US Army Corps
of Engineers
Construction Engineering
Research Laboratories

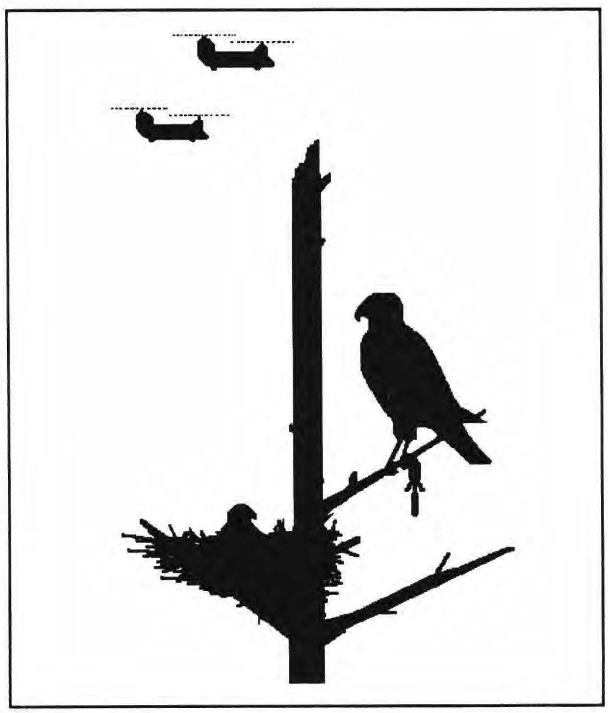
USACERL Technical Report 95/45
September 1995

Abundance, Distribution, and Selected Characteristics of Nesting Raptors on the Fort Sill Military Reservation, 1987 to 1992

by
William R. Whitworth

Raptors receive protection under both federal and state laws, and play an integral role in the ecology of the great plains region. Because of their high position in the food web, raptors can be an indicator of ecosystem health. This study located, mapped, and monitored raptor nests on the Fort Sill Military Reservation, in southwestern Oklahoma, which includes four major impact areas and is the Army's primary field artillery training center. The survey characterized the nest-tree and nest-site, emphasizing the larger species that construct or use more conspicuous stick-nests.

Few direct negative impacts from military activities were perceived. Overall density and productivity rates compared favorably with values reported for other regions. Nesting Red-shouldered and Red-tailed Hawks were strongly associated with bottomland forest; Great Horned Owls appeared tolerant of a broader range of habitat conditions. Competitive interactions clearly influenced nest distribution, with little evidence of competitive exclusion. Recommendations were made to reduce disturbance to nesting raptors, and to suggest areas of future research.



USER EVALUATION OF REPORT

REFERENCE: USACERL Technical Report 95/45, *Abundance, Distribution, and Selected Characteristics of Nesting Raptors on the Fort Sill Military Reservation, 1987 to 1992*

Please take a few minutes to answer the questions below, tear out this sheet, and return it to USACERL. As user of this report, your customer comments will provide USACERL with information essential for improving future reports.

1. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

___

___

___

2. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.)

___

___

3. Has the information in this report led to any quantitative savings as far as manhours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

___

___

4. What is your evaluation of this report in the following areas?

a. Presentation: ___

b. Completeness: ___

c. Easy to Understand: ___

d. Easy to Implement: ___

e. Adequate Reference Material: ___

f. Relates to Area of Interest: ___

g. Did the report meet your expectations? ___

h. Does the report raise unanswered questions? ___

i. General Comments. (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.)

5. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: __________

Telephone Number: __________

Organization Address: __________

6. Please mail the completed form to:

Department of the Army
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES
ATTN: CECER-TR-I
P.O. Box 9005
Champaign, IL 61826-9005

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*

2. REPORT DATE
September 1995

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Abundance, Distribution, and Selected Characteristics of Nesting Raptors on the Fort Sill Military Reservation, 1987 to 1992

5. FUNDING NUMBERS
MIPR
Z22
4A162720
A896
EN-UD-5

6. AUTHOR(S)
William R. Whitworth

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
TR 95/45

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HQ-USA-FAC-FS
ATTN: ATZR-BN
Natural Resources and Enforcement Division,
Bldg 1450
Fort Sill, OK 73503-5100

Directorate of Environmental Programs, Assistant Chief of Staff (Installation Management)
ATTN: DAIM-ED-N
7701 Telegraph Road
Alexandria, VA 22315-3800

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Raptors receive protection under both federal and state laws, and play an integral role in the ecology of the great plains region. Because of their high position in the food web, raptors can be an indicator of ecosystem health. This study located, mapped, and monitored raptor nests on the Fort Sill Military Reservation, in southwestern Oklahoma, which includes four major impact areas and is the Army's primary field artillery training center. The survey characterized the nest-tree and nest-site, emphasizing the larger species that construct or use more conspicuous stick-nests.

Few direct negative impacts from military activities were perceived. Overall density and productivity rates compared favorably with values reported for other regions. Nesting Red-shouldered and Red-tailed Hawks were strongly associated with bottomland forest; Great Horned Owls appeared tolerant of a broader range of habitat conditions. Competitive interactions clearly influenced nest distribution, with little evidence of competitive exclusion. Recommendations were made to reduce disturbance to nesting raptors, and to suggest areas of future research.

14. SUBJECT TERMS
bird populations
raptors
Fort Sill, OK

15. NUMBER OF PAGES
128

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

Foreword

This study was conducted for the U.S. Army Field Artillery Center (USAFAC) and the Directorate of Environmental Quality, Fort Sill under Military Interdepartmental Purchase Request (MIPR) No. Z22; Work Unit Z22, "Raptor Monitoring at Fort Sill." Additional funding was provided by the Office of the Directorate of Environmental Programs (DAIM), Assistant Chief of Staff (Installation Management) (ACS(IM)) under Project 4A162720A896, "Environmental Quality Technology"; Work Unit EN-UD-5, "LCTA Applications for Natural Resources Management and Compliance." The Fort Sill technical monitor was Glen Wampler, ATZR-BN and the ACS(IM) technical monitor was Dr. Victor E. Diersing, DAIM-ED-N.

The work was performed by the Natural Resources Assessment and Management Division (LL-N) of the Land Managment Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL). Thanks are given to the following USACERL researchers for technical assistance and manuscript review: Gary Senseman, Timothy Hayden, Keith Harris, and William Jackson. Special thanks are given to many past and present Fort Sill staff: Gene Stout, former Chief Administrator of the Natural Resources Division, DEQ, Fort Sill, who consistently provided a high level of logistical support critical to the study; Glen Wampler, Acting Chief Administrator of the Natural Resources Division, and William Bartush, former Fish and Wildlife Administrator for additional logistical support and helpful advice; Dr. James Gallagher, Kevin McCurdy, Tony Montaperto, Jay Banta and other staff who reported raptor observations and provided other needed services. Samuel Orr, for graciously allowing the use of his unpublished data and for his countless hours of monitoring nests; and Wallie Breadon, who frequently assisted Mr. Orr in banding the young and collecting incidental food habit information. Dr. David J. Tazik is Acting Chief, CECER-LL-N, Dr. William D. Severinghaus is Operations Chief, and William D. Goran is Chief, CECER-LL. The USACERL technical editor was William J. Wolfe, Technical Resources Center.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

Contents

List of Figures and Tables

Figures

Tables

1 Introduction

Background

Fort Sill has grown considerably since its establishment as an isolated cavalry post in 1869. Fort Sill received an additional 9,328 hectares in 1871 and continued to expand intermittently up to 1957 (USDA Soil Conservation Service 1970). The Fort Sill Military Reservation now encompasses approximately 38,500 hectares, including four major impact areas. The installation houses the Army's primary field artillery school, where more than 15,000 officers and enlisted personnel are trained annually (USDA Soil Conservation Service 1970).

Fort Sill's change from a simple cavalry post of a few acres to a large mechanized field artillery school employing an array of tracked and wheeled vehicles with sophisticated weapons systems has undoubtedly impacted the soils, flora, and fauna of the area. However, the lack of a standardized monitoring program has made documentation of changes in the ecosystem composition and structure during this period impossible. Fortunately, efforts have recently been initiated on Fort Sill to collect the long-term data essential for integrated resource management, impact assessment, and biodiversity conservation. Under the U.S. Army's Integrated Training Area Management (ITAM) program, 184 Land Condition-Trend Analysis (LCTA) permanent plots were established and first inventoried on Fort Sill in 1989. In addition to information characterizing vegetation and soils, songbird and small-mammal data are being collected on a regular basis from LCTA plots to monitor long-term population trends and resource availability (Tazik et al. 1992). The LCTA database provides installation-wide environmental documentation on present wildlife resources and can serve as a foundation for developing more detailed studies required to address cause-effect and species-specific issues.

Qualitative field observations by Fort Sill personnel knowledgeable about the avifauna indicated that both breeding and nonbreeding raptor populations on Fort Sill appeared to be proportionally higher than that observed on the adjacent Wichita Mountains Wildlife Refuge and other lands bordering the installation (Sam J. Orr, Staff Photographer, U.S. Field Artillery Center and Fort Sill, Fort Sill, OK, professional discussion, 10 December 1988 [hereafter referred to as "Orr, 10 December 1988"]). Additional noteworthy occurrences suggest the attractiveness of Fort Sill to both wintering and nesting raptors. The Black-shouldered Kite, considered a rare species in Oklahoma, has been recorded on the East Range of Fort Sill on several recent occasions (Andrew et al. 1983). Also, the first documented nesting records for Red-shouldered Hawk (Tyler et al. 1989) and Northern Harrier (Montaperto 1988; Regosin et al. 1991) in southwestern Oklahoma were reported from Fort Sill. Finally, possibly the largest known Northern Harrier (*Circus cyaneus*) winter roost in the world was documented on the Bluestem Prairie of the South Arbuckle Range on Fort Sill (Lipske 1995) in 1988. Northern Harrier winter roost censuses initiated in January 1986 have been conducted twice annually in a 890 ha section of the South Arbuckle Range (Figure 1). Averaging 482 harriers per census, as many as 1,053 individuals have been recorded leaving the roost during the 3-hour census periods (Sam J. Orr, Staff Photographer, U.S. Field Artillery Center and Fort Sill, Fort Sill, OK, professional discussion, 15 April 1992). At least six additional, but considerably smaller, roosts are known to exist in the tallgrass prairie of the East Range, but none have been investigated to date.

Raptors receive federal protection under the Migratory Bird Treaty Act of 1918, the Bald Eagle Protection Act of 1940, and the Endangered Species Act of 1973 and its amendments (Johnson 1984) in addition to legal protection at the state level. Moreover, raptors play an integral role in the ecology of the great plains region and, because of their high position in the food web, can be an indicator of ecosystem health. To date, standardized LCTA methodologies have not yet been developed specifically for monitoring raptors or their nests, largely due to two inherent difficulties associated with censusing them and one constraint unique to the military. First, raptors typically occur in very low numbers relative to most songbirds, greatly reducing sample sizes and limiting subsequent data analyses. Secondly, several survey methods often must be employed, as raptors species can exhibit great differences in detectability and daily periods of activity. Finally, consistent survey times and routes are especially difficult to maintain on an Army installation. Training activities and schedules are finalized just 1 or 2 days in advance, and often require the temporary closure of one or more training areas as well.

Objectives

Recognizing the size of the study area and limited resource availability, the five general objectives of this study were to:

1. Locate and map raptor nests within the boundaries of the Fort Sill Military Reservation, emphasizing the larger species that construct or occupy the more conspicuous and persistent stick-nests

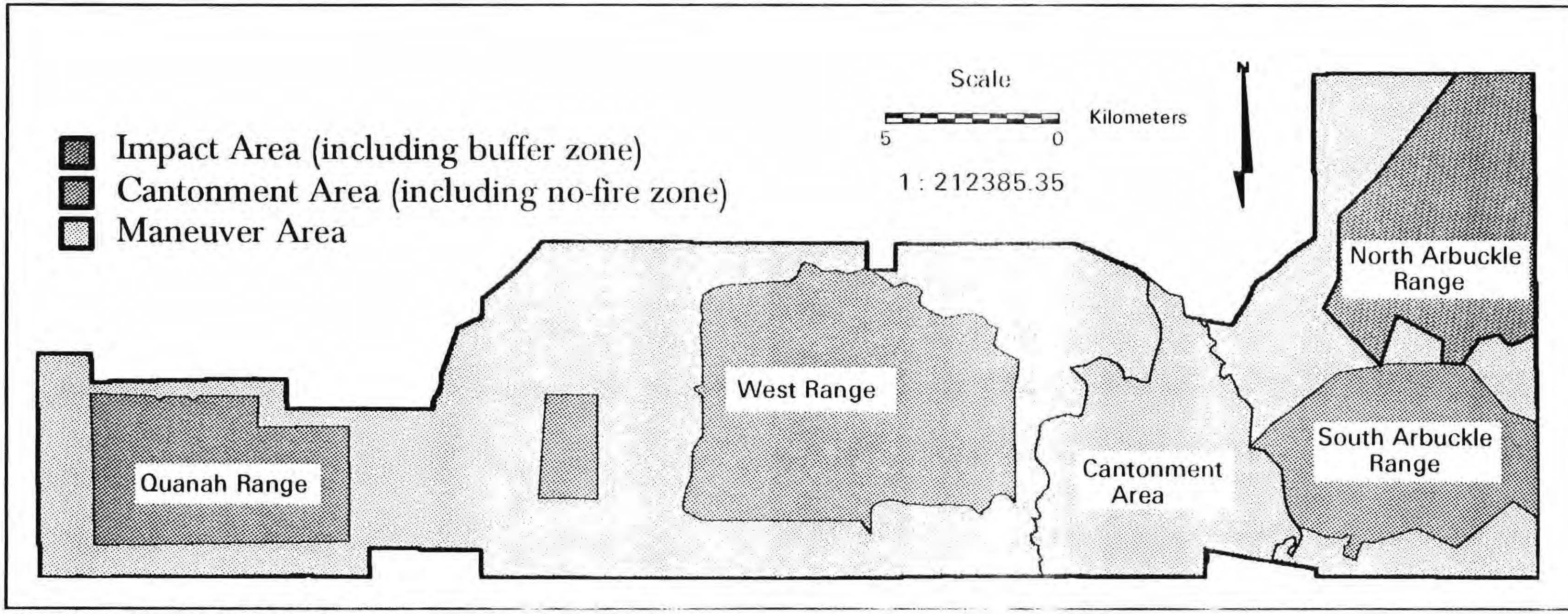


Figure 1. Military land use categories.

2. Monitor each of the identified nests to determine if it is being occupied by a breeding pair, and if so, determine success and estimate productivity
3. Quantify selected nesting-habitat and nest-tree variables known to influence nest location in raptors, and identify other factors perceived to be important in determining nest distribution and abundance on the installation
4. Based on the results of this study, provide management recommendations conducive to minimizing disturbance and maintaining stable nesting populations of raptors
5. Suggest areas of future raptor research.

Approach

1. Fort Sill Fish and Wildlife personnel were interviewed to determine the most common raptors regularly nesting on Fort Sill.
2. A monitoring strategy was determined to account for inherent limitations associated with stick-nesting, ground-nesting, and cavity-nesting species. While all species are equally important, each type of nest requires a different level of field effort to detect. For example, nests located on the ground are detected only after accidentally flushing the adults or by observing the courtship displays and/or nest building behaviors in the field. Cavity-nesting species are most effectively discovered when personnel are readily available to climb potential nest trees. Additionally, relatively small raptor species like the Mississippi kite commonly nest on Fort Sill, but construct relatively small and fragile nests during or post leaf-out, making them especially difficult to detect and monitor.
3. The field of species to be monitored in the study was narrowed, based on the most feasible nest monitoring strategy, and on a final constraint: the relatively high frequency of range access restrictions in areas associated with artillery and/or small arms firing. Searching for the nests of all raptor species known to nest on Fort Sill would have been extremely labor-intensive and expensive. The field effort was therefore directed toward nesting species that tend to build or use fairly robust and conspicuous stick nests.
4. Extensive field studies were conducted from January through July in 6 consecutive years (1987 to 1992) to locate new nest structures, inspect previously identified nests for structural integrity, and monitor each nest for signs of current-season breeding activity. Although nest searching techniques were intentionally biased toward stick-nests, nests in cavities or on the ground were recorded whenever possible. Once a nest was deemed "occupied," it was generally monitored once every 1 to 2 weeks thereafter until either the nestlings fledged, the nest was destroyed, or the pair abandoned the nest. However, many of the nests adjacent to frequently traveled roads were occasionally checked

several times per week, while nests in difficult access areas could only be monitored once per 2 to 3 weeks. Total field effort was conservatively estimated at 2,100 labor-hours.

5. Data were collected at each nest tree to quantify selected variables pertaining to the tree and nest itself, and certain variables pertaining to the woody species in the immediate nest site were quantified on a random subset of the nests. Data were analyzed for significant trends, and specific recommendations were made regarding the implications of the data for continued monitoring and land-management activities.

Mode of Technology Transfer

Information derived from this study may impact Army Regulation (AR) 420-74, *Natural Resources—Land, Forest, and Wildlife Management*, which is currently under revision. Methodologies developed in this study will be made available to military, land, and wildlife managers at Fort Sill, Headquarters (HQ), U.S Army Training and Doctrine (TRADOC) Command, and HQ, Department of the Army in conjunction with the Army's Integrated Training Area Management (ITAM) program, and through the U.S. Army Center for Public Works (USACPW), Alexandria, VA, which sponsors annual LCTA training workshops conducted by USACERL staff, for Army Resource Management personnel.

Metric Conversion Factors

U.S. standard units of measure are used throughout this report. A table of metric conversion factors is presented below.

1 in.	=	25.4 cm
1 ft	=	0.305 m
1 yd	=	0.915 m
1 acre	=	0.404 ha
1 mi	=	1.61 km
1 sq mi	=	2.56 km^2
1 lb	=	0.453 kg
°F	=	(°C x 1.8 + 32)

2 Study Area

General Description

The Fort Sill Military Reservation is located entirely within Comanche County, OK, immediately adjacent to the city of Lawton (pop. 80,000), approximately 160 km southwest of Oklahoma City (Figure 2). Several smaller towns in close proximity to the installation include Cache, Elgin, and Medicine Park. The 21,052 ha Wichita Mountains Wildlife Refuge adjoins Fort Sill's northwestern border for almost half of its length.

Fort Sill is in the Osage Plains section of the Central Lowlands physiographic province (Hunt 1974), and is characterized by gently rolling, slightly dissected upland, of low relief to hills with steep rocky slopes and moderate relief. Elevations on Fort Sill range from 329 to 673 m. Approximately 52 percent of Fort Sill lies within the East Cache Creek watershed with the remainder draining into the West Cache Creek

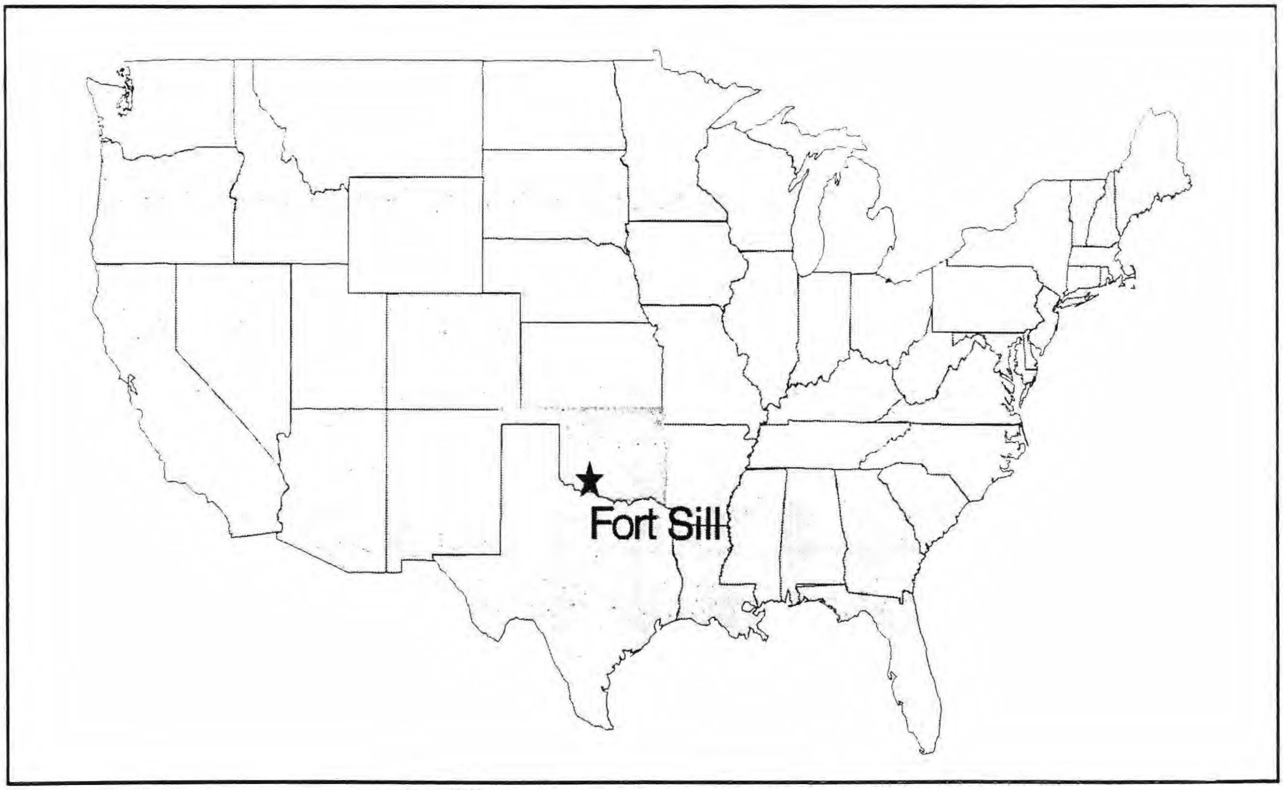


Figure 2. Approximate location of Fort Sill.

watershed. With few exceptions, drainage on the installation is south to the Red River, through many intermittent streams (Figure 3).

Precipitation averages 79 cm per year. May and June are generally the wettest months, but rainfall is highly variable and droughts are not uncommon. Summers are long and hot, reaching 43 °C or higher. Winters are mild, with temperatures seldom reaching -18 °C (Fort Sill EIS). The average wind speed is 19 km/hr, but gusts of 48 to 81 km/hr are common and have occasionally approached 137 km/hr during severe thunderstorms.

