate the need for further studies with similar approaches. Unfortunately, many of these studies will face two limitations that we encountered. First, goshawk populations available for study will impose the statistical difficulties of relatively small sample sizes. Second, habitat modification has been increasing, especially over the past 10 years, and promise to continue. Multiple-year studies will be complicated by the possibility that significant changes in population dynamics will be taking place during the next few years. Studies may be compromised by these uncontrollable variables, and may produce important information too late for it to be implemented to produce positive effects for goshawk viability in the southwest.

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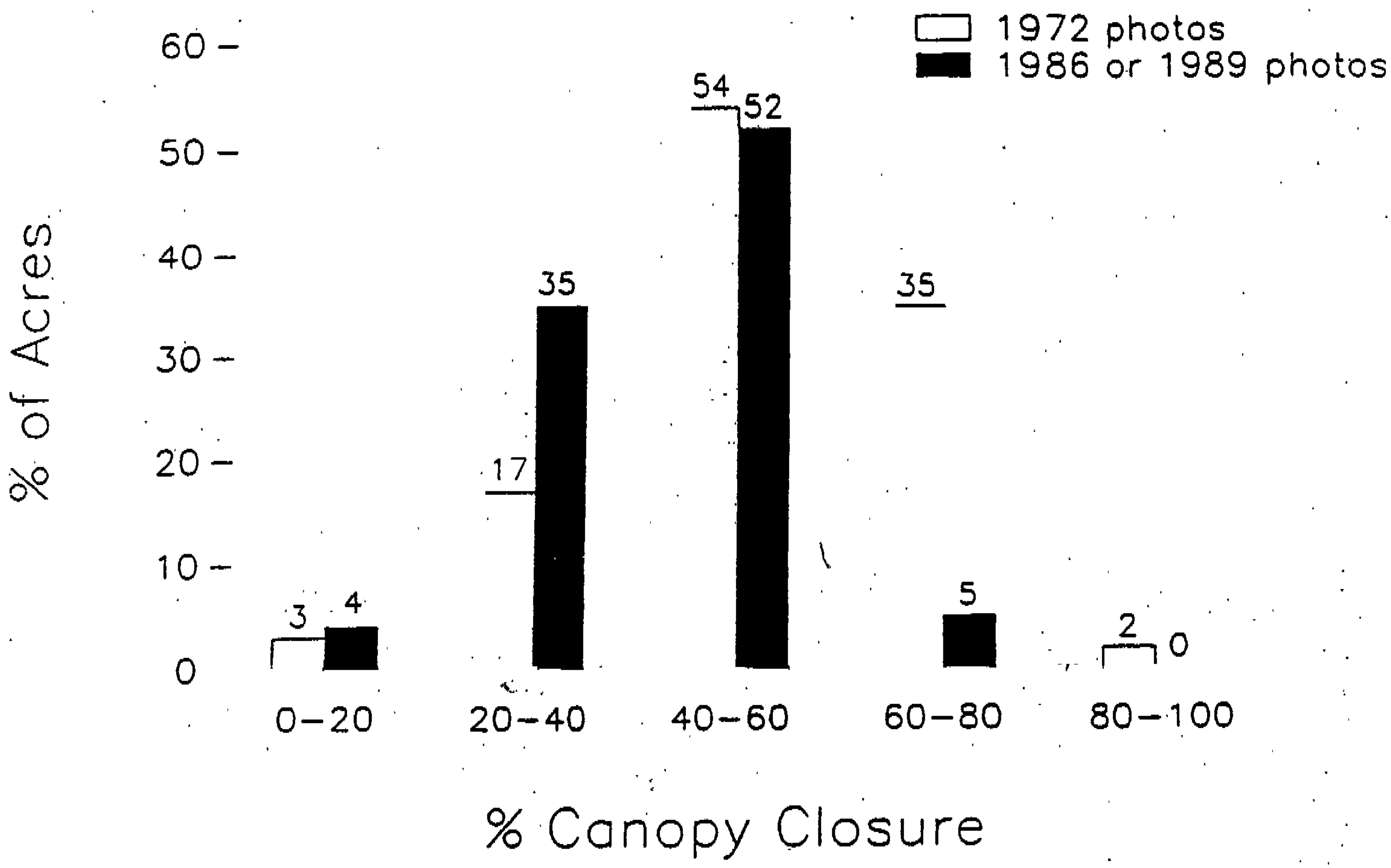

Figure 8. Changes in canopy closure 1972 to 1986/1989 as estimated from aerial photographs, North Kaibab Ranger District, Kaibab National Forest, Arizona.