The most prominent geological feature in the immediate area of Fort Sill is the Wichita Mountain range, which is composed primarily of granite and rhyolite. At the higher elevations, the weathered and deeply eroded slopes support shallow soils and a sparse vegetative community. Toward the lower slopes and the gently rolling plains, approximately fourteen distinct soil types support a greater diversity of plant communities ranging from shortgrass prairies to bottomland hardwoods (Johnson et al. 1990; USDA Soil Conservation Service 1970). Oil- and natural gas-producing horizons are limited to the Pennsylvanian sandstones and granite washes. Some gabbro has been quarried and gypsum is being mined in close proximity to Fort Sill.

Major Plant Communities

Because the landscape is often dissected by narrow stream beds, broad drainages, hills, and other slight to moderate topographic changes, the ecotones between many plant communities on Fort Sill are often not visually distinct, but tend to reflect a continuum. The plant communities on Fort Sill were placed into six categories (Figure 4), broadly derived from Kuchlers general classification (1964) and modified based on a recent floral inventory conducted by the Oklahoma Biological Survey (Johnson et al. 1992).

Bluestem-Grama Prairie

This plant community is characterized by little bluestem (*Schizachyrium scoparium*) blue grama (*Bouteloua gracilis*) and sideoats grama (*B. curtipendula*), which generally reach heights of 1 to 3 ft. The bluestem-grama type occurs on level to rolling terrain and can be found over much of West and Quannah ranges. This community covers approximately 20 percent (77 km^2) of the installation.

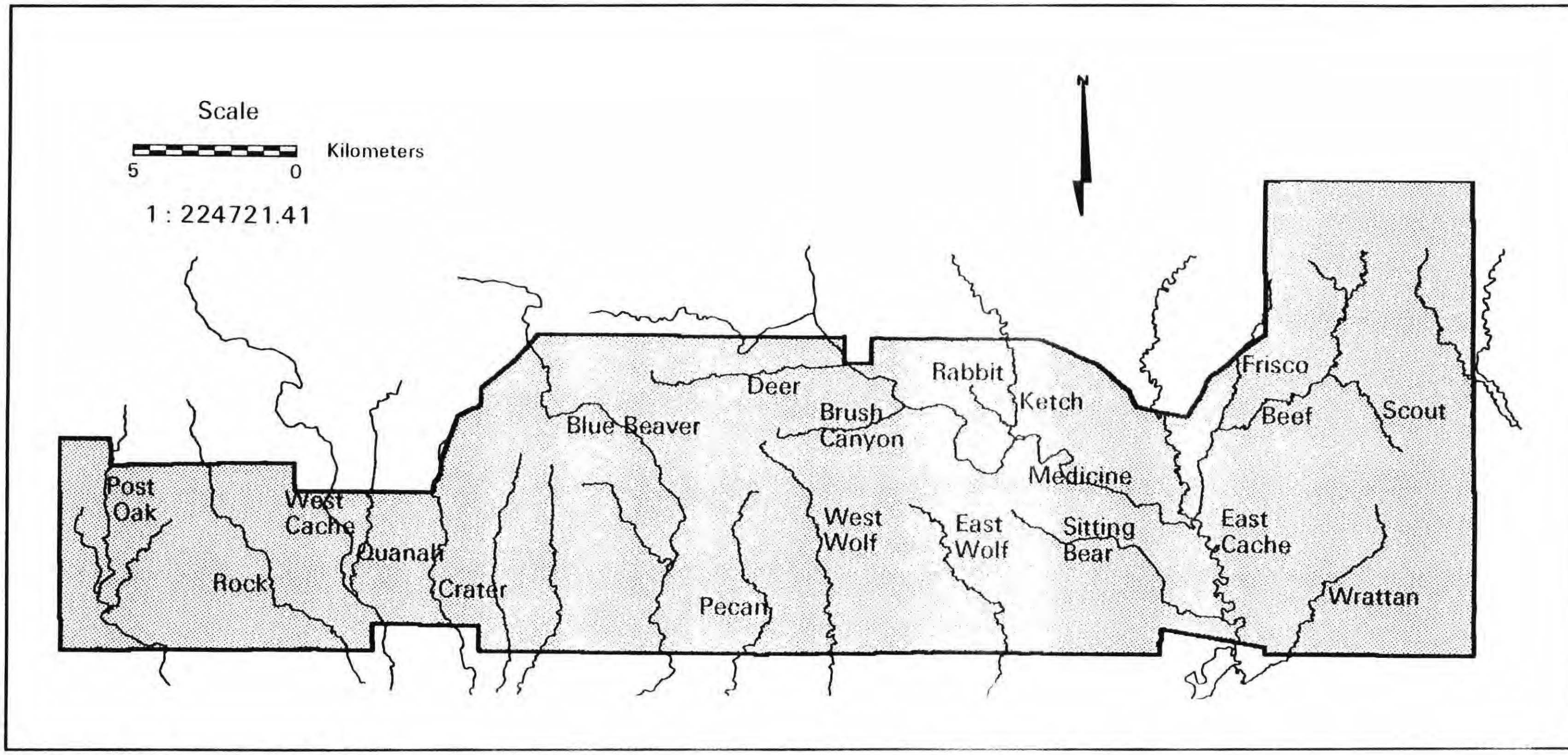


Figure 3. Major streams of Fort Sill.

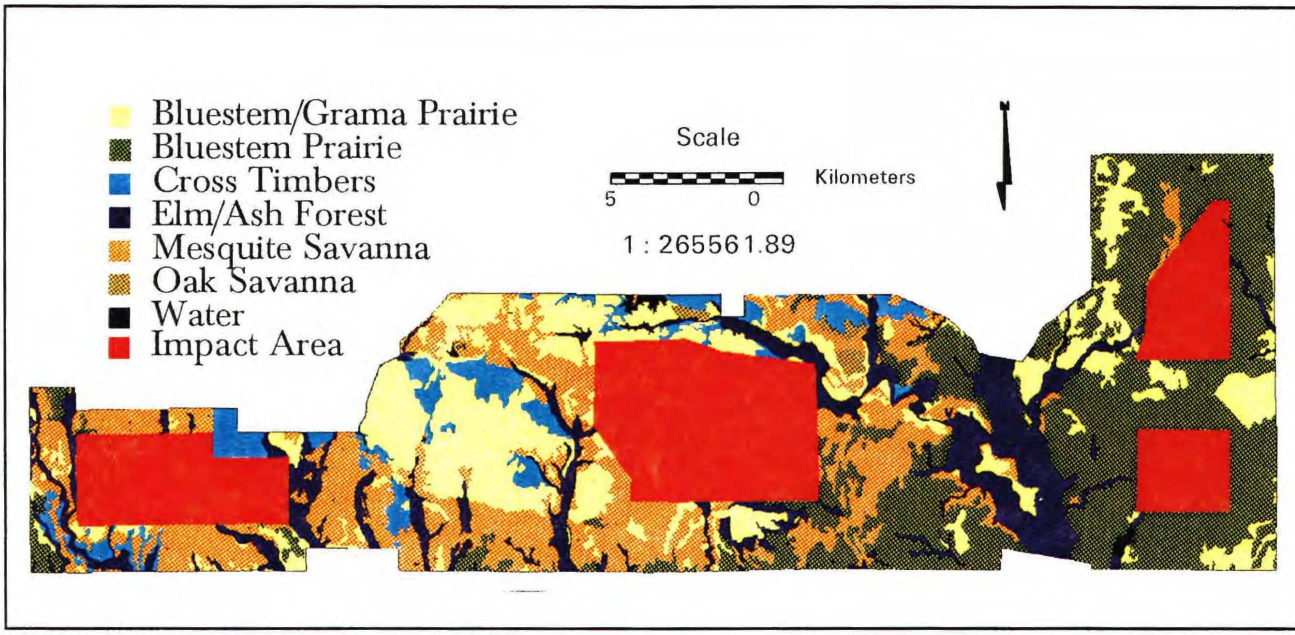


Figure 4. Major plant communities on Fort Sill.

Bluestem Prairie

This prairie is dominated by medium to tall grasses, including both little and big bluestem (*Andropogon gerardii*), indian grass (*Sorgastrum nutans*), and switchgrass (*Panicum virgatum*). These species often reach heights of 1.5 to 2.0 m or more in years with adequate precipitation. Bluestem Prairie makes up most of the East Range, but can be found on the better upland soils over much of the installation. Bluestem Prairie is the largest of the six plant community types, covers an estimated 27 percent (103 km^2) of the installation, and might constitute the largest tract of ungrazed tallgrass prairie remaining in the country (Lipske 1995).

Mesquite Savannah

This community occurs on fairly level ground and is dominated by the honey mesquite (*Prosopis glandulosa*). Mesquite Savanna covers approximately 21 percent (79 km^2) of the installation. The average mesquite grows to a maximum height of about 5 to 6 m, provides good to excellent concealment cover and, along with the level terrain and fairly open tree spacing, makes these sites especially attractive for many types of military training exercises. Consequently, this habitat type tends to include more disturbance-tolerant species than would normally be expected. The largest tracts of Mesquite Savannah are found on the southern portions of West and Quannah ranges, and are intersected occasionally by thin corridors of Elm-Ash paralleling the wetter drainages.

Oak Savannah

This terrain is found throughout West Range and is characterized by a relatively open Bluestem-Grama prairie frequently interspersed with post oak (*Quercus stellata*). The soil is rugged and rocky and is therefore less disturbed than the Mesquite Savannah by military exercises. Tree growth tends to be noticeably stunted and the limbs relatively short and twisted, reflecting the harsh soil and weather conditions. This is the least common of the plant community types in area, covering an estimated 3 percent (12 km^2) of the installation. Two of the larger stands of Oak Savannah are located just east of Tower Two Road, between Rabbit Hill and Indian Hill.

Cross Timbers

This typical upland forest type on Fort Sill is codominated by post and blackjack oak (*Q. marilandica*). Cross Timbers plant communities have irregular boundaries and are quite variable in size. The woody and herbaceous understory is generally sparse relative to the elm-ash type. Cross Timbers occurs throughout West and Quannah ranges, and overall comprise an estimated 7 percent (26 km^2) of the installation. Similar to the Oak Savanna forest type, tree growth within Cross Timbers is frequently stunted with limbs tending to be relatively short and twisted.

Elm-Ash Forest

Elm Ash forest more closely approximates true bottomland forest on Fort Sill than any of the other forest types. Largely limited to lake and stream borders, this plant community exhibits a distinctly dendritic pattern that is especially pronounced along the upper drainages. Elm-Ash forest covers an estimated 13 percent (51 km^2) of the installation and has a more diverse overstory in comparison to the other forest types on the installation. According to Johnson et al. (1992), the East Cache Creek drainage represents the best example of Elm-Ash forest on the installation. Elm-Ash generally has a dense understory of woody shrubs and vines with a relatively minor herbaceous component. Typical dominant tree species (in decreasing order of abundance) include sugarberry (*Celtis laevigata*), soapberry (*Sapindus drummondi*), box elder (*Acer negundo*), American elm (*Ulmus americana*), Shumard's oak (*Q. shumardii*), bur oak (*Q. macrocarpa*), pecan (*Carya illinoensis*), and cottonwood (*Populus deltoides*). Ironically, Ash species are relatively uncommon in much of the bottomland forest on Fort Sill at present, indicating the Elm-Ash label is largely a misnomer. With regards to tree height and diameter at breast height (DBH), the majority of the largest trees on the installation occur within this forest type.

Military and Civilian Land-Use

Fort Sill is considered a relatively "open" military installation. That is, civilians are not restricted from entering nonimpact areas of the installation and engaging in various recreational or sightseeing activities, although temporary access restrictions are occasionally in place because of military training exercises. The residential areas, administration buildings, warehouses, airfield, and golf courses are located within the 3,360 ha Cantonment Area. An additional 3,219 ha are reserved for other nonfiring and light training activities. The remainder of the installation is available for the more "typical" military training activities such as artillery firing, land navigation, force-on-force training exercises, military-style camping or "bivouacking," and small arms and machine-gun firing. Beginning in 1988, training areas were placed on a 10-year renovation schedule to reduce environmental impacts and improve the habitat for training and wildlife, with up to 15 percent of the training lands being closed for renovation at any one time (Boice 1992).

Grazing by domestic livestock has not been permitted since 1957, and no standing timber is removed for commercial or private use. An active wildlife management program centered around habitat improvements and controlled harvest provides stable, consistently high annual game populations. Additionally, 165 ponds and lakes scattered throughout the installation provide substantial fishing opportunities throughout the year. Off-road use of Fort Sill lands by civilian personal vehicles is restricted to a relatively small area located within the extreme southeastern corner of the Cantonment Area. A relatively minor amount of land is maintained for hay or crop production annually under lease agreements. These agricultural fields of varying sizes are irregularly scattered throughout the installation. Lastly, of the six cemeteries on post, four are entered in the National Register of Historic Places as the Fort Sill Indian Cemeteries National Historic District.

Known and Potential Nesting Species

A minimum of 26 raptor species have recently been confirmed on Fort Sill. Some of the documented species spend a portion of the winter months on the installation. Others are spring and fall migrants (e.g., Bald eagle, Osprey, and Ferruginous hawk) that use the installation as a temporary resting or foraging site en route to or from their normal nesting areas further north. However, range access restrictions coupled with the moderate relief of the land make it probable that some of the rare or more secretive species have come and gone unnoticed. Therefore, the number of raptor species nesting, wintering, or migrating through Fort Sill at any one time is likely to be considerably less than the 26 known species:

1. Turkey Vulture (*Cathartes aura*). Common in the spring, summer, and fall. Vultures possibly nest on Fort Sill but none have been reported.
2. Osprey (*Pandion haliaetus*). Occasionally sighted during spring and fall migration. Not known to nest on the installation.
3. Cooper's Hawk (*Accipiter cooperii*). Fairly common in the fall, winter, and spring. Not known to nest on Fort Sill.
4. Northern Goshawk (*Accipiter gentilis*). Rare. The only reported sightings for this species occurred in the winter of 1985/86.
5. Sharp-Shinned Hawk (*Accipiter striatus*). Common summer resident and likely nester, although no nests have been confirmed. Fairly common in the fall-winter-spring.
6. Red-tailed Hawk (*Buteo jamaicensis*). The most abundant Buteo on Fort Sill. An exceptionally abundant nester and year-round resident. Redtails most often are responsible for constructing the relatively large and conspicuous stick nests commonly observed in the tall cottonwood trees. Harlan's Hawks, Kriders, or other recognized subspecies of the RTHA are observed on the installation each year as nonnesters.
7. Red-shouldered Hawk (*Buteo lineatus*). A fairly common year-round resident and nester associated with woodlands, but somewhat more secretive than the other large hawks and consequently observed less often.
8. Ferruginous Hawk (*Buteo regalis*). Uncommon winter resident. The largest Buteo on Fort Sill, one to four usually winter each year on Fort Sill.
9. Swainson's Hawk (*Buteo swainsoni*). A common migrant. Known to nest on the installation only infrequently.
10. Rough-legged Hawk (*Buteo lagopus*). Common winter resident. Generally, both the light and dark phases can be observed each winter.
11. Northern Harrier (*Circus cyaneus*). Unusually large numbers winter on Fort Sill each winter, especially throughout the East Range. Two nests were discovered on the East Range and one on the West Range in recent times. Harriers nest on the ground and often in dense herbaceous groundcover making the nests difficult to locate. In spite of the relatively few confirmed nests, this species is believed to be a common nester.
12. Black-Shouldered Kite (*Elanus caeruleus*). Rare. Only one confirmed sighting on the East Range of Fort Sill. Andrew and others (1983) observed apparently the same individual on several different occasions in March and April 1983.

13. Mississippi Kite (*Ictinia mississippiensis*). A fairly common nester and spring/summer resident. Very tolerant of human activity and often nests in close proximity to golf courses and other residential areas.
14. Bald Eagle (*Haliaeetus leucocephalus*). An uncommon fall migrant. Known to winter in the adjacent Wichita Mountains Wildlife Refuge to the north.
15. Harris' Hawk (*Parabuteo unicinctus*). Rare. The only confirmed individual on Fort Sill was observed several times throughout the fall-winter of 1986/87 on the East Range (Banta and McMahon, 1987). Not known to nest on the installation.
16. Merlin (*Falco columbarius*). An uncommon winter resident. Not known to nest on the installation.
17. Prairie Falcon (*Falco mexicanus*). Two to three individuals typically winter each year on the installation, but leave prior to the nesting season.
18. American Kestrel (*Falco sparverius*) (hereafter referred to as AMKE.) A common nester and year-round resident. This small falcon is known to occasionally nest in the artificial nest boxes installed by Fort Sill Fish and Wildlife personnel.
19. Common Barn-Owl (*Tyto alba*). A year-round resident and fairly common nester.
20. Short-eared Owl (*Asio flammeus*). A common winter resident. Not known to nest on Fort Sill.
21. Long-eared Owl (*Asio otus*). Rare winter resident. The only known sighting was in January 1992.
22. Burrowing Owl (*Athene cunicularia*). Known to nest on Fort Sill, and fairly common on the shortgrass prairie of the West Range impact area in summer. They frequently occupy abandoned burrows dug by prairie dogs, badgers, and coyotes.
23. Great Horned Owl (*Bubo virginianus*). Abundant year-round resident and the earliest nesting raptor species on Fort Sill. Occupied nests have been recorded as early as mid-January. They are not known to build their own nests, and rely heavily on nests constructed by Red-tailed hawks or other raptor species.
24. Snowy Owl (*Nyctea scandiaca*). Rare. The only known sighting was in December 1986. Any sightings in Oklahoma are likely a consequence of low prey availability (primarily lemmings) in the northern U.S and Canada, which forces many dispersing Snowy Owls to venture further south than normal in search of prey.
25. Eastern Screech Owl (*Otus flammeolus*). Relatively common on the West and Quanah Ranges. Much smaller than the GHOW, Screech Owls undoubtedly nest on the installation, but none have been recorded to date.
26. Barred Owl (*Strix varia*). This dark-eyed owl is believed to be more abundant than the GHOW, nearly as common as the RTHA, and a common nester on Fort Sill. More closely associated with streams than the GHOW, this species most often nests in tree cavities, but have been known to occupy stick-nests constructed by RTHAs.

3 Methods

Research Emphasis and Field Effort

Installation-wide nest location and monitoring were initiated in January 1987. The scope of the project was expanded in 1989 to include habitat, nest-tree, and nest-site characterization, and to quantitatively address raptor distributions both spacially and temporally. Because the field methodology and level of effort before 1989 remained comparable to that post-1989, much of the data collected during the first 2 years was incorporated into subsequent analyses. The mean level of field effort over the study period was estimated at 350 labor-hours annually, including time spent on nest searches on foot or from a vehicle, banding nestlings, characterizing the nest-site and tree, and monitoring nests from the ground. An additional 8.2 labor-hours were required annually for helicopter support to provide adequate coverage of the installation throughout the nesting season. Finally, many other people assisted in varying degrees over the course of the study in an unofficial capacity. Their time was difficult to estimate and was not included in the total project effort, resulting in a conservative estimate of field effort.

Nesting Chronology

The period in which each breeding pair of RTHAs and GHOWs occupied their nests was estimated based on the condition of the young at the time of banding or the last visual record. Fledging dates are believed to be within 1 week of the actual fledging date. Since relatively few RSHAs were banded, they were omitted from this analysis, but seem to roughly parallel or be somewhat later than the Red-tail with regards to nesting dates. Nest occupancy was defined as the period between the initiation of incubation and fledging. Average incubation periods and fledgling ages were based on available literature. For the RTHA, the mean incubation period and age at first flight are approximately 34 and 44 days, respectively (Palmer 1988b). Heintzelman (1979) believed the mean incubation period to be 30 days and the average age at first flight at about 63 days for the GHOW. Other nesting species (e.g., RSHA) were banded in such low numbers that a reasonable characterization of their nesting chronology was not possible. They were therefore omitted from this analysis.

Nest Location

Military helicopter (OH-58 and UH-1) flights and intensive ground searches by foot and vehicle were utilized to document all existing raptor nests and to locate any new nests being constructed for the upcoming nesting season. The entire installation was searched as systematically as possible, using an extensive network of existing roads and trails in an effort to minimize nest searching by foot. Helicopter flights were designed to augment the ground effort, and were generally reserved for those areas and/or nests that were difficult to access because of safety considerations, poor road access, or frequent military activity. Impact areas or any other restricted sites were not excluded from this study, although frequent military exercises or safety considerations severely limited or prohibited ground access to a small percentage of these nests, particularly those in the "dud" areas of each impact area. As a general rule, dud areas are strictly off-limits to foot or vehicular traffic, and in some cases access from the air as well because of the high concentration of unexploded ordnance. Data collected for the relatively few nests in these areas were minimal and limited to observations that could be made from the air.

Field effort within years was most intensive prior to the leaf-out of the woody species as the visibility of many nests decreases rapidly once trees start to leaf. A small number of nests were discovered when individuals were inadvertently flushed from their perch or nest during the relatively low altitude helicopter flights en route to monitoring known nests.

Nests located from the air or the ground were recorded on 7.5 minute USGS Quadrangle Maps after being assigned a unique number. The three nests in the South Arbuckle Range Impact Area represent the only nests not ground-truthed. Nests located while searching on foot were immediately recorded on the appropriate USGS quad map. Each location was digitized into a Geographic Resource Analysis Support System (GRASS) site file maintained at USACERL. In 1992, two Global Positioning System (GPS) units were used to obtain satellite-derived location coordinates on approximately one third of the nest trees. The GPS data were used to check the accuracy of the nest locations previously recorded on the USGS quadrangle maps, to facilitate the spatial analyses, and to help future biologists unfamiliar with the terrain to find the nests. The two GPS PATHFINDER PROFESSIONAL units used have a published post-processing accuracy of 3 to 5 m (Trimbull Navigation Systems, Inc.) when used tandemly in the field.

Nest Tree and Site Characterization

Nest Tree

Each nest tree was identified to species, and several measurements (Table 1) including diameter at breast height (DBH), nest height (NH), and tree height (TH) were taken. Nest and tree height measurements were taken with a clinometer and DBH with a steel DBH tape. For those nests in which fledglings were banded, the nest heights were measured a second time using the rope used to lower each fledgling to the ground. This rope was marked in 1-ft increments and measurements were converted to meters before analyses. These rope measurements were used to validate the accuracy of the clinometer estimates, which were then found to fall within acceptable limits (± 1.5 m).

Table 1. Mean nest height (NH), tree height (TH), diameter at breast height (DBH), and number of nest supporting branches for each tree species.

	Nest Supporting Branches			Nest Tree		
	<5cm	5-10cm	>10cm	TH(m)	NH(m)	DBH(cm)
E. Cottonwood (61)*	0.9	1.7	1.2	20.2	13.9	80.8
Post oak (39)	1.3	2.0	1.3	13.0	9.1	50.7
Pecan (27)	0.9	1.7	1.4	19.2	13.2	67.5
American elm (24)	1.3	2.5	0.7	11.8	7.7	60.8
Shumard's oak (8)	0.7	1.2	2.0	17.1	15.7	69.7
Sugarberry (8)	1.5	2.0	1.3	13.2	9.8	52.9
Black walnut (6)	1.3	1.3	1.0	16.0	11.3	59.6
Red elm (6)	2.2	0.5	0.4	12.4	7.7	69.0
Bur oak (5)	2.1	1.1	1.2	18.3	12.8	57.5
Blackjack oak (5)	1.8	1.6	1.0	12.5	9.8	47.5
Hackberry (4)	1.4	2.0	0.8	14.0	9.1	39.8
Black willow (4)	1.3	1.2	1.0	12.5	9.1	37.0
Green ash (2)	1.0	3.0	1.0	17.0	11.7	66.5
Wooly buckthorn (2)	1.6	3.2	1.1	14.5	10.2	52.3
W. Soapberry (2)	0.5	3.0	0.5	8.2	6.1	31.3
Mean	1.3	1.9	1.1	16.0	10.9	63.1
SD	0.5	0.8	0.4	5.7	4.4	27.0

* All years have been pooled. Numbers in parenthesis indicate sample size.

The crown of each nest tree was classified into one of four categories (Spurr and Barnes 1980) to characterize the trees upper structure relative to adjacent trees in the immediate area. ***Dominant*** trees have crowns extending above the general level of the canopy and receive full light from above and high to moderate amounts from the sides. These trees are often the largest trees in the stand and generally have well developed crowns. ***Codominant*** trees have crowns forming the general level of the canopy and receive full light from above, but are more crowded on the sides. ***Intermediate*** trees are generally shorter than the other overstory trees and have crowns extending into the canopy formed by the preceding two groups. These crowns receive partial light from above and little from the sides. Finally, ***suppressed*** trees have crowns entirely below the general level of the canopy and receive no direct light from above or the sides.

The number and diameter of branches supporting each nest were recorded in addition to the other nest-tree variables. While viewing the nest from the ground, each supporting branch was placed in one of three arbitrarily derived size classes; 4 cm or less, 5 to 10 cm, and greater than 10 cm. Branch diameters were consistently placed into their correct categories by the author after just 2 or 3 hours of measuring practice. Whether the nest was constructed during the current nesting season or a previous one was based on a close inspection of the twigs at the nests base, and to a lesser degree on the overall size of the nest. This information was collected primarily to evaluate nest-survey efficacy, to estimate the number of new nests being built each year, and to estimate the longevity of a typical nest.

It was generally not possible to witness what species built each nest, but this information was recorded when possible. Heintzelman (1979) and Peterson (1979) found little or no evidence to indicate that GHOWs construct their own nests, and almost without exception found them occupying a nest that was constructed by a different species. A similar situation was believed to exist at Fort Sill (Orr, 10 December 1988). Based on this apparently inherent tendency for GHOWs not to construct their own nests, it was presumed that RTHAs constructed the great majority, if not all, of the stick-nests occupied by the GHOW each year.

Nest Site

Each nest site was characterized in terms of the plant community immediately surrounding it, density of woody species, distance to water, and military land-use. First, the determination of general habitat was made within GRASS by overlaying the nest location and plant community map layers. The six broad plant community types were identified by Kuchler (1964) and revised based on work performed by Johnson and others (1990), and are briefly described in Chapter 2 of this report. Slight changes in plant community boundaries have occurred since Kuchler (1964) originally published his highly generalized map (Johnson et al. 1990); habitat designations for several nest trees were subsequently changed after visual inspection in the field.

Secondly, a random subset of all occupied and unoccupied nests were characterized with regard to the woody species surrounding the nest tree via a 0.04 ha circular plot (11.3 m radius), with the nest tree constituting the plot center. In September 1990 and August 1991, a randomized subset (approximately 25 percent) of all nests existing as of this date were surveyed. Overstory trees within the plot were identified to species; DBH and tree height were also recorded using a steel DBH tape. All trees with one-half or more of their trunk within the plot were counted. All understory trees greater than 1 m in height were counted and placed into one of three arbitrarily-defined size classes based on their DBH (5 cm or less, 6 to 10 cm, and greater than 10 cm). Understory trees were not identified to species. Although standard sizes classes for woody variables have not been suggested, a number of researchers have found these and other woody overstory and understory variables to be important in raptor nest-site selection (Armstrong and Euler, 1982; Morris and Lemon, 1983; Titus and Mosher, 1981; Titus et al. 1986), and an increasing number advocate the use of standard 0.04 ha circular plots to allow comparison between different studies. Distance from the nest tree to a stream (Figure 3) or other source of water was measured via a 100 m tape or calculated within GRASS if it was over 100 m. Due to persistent military activity, the relatively few nests that fell within the North and South Arbuckle Ranges were excluded from this analysis.

Thirdly, each nest site was characterized in terms of its military land-use (Figure 1). Because many boundary delineations are largely arbitrary or politically-driven, all lands within each category were not assumed to be identical with respect to frequency or intensity of use, habitat homogeneity, composition, or structure. Rather, each land unit under the same category was, however, capable of supporting a similar set of military activities and missions. Boundaries of the military land-use areas (cantonment, impact, and maneuver) were provided by Fort Sill Directorate of Environmental Quality (DEQ) personnel via GRASS vector files and on 1:50,000 scale installation maps.

Cantonment Area

The Cantonment Area category includes the residential areas and most of the buildings housing troops, support staff, administrative offices, warehouses and other buildings used to support the installation's mission. Much of the Cantonment Area (east of Highway 277) is heavily populated and sustains a great deal of civilian/ military vehicle and pedestrian traffic.

The smaller no-fire zone on the northern border of the Cantonment Area (no-fire zone) differs in terms of the lack of residential housing and other support buildings and may seem more appropriately placed into the maneuver area category. However, since no artillery or live small arms fire originates from this area, and because of its close proximity to the Cantonment Area and a major interstate highway (the H.E. Baily Turnpike/I-277 parallels its eastern edge), the two areas were regarded as having similar military land use and were therefore combined. Total land base for this category is approximately 6,500 ha, or 17 percent of the installation.

Maneuver Areas

The Maneuver Area category consists of all the land not classified as impact or cantonment. Typical uses include bivouacking (military-style camping), off-road tracked and wheeled vehicle training, artillery and mortar firing from permanent or temporary locations, land navigation, and many other activities related to military training. The total land available for maneuvering and associated training exercises is approximately 18,923 ha, or 50 percent of the installation. The 105 mm Howitzer, 155 mm Howitzer, and Multiple Launch Rocket System (MLRS) units may fire from any location on or off-road from within the maneuver areas and impact area buffer zones into an impact area. Live small-arms and machine-gun fire is restricted primarily to ranges in the buffer safety zone on the perimeter of each impact area, with fire being directed towards the impact area. Off road driving by tracked and wheeled vehicles is permitted almost everywhere within the maneuver areas and impact area buffers. Bivouacking is most frequently conducted in the maneuver areas, followed distantly by some no-fire areas.

Impact Areas

The Impact Area category consists of four major impact areas plus their associated safety buffer zones, encompassing a total land area of approximately 12,250 ha, or 32 percent of the installation. Within each impact area is an especially hazardous zone called the "dud area." Dud areas receive concentrated fire or otherwise contain large quantities of unexploded and exploded munitions. Impact areas receive small arms and artillery fire throughout the year, which can occur during the day and/or night. Unlike the three other impact areas, Quanah Range (Figure 1) is jointly operated with the U.S. Air Force and is subjected to low altitude aircraft flights, aerial strafing, and bombardment training as often as 5 days per week. Impact areas also have a greater tendency to burn more frequently than the other land-use types because of the exploding rounds, machine gun fire, and the use of incendiary devices. Conversely, because of these same hazards, foot and vehicle traffic are considerably less intense in impact areas than in maneuver or cantonment areas. Lastly, while no artillery rounds are *supposed* to land within the Impact area buffer zones, they were included in this category because of their close proximity to the dud areas and the frequent small arms and artillery fire originating from within them.

Nest Monitoring

Raptor nests were checked for activity starting approximately in mid-January. As new nests were discovered, they were incorporated into the monitoring schedule. When monitoring from a vehicle or on foot, each nest was checked from a minimum of two angles to reduce the possibility of overlooking a bird sitting low in the nest. A pair was considered to be "occupying" a nest if eggs were known to have been laid, or birds exhibited incubation posture during two or more consecutive visits separated by a minimum of 7 days. It is acknowledged that not all birds exhibiting incubation posture lay eggs, but was presumed to avoid unnecessary disturbance to the adults as suggested by Steenhof and Kochert (1982). When monitoring occupied nests from a helicopter, the nests were approached and viewed tangentially and as high as possible above the nest and still see inside it to reduce disturbance to the bird(s).

The majority of the nests were monitored once every 7 to 14 days. For a significant number of the nests, however, military activities often interrupted this schedule. The net result was that a few nests were checked once or twice per week while others were checked once every 2 to 3 weeks. Each nest was checked regularly until full leaf-out, generally occurring in late April, then all nests not deemed occupied were omitted from the monitoring route for the remainder of the season. The nests of breeding pairs were monitored regularly throughout the nesting season until either the young fledged or the nest failed. A record for each occupied nest was maintained that included the dates the nest was checked, the type of activity observed, and any incidental notes (Figure 5).

Nest Failure, Success, and Productivity

Nesting success was defined in the study as a breeding pair that produced one or more fledglings; productivity was defined as the number of young fledged per successful nest. A "failed" nest was an occupied nest that either was destroyed, abandoned, or one where no viable eggs were laid, or where none of the nestlings survived. Unfortunately, it was difficult to check each nest during the critical period just prior to fledgling, and consequently many fledglings were not banded or observed leaving their nest. The average age at first flight for the RTHA and GHOW is 78 and 93 days respectively (Heintzelman 1979; Palmer 1988b).

FORT SILL RAPTOR NEST RECORD

NEST No. 562378 YEAR 19 89 Hunting Compartment Cantonment Chatto Flats Park

Species Red-tailed Hawk Location I-44 and Park

Month	Day	On	Remarks
January	28		Not on
February	12		Not on
February	25		Not on
March	3		Looks like R.T. on can not be sure
March	10		Not on
March	29	✓	
April	11	✓	
April	15	✓	
April	21	✓	
May	5		feeding young
May	26		Banded 2-young
June	3		Adult flew to nest
unable	to	see	nest because of foliage

No. of Egg or Young 2-young No. of Young Fledged unknown

Nest Tree Oak Height of Nest 71'11½" Used in past years Yes

by & year 1988 2-young fledged - RTHA

Nest Lining — Green Oak and Cottonwood Other

Young Band No.s 1207-25535 1207-25536

Notes Young were checked for bird nest screw worms - none found Snake scales and Squirrel Hair (Pellets removed for (CERL)

Figure 5. Sample raptor nest record.

Red-tailed Hawk and GHOW young were assumed to have fledged if they were observed at approximately 80 percent or more of their fledgling age (Steenhof and Kochert 1982), appeared healthy, and if a timely nest-site inspection after they were no longer observed in or near the nest revealed no evidence of predation or foul play. If all criteria were not satisfied, the nest was classified as "unknown" with regards to success and productivity. The *total* number of young fledged each year (Table 2),

Table 2. Total number of fledglings and the mean number per successful Red-tailed Hawk, Great Horned Owl, and Red-shouldered Hawk nest by year.

	RTHA		GHOW		RSHA	
YEAR	Total	#/nest	Total	#/nest	Total	#/nest
1987	40	2.00	3	1.51	0	—
1988	51	2.04	27	2.00	0	—
1989	8	1.75	2	2.02	2	2.00
1990	22	1.70	9	1.41	6	3.00
1991	23	1.91	4	1.53	0	—
1992	23	1.84	11	2.75	0	—
Grand Total	167.0	—	56.0	—	8.0	—
MEAN	27.8	1.87	9.3	1.82	1.3	2.7

therefore, was intended to be conservative as a fraction of the unknown nests would likely be successful. In contrast, the observed productivity and success *rates* could more closely reflect the true values, as there was no *a priori* knowledge that either rate for the unknown nests would differ significantly than that for the known nests.

Raptor Banding and Food Habit Observations

Young raptors were banded with U.S. Fish and Wildlife Service (USFWS) bands prior to fledgling. As each fledgling was banded, it was checked for the presence of screw-worm larvae. Myiasis caused by larval infestations has been documented in red-tailed and red-shouldered hawks in some northern areas of the great plains (Tirrell, 1978) and Midwest (Peterson, 1979). While not known to be a significant problem in Oklahoma, these larvae can result in reduced fitness and contribute towards increased fledgling mortality (Tirrell, 1978; Orr and Tirrell, 1988).

During the short time the young raptors were being banded, observations were recorded of any prey items found in the nest (Table 3). Any prey items deposited during the current nesting season were recorded. Biomass of prey consumed was not estimated. Furthermore, these observations tended to be biased toward avian and larger mammalian prey species that are not consumed whole, and as such are likely to leave evidence of their existence (e.g., bones, scales, feathers, hair). Table 3 does not constitute a comprehensive food habits list, but does serve to document some of the food items consumed by the young during a critical period in their development.

Table 3. Frequency of occurrence (%) of prey items found in occupied nests at the time young were banded (based on 165 nest inspections, one per nest).

Prey Item	1987	1988	1989	1990	1991	1992	Mean
Rabbit	57.8	76.7	33.3	50.0	66.7	50.0	61.4
Snake	10.5	40.0	66.7	75.0	50.0	33.3	42.2
Squirrel	21.0	33.3	33.3	43.4	16.7	50.0	32.5
Misc. rodent	36.8	23.3	16.7	25.0	16.7	66.7	28.9
Bird	15.8	10.0	16.7	25.0	16.7	33.3	16.9
Misc. reptile	5.3	3.3	—	—	—	—	2.4
Prairie dog	5.3	—	—	—	—	—	1.2
Crayfish	—	3.3	—	—	—	16.7	2.4
Eastern mole	5.3	—	—	—	—	—	1.2

4 Data Analyses

Statistical Considerations

Differences in nest detectability of the raptor species, periodic access restrictions in many training areas, and inherently small sample sizes expected for several of the species thus dictated that any *a priori* statistical analyses be simple, based on few assumptions, emphasize descriptive statistics (e.g., mean, range, and standard deviation) over tests of significance. Chi-square analyses were employed to test for nest abundance *X* military land-use and nest abundance *X* habitat interactions at the 0.05 significance level. The interactions between land-use and habitat on nest success and productivity were not tested because of the relatively high number of nests for which success or failure could not be conclusively determined (42 percent). All statistical analyses were performed using SYSTAT Version 5.02 for Windows (SYSTAT Inc., 1990-1993). Nest site locations and subsequent spatial analyses and graphic displays were performed within GRASS, a geographic information system developed at USACERL (USACERL, 1993).

Nest Distribution and Abundance

Distributions of occupied nests over the installation were considered with respect to vegetative habitat and military land use. These categories were intended to be broad in scope to maximize sample size within each group. The distribution of breeding pairs within the East Cache Creek drainage was also examined based on intraspecific (RTHA-RTHA or GHOW-GHOW) and interspecific (RTHA-GHOW, RTHA-RSHA, and RSHA-GHOW) juxtaposition of the occupied nests.

The relationships between nest distributions, plant community, and military land-use were analyzed using the Chi-Square test at the 0.05 significance level. Because GHOWs do not construct their own nests on Fort Sill, expected Chi Square values were based on the number of available nest structures, while RTHA and RSHA expected values were based on land area availability (plant community/military land use type). The null hypotheses were that there was no significant interaction between nest distribution and military land-use or nest distribution and plant community. Additive effects of land use *and* plant community on nest distribution could not be evaluated due to expectedly low sample sizes within subgroups. Evaluating nest distribution with regards to military land-use was an attempt to quantify a broadly defined but potentially significant variable, the data being suggestive rather than conclusive. When appropriate, all years were pooled to increase sample sizes. Barred Owl and NOHA were excluded from all Chi-Square analyses due to small sample sizes and the *a priori* knowledge that the majority of their nests would remain undetected.

Minimum overall nest density was calculated as the number of square kilometers per nesting pair, with 382 km^2 being the total available area. Minimum density is presumed because it is unlikely 100 percent of the nests were discovered each year, or that 100 percent of the area is actually available. Some researchers (e.g., Andersen 1984), however, advocate that estimates of nesting density should consider only the acreage of available nesting habitat and not simply the total study area. Exactly what percentage of Fort Sill constitutes available nesting habitat for each species was not determined, nor is it likely these determinations would be completely objective or without controversy. Regardless, to view the results of this study in a similar context as those from other regions, densities *within-habitats* were also determined based on the estimated area of each habitat as calculated within GRASS (USACERL 1993).

Nest Tree and Site Characterization

No attempt was made to compare the woody under- and overstory variables between years, rather, multiyear nest site data collected on the 0.04 ha circular plots were pooled to increase sample size in the analyses and generate mean values. Mean values were then used to characterize the "typical" nest tree and site for each species. Analyses pertaining to military land use were performed from pooled data in a similar effort to offset the small sample sizes occurring within 1 or more years.

In most cases the actual construction of each nest was not observed. Red-tailed Hawks have nested in the greatest numbers on Fort Sill during each year of the study, and are often known to build alternative nests early in the nesting season (Palmer 1988b). Because GHOWs are not known to build their own nests on Fort Sill (Orr, 10 December 1988), it is probable and was therefore assumed that RTHAs constructed the overwhelming majority of nests used by the GHOW.

Finally, Forrest Johnson and others (1990) listed tree species and their densities for characteristic stands of Elm-Ash and Cross Timbers forest types. Relative frequencies were then calculated from their tree density figures to produce Tables 4 and 5. Based on the assumption that their findings accurately reflect stand overstory and composition in the majority of these habitat types on Fort Sill, conclusions were drawn regarding nest-tree preferences within a stand.

Table 4. Overstory tree frequency (%) within Elm-Ash plant communities and nest-tree selection by breeding raptors.

Tree Species*	Tree Frequency	Nest Frequency	Observed Difference
Sugarberry	30.3	2.6	-27.7
Soapberry	17.3	0.9	-16.4
Boxelder	16.1	0.0	-16.1
American elm	12.8	10.2	-2.6
Shumard's oak	7.0	8.9	+1.9
Bur oak	5.7	2.4	-3.3
Pecan	3.3	23.6	+20.3
Red mulberry	2.2	0.0	-2.2
Big-tree plum	1.6	0.0	-1.6
Black walnut	1.2	4.9	+3.7
Red [Green] ash	0.8	0.0	-0.8
Eastern cottonwood	0.8	44.5	+43.7
Wooly buckthorn	0.4	0.9	+0.5
American redbud	0.4	0.0	-0.4

* Raptor species and years have been combined. Tree frequencies based on Johnson et al. (1990).

Table 5. Overstory tree frequency (%) within Cross Timbers plant communities and nest-tree selection by breeding raptors (raptor species and years have been combined).

	Tree Frequency*	Nest Frequency	Observed Difference
Blackjack oak	56.5	9.9	-46.6
Post-oak	43.3	85.9	+42.6
Netleaf hackberry	0.2	4.2	+4.0

* Tree frequencies based on Johnson et. al (1990).

5 Results

Nesting Chronology

The first nesting attempts each year were invariably made by GHOWs (Figure 6), with one individual exhibiting incubation posture as early as 10 January (Figure B7, nest #65). While some overlap did occur, as a general rule RTHAs began laying eggs 4 to 6 weeks after the GHOWs. Some fluctuation in nesting dates occurred, but Figure 6 shows that the general pattern at Fort Sill remained consistent over the entire study period. Great Horned Owls generally laid eggs from mid-January through mid-February and red-tails in early February through early March. Fledging occurred most frequently for the GHOW in mid-April to mid-May (mean=17 April), and in May through early June for the RTHAs (mean=10 May). Nesting occurred relatively late in 1989 for both species, probably in response to unusually persistent cold weather relative to the other 5 years. Conversely, 1987 was the mildest winter relative to the other five and nesting occurred relatively early. Fledging was usually completed for RTHAs and GHOWs by 15 June in all years, and often by 1 June. An artifact of consistently small sample sizes each year (n=0 to 3), determining nest occupancy for the RSHAs, BAOWs, and other documented species had questionable quantitative value and were therefore omitted from Figure 6. The limited data shows that RSHAs tended to initiate nest occupancy concurrently or slightly later than the average RTHA while BAOWs were intermediate between the GHOWs and RTHAs.

Nest Distribution, Tree and Site Characterization

General

Overall nesting activity during the study period appeared to be bimodal. Thirty-four occupied nests were documented in 1987 (Table 6) followed by the first peak in 1988 (n=66). There was a dramatic decline to just 23 occupied nests in 1989. Overall nest abundance gradually increased in 1990 and 1991 to the second peak of 60 in 1992. A noticeable decline in overall nest abundance was perceived in 1993 (Samuel J. Orr, Staff Photographer, U.S. Field Artillery Center and Fort Sill, Fort Sill, OK, professional discussion, 8 August 1993), but quantitative corroboration was not available due to the studies' termination.

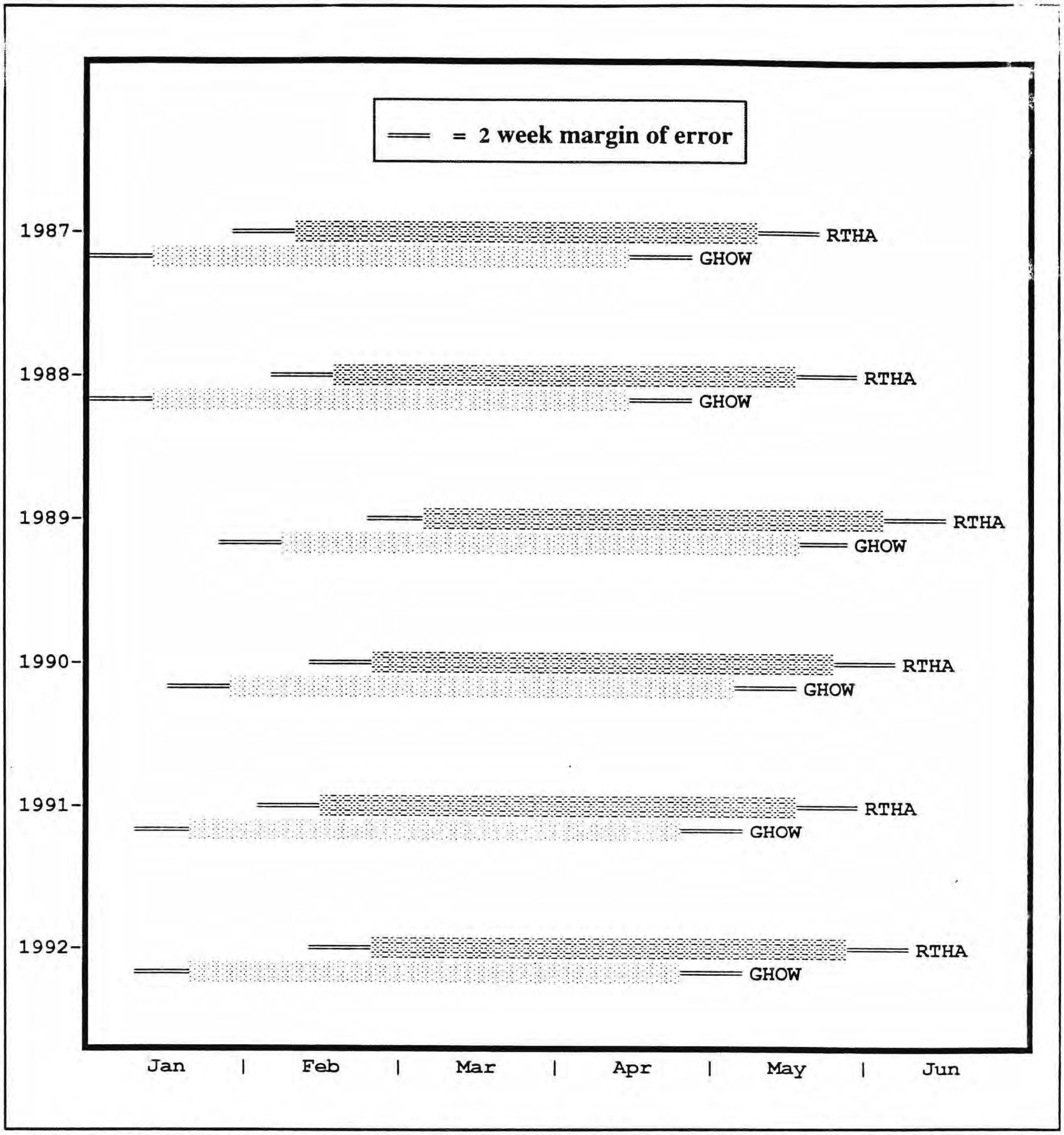


Figure 6. Periods of nest occupancy for the Red-tailed Hawk and Great Horned Owl based on annual means with a 2-week margin of error added to each end.

Table 6. Total number of occupied raptor nests recorded by year.

	1987	1988	1989	1990	1991*	1992	Total
Red-tailed Hawk	31	42	14	24	36	44	191
Great Horned Owl	2	24	8	15	16	11	76
Red-shouldered Hawk	0	0	1	3	0	3	7
Barred Owl	1	0	0	1	1	2	5
Northern Harrier	0	0	0	0	2	0	2
Total	34	66	23	43	55	60	281

* One more pair of Red-shouldered hawks were believed to have nested in 1991, but none were confirmed.

Figure 7 shows the locations of all 217 occupied and unoccupied raptor nests located during the 6-year study. Two species comprised the great majority (95 percent) of the occupied nests (Table 6). Red-tailed Hawks (Figures B1 to B6) and GHOWs (Figures B7 to B12) comprised 68 and 27 percent of the breeding pairs respectively. Red-shouldered Hawks (Figure B13), BAOWs (Figure B14), and NOHAs made up the remaining 5 percent of the total. And although they are probably not as abundant in terms of breeding pairs as the RTHA, it is strongly believed that BAOWs and NOHAs nested in significantly greater numbers than were documented. Additionally, two NOHA, four AMKE, and one Swainson's Hawk nest were found in the year (1986) prior to the study, and are mentioned in this report for informational purposes only.

Of the 217 recorded nests, 73 percent (n=158) were occupied by breeding pairs in 1 or more years with the remaining 27 percent (n=59) not known to have been occupied during the study (Appendix A). Military land-use and plant community were both found to influence overall nest distributions. Combining all occupied RTHA, RSHA, and GHOW nests, overall distribution was statistically significant with respect to military land-use ($X^2=10.0$; df=4, p=0.05), and highly significant with respect to plant community ($X^2=334.6$; df=10, $p \leq 0.005$). However, after combining occupied and unoccupied nests, observed values closely approximating expected values for the maneuver areas (52.1 vs. 50 percent), impact areas (34.1 vs. 32 percent) and the Cantonment/no-fire areas (13.7 vs. 17 percent), resulting in statistical *non*significance ($X^2=12.2$; df=6). By contrast, combining occupied and unoccupied nests with respect to distribution among plant communities still resulted in a highly significant outcome ($X^2=376.8$; df=15, $p \leq 0.005$). The average distance between each occupied nest and the closest occupied nest of a different species was not found to be strongly correlated (r=0.20) with overall nesting density, at least within the East Cache Creek watershed (Figure 8).

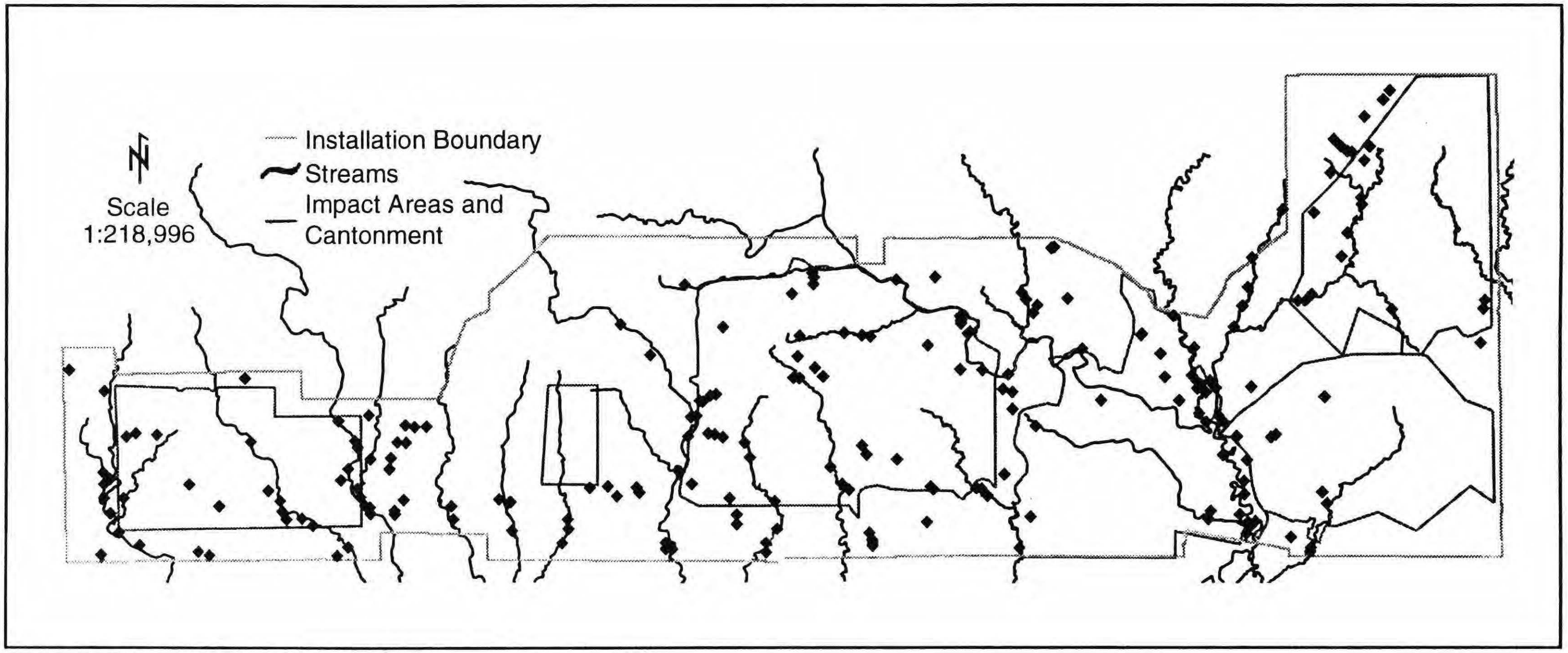


Figure 7. All recorded nests, 1987 to 1992.

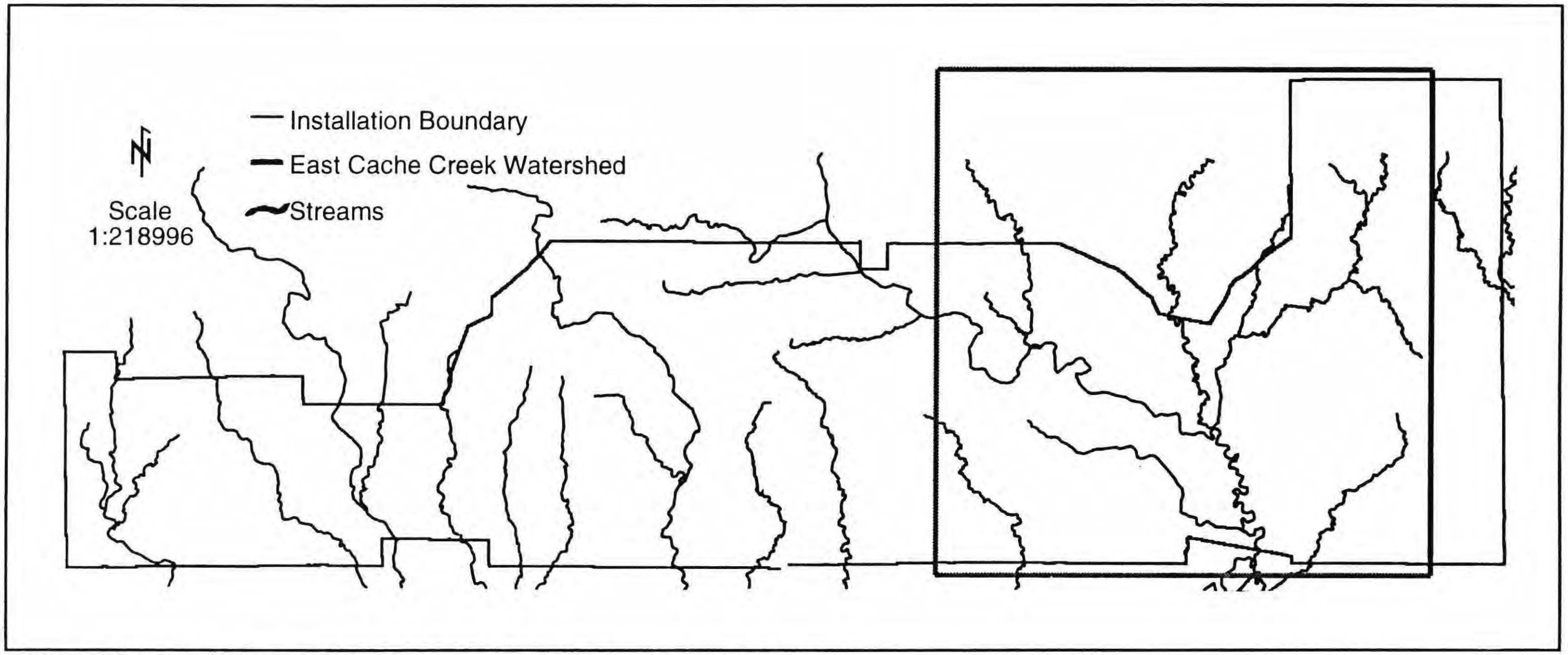


Figure 8. Approximate delineation of the East Cache Creek watershed of Fort Sill.

Approximately 8 to 15 percent of the nests identified each year had not been recorded in the previous year(s). Conversely, each year 10 to 16 percent of the nests blew down or simply degraded to a point where they were unusable. The number of newly constructed or previously unknown nests each year often approximated or slightly exceeded the number of nests lost, resulting in a remarkably consistent number of available nests annually (n=141 to 160). Of the previously unknown nests, 60 to 75 percent appeared to be constructed in the year they were detected. In other words, the majority of the new nests discovered probably were not overlooked in the previous nesting season, but were in fact "new" nests. An average of 30 percent of the available nests were occupied annually, but varied considerably from 13 to 41 percent (Table 7).

Thirty-three species of native trees are known to occur on Fort Sill (Johnson et al. 1990), of which 15 (45 percent) were used as nest trees during the study. No nests were constructed in the six or so introduced tree species occurring on the installation, which generally were planted as ornamentals within the Cantonment Area. Cottonwood, post oak, pecan, and elm (American and red) held nearly 75 percent of the 203 documented nests (Table 8). The remaining 25 percent of the nests were distributed among 10 other tree species. The overwhelming majority (96 percent) of nest trees had crowns classified as dominant (48.2 percent) or codominant (47.6 percent). The remaining 4.2 percent of the nest trees had intermediate crowns, which were not strongly associated with any one tree species. None of the nests were in trees with suppressed crowns, which in the circular plot analyses were regarded as an understory component. The various crown categories are defined by Spur and Barnes (1980) and have been provided in the methods section of this report.

Nest tree selection was quantified in the previous paragraph, but to make inferences about preference, it is necessary to know how abundant each tree species is relative to each other. Johnson and others (1990) estimated the density of the dominant overstory species within the two most common forest types on Fort Sill. Table 4 clearly indicates that many of the overstory tree species found in Elm-Ash forest are not being selected as nest trees in proportion to their abundance. Pecan and cottonwood in particular were being nested-in in proportions greatly exceeding their relative

Table 7. Total number of available nests and the percentage occupied.

	1987	1988	1989	1990	1991	1992	Mean
Nest total*	141.0	160.0	155.0	156.0	155.0	147.0	153.0
No. occupied	33.0	66.0	23.0	43.0	53.0	60.0	47.0
% occupied	23.2	40.6	13.0	27.6	37.5	39.5	30.3

* Raptor species combined excluding northern harrier nests.

Table 8. Percentages of occupied and unoccupied nests by tree species.

	RTHA* (*n*=178)	GHOW (*n*=72)	RSHA (*n*=7)	BAOW (*n*=4)	Unoccupied (*n*=51)
E. Cottonwood	47.8	25.0	—	25.0	19.6
Post oak	13.5	31.9	14.3	25.0	23.5
Pecan	13.5	8.3	14.3	—	15.7
American elm	7.9	15.3	—	50.0	11.8
Shumard's oak	4.5	—	28.6	—	5.9
Sugarberry	1.1	4.2	14.3	—	2.0
Black walnut	2.8	6.9	—	—	—
Red elm	—	1.4	—	—	7.8
Bur oak	1.1	2.8	28.6	—	—
Blackjack oak	1.1	1.4	—	—	7.9
Hackberry	1.1	1.4	—	—	—
Black willow	2.8	—	—	—	—
Green ash	1.7	1.4	—	—	—
Wooly buckthorn	—	—	—	—	3.9
W. Soapberry	1.1	—	—	—	2.0
Total (%)	100.0	100.0	100.0	100.0	100.0

* RTHA = Red-tailed Hawks; GHOW = Great Horned Owls; RSA = Red-shouldered Hawks; BAOW = Barred.

abundance while the reverse was true for sugarberry, western soapberry, and box elder. American elm, bur oak, red mulberry, big-tree plum, green ash, American redbud, Shumard's oak, black walnut, and woolly buckthorn were nested in proportions approximating what would be expected if tree selection was random.

The average raptor nest was supported by 4.2 branches (Table 1), the majority of which tended to be in the 5 to 10 cm size class. Occupied nests were found to be supported by a similar number of branches as were the unoccupied nests (4.2 vs. 4.0 respectively). Somewhat unexpectedly, when considering all nests irrespective of occupancy status or species of tree, the number of nest supporting branches was a weak predictor of nest longevity ($r=0.49$, $df=1$).

Nest height was strongly correlated with tree height ($r=0.91$; Table 9) when considering all nests irrespective of species. Nest height was also positively correlated with Diameter at Breast Height (DBH) but to a much lesser degree ($r=0.67$), suggesting tree height as a more reliable predictor of nest height. As a general rule,

Table 9. Mean nest height (NH), tree height(TH), and relative nest height (RNH) of raptor nests.

	NH (m)			TH (m)			RNH (%)		
	MEAN		SD	MEAN		SD	MEAN		SD
RTHA	14.1	±	4.6	19.8	±	5.6	73.2	±	15.1
GHOW	10.7	±	4.0	15.9	±	4.9	67.3	±	13.5
RSHA	13.8	±	3.2	20.9	±	3.4	65.6	±	11.2
Unoc.	9.5	±	2.7	13.8	±	4.0	70.0	±	9.2

cottonwood were the largest nest trees both in height and especially DBH (Table 1). Pecan, bur oak, and Shumard's oak followed (in descending order) behind cottonwood in overall size. As intuitively expected, mean nest height in cottonwood exceeded that for the other species with only one exception. Nests in Shumard's oaks were actually higher than those in cottonwood by 1.8 m, although this difference could simply be a consequence of the relatively small sample size associated with Shumard's oak (n=8). Species-specific results regarding nest site variables and nest distribution follow.

Species-Specific

Red-tailed Hawk. Chi-Square analysis indicated a highly significant ($p<0.005$) interaction between nest distribution and plant community type (Table 10). Red-tailed hawks were strongly associated with Elm-Ash forest (55 percent of the nests), especially those stands associated with East Cache Creek drainage. The combined percentage of nests in the Cross Timbers and Mesquite Savanna types totaled less than one-half of those in Elm-Ash forest. Relatively few nests were documented within the eastern one-fourth of Fort Sill. This area is primarily Bluestem Prairie with any

Table 10. Chi-square Goodness of Fit analysis of the relationship between plant community and nest distribution.

Plant Community[ab]	BGP		BP		MS		OS		CT		EA		X^{2c}
RTHA	17	(42)	19	(55)	30	(42)	0	(8)	19	(17)	105	(27)	281.1**
GHOW[d]	6	(6)	10	(21)	16	(16)	0	(2)	19	(5)	24	(10)	11.5*
RSHA	0	(1)	0	(2)	0	(1)	0	(1)	0	(1)	7	(1)	42.0**
Unocc.	4	(12)	4	(16)	16	(12)	0	(2)	8	(4)	21	(8)	42.2**

[a] Habitat Symbols: BGP=Bluestem-Grama Prairie; BP=Bluestem Prairie; MS=Mesquite Savanna; OS=Oak Savanna; CT=Cross Timbers; EA=Elm-Ash forest.
[b] Numbers in parentheses are expected values, based on the percentage of Fort Sill's land base classified as each plant community type.
[c] X^2 Symbols: $^*p\leq0.05$, $^{**}p\leq0.005$; d.f.=5.
[d] GHOW expected values based on the percentage of avaliable nests in each land use type each year.

potential nest trees restricted to the relatively few pseudo-riparian intrusions associated with the intermittent creeks and shallow drainages. These sites are typically dominated by cottonwood and support few trees large enough for suitable nesting. Not surprisingly, all but two of the occupied RTHA nests east of East Cache Creek were in cottonwood (n=21).

Elm-Ash forest was the most densely occupied plant community in each of the 6 years, with a mean *within-habitat* density of one nest per 3.3 km^2 (Table 11). Red-tailed Hawk density within Elm-Ash forest was the least variable (SD=1.6 km^2) of the plant community types. Nest density was the most variable within Mesquite Savanna, the standard deviation nearly approaching the mean (27.0 vs 29.1 km^2). Red-tailed Hawk nesting-use of the Cross Timbers plant community was consistently high as well, with a mean density of one pair per 10.5 km^2. No RTHA nests were located within the Oak Savanna habitat type. Combining all years and habitats the mean *overall* RTHA density was one pair per 11.9 km^2.

Chi-Square analysis revealed a nonsignificant (X^2=3.7; df=2) interaction between RTHA nest distribution and military land-use (Table 12). Red-tailed Hawks nested within the Cantonment Area, impact areas, and maneuver areas in frequencies closely approximating what would be expected in a random distribution. The average distance between adjacent RTHA nests within the East Cache Creek watershed (Figure 8) was 1558 m (± 1069), but some pairs were found to nest as close as 112 m (Table 13). Mean distances between RTHA nests were found to be strongly correlated with RTHA density (r=-0.85). The average distance between RTHA and another species (GHOW or RSHA) was noticeably less (Mean=1199 ± 1093 m), with the shortest distance being 85 m.

Table 11. Overall and within-habitat Red-tailed Hawk nest densities (km^2 per pair).

	BGP[a]	BP	MS	OS	CT	EA	Overall[b]
1987 (n=31)	25.7	20.6	19.8	—	26.0	2.8	12.3
1988 (n=42)	19.3	17.2	7.9	—	6.5	2.8	9.1
1989 (n=14)	77.0	—	39.5	—	8.7	6.4	27.3
1990 (n=24)	77.0	51.5	79.0	—	6.5	3.6	15.9
1991 (n=36)	19.3	34.3	19.8	—	6.4	2.4	10.6
1992 (n=44)	38.5	34.3	8.8	—	8.7	2.0	8.7
MEAN (n=32)	42.8	26.3	29.1	—	10.5	3.3	11.9
SD	27.4	17.8	27.0	—	7.7	1.6	7.0

[a] Bluestem-Grama Prairie (BGP); Bluestem Prairie (BP); Mesquite Savanna (MS); Oak Savanna (OS); Cross Timbers (CT) and Elm-Ash forest (EA).
[b] Overall density based upon the estimated total area of Fort Sill (382 km^2).

Table 12. Chi-square Goodness of Fit analysis of the relationship between military land-use and nest distribution.

	Military Land-Use Type[a]						X^{2b}	d.f
	Cantonment		Impact		Maneuver			
RTHA	37	(33)	49	(61)	105	(96)	3.7	2
GHOW[c]	4	(7)	37	(30)	35	(39)	3.3	2
RSHA	1	(1)	0	(2)	6	(4)	3.0	2
Unocc.	4	(5)	25	(19)	27	(29)	2.2	2

[a] Numbers in parentheses are expected values, based on the percentage of Fort Sill's land base classified as each land-use type.
[b] All values are nonsignificant at the $p \leq 0.05$ level.
[c] GHOW expected values based on percentage of available nests in each land use type each year.

Table 13. Mean distance (m) between each occupied nest and the nest of its nearest conspecific neighbor within the East Cache Creek Watershed.

Year[*]	RTHA-RTHA (*n*=110)	GHOW-GHOW (*n*=26)	RTHA-GHOW-RSHA-RTHA (*n*=39)
1987	1341 ± 742	—	—
1988	1402 ± 501	2663 ± 2811	685 ± 997
1989	2693 ± 2065	—	2739 ± 2081
1990	1662 ± 1095	2931 ± 1146	1495 ± 1028
1991	1718 ± 1247	4436 ± 2983	1141 ± 1202
1992	1220 ± 649	4094 ± 2960	615 ± 366
Mean	1558 ± 1069	4303 ± 3530	1199 ± 1093
Range	112 - 6270	715 - 13162	85 - 4200

[*]Sample sizes of three or fewer occupied nests in any one year were omitted.

Mean nest height and tree height were 14.1 and 19.8 m respectively (Table 9). The average RTHA nest was situated higher in the trees crown (RNH=73.2 percent ± 15.1) when compared to the other species (Table 9). Nest tree selection was strongly skewed towards a relatively few tree species. Nearly one-half (47.8 percent) of the RTHA nests were in cottonwood (Table 8). Post oak and pecan were nested in equally (13.5 percent), but substantially less often when compared to cottonwood. Overall, cottonwood, post oak and pecan held nearly 75 percent of all RTHA nests. The remaining 25 percent of the nests were distributed among 10 tree species, with no species comprising more than 8 percent of the total. Sam Orr (S. J. Orr, Supervisory Photographer, U.S. Army Field Artillery Center and Fort Sill, Fort Sill, OK, telephone conversation, 2 February 1992 [hereafter referred to as "Orr, 2 February 1992"]) reported one possible case of a RTHA nesting in a mesquite tree. The nest was reported to have been located in a shallow drainage just east of the south Cantonment Area. Unfortunately, evidence corroborating this report was not found in spite of several intensive ground searches.

All stick-nests constructed by RTHAs were located in trees with just one known exception. In 1988, a pair built a nest in a power line tower along Deer Creek, just south of Medicine Park (Figure B3, nest #79). This nest failed when it blew out because of high winds and was not rebuilt. No other RTHA nests were constructed in power line towers or any other man-made structures during the study. One hundred and four (54.4 percent) of the 191 RTHA-occupied nests were located in the maneuver areas, 49 in the impact areas (25.7 percent), and 37 (19.4 percent) in the cantonment/no-fire areas (Table 12). The mean distance from a RTHA nest to a stream or pond was 160 m ± 189 and was intermediate with respect to the GHOW and RSHA (Table 14). Red-tailed Hawks re-occupied nests from 1 to 6 years (Table 15). While a majority (59 percent) were occupied for just one nesting season, a significant percentage (17 percent) of RTHAs continued to use the same nests for 3 to 6 years.

Selected understory and overstory structural variables were collected on a random subset of 45 RTHA nests (40 percent of all occupied RTHA nests; Table 16) via circular plots. Mean DBH and tree height of the overstory trees in the plot were 51.9 cm and 14.1 m respectively. The mean nest tree DBH and height were 72.5 cm and 17.9 m respectively. Thus, those RTHA pairs that are constructing nests with the intent of occupying them tended to select the larger trees within the stand that exhibit a limb structure capable of supporting a relatively large nest. Red-tailed Hawk plots had the highest understory stem densities when compared to GHOWs and the unoccupied nests. Mean understory tree density was 2770, 154, and 42 stems/ha for the 1 to 4, 5 to 9, and greater than 10 cm size classes respectively. Mean species richness for the overstory trees was 2.2 with a mean density of 138 trees per hectare. The density of both under and overstory trees in the immediate nest sites were higher than that exhibited by GHOWs and in the unoccupied nests, and is a reflection of the greater tree density and diversity typical of Elm-Ash forest.

Table 14. Mean distances of raptor nests from a stream or pond (includes intermittent streams; all years combined).

	RSHA	RTHA	GHOW	Unoccupied
No. nests	6	131	66	48
Minimum (m)	10	0	1	1
Maximum (m)	148	700	950	1350
Mean/SD (m)	53 ± 51	160 ± 189	204 ± 240	216 ± 285

Table 15. Percentage of nests that were occupied in 1 or more years by the same species (excluding nests constructed in 1992).

	RTHA (*n*=107)	GHOW (*n*=54)	RSHA (*n*=6)	Mean
1 year	58.9	68.5	100.0	75.8
2 years	24.3	27.8	0.0	17.4
3 years	12.2	3.7	0.0	5.3
4 years	0.9	0.0	0.0	0.3
5 years	2.8	0.0	0.0	0.9
6 years	0.9	0.0	0.0	0.3
	100.00	100.00	100.00	100.00

Table 16. Circular plot data summary for occupied and unoccupied nests.

	NestTree[a]		Overstory[b]				Understory[c]		
	TH (m)	DBH (cm)	DBH	XTH	Trees	Species	<5	5-10	>10
RTHA (*n*=45)	17.9	72.5	51.9	14.1	138.0	2.2	2770	154	42
GHOW (*n*=20)	16.4	61.9	50.2	14.2	111.3	1.9	2090	119	41
RSHA (*n*=3)	18.9	46.3	38.0	14.7	125.0	3.0	2475	25	8
Unoc. (*n*=22)	14.6	55.6	47.7	13.0	102.3	2.0	700	44	15

[a] Nest Tree variables: Mean diameter at breast height (DBH); Tree height(TH).
[b] Overstory variables: Mean DBH for the overstory trees (XDBH); Mean tree height for the overstory trees (XTH); number of trees per hectare (TREES); number of tree species present (SPECIES).
[c] Number of trees/ha for three size classes (1-4, 5-9, and >10 cm DBH).

Great Horned Owl. While never as abundant as RTHAs, GHOWs exhibited a parallel trend in nesting abundance during the first 5 years, deviating only slightly from RTHAs in the sixth year (Table 6). Great Horned Owl density in 1992 dropped somewhat whereas RTHAs continued to increase slightly. GHOW nesting activity was greatest in 1988 with 24 breeding pairs documented, resulting in an *overall* nest density of one nest per 15.9 km^2 (Table 17). Nesting GHOWs, unlike RTHAs, did not show a strong preference for Elm-Ash forest, nor did they appear to avoid it. Nest density within the Cross Timber community consistently exceeded that found within Elm-Ash forest (14.0 vs. 19.8 km^2 per pair). Mean *within-habitat* nest density ranged

Table 17. Overall and within-habitat Great Horned Owl nest densities (km^2 per pair).

	BGP[a]	BP	MS	OS	CT	EA	Overall[b]
1987 (n=*2*)	—	103.0	—	—	26.0	—	191.0
1988 (n=*24*)	38.5	34.3	19.8	—	9.2	5.1	15.9
1989 (n=*8*)	—	—	19.8	—	8.7	51.0	47.8
1990 (n=*15*)	38.5	34.3	39.5	—	21.8	10.2	25.5
1991 (n=*16*)	—	51.5	26.3	—	5.2	7.3	23.9
1992 (n=*11*)	38.5	103.0	26.3	—	13.0	25.5	34.7
MEAN (n=*13*)	38.5	65.2	26.3	—	14.0	19.8	30.1
SD	0.0	35.2	8.0	—	8.2	19.2	66.8

[a] Bluestem—Grama Prairie (BGP); Bluestem Prairie (BP); Mesquite Savanna (MS); Oak Savanna (OS); Cross Timbers (CT) and Elm-Ash forest (EA).
[b] Overall density based upon the etimated total area of Fort Sill (382 km^2).

from a high of one nest per 14.0 km^2 in Cross timbers to the low of one nest per 65.2 km^2 in Bluestem Prairie.

Chi-Square analysis revealed an overall nonsignificant (X^2=3.3; df=2) interaction between GHOW nest distribution and military land-use (Table 12). In contrast to the RTHA and RSHA, expected values for the GHOW were based on the proportion of *available nests* in each land use type, and not on *total area* of each land use type. The Cantonment Area was nested in the least with regards to the three land-use categories, with just 5 percent (*n*=4) of GHOW-occupied nests occurring there. Impact areas were nested in somewhat more frequently than would be expected based on nest availability (49 percent; *n*=37), and maneuver areas were nested in proportions closely approximating what would be expected in a random distribution (46 percent; *n*=35).

Table 10 shows that GHOW nest distribution with respect to habitat was significant (X^2=11.5; df=5, $p \leq 0.05$). Expected values for the GHOW were based on the proportion of *available nests* in each plant community type, and not on *total area* occupied by each community. Great Horned Owls selected nests in the two grassland habitats approximating what would be expected based on nest availability in those communities, and in the oak and mesquite savannah communities in numbers less than would be expected. Great Horned Owls nested in Elm-Ash forest less often than expected, and nested in Cross Timbers habitat nearly twice as often as expected. Annually, however, GHOW nest distribution over the installation tended to be relatively even (spatially) when compared to RTHAs, with no one habitat type or drainage appearing to support a disproportionally high number of nesting pairs.

Annual distance between adjacent GHOW nests in the East Cache Creek watershed averaged 4303 m (± 3530), a distance approximately three times greater than the average RTHA-RTHA distance during the same period (Table 13). Great Horned Owls were not known to nest any closer to a conspecific than 715 m, and in general, intraspecific nest distance was weakly correlated with overall GHOW nest density within the watershed (r=+0.20).

Mean nest height and tree height were 10.7 and 15.9 m respectively (Table 9). The average GHOW-occupied nest was in a shorter (16.4 vs. 17.9 m) and smaller (61.9 vs. 72.5 cm) tree than that occupied by the average RTHA or RSHA. The relatively high frequency of nest trees on upland sites is largely responsible for the lower tree and nest heights, as trees on the drier sites generally do not grow as tall as those closer to the drainages or adjacent to streams. The average GHOW-occupied nest was slightly lower in the trees crown (RNH=67.3 percent ± 13.5; Table 9) than the average RTHA, and slightly higher than for RSHAs.

Table 8 shows that nearly 32 percent of the GHOW nests were in post oak, followed by cottonwood (25 percent), American elm (15.3 percent) and pecan (8.3 percent). Within the preferred Cross Timbers habitat, GHOW nest-tree selection was strongly skewed towards post oak over the more abundant but smaller blackjack oak (Table 5). Because GHOWs do not construct their own nests, the apparent avoidance of blackjack oak may be more appropriately attributed to the nest building species (RTHA). Seven tree species held approximately 20 percent of the remaining nests, with no one species comprising more than 7 percent of this total. No GHOWs were known to have nested on the ground or in any manmade structures over the course of the study, although it was possible.

Thirty-five percent of the 57 GHOW nest trees were characterized with regard to woody understory and overstory variables. Great Horned Owls occupied nest sites lower in overstory species richness, and were often less dense with respect to the understory and overstory trees surrounding the tree than for RTHAs (Table 16). Mean DBH and tree height of the overstory trees in the plot were 50.2 cm and 14.2 m, respectively. The mean nest-tree DBH and height were 61.9 cm and 16.4 m, respectively. Expectedly, GHOWs also occupied nests in trees that were taller and bigger (DBH) than adjacent trees since the majority if not all of the GHOW-occupied nests were initially constructed by RTHAs.

Great Horned Owls were more likely to occupy a nest that was relatively farther from a stream or pond than the other species (Mean=204 m; Table 14). This mean distance exceeds that of RTHA by just 38 m, but was nearly four times that exhibited by the RSHA. Additionally, GHOWs were more likely than RTHAs to re-occupy a nest structure for just one season (69 percent; Table 15). Relatively few nests (n=2) were re-occupied in three nesting seasons, and none in more than three seasons.

Red-shouldered Hawk. A pair of RSHAs built and occupied nest # 10 along the Post Oak Creek in Quanah Range in 1989 (Appendix B; Figure 13). This represents the first nesting record for this species on Fort Sill. This nest was not occupied again for the remainder of the study. In 1990 three additional RSHA nests were documented (Appendix B; Figure 13). The first two were along East Cache Creek and were separated by approximately 800 m, and the third (Nest #9) also located approximately 800 m to the north of Nest #10 along the west fork of Post Oak Creek.

No RSHA nests were located in 1991, but several pair exhibiting courtship behavior were observed on several occasions. It is highly probable one or more of these pairs nested on the installation as three additional RSHA nests were confirmed in 1992, all of which were along the East Cache Creek (Appendix B, Figure 13). Nest #195 is in a hand grenade training area between Quarry Hill and Cache Creek Road, nest #216 in a closed training area north of the Peachtree Crossing, and nest #197 on the west edge of the pig farm woods near the South Boundary road.

Chi-Square analyses revealed a nonsignificant (X^2=3.0; df=2) interaction between military land-use and RSHA nest distribution (Table 12). In contrast, there was a highly significant (X^2=42.0; df=5, $p \leq 0.005$) interaction between plant community and RSHA nest distribution (Table 10). Elm-Ash forest was nested in twice as often as expected while the remaining habitats were nested in less frequently than expected.

Mean nest height and tree height were 13.8 and 20.9 m respectively (Table 9). Red-shouldered hawks consistently placed their nests lower in the trees crown (RNH=65.6 percent ± 9.2) and closer to the main trunk than did the other species (Table 9).

Table 8 indicates that no clear tree preference was exhibited by RSHAs, as the seven nests were evenly distributed among pecan (n=1), post oak (n=1), Shumard's oak (n=2), sugarberry (n=1), and bur oak (n=2). Notably, none of the RSHA nests were found in cottonwood. The relatively small sample size for this species warrants these results be interpreted with caution, however.

Each of the seven confirmed nests occurred in maneuver areas and in Elm-Ash (bottomland) forest. Circular plots 0.04 ha in diameter were established at 50 percent (n=3) of the seven known nest trees to determine woody species densities (Table 16). Mean DBH and tree height of the overstory trees in the plot were 38.0 cm and 14.7 m respectively. Mean understory tree densities were 2491, 69.3, and 8.3 stems per hectare for the 1 to 4, 5 to 9, and greater than 10 cm size classes respectively. Mean species richness for the overstory trees was 3.0 with an average of 125 trees per hectare. Two of the three sites were located in or adjacent to sites frequently used for bivouacking or other troop activities and consequently tend to have a reduced density of understory woody vegetation relative to other sites. Red-shouldered Hawks nested noticeably closer (Table 14) to a water source than GHOWs or RTHAs, the average nest being just 53.8 m (± 51) away from either an intermittent or permanent stream.

Barred Owl. As shown in Appendix B, Figure 14, five BAOW nests were discovered over the study period and were widely separated both spatially and temporally. Nest #83 was discovered in 1987 and was adjacent to East Cache Creek close to the south boundary road. Nest #94 was occupied by a BAOW pair in 1990 and 1992, and is located between Mount Hinds and Medicine Creek within the impact area safety zone. Nest #34 was documented in 1991 and is along West Cache Creek near Falcon Range. The remaining nest (#196) was in the Lake George drainage on the South Arbuckle Range and was discovered in 1992.

Barred owls frequently nest in tree cavities rather than stick nests, and it is acknowledged that the majority of Barred owl nests went undetected throughout the entire study period. Because of the relatively few detections and the likelihood that the sample may not adequately represent the typical nest site and/or tree, circular plot analyses were not conducted on BAOW nests with the exception of nest #94 that was also occupied by at least two other species in other years. Nevertheless, two examples follow that illustrate their adaptability in both nest type and location. Of three nests located, two occurred within Elm-Ash communities and the third in a Cross Timbers stand that was immediately adjacent to Medicine Creek and its associated Elm-Ash community. The first BAOW nest discovered during this study (1987) was situated on the top of a damaged and dead cottonwood trunk (#183) near the intersection of East Cache Creek and the south boundary road. Technically, this area is within the East Range maneuver area, but is in close proximity to several buildings and soldier dormitories located within the Cantonment Area to the east. In 1990, the second confirmed evidence of breeding (nest #94) was in a stick nest located just east of Mount Hinds and within the West Range impact area buffer zone. This relatively massive nest, probably the largest on Fort Sill, is in an 80-cm DBH post oak and was occupied by RTHAs in 1988 and 1989, by GHOWs in 1991, and again by BAOWs in 1992.

Swainson's Hawk. One Swainson's hawk nest was recorded in 1985 on the east side of Elgin road immediately north of the North Arbuckle small arms range (Appendix A, nest #198). This nest constitutes the only known nesting record for Fort Sill in recent times. No records exist during the study period.

Northern Harrier. Prior to this study, a NOHA nest was documented in May 1986 on the South Arbuckle range. This constitutes the first confirmed nesting record for this species on Fort Sill. During this study, two additional harrier nests were found, both in 1991 and in Bluestem Prairie habitat. One nest (Appendix A; nest #191) was located between the West Range Impact Area (Tower Two Road) and the ammunition storage area west of the Cantonment Area, and the second near the tar pit just west of Lake George and east of the Cantonment area (Appendix A, nest #190).

American Kestrel. Four AMKE nests were discovered over the study period, and all were within artificial nesting boxes constructed and maintained by Fort Sill Fish and Wildlife personnel. Each box was secured to the trunk of a tree, approximately 4 m above the ground and with the entrance facing south.

Unoccupied Nests. Nest occupancy rates were strongly correlated (r=0.99) with nesting abundance. Derived from data presented in Table 7, the percentage of nests that were unoccupied averaged 69.7 percent (n=106), but varied considerably between years from 59.4 to 87 percent (Table 7). Fifty-nine nests that were documented during the study were never known to be occupied and were included with the occupied nests in Figure 7. Approximately 4 and 32 percent of the unoccupied nests were within 100 and 300 m of occupied nests, respectively. However, the majority of unoccupied nests (54 percent) in any 1 year was greater than 500 m from the nearest occupied nest of any species.

Most of the nests that were never known to have been occupied were in post oak (23.5 percent) followed by cottonwood (19.6 percent), pecan (15.7 percent) and American elm (11.8 percent). Woolly (bumelia) buckthorn was the only tree species that was nested in (*n*=2) but never known to have been occupied (Table 8). Unoccupied nests tended to be in shorter and/or smaller DBH trees and closer to the ground than occupied nests, although considerable overlap did occur. The mean relative nest height (70 percent ± 9.2) value lies intermediate between that of the RTHA (73 percent) and GHOW (67 percent). As a general rule, unoccupied nests had a tendency to be further away from a water source than occupied nests (Table 14), but exhibited a tremendous range and were often in close proximity to it. The mean distance from an unoccupied nest to a water source was 216 m, slightly greater than that for the average GHOW nest. In the majority of situations, the unoccupied nests or nest-trees did not display any obvious structural characteristics differentiating them from an occupied nest.

Twenty-two of the 59 (37 percent) unoccupied nests were randomly selected for woody under- and overstory characterization via 0.04 ha circular plots (Table 16). Mean DBH and tree height of the overstory trees in the plot were 47.7 cm and 13.1 m respectively. Mean understory tree density were 700, 44.3, and 14.8 stems/ha for the 1 to 4, 5 to 9, and greater than 10 cm size classes respectively. Mean species richness for the overstory trees was 2.0 with an average of 102.3 mature trees per hectare. Unoccupied nests also tended to be in slightly larger trees (TH and DBH) than the adjacent ones, although this difference is less pronounced than for occupied nests.

Nest Longevity, Turnover, and Fidelity

Invariably, a small percentage of the nests blew down each year or degraded to the point where they were deemed unusable. Often it was just the nest but occasionally the major branches supporting the nest broke off due to the poor condition of the tree and/or the weight of the nest (e.g., nests #130 and #131, Appendix A). Both nest destruction and construction were slightly variable from year to year, resulting in a relatively consistent number of available nests (range=141-160; Table 7). No nest destruction was directly attributed to military or civilian activities, but the potential that it went undetected is acknowledged. Of the 142 nests documented in 1987, 53.5 percent (n=76) still remained intact 5 years later. The mean loss rate for nests over the study period was 11.5 percent per year, and varied from 8.4 percent (1990) to 16.1 percent (1992). Although somewhat counterintuitive, only a weak to moderate relationship was observed between a nests' ability to persist over time and how often it had been occupied. Seventy-six percent (n=58) of the 76 nests surviving 6 years had been occupied in 1 or more years, but just 52 percent of nests persisting for exactly 5 years (n=23) and 59 percent persisting for exactly 4 years (n=24) were ever occupied. Nest destruction was frequently attributed to wind gusts during periods of inclement weather in which either a branch supporting the nest broke or the nest itself simply blew out of the tree. Therefore, under similar weather conditions, breeding densities and nest loss rates, nest turnover on Fort Sill is estimated at approximately 8 to 10 years.

Twenty-one percent of the occupied nests were used by two or more species over a 6-year period. The clear majority (79 percent) of nests, however, were re-occupied by the same species one or more times. Table 15 shows that RTHAs exhibited a greater degree of species-level nest fidelity than GHOWs and RSHAs during the study. Nearly 17 percent of RTHA nests were occupied 3 or more years versus less than 4 percent for GHOWs and zero percent for RSHAs. For example, nests # 111, 113, and 155 were each occupied by RTHAs for five consecutive nesting seasons (Tables B6, B10-B13, and B17). The first two nests are located within the outer edge of the Cantonment/no-fire area and the latter is near the installations eastern boarder fence and at the western edge of the South Arbuckle Impact Area (Figure 2). The only raptor nest to have been occupied by the same species for all six nesting seasons was RTHA nest #132 (Figures B1-B6). This nest is in the East Range maneuver area and is located just east of East

Cache Creek and 2 km south of Hoyle Bridge, down Cache Road. Because individual birds were not marked, nest fidelity at the individual or pair level was not determined. A complete occupancy history for each known nest is provided in Appendix A.

There were at least three instances in which a nest was constructed in a tree that had previously supported a nest. Red-tailed Hawk nest #137 (Figure B2) blew out of the cottonwood tree following the 1989 nesting season, and 2 years later (1992) a new nest was built and occupied by RTHAs in a slightly different location in the trees crown. Secondly, RTHA nest #175 (Figure B5) was built in an American elm a year after a large limb broke off the tree during inclement weather, taking with it a previously unoccupied nest. And lastly, RTHA nest #159 (Figure B1) was built in nearly the identical place as the nest lost the previous season, but unlike its predecessor, was subsequently not occupied by a breeding pair.

Nest Failure, Success, and Productivity

General Results

Determining whether each nest was successful or had failed was largely a function of military activity and road conditions during the monitoring periods. The number of nests in which success or failure could not be determined was distributed relatively evenly among the land-use categories, and not skewed towards the impact areas in which access is limited but more predictable. The majority of RTHAs on Fort Sill fledge their young in May or early June (Figure 6). Unfortunately, military training activity tends to be more frequent in May and June than in the pre-fledging months of January through April, in part because May is the month when many National Guard units initiate their annual 2-week summer annual training periods. Consequently, a significant percentage of occupied nests were classified as unknown with regards to success over the course of the study (mean=38.1 percent; range=21.4 to 64.9). Again, there was no *a priori* knowledge to suspect that the nests having unknown fates should exhibit failure or success rates significantly different from the known nests.

Of the 29 confirmed nest failures, two (6.9 percent) were known to be a *direct* result of military activity; 24.1 percent (n=7) were attributed to adverse weather; and 68.9 percent (n=20) failed for unknown reasons. Considering only failed nests with known causes, adverse weather and military activity accounted for an estimated 77.8 percent and 22.2 percent of nest failures, respectively.

Nesting success varied based on military land-use (Table 18) from approximately 65 to 80 percent. Maneuver areas exhibited the highest success rate. Impact areas and the Cantonment area exhibited similar levels of success. Nest success based on habitat was slightly more variable than land-use, with values ranging from 58 to 82 percent (Table 19). Considering all raptor species collectively, Elm-Ash forest exhibited the highest success rate while Mesquite Savannah the lowest.

Red-tailed Hawk

Of the nests with known fates, 85 percent (n=75) were successful and the remaining 15 percent (n=25) failed (Table 18). The distance of a nest from a stream or pond was not a reliable predictor of nesting success, as successful RTHA nests were not significantly closer (T=0.937; df=18, prob=0.413) to a stream or pond (189.5 ± 256 m) than were failed nests (167.0 ± 169 m) (W. Whitworth, unpublished data).

Table 2 shows RTHA productivity remained relatively constant over the study period, with a mean rate of 1.87 fledglings per successful nest (range=1.70 to 2.24). Combining failed nests with successful, productivity averaged 1.67 fledglings per

Table 18. Red-tailed Hawk and Great Horned Owl nesting success/failure based on military land use (Nests classified as unknown (n=108 or 40% of total) were omitted; all years have been combined).

	Cantonment	Maneuver	Impact	Overall
Failed (%)				
Red-tailed Hawk	33.3 (8)*	18.5 (10)	31.8 (7)	25.0 (25)
Great Horned Owl	- (0)	23.1 (6)	37.5 (9)	30.0 (15)
Mean	33.3	20.8	34.8	26.7
Successful (%)				
Red-tailed Hawk	66.7 (16)	81.5 (44)	68.2 (15)	75.0 (75)
Great Horned Owl	- (0)	76.9 (20)	62.5 (15)	70.0 (35)
Mean	66.7	80.0	65.2	73.3

* Numbers in parentheses indicate sample size.

Table 19. Mean percentages (%) of successful and failed nests within the Bluestem-Grama Prairie (BGP), Bluestem Prairie (BP), Mesquite Savanna (MS), Cross Timbers (CT) and Elm-Ash Forest (EA) plant communities.

	BGP	BP	MS	CT	EA
Failed	37.5 (3)	23.5 (4)	42.3 (11)	30.4 (7)	18.3 (15)
Successful	62.5 (5)	76.5 (13)	57.7 (15)	69.6 (16)	81.7 (67)

* All species and years are combined; numbers in parentheses indicate sample sizes; nests classified as unknown were omitted (n=108 or 40% of total).

nesting attempt. Similar to nesting success rate, productivity did not appear to vary significantly with respect to military land use or habitat type (Table 20). A minimum of 159 RTHA young fledged during the study, of which 70 percent (112) were banded with USFWS bands 1 to 2 weeks before leaving their nests.

Great Horned Owl

Nest success or failure could not be confirmed in approximately 34 percent (*n*=26) of the GHOW occupied nests, only slightly more than for RTHAs. The period of greatest fledgling activity was in late March and early April, a time in which military activities are somewhat reduced, thus permitting more frequent periods of unrestricted access and a greater confirmation rate. Of the nests with known outcomes (*n*=50), 35 (70 percent) were successful and the remaining 15 nests (30 percent) failed. The mean success rate did not appear to vary appreciably with respect to either military land-use type (Table 18) or plant community (Table 19).

Productivity remained relatively constant over the study period, with a mean rate of 1.82 fledglings per successful nest (Table 2; range=1.41-2.75). Combining failed nests with successful, productivity averaged 1.12 fledglings per nesting attempt. These annual rates tended to be slightly less than, and more variable than that exhibited by RTHAs. But similar to RTHAs, productivity rates for GHOWs did not appear to be greatly influenced by military land use, type of plant community (Table 20), or the distance of the nest from water (Whitworth, unpublished data). Successful GHOW nests were not significantly closer (T=1.132; df=11, prob=0.282) to a stream or pond (227.9 ± 348 m) than were failed nests (304.6 ± 338 m). Twenty-seven of the 53 GHOW young (51 percent) were banded before they left the nests.

Table 20. Red-tailed Hawk, Great Horned Owl, and Red-shouldered Hawk productivity within military land-use types and plant communities (all years combined; numbers in parentheses indicate sample sizes).

	RTHA	GHOW	RSHA
Military Land-use			
Cantonment Area	1.67 (18)	3.00 (1)	—
Impact Area	1.89 (18)	1.83 (12)	—
Maneuver Area	1.90 (50)	1.93 (14)	2.67 (3)
Plant Community			
Bluestem-Grama Prairie	2.20 (6)	—	—
Bluestem Prairie	2.00 (7)	1.75 (8)	—
Mesquite Savannah	1.83 (12)	2.25 (4)	—
Oak Savannah	—	—	—
Cross Timbers	2.00 (6)	1.50 (8)	—
Elm-Ash Forest	1.80 (54)	2.00 (10)	2.67 (3)

Red-shouldered Hawk

Overall, 43 percent (n=3) of the RSHA nests were known to be successful, with a mean productivity rate of 2.7 young fledged per successful nest. All but one (88 percent) of the young were banded. None of the RSHA nests were known to have failed. In the majority of RSHA nests (57 percent; n=4), success or failure could not be determined. Productivity of the RSHA exceeded that exhibited by the other species, but may be a reflection of a smaller sample size. Subsequently, further success and productivity analyses with regards to military land use or habitat type were not conducted due to the small sample size and high percentage of unknown nests.

Barred Owl

Five successful nesting attempts were documented over the study period (Figure B14). Nest #94 was successful in 1990 and nest #196 in 1992, each producing two fledglings. Because of persistent military activity in the area, it could not be determined if nests #159 (1988), #94 (again used in 1992), or #34 (1991) were successful. As with the RSHA, success and productivity with regards to military land use or habitat type was not assessed due to the small sample size.

American Kestrel

The failure rate of the four known nests within artificial nest boxes approached 50 percent. One nest fledged as many as five young, all of which were banded. Five eggs were produced in the other nest of which three hatched and were banded. Four or five eggs were laid in the other two nests that failed. Bees constructed nests in some of the nest-boxes making them unavailable for kestrel use, and potentially could have been a factor in nest failure. It is possible that one of the nests failed in response to inquisitive humans examining the box contents. An average of 5 percent of the available kestral nest boxes were nested in by AMKE in any 1 year. Eight AMKE young were banded in nest-boxes and thought to have fledged.

Incidental Food Habit Observations

Table 3 represents the frequency of occupance of various prey items found in the nests at the time the young were banded. Thus, each nest in which young were present was visited only once in a season. Rabbits, which includes both cottontail (*Sylvilagus sp.*) and Black-tailed jackrabbit (*Lepus californicus*), were observed in more than 50 percent of all nests in all years except 1989. Snakes were observed in just under 50 percent of all nests on average and were generally more variable than rabbits in terms of frequency. Snakes were the most frequently observed food item in the nest in 1989, the year of lowest overall raptor abundance. Fox squirrels (*Sciurus niger*), unidentified rodents, and unidentified birds comprised 27, 24, and 14 percent of the observed prey items overall. Prey items observed only infrequently include prairie dogs, turtles, crayfish (found in two Barred owl nests), eastern moles (*Scalopus aquaticus*), and assorted lizards.

6 Discussion

Nesting Chronology

Great Horned Owls were often observed on nests in mid to late January. Their incubation period is from 26 to 30 days with an additional 8 to 10 weeks before fledglings leave the nest for good (Heinzleman 1979). Figure 6 indicates GHOWs did not nest early enough to fledge their young and vacate the nest prior to RTHAs nesting, a phenomenon Palmer (1988b) reports as occurring in more southern latitudes. Red-tailed and RSHAs generally began egg laying 4 to 6 weeks after GHOWs. Other investigators including Bent (1961b), Petersen (1979), Andersen (1984), Palmer (1988, 1988b), and Craighead and Craighead (1969), have observed a similar temporal relationship between the RTHA and RSHA in other regions. Incubation periods for RTHA are approximately 34 days, with the young remaining in or near the nest for an additional 6 weeks or so before permanently leaving the nest (Palmer 1988b). Palmer also reported that incubation and pre-fledging time requirements for the RSHA more closely parallel that of the RTHA than the GHOW. Barred Owls were observed sitting on eggs as early as 22 February and young were banded as late as 23 May, but because of the difficulties in detecting and monitoring this species, a definitive assessment of their nesting chronology was not attempted.

The evolutionary basis and potential benefits of early nesting by GHOWs throughout their range is debatable. Early nesting by GHOWs allows them to establish breeding territories and effectively reduces direct interspecific competition and allows breeding GHOWs a greater flexibility with regard to nest-structure selection. On the downside, early nesters are more susceptible to cold weather-associated nest failure. Once a nest is selected, GHOWs are well able to defend their nests from RTHAs or other breeding raptor species in the area, at least during nondaylight hours. Both Palmer (1988, 1988b) and Craighead and Craighead (1969) provided evidence of GHOWs preying not only on RTHA young but adult RTHA and RSHA females on their nests incubating eggs. Palmer (1988) believed that young owls developing their hunting skills may have found young RTHAs easy prey at night, and went on to describe incidents whereby persistent harassment by GHOWs eventually caused the desertion of other RTHA nests. Craighead and Craighead (1969) more emphatically characterized the owls aggressiveness by stating "...the [Great] Horned Owl is the most powerful bird, as well as the earliest nester, it has preference as to its nest location and cannot be evicted by other raptors," and that, in most cases, "...the Red-shouldered nor the Red-tailed Hawks nested close to or in the same woods with the Horned Owl." In fact, few RSHA nests were in close proximity to nesting GHOWs during this study, although this relationship could more likely be a reflection of strong habitat preferences or simply be an artifact of the small sample size. However, throughout this study RTHAs often nested in close proximity to GHOWs, as close as 85 m, with the remains of an unidentified hawk being found in just one GHOW-occupied nest. However, incidental food habit observations were recorded only once per successful nest at most, and other hawk remains could easily have gone unnoticed.

Nest Distribution, Tree and Site Characterization

The average number of nests existing at the end of each nesting season remained remarkably consistent from year to year (n=153 ± 7), with 13 to 40 percent (mean=30 percent) of the nests being occupied by a breeding pair in any 1 year. Olendorff and Stoddard (1974) believed adequate nest sites were especially critical, ranking them as the second most critical factor in regulating raptor abundance in western grasslands. On Fort Sill, however, the mean nest occupancy rate of 30 percent, the use of at least 15 species of trees as nest-sites, and the fact that just one nest was constructed in an artificial structure suggests neither nest-site nor nest availability was a major limiting factor to nesting abundance during the study period. The potential for nests sites/nests to become a constraint to raptors in the future is greater for the GHOWs, which do not build their own nests but choose from existing ones.

Qualitative observations suggested there was an abundance of potential nest trees exhibiting the typical limb structure and minimum height requirements for nesting raptors throughout the study area. In general, the total amount of woody cover is believed to have been fairly consistent over the past few decades (W. Bartush, Fish and Wildlife Administrator, U.S. Army Field Artillery Center and Fort Sill, Fort Sill, OK, professional discussion, 10 December 1988). However, one particular species of tree seems to be increasing in abundance in the western half of the installation. Mesquite has become noticeably more abundant since about 1946 (Johnson et al. 1990). From a military standpoint, this is not undesirable as it seems to provide good concealment cover for many types of training activities and is well-adapted to the region. Many game and nongame wildlife species benefit from the relatively low growing trees interspersed among the grasses as well. The increase in mesquite, while possibly providing support to raptors via a more diversified prey-base, has not provided raptors with a greater pool of potential nest trees.

Raptors appear to avoid mesquite primarily for structural reasons; over the course of the study, no raptor nests were ever found in mesquite. This finding was not surprising, as few if any published reports of RTHA nests in mesquite have been documented, even in southern Texas where it generally grows in even greater abundance. The growth form and branch diameter of a typical mesquite tree on the installation at about 5 to 6 m does not appear adequate to support the average-sized stick nest. The minimum recorded nest height during this study was approximately 5 m. In contrast, Sutton (1967) reported a slightly higher minimum height of 7.5 m for RTHAs in Oklahoma. Specifically, nests in nonmesquite trees on Fort Sill are typically supported by several branches in the 5 to 10 cm diameter or larger size classes. Branches of this diameter at 5 to 6 m in mesquite on Fort Sill were rarely observed. Moreover, the tendency of mesquite branches in the upper portion of the crown to droop possibly makes access to an incoming bird more difficult, and although a fair number of raptor nests did occur in the Mesquite Savanna plant community, they were built in other species that tend to be associated with narrow drainages such as cottonwood, sugarberry or American elm. Sutton (1967) reported instances of RTHAs nesting on cliffs in other regions of Oklahoma, and although suitable cliffs occur on Fort Sill, no RTHA or GHOW nests have been reported or found on them to date.

One area on Fort Sill was clearly avoided by nesting raptors which was likely due, to a large degree, to a paucity of adequately sized trees. In the rocky hills north by northwest of the West Range Impact Area (Figure 7) is a portion of the Wichita Mountains complex characterized by rocky slopes with shallow soil and subject to high wind velocities. Because of these harsher environmental conditions, tree growth rarely exceeds 4 to 5 m. The obvious lack of raptor nests in this approximately 33.8 km^2 area is likely due, to a large degree, to relatively few trees meeting this apparent minimum nest height requirement, although prey accessibility and/or availability, environmental exposure, or other factors could contribute as well.

The majority of all RTHA (55 percent) nests occurred within the Elm-Ash plant community. Table 21 shows that overall RTHA nest densities of one pair per 11.9 km^2 compare favorably to those reported for other regions, and when considering RTHA densities within Elm-Ash forest (3.3 km^2/pair), exceed most others. Note that none of the values in Table 21 reported for other regions were derived from research prior to this study. Thus, while direct comparison is not possible, these values can provide a broader context in which to assess RTHA densities on Fort Sill. Moderate use was made of the Cross Timbers habitat, where mean RTHA density reached 10.5 km^2/pair. Of all the habitat types, RTHA densities were the most variable between-years within Mesquite Savanna. This habitat was nested in appreciably only in those years when Elm-Ash forest appeared to be at or nearing RTHA carrying capacity (1988 and 1992).

Table 21. Red-tailed Hawk, Great Horned Owl and Red-shouldered Hawk nest densities (km^2 per occupied nest) on Fort Sill relative to other selected regions.

Region/State	Species			Source
	RTHA[a]	GHOW	RSHA	
Fort Sill[b]				
(Elm-Ash)	3.3	19.8	23.9	This study
(Cross Timbers)	10.5	14.0	—	This study
(overall)	11.9	30.1	166.1	This study
Colorado	25.1	24.2	—	Anderson (1984)
Michigan	33.7	15.0	4.7	Craighead and Craighead (1969)
Wyoming	2.6	7.8	—	Craighead and Craighead (1969)
S. Wisconsin	7.3	14.5	—	Orians and Kuhlman (1956)
Wisconsin	4.1	9.3	—	Peterson (1979)
Wisconsin	10.6	—	—	Gates (1972)
New York	—	—	1.7	Crocoll and Parker (1989)
New York	5.7	11.4	—	Hagar (1957)
Alberta	7.5	22.0	—	McInvaille and Keith (1974)
California	1.3	—	—	Fitch et al. (1946)
California	3.2	—	—	Wiley (1975)
Utah	—	25.9	—	Smith and Murphy (1973)
Ohio	6.2	8.2	—	Kirkley and Springer (1980)
Maryland	—	—	0.5	Henny et al. (1973)
New Jersey	—	—	4.5	Bosakowski et al. (1992)

[a] Note: Some density estimates may be calulated differently and may not be directly comparable.
[b] Fort Sill estimates based on a 6-year average except for the RSHA, which were based on 3 years of occurance.

The two grassland habitats, Bluestem-Grama and Bluestem Prairie, supported a proportionally low number of nests simply because of the low number of potential nest trees, an expected characteristic of prairie habitats.

Nesting RSHAs were even more strongly associated with Elm-Ash forest than RTHAs, with 100 percent of their nests occurring there. In contrast to the RTHA, however, even maximum RSHA annual densities within this habitat of one pair per 23.9 km^2 were substantially lower relative to all values reported in Table 21.

Although approximately one-third of GHOW nests were within Elm-Ash forest, the relatively low density (mean=19.8 km^2/pair) suggests little preference for this habitat. Great Horned Owls reached their highest densities within the Cross Timbers

(8.2 km^2/pair) and Mesquite Savanna (8.0 km^2/pair) plant community types, more than twice that for Elm-Ash forest. Within Elm-Ash forest, GHOW densities reached comparably high levels in only 1 year (1988), suggesting a preference of Cross Timbers or Mesquite Savanna nest sites over those in Elm-Ash. However, GHOWs did not appear to avoid Elm-Ash or any other habitat type. Palmer (1988b, p 118) found GHOW nest distribution throughout their range in general tended to be ". . . spread more evenly through different habitats than the Redtail." Gilmer and others (1983) similarly reported RTHA distribution in North Dakota as clumped in wooded drainages while GHOWs were more evenly distributed. The results of this study seem to parallel these findings.

A number of researchers (Thomas et al. 1979; Glinski et al. 1983; Bohall and Collopy 1984) have emphasized the great importance of snags as perching and hunting sites to raptors. Fager and others (1984) report that a minimum of 11 snags of 50 cm DBH or greater be provided per 40 ha (or 1 snag per 0.3 ha). Data collected via the Army's LCTA permanent plots suggests overall snag density is adequate (1.28 snags/ha; W.R. Whitworth, unpublished data). However, the distribution of these snags was not uniform across plant communities, and this component of their habitat might play a greater role in nest distribution than previously believed.

Of the variables quantifying nest-tree and nest-site characteristics, some were clearly more important to certain raptor species than to others. These variables are considered with respect to the RTHA, GHOW, and RSHA.

Red-tailed Hawk

The consistent and relatively high densities of RTHAs within Elm-Ash forest even in years of low prey and raptor abundance suggests a preference for this habitat type over the others.

Woody understories at the nests sites varied widely from zero to several thousand stems per hectare in the <5 cm DBH size class. The other understory size classes were highly variable as well. The structure of the nest tree relative to the adjacent trees was clearly more important in influencing nest-tree selection than was the density of understory trees. Red-tailed Hawk nest trees were consistently taller and larger (DBH) than the other trees at the nest site by 3.7 m and 20.6 cm respectively.

Based on the mean values of all variables collected, the following profile was composed and serves to characterize the "typical" RTHA nest-tree and nest-site: a 20.2 m tall and 80.8 cm DBH eastern cottonwood located within the Elm-Ash plant community. The approximate nest height is 14.1 m, located within the upper one-third of the crown. The nest tree could be within a relatively open stand or part of a closed canopy. Both overstory and understory species diversity is low to moderate. The nest tree is approximately 160 m from a stream, lake, or pond, about 1500 m away from the next closest RTHA nest, and likely within 1000 m of a GHOW nest.

Great Horned Owl

Based on the nest and site variables collected during this study, a profile of the "typical" GHOW nest/site was constructed as follows: the nest-tree site is part of an open woody overstory with a sparse to moderate woody understory of low diversity occurring within the Cross Timbers plant community, approximately 204 m from an available water source, at least 850 m away from the next closest conspecific nest, and more likely to be in a maneuver or impact area than the cantonment area. The nest-tree itself is 15.9 m high and 50.7 cm DBH post oak, with a nest height of 10.7 m and located within the middle one-third of the crown.

Since GHOWs heavily rely on the RTHA and other raptors for nesting structures, trends in nest-site characteristics are largely a function of the number of nests in late winter. One of two general scenarios is likely occurring at Fort Sill. First, GHOWs are selecting nest structures randomly, in which case the average nest tree and nest-site should exhibit characteristics similar to the typical RTHA or RSHA nest tree and site. Secondly, GHOWs are selecting those RTHA or RSHA nests exhibiting specific nest tree and/or site characteristics, in which case the average nest tree and nest-site would not be expected to exhibit characteristics similar to the typical RTHA or RSHA nest tree and site. In comparing the typical RTHA nest tree/site and the typical GHOW nest tree/site described previously, the latter scenario is clearly supported.

Red-shouldered Hawk

Unlike GHOW or RTHA nests, RSHA nests were never located more than 148 m away from a stream or pond, and always within the Elm-Ash habitat type. And unlike the other species, the seven RSHA nests were all adjacent to permanent streams. The RSHAs tendency to be near water has been well documented (Bednarz and Dinsmore 1982; Bent 1961; Stewart 1949; and Henny and others 1973) many of which further reported the moist areas tend to be within stands of mature forest. Bednarz and Dinsmore (1982) found that in Iowa, RSHA nest to water distance approached one-third (27 percent) of the mean distance exhibited by RTHAs. Similar to Bednarz and Dinsmore (1982) results in Iowa, RSHA nest distance to water distance on Fort Sill approximated one-third (33 percent) of the mean RTHA distance. The relative closeness of RSHA nests to water suggests a similar association exists at Fort Sill. No preference for a particular species of tree was evident, but each nest was consistently located in the lower one-third of the crown and tended to be near the main trunk. In Maryland, Stewart (1949) estimated that nearly 90 percent of the RSHA nests were built in the crotches of the main trunks. Decades later, Bednarz and Dinsmore (1982) reported that 86 percent of RSHA nests in their Iowa study site were located on the main trunk, and further maintained that tree species appeared to be relatively unimportant in nest-site selection. Titus and Mosher (1980) and Morris and others (1982) provide additional evidence of the RSHAs inclination to nest lower in the trees crown than the RTHA.

In spite of the relatively small number of RSHA nests, several nest tree/site characteristics were consistently exhibited. Typical RSHA nest-site were characterized as occurring within an Elm-Ash corridor, having a moderately dense woody overstory and understory of high species diversity, approximately 54 m from a stream or pond, and at least 800 m away from the next closest RSHA nest. Nest-tree location was in the cantonment or a maneuver area simply because this is where most of the suitable habitat is. The nest-tree is approximately 20.9 m high and 49.3 cm DBH tree (no clear species preference) with a nest approximately 13.8 m off the ground and located within the lower to middle one-third of the trees crown and close to the main trunk. In contrast to the RTHA, the RSHAs tend to construct nests close to the main trunk, which often hides the nest from view from one or more sides, making them considerably more difficult to detect both from the air and ground.

Bednarz and Dinsmore (1982) reported RSHAs nested significantly farther from buildings than did RTHAs. Bosakowski and others (1992) also reported that RSHAs avoided development (houses, paved roads). In contrast to observations by Bosakowski and others (1992), RSHAs on Fort Sill did not appear to avoid developed areas nor roads. In fact, two RSHA nests (28.5 percent) were within bivouac (military-style camping) sites, areas in which there is frequent troop activity, some development to accommodate bleachers, latrines, and possibly a small building, and in general the removal of a substantial quantity of underbrush to facilitate movement of vehicles and equipment.

Bednarz and Dinsmore (1981,1982) found the RSHAs in Iowa were most often found in stands of bottomland forest 100 to 250 ha in size and 70 ha for upland stands. In contrast, Preston and others (1989) found only two of 19 nests (10.5 percent) in bottomland stands less than 250 ha, and attributed the general decline of this species in Arkansas primarily to destruction of bottomland habitat. For RSHAs in New Jersey, Galli, Leck and Foreman (1976) surmised that each pair requires a minimum of 10 ha of contiguous suitable forest in which to nest. Armstrong and Euler (1982) asserted that RSHAs preferred dense contiguous forest and avoided disturbed habitat but gave no minimum stand size requirements.

An estimated 4,500 ha of Elm-Ash forest occurs on Fort Sill, but typically in a nearly linear or dendritic configuration, making stand-size quantifications difficult. Furthermore, wooded habitat on Fort Sill likely is subjected to a greater level of disturbance as considered by Armstrong and Euler (1982). Despite the fact that Fort Sill's habitat and land-use characteristics were reported to be less desirable for the RSHA, this species appears to have established and maintained a small breeding presence on Fort Sill. But Fort Sill remains at the extreme western edge of the RSHA breeding range (Tyler, Orr, and Banta 1989), and RSHA nesting densities significantly exceeding densities of one pair per 23.9 km^2 (Table 21) under present conditions might not be realistic. While the restriction on cutting standing timber has undoubtedly helped the RSHA and other woodland species, development or degradation of bottomland forest in west-central Oklahoma in the recent past could have been a contributing factor in the increase in nesting activity on Fort Sill. Soil conditions, fire frequencies, and precipitation patterns at Fort Sill simply do not allow for the establishment of large contiguous timber stands seemingly preferred by RSHAs throughout most of their range. And while the relatively contiguous but narrow tracts of Elm-Ash forest on Fort Sill cannot be considered optimal nesting habitat for this species, they could become increasingly more important to RSHAs if the remaining bottomland forest in the region degrades or is lost to development.

Unoccupied Nests

Assuming the number of nesting raptors is, at least in part, a function of prey availability, and assuming the average nest persists for more than one breeding season, it follows that nest occupancy rates in any 1 year could be considerably less than 100 percent. Observed vacancy rates averaged 70 percent (n=106) for this study and as expected, showed a strong inverse correlation with raptor nesting abundance. Unfortunately, few published papers have reported this type of information providing a narrow context in which to interpret this result. A related issue is why some nests (n=57, or 26 percent of the total), each available (structurally sound) for an average of 4.4 years, were *never* occupied during the study. An average of 15 percent (n=9) of these unoccupied nests, which could have been alternate nests constructed by the resident nesting pair, were in very close proximity (<100 m) to an occupied nest each year and could have remained unoccupied for that reason. The majority (54 percent) of the unoccupied nests each year, however, were greater than 500 m from an occupied nest, and their unoccupancy cannot be totally attributed to competitive forces. In contrast to occupied nests, unoccupied nests tended to be somewhat farther from a water source, constructed in smaller trees, lower to the ground, and on sites with a sparse woody understory (<5 cm DBH class; Table 16). Similar to occupied nests, however, the average unoccupied nest was still constructed in the largest tree within the plot, was located in the mid to upper part of the trees crown, and appeared to be supported by a comparable number of branches in the recognized size classes. Thus, why some nests were never known to be occupied seems readily apparent in a few cases, but not completely understood in the majority. Further research is clearly warranted in that regard.

Nest Failure, Success, and Productivity

It was impractical to monitor all nests at all times to attribute nest failure to a specific cause, nor was it advisable to check the contents of each nest periodically for the presence or condition of eggs (Steenhof and Kochert 1982). Negative impacts to raptors, including nest failure from researcher-related disturbance, have been suggested or confirmed in numerous other studies (e.g., Grier 1969; Nelson 1969: White and Sherrod 1973) and was therefore a primary consideration in this study. Known causes of nest failure in this study were weather and military activity, but many nest failures could not be attributed to any one cause. Craighead and Craighead (1969) believed the nesting success of RTHAs and RSHAs was negatively affected if they nested in close proximity to nesting GHOWs, and recounted several instances in which GHOWs were found to have either preyed on hawk adults and young or just destroyed their nest. While GHOWs and RTHAs often nested in relative close proximity to each other during this study, little evidence was found that indicated RTHA nesting success was negatively impacted. Unfortunately, attributing nest failure to specific events such as military activity or acts of interspecific aggression is often difficult to confirm unless directly observed. Regardless of why each nest failed, estimated success rates on Fort Sill of 75 percent for the RTHA and 70 percent for the GHOW are comparable with average North American values of 73 percent and 78 percent, respectively (Henny 1972).

As with nesting failure and success, productivity rates did not appear to differ significantly between or within raptor species regarding military land use or habitat type. Howell and others (1978) found productivity of a RTHA population in Ohio was not related to preference for a specific tree species or to stand composition or density. Because a relatively high percentage of occupied nests were ultimately classified as unknown with respect to success or failure, the influence of land-use or habitat on raptor success and productivity is still unclear. Both the RTHA and GHOW populations exhibited a fairly dramatic decrease in nesting abundance and success in 1989. These declines were primarily attributed to a perceived decrease in the prey base (Orr, 2 February 1992), but several intense spring thunderstorms contributed directly to a number of occupied nests failing. Productivity remained comparable but did deviate slightly from year to year.

Andersen (1984) identified high winds or other adverse weather conditions at Fort Carson, CO as directly or indirectly inducing nest failure. More specifically, Andersen reported 29 percent of the GHOW nest failures and 43 percent of the RTHAs failures to adverse weather. Three of the RTHA nests and none of GHOW nest failures on Fort Carson were attributed to military activities (Andersen 1984). Of the occupied nests on Fort Sill, adverse weather accounted for an estimated 65 to 90 percent of the GHOW and RTHA nest failures annually, in which the cause could be clearly determined. Approximately 10 to 35 percent of the nest failures on Fort Sill could not be determined each year so the actual percentage of weather-related failures is unknown.

Productivity (#young per successful nest) for RTHA (1.88), RSHA (2.7), and GHOW (1.83) did not vary appreciably between years. Table 20 addresses raptor productivity with respect to military land-use and plant community. While slight differences were observed, neither variable appeared to be significant influence, and in general, productivity on Fort Sill appeared comparable to published reports in other regions, which often range from 0.9 to 2.8 young per nest for these two species (Hagar 1952; Gates 1972; Henny et al. 1973; Peterson 1979; Andersen 1984).

The distance of a nest from a permanent or intermittent source of water did not appear to be a reliable predictor of nest success or productivity. Successful RTHA nests were not significantly closer (T=0.937; df=18, prob=0.413) to a stream or pond (189.5 ±256 m) than were failed nests (167.0 ±169 m). Likewise, successful GHOW nests were not significantly closer (T=1.132; df=11, prob=0.282) to a stream or pond (227.9 ± 348 m) than were failed nests (304.6 ± 338 m). Wiley (1975) found the distance from a nest to a road influenced RTHA and RSHA nest success in California. However, in this study, distance to a road was not measured principally because, unlike Wiley's study site, military reservations typically have extensive road and trail systems that leaves very few areas not close to or intersected by a trail or road.

Population Stability

Henny (1972), and Henny and Wight (1972) estimated that breeding populations of RTHAs and GHOWs south of the 42 N latitude must fledge 1.84 and 1.47 young per nesting attempt respectively to maintain stable populations. For breeding populations frequently exhibiting a depressed breeding standard, recruitment of additional breeding-age individuals into the population becomes increasingly more important in maintaining population levels. Henny and Wight (1972) and Henny's (1972) "recruitment standard" estimates were often based on 40 to 50 years of banding data collected before 1968, with productivity rates and mortality rates being averaged from numerous populations throughout North America. The estimated mean number of fledglings per nesting attempt (with known outcomes) by RTHAs (1.67) and GHOWs (1.12) during this study were both slightly lower than the recruitment standard suggested by Henny and Wight (1972) and Henny (1972). Based on a 2-year study at Fort Carson, Andersen (1984) found GHOW were productive enough to sustain their population level while RTHAs likely required additional sources of recruitment. The lower fledgling per nesting attempt ratio for RTHAs and GHOWs on Fort Sill could have been biased by unusually high numbers of weather-related failures in 1 year, relatively low sample sizes (in the case of the GHOW) in several years, or a possible underestimation of the number of young per known successful nest for all species. Regardless, Steenhof (1987) asserted that occasional years of low reproduction are common and often do not affect the long term stability of the population.

Productivity rates by themselves are not an adequate measure of a habitats' quality or "value" to a particular species. Habitats supporting a population that requires emigration from other areas to maintain a sustained breeding population have been termed ecological "sinks" with respect to that population. In contrast, habitats supporting populations in which reproduction exceeds the collective influence of mortality and emigration are termed ecological "sources" (Van Horne 1983; Brittingham 1994). Source and sink habitats could exhibit the same initial productivity rate, but each clearly requires a different management strategy. Thus, from a management perspective, it is important to know whether a raptor population within a community or landscape is self-sustaining. If not, management dollars could then be allocated to improve the quality of sink habitats or increase the usage of source habitats. However, quantifying all variables required to characterize habitats as sources or sinks is often times not practical. Moreover, because Henny's (1972) thresholds of raptor population stability were based on long-term means reported from all over the country, he and others (Petersen 1979) cautioned against comparing productivity estimates from either short-term or localized studies against his. More recently, Steenhof (1987) corroborated Henny's concerns by stating that population stability conclusions based on less than 5 years of productivity data are tentative at best. Although this study did exceed the "minimum" recommended study length, raptor recruitment, mortality, and dispersal were not quantified. Although desirable, characterizing Fort Sill as an ecological source or sink with respect to each raptor species would have had little scientific basis and was not attempted.

Nest Fidelity and Longevity

Occupied nests were most likely to be used by a single species (Table 15), but 6 years might not be adequate to conclusively assess this tendency. Approximately one-fifth of the nests seemed to elicit a greater degree of competition each year, with two to three species eventually occupying the nest sometime during the 6-year period. The ability to predict the occupancy of a nest, or the nesting habits of an individual bird would have obvious research and management value to an installations biologist, but assessing nest fidelity during this study was limited due to the fact that most adults were not visibly marked, that is, unless they happen to be one of the young banded prior to fledgling. Even then, an aluminum leg band cannot be easily read from a distance. As a species, however, RTHAs were clearly more likely to re-occupy the same nest than GHOWs and RSHAs. Craighead and Craighead (1969) described a similar situation for the RTHA and GHOW both in Michigan and Wyoming. On Fort Sill, 17 percent of the RTHA nests were occupied three or more times as compared with zero percent for the GHOW and RSHA. Overall, however, the great majority (75 percent) of breeding raptors tended to occupy a nest just once. This apparent lack of nest-tree fidelity suggests a number of scenarios including but not limited to the following: (1) there was a consistent surplus of existing nests or suitable nest-trees within each pairs nesting territory, (2) population and/or mate turnover or interspecific pressure was particularly variable, and breeding pairs were forced into adjusting their nesting territory boundaries more often than expected, (3) prey abundance was particularly variable with respect to space and time, (4) nest switching is an inherent behavior with adaptive significance, and (5) 6 years is not long enough to adequately assess population-level nest fidelity. Nest fidelity is likely a function of a combination of the first four.

Little information concerning the life expectancy of raptor nests has been published to date. Intuitively, it seems reasonable to believe that nests that had been occupied in 1 or more years would tend to be maintained and therefore persist longer than nests built but never occupied. However, nearly 75 percent of the nests that had blown down or otherwise degraded to an unusable condition had been occupied at least once. The reason for this apparently poor correlation between occupancy and nest survivorship could be attributed, at least in part, on nest tree preference. Cottonwoods appear to possess the desired tree structure and height requirements (at least for the RTHA), but they also seem to be prone to wind damage to a much greater degree than the other commonly used tree species. Qualitative observations indicate that nests occupied for several years often increased in bulk each time. And as the size of the nest grows, the pressure it exerts on the supporting branches grows as well. Cottonwood branches are relatively weak and a number of nests were destroyed when the main supporting branches (some >10 cm diameter) snapped from the trunk of the tree. Although nests blew out of other species of trees fairly often, it was generally only the nest that blew out, and fairly uncommon for supporting branches of even moderate size (5 to 10 cm) to break.

The mean loss rate for all nests over the study period was estimated at 11.5 percent per year. Thus, under similar weather conditions, breeding densities and nest loss rates, nest turnover on Fort Sill is estimated at 8 to 10 years.

Competitive Interactions and Nest Distributions

Quantifying the importance and magnitude of competitive interactions was beyond the scope of this study, but spatial analyses have elucidated some general aspects of intra/interspecific competition. Temporal stratification of RTHA (diurnal) and GHOW (nocturnal) foraging and other activity patterns greatly reduce the frequency of direct interspecific contact, but it is doubtful that interspecific competition is thereby avoided. Since the GHOWs must rely on the nest structures of RTHAs and other species (Hager 1957; Bent 1961b; Wilson and Grigsby 1980; Palmer 1988b), and because there is considerable temporal overlap in nesting chronology, nest structures may be the primary resource for which these ecologically similar species compete.

Figures 9 and 10 illustrate RTHA, GHOW, and RSHA nest distribution within the East Cache Creek watershed (Figure 8) in 1988 and 1992, respectively, the 2 peak years in overall nesting abundance. These figures are useful in visualizing the influence of competition on nest distribution. Red-tailed hawks in all years show a strong association with streams, while GHOW nests were more spread out and not particularly abundant in any one stream or drainage (see also Figures B1 to B12). The relatively consistent spacing of RTHA nests along the East Cache Creek, even in years of low abundance, indicates RTHA density along this creek may be very close to the upper limit. In all years, each GHOW nest is noticeably closer to a RTHA nest than to another GHOW nest, with several of the RTHA-GHOW nest pairs being within unobstructed eyesight of each other. This spacial relationship was especially evident in 1988 (Figure 9).

In general, both *intra* and *inter*specific nest distances varied considerably among species, within species, and from year to year. Specifically, distances between adjacent RTHA nests exhibited a strong, inverse correlation with density ($r=-0.85$). When viewing GHOW nest locations over the 6-year period, the nests clearly appear more regularly spaced over the entire installation and throughout the six plant communities than do the RTHA nests. Mean distances between adjacent RTHA nests within the East Cache Creek watershed were consistently greater than the average distance between RTHA and GHOW nests (Table 13). Great horned owl pairs exhibited a similar intraspecific tendency, but appeared much less tolerant of conspecifics, as GHOW-GHOW nests were nearly three times as far apart (mean=4303 m) than were RTHA-RTHA nests (mean=1558 m).

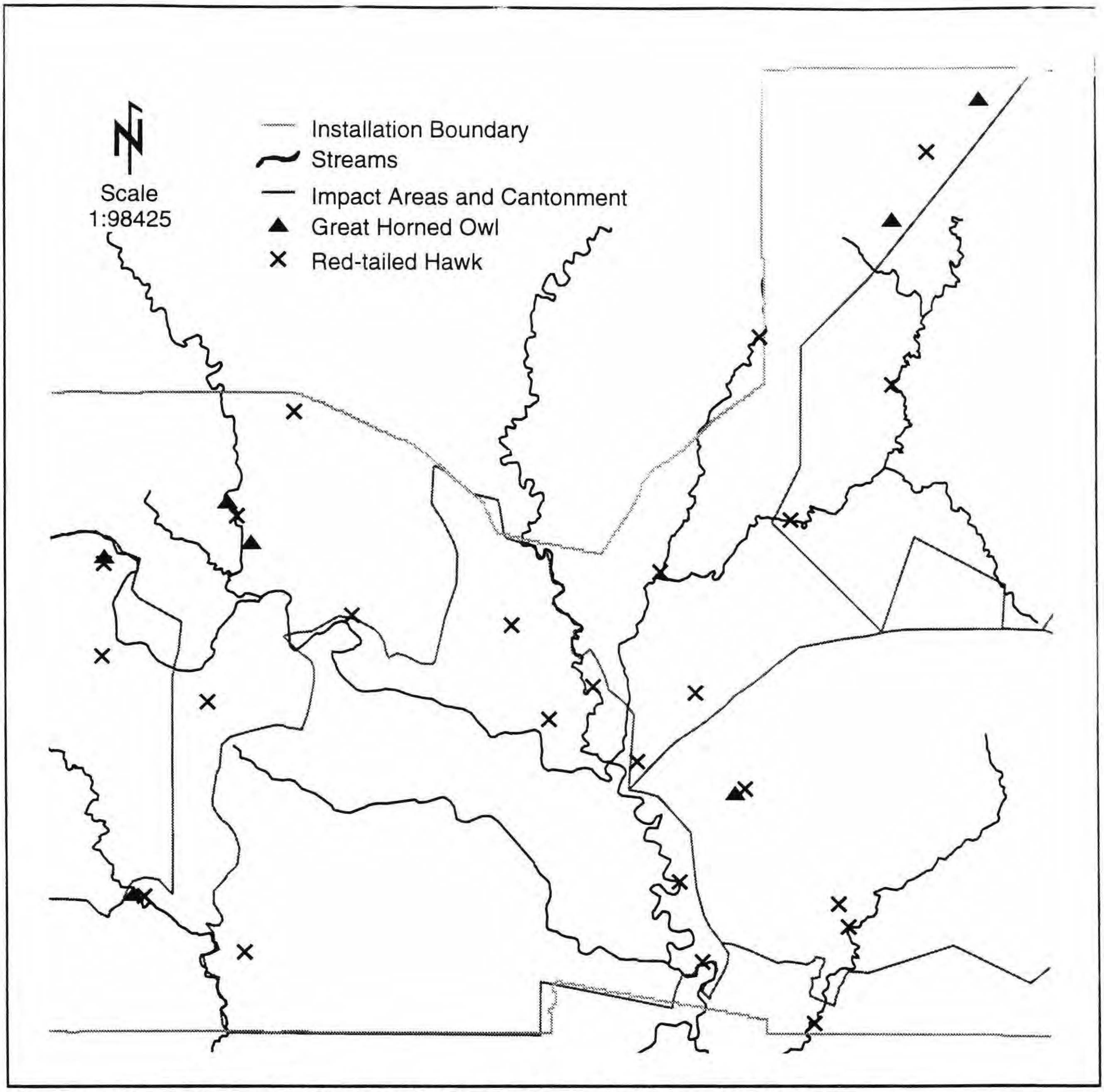


Figure 9. Interspecific nest distribution within the East Cache Creek watershed, 1988.

The spatial arrangement cannot be explained fully because of inherent difference in overall density (approximately a 3:1 ratio favoring the RTHA), as intraspecific nest distances for the GHOW and nest density were *not* strongly correlated (r=+ 0.20). Rather, the data suggest that, at least for the GHOW, intraspecific forces (territoriality) may be an equal or stronger regulatory force than interspecific in limiting GHOW population levels on Fort Sill than for the RTHA. Lastly, considering only the East Cache Creek drainage, interspecific nest distances exhibited a weak negative correlation (r=-0.30) with nest abundance. This result seems to represent a compromise between the RTHAs apparent ability to tolerate other nesters and the GHOWs tendency to maintain them at a greater distance.

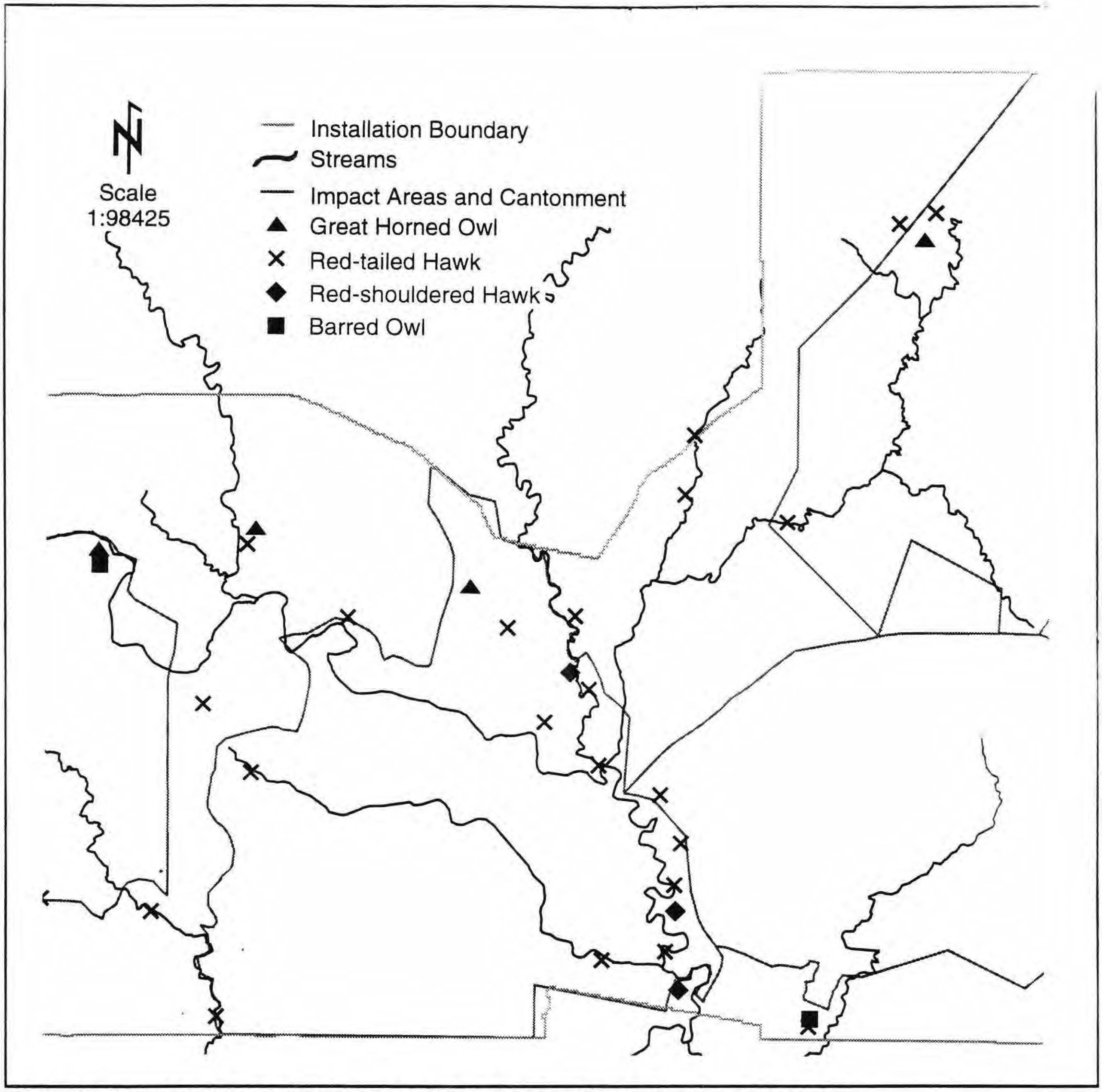


Figure 10. Interspecific nest distribution within the East Cache Creek watershed, 1992.

Peterson (1979) found GHOWs and RTHAs in their Waterloo (WI) study area clearly avoided nesting in the woodlots occupied by the other species, and found these species occupying similar habitats and consuming similar prey. Peterson thus considered this particular RTHA-GHOW relationship as evidence of competitive exclusion. Briefly, the Competitive Exclusion Principle (Hardin 1960) states that species with no differentiation in realized niches cannot coexist. Newton (1979) believed that many abandoned farmsteads in western North America were occupied by just one raptor species and that the GHOW had precedence, thereby suggesting competitive exclusion.

Craighead and Craighead (1969) asserted that early nesting coupled with their aggressive nature enabled GHOWs to have "...a marked influence on the dominance of this owl over [all] other raptors." The Craigheads further reported numerous instances of GHOWs preying upon nesting adult RTHAs and RSHAs and eating them or their young, destroying or inducing the abandonment of their nests, or exhibiting such a "disturbing influence" on RTHAS and RSHA they did not lay any eggs. Although the remains of either a BAOW or Short-eared Owl was found in one GHOW nest (#150 in 1992), the complete dominance of the GHOW over other species as reported by Craighead and Craighead (1969) was not readily evident on Fort Sill. Red-tail nests' were often in close proximity (85 to 500 m) to a GHOW nest, and did not exhibit unusually low success or productivity rates compared to more isolated nests, although the relatively small sample size (n=12) highlights the need for a conservative interpretation.

Other investigators provide evidence of a somewhat greater level of interspecific tolerance between GHOWs and RTHAs. In an area of New York where RTHA and GHOW densities are reported to be greater than on Fort Sill, Hagar (1957) found adjacent GHOW nests separated by about 2900 m while RTHA nests were separated by 1800 m. Hagar reported the closest distance between occupied nests of these two species was 318 m (mean not given), and generalized that the two species appeared quite tolerant of each other. Furthermore, Houston (1975) considered the RTHA and GHOW complimentary species, often nesting 32 to 72 m from each other. While Houston (1975) and Hagars (1957) observations are probably not best described as coexistence, they do indicate a greater degree of interspecific tolerance than Peterson (1979) and Newton (1979) assert. Furthermore, Smith (1969) acknowledge that while GHOWs and RTHAs compete for a number of resources, they did not appear to be mutually exclusive in his Utah study site. During this study, the closest distance recorded between RTHA and GHOW nests was 85 m (mean=1199 m), and it was not uncommon for nests to be within eyesight of each other. Thus, the competitive relationship between the RTHAs and GHOWs on Fort Sill is more appropriately described as competitive tolerance (in the sense of Hagar 1957 and Smith 1969), a result of differential habitat preferences and activity patterns rather than competitive exclusion, as inferred by Peterson (1979) and Newton (1979).

All seven of the RSHA nests on Fort Sill were within Elm-Ash stands associated with a perennial creek (Appendix B, Figure 13). In the 2 years of highest RSHA abundance (1990 and 1992), adjacent nests were consistently located 900 to 1,000 meters apart. This uniform spacing is perceived as evidence of intraspecific forces rather than a spatial coincidence attributed to a small sample size. Red-shouldered hawks nested along Elm-Ash drainages co-inhabited by RTHAs in 1989, 1990, and 1992. A review of the literature suggests the RSHA often is the loser in interspecific interactions, at least with respect to the RTHA (Fitch 1958; Bryant 1986; Bent 1961; Bednarz and Dinsmore 1982). Fitch (1958) found RTHAs and RSHAs in Kansas were largely intolerant of each other, with the more aggressive RTHAs dominating the relatively passive RSHAs. Stewart (1949) inferred RTHAs excluded RSHAs from nesting in suitable habitat in Maryland, and believed differing habitat preferences greatly reduced interspecific competition. Bent (1961) did not discuss RTHA-RSHA interactions in quantitative terms, but strongly implied they were mutually exclusive species by describing RSHAs and RTHAs as "...antagonistic and occupying entirely separate ranges," and that RTHAs drove out or otherwise "...supplanted the redshoulders in some of their long-established haunts." Bryant (1986) found that in the Waterloo region of Canada, RTHAs displaced RSHAs in mature stands after thinning reduced canopy closure. Palmer (1988) and Bednarz and Dinsmore (1982) further concluded the conversion of woods to agriculture favors the RTHA over the RSHA. On Fort Sill, the average RSHA nest in this study was much closer to a RTHA nest (mean=495 m) than it was to the next RSHA (mean=991 m). In Figure 10, the three RSHA nests are all adjacent to the East Cache Creek and among numerous RTHA nests. This suggests the RSHAs relationship with the RTHA on Fort Sill is unlike that described by Bent (1961) and others. At present, however, simply not enough is known on the ecology of the RSHA to clearly define its relationship with the RTHA or the other resident raptor species.

Lastly, in spite of their nocturnal aggression towards other birds of prey, diurnal interspecific encounters tend not to favor the GHOW. Biologists in Ottawa County, Oklahoma reported that soon after a GHOW was flushed from its perch one afternoon, it was attacked by a pair of RTHAs (Wilson and Grigsby 1980). Palmer (1988b) also recounted several reported instances in which RTHAs have aggressively attacked GHOWs during daylight hours. One instance of a RTHA attacking a GHOW was witnessed during the study (spring of 1990), but such events are difficult to substantiate.

Raptor Abundance and Prey Populations

Baumgartner and Baumgartner (1944) studied the food habits and abundance of a raptor population in north central Oklahoma. They concluded that, as a general rule, raptor populations tended to be high when hispid cotton rat populations were high and to decrease as cotton rat populations decreased. They also reported the Plains harvest mouse (*Reithrodontomys montanus*) was the second most abundant small mammal species consumed and that rabbits constituted a relatively small component of raptor diets. More recently, Tyler and Jensen (1981) investigated the food habits of the GHOW in the Fort Sill area (Comanche County). Based on pellet analysis, they found that hispid cotton rats ranked the highest in occurrence, and second only to rabbits (*Sylvilagus* sp.) in terms of total biomass consumed. Tyler and Jensen deviated from Baumgartner's results, (1981) ranking rabbits first, cotton rats second, and several other small mammal species (*Perognathus* sp., *Peromyscus* sp. and *Reithrodontomys* sp.) a collective third with respect to overall importance. Unfortunately, Tyler and Jensen did not address the relationship between prey and raptor abundance.

A limited amount of site-specific small mammal abundance date is available. Based on 60 sampling locations and 100 trap-nights per location per year, the results of the Army's LCTA small mammal surveys support Baumgartner and Baumgartner's (1944) general conclusion that raptor densities are positively correlated with cotton rat abundance. Table 22 illustrates that LCTA hispid cotton rat captures increased dramatically from 1.03 animals/100 trap-nights in 1990 to 4.03 animals/100 trap-nights in 1991. Rabbit harvest records from Fort Sill (G. Wampler, personal comm; Table 23) also showed a low in 1989 (166 animals captured) increasing to a high in 1991 (1186 animals), suggesting rabbit populations followed a parallel trend in abundance. In contrast, the majority of other small mammal species showed either a steady decline or remained comparable over the 3-year LCTA survey period. The mean number of rodent captures (excluding cotton rats) decreased from 4.1 animals/100 trap nights in 1989 to 1.6 animals/100 trap nights in 1991. Harvest mice, believed to be a frequent prey item (Baumgartner and Baumgartner 1944), were most abundant in 1989 (0.9 animals/100 trap-nights), but decreased to 0.2 animals/100 trap-nights in 1990 and remained at a comparable level in 1991.

Synchronous fluctuations in some raptors and their prey has been reported elsewhere. Galushin (1974) determined that Harriers, Kestrels, and other raptor species appeared synchronized with their prey over relatively large areas in Russia. Galushin found no typical time lag between mammalian predators and prey populations, but that dramatic decreases in prey abundance resulted in concurrent decreases in raptor nest densities. Visual observations by Fort Sill Fish and Wildlife personnel in the field (Orr, 2 February 1992) suggested that hispid cotton rat abundance decreased rather dramatically from 1988 to 1989, with a corresponding known decrease in the number of nesting raptors. Unfortunately, the perceived drop in cotton rat abundance could not be quantitatively confirmed as LCTA small mammal data collection was not initiated until May 1989. No determination of abundance was made by Fort Sill Fish and wildlife personnel regarding harvest mice, which, unlike cotton rats, are largely nocturnal and also tend to be rather inconspicuous even at high densities.

Table 22. U.S. Army Land Condition-Trend Analysis (LCTA) small-mammal abundance (captures/100 trap nights).

Species	1987[a]	1988	1989	1990	1991	1992
Hispid cotton rat	—	—	0.55[b]	1.03	4.03	—
Fulvous harvest mouse	—	—	0.43	0.12	0.12	—
Plains harvest mouse	—	—	0.40	0.10	0.12	—
Prairie vole	—	—	0.03	0.13	0.05	—
Woodland vole	—	—	—	0.03	—	—
House mouse	—	—	—	0.02	0.03	—
Eastern woodrat	—	—	0.07	0.12	0.07	—
Southern plains woodrat	—	—	—	0.02	—	—
Texas mouse	—	—	0.25	0.93	0.12	—
White-footed mouse	—	—	1.73	1.18	0.62	—
Deer mouse	—	—	1.40	1.17	0.47	—
Hispid pocket mouse	—	—	0.05	0.12	0.05	—
13-lined ground squirrel	—	—	0.02	—	—	—
Least shrew	—	—	0.05	0.10	0.03	—
Total	—	—	4.98	5.09	5.71	—

[a] LCTA small mammal data was not collected in 1987-88, or in 1992.
[b] Captures are based on 6000 trap nights per year for a total of 18,000.

Table 23. Hunter-reported rabbit harvest records for Fort Sill: 1987-1992.

	1987	1988	1989	1990	1991	1992
Total	1700	491	166	203	1186	768

* Eastern cottontail and Swamp rabbit combined, data obtained fron Fort Sill Fish and Wildlife Branch, DEQ.

Whether the small mammal species were consumed in proportion to their abundance and availability on Fort Sill is not known. Korschgen and Stuart (1972) believed that, while diet was generally a poor indicator of prey abundance (especially for rabbits) in Missouri, unusually high abundances of certain rodents (e.g., cotton rats) could be detected. One-time incidental observations made in nests in which young were being banded did reveal some insight into what prey items were being fed to the young, however. Table 3 suggests that rabbits, squirrels, snakes, and birds all appear to be important prey items for both GHOWs and RTHAs. Choate (1988) suggested that prairie vole (*Pitymys* [*Microtus*] *ochrogaster*) populations on Fort Sill likely play "... a large role as prey, in conjunction with other high-density prey such as *Sigmodon hispidus*." Hares (*Lepus* sp.) and rabbits were especially common prey items on Fort Sill, occurring on average in 60 percent of all nests checked. Peterson (1979) also reported that cottontails were an important and critical food staple of GHOWS and RTHAs in southeastern Wisconsin, and acted as a buffer during population fluctuations in other prey species. Similarly, Andersen (1984) found cottontails to be the most common prey item for both GHOWs and RTHAs at the Fort Carson Military Reservation in east-central Colorado, followed in decreasing importance by woodrats (*Neotoma sp.*) and the Ords kangaroo rat (*Dipodomys ordii*). The frequency of rabbits in their diet was fairly consistent and seemed independent of the estimated density of other small mammal species. Finally, Korschgen and Stuart (1972) found that raptors exhibited a heavy reliance on rabbits and small rodents as staple prey, taking high numbers of cotton rats only during peak years of abundance.

Baumgartner and Baumgartner (1944) found that cottontails were consumed regularly by Oklahoma raptors, but in general found that cottontail rabbit and hispid cotton rat consumption were inversely related to each other. In other words, hispid cotton rats were the preferred prey of most raptor species, many of which took significant numbers of cottontail rabbits only during periods of low hispid cotton rat abundance. The high number of snake remains in raptor nests on Fort Sill in 1989 relative to all other prey species, including rabbits, tends to support the perception of low cotton rat abundance in that year. No apparent difference was detected between GHOW or RTHA nests, but this could very well be a relict of the low sample sizes within certain years and the fact that only certain sizes of prey species were readily observed.

The influence of prey abundance on nest site selection is not known, but potentially significant. Peterson (1979) and Craighead and Craighead (1969) found nest-site selection by several RTHA and GHOW populations in the northern United States was not driven solely by prey abundance, but was just one of several contributing factors. Throughout this study there appeared to be a positive relationship between cotton rat and raptor nesting abundance. Optimal habitat for the cotton rat consists of dense stands of grasses and forbs in which to construct their runways, with low-growing woody vegetation occasionally interspersed (Caire et al. 1989; Jones et al. 1985). Mowing practices within the Cantonment area have undoubtedly limited cotton rat habitat and therefore their abundance. A correlation between cotton rat abundance and nest-site selection might therefore contribute towards making some of the potential trees within the Cantonment area less attractive to nesting raptors. On relatively few occasions were raptor nests constructed in trees located in areas of frequent mowing and pedestrian activity. Nest #107 (Appendix B; Figure 1) is located in a cottonwood tree within a high security, fenced-in area of the Cantonment Area where ammunition is stored. The grass is maintained very low and the only woody vegetation consists of a few medium-sized cottonwood trees. The resulting habitat is clearly more attractive to the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), a species preferring mowed areas, than to the hispid cotton rat. Regardless, this RTHA nest was occupied in 1987 (successful) and 1991 (failed) prior to blowing down in the summer of 1991. A new nest was built and occupied by a RTHA pair in the same tree during the 1992 nesting season, but it was not determined if the nest was successful.

In summary, while hispid cotton rat populations appear to have a direct influence on raptor nesting *abundance* in general (as hypothesized by Baumgartner and Baumgartner, 1944), the role, if any, of the cotton rat in influencing patterns in species-specific nest *distribution* remains largely unknown.

Disturbance and Nesting Raptors

Major factors differentiating the nesting raptors on Fort Sill from those nesting elsewhere in southwestern Oklahoma are the unique types of disturbances and land management practices associated with Army training activities. Quantifying direct and indirect impacts and assessing cause and effect from military activities was beyond the scope of this investigation, but it was possible to identify some of these potential impacts. A brief review of previous reports may be helpful in interpreting other aspects of this study. Fortunately, impacts to raptors and other wildlife from civilian activities, and to a lesser extent military, has received some needed attention in recent years (e.g., Andersen 1984; Awbrey and Bowles 1990; Boeker and Ray 1971; Bryant 1986; Ellis 1981; Fernandez and Azkona 1993; Geese et al. 1989; Jackson et al. 1977; Fyfe et al. 1976; Holthuijzen 1989; Mathisen 1968; Snyder et al 1978; Severinghaus and Goran 1981; Severinghaus et al. 1979; White and Thurow 1985). Many of the published reports on raptors and other birds have been focused either in other regions or on threatened and endangered species. Unfortunately, however, many of the investigators commonly reported inconsistent and/or inconclusive results.

It was possible that military training activities in one training area induced some breeding pairs to select an existing nest structure or construct a new one in a different area. However, disturbance to nesting raptors can come from a wide array of sources including the weather, the presence of other raptors, recreationists, vehicles, fire, and mammalian and reptilian predators. For raptors, and most likely other birds, the nest-building and egg-laying phases are periods in which sensitivity to noise disturbances is greatest (Fyfe and Olendorff 1976; Grier and Fyfe, 1987). Potential outcomes from disturbances range from insignificant to severe and can vary considerably from bird to bird. Often, if the adults do leave the nest, they soon return after the source of disturbance leaves with no apparent ill-effects. However, nests have often been abandoned following disturbances (Garber 1972; Herren 1969), or eggs have been inadvertently damaged or knocked out of the nest by adults quickly leaving the nest (Ames and Mersereau 1964). Eggs left unattended for prolonged periods could cool down sufficiently to slow or stop embryo development. Disturbance to nesting raptors during inclement weather should be avoided, as eggs and young are vulnerable to chilling and dehydration. As young birds get older, they require progressively less attention by the adults, and can usually tolerate several hours without feeding. However, frequent or prolonged stress to the adults and/or young can potentially decrease the overall fitness of the young and contribute towards post-fledging mortality.

Andersen (1984) believed that military activities at Fort Carson, CO, in general had negative effects on many nesting raptor species during a 2-year period. The destruction of an entire cohort of sooty terns (*Sterna fasca*) in Florida was attributed to frequent sonic booms produced by jet aircraft flying over a colony (Austin et al., 1970). Fernandez and Azkona (1993) believed that even minor human disturbances to marsh harrier (*Circus aeruginosus*) nestlings could not only negatively impact their condition, but cause long-term effects on this species by increasing energy and time expenditures in nonreproductive activities. Several other researchers have reported human disturbance as being a major cause of raptor nest failure (Boeker and Ray 1971; Grier and Fyfe 1987; Shaw 1970; Verbeek 1982).

Although few researchers have identified benefits to raptors from loud noises, few have concluded noise disturbance to be inherently detrimental. A growing number of investigators are reporting evidence of habituation in raptors (e.g., Andersen, Rongstad, and Mytton 1989; Edge and Marcum 1985; Krzysik 1987 & 1989; Lee 1981). Much of the evidence suggests the potential for adverse effects on raptors is greater if a disturbance is infrequent rather than if the disturbance is predictable or repetitious. For example, Lee (1981) reported that a female goshawk occupied a nest directly adjacent to a frequently used hiking trail. The female successfully fledged her young in spite of hikers walking under the nests daily, some of whom stopped and yelled at the bird. Lee also recounted a case of a Cooper's hawk nest in a Utah ski resort. The hawk remained on the nest if hikers stayed on the trail, and invariably left the nest if the hikers left the trail and ventured into the woods. Ames (1964) determined that osprey nesting in remote sites that were suddenly exposed to human disturbance fledged fewer young than those nesting in sites subjected to persistent human (recreational) disturbance. In British Columbia, Bebe (1974) found that bald eagles in wilderness situations were greatly disturbed by human activity. However, in areas where both foot and boat traffic were especially frequent, Bebe affirmed the eagles became disturbed only after someone started to climb the nest tree itself. Stalmaster and Newman (1978) suggested wintering Bald eagles had the ability to habituate to normal activities as well.

Mathisen (1968), found little evidence that recreational activities negatively impacted eagle productivity. However, Mathisen (1968) and McGarigal, Anthony, and Isaacs (1991) both concluded that disturbance from boating and other recreational activities has the potential of altering bald eagle foraging patterns with possible negative consequences. Considering the osprey, Swenson (1979) reported nesting success in Yellowstone National Park was lower in areas with heavy boating pressure than for undisturbed sites whereas Schroeder (1972), concluded that human activity, in general, was not detrimental to osprey nesting success in northern Idaho. In fact, Schroeder describes one situation in which an osprey nest, located on pilings at the mouth of a major river, successfully fledged three young in spite of hundreds of boats passing close by each weekend. On Fort Sill, nest #53 was occupied by a GHOW pair in 1989 (Appendix B; Figure 9). This nest was approximately 9 m high in a pecan tree in the middle of the Blue Beaver driving course, the base of the tree being less than 4 m from two bleachers where soldiers routinely received verbal instruction. This nest failed not because of frequent troop and vehicular activity, but as a result of 40 mph winds occurring on 3 March that severely damaged the structural integrity of the nest.

Both vehicular and aircraft noises have been shown to be potential sources of disturbance to wildlife and raptors, and in general, helicopter noise seems to be somewhat more disturbing than fixed-wing or jet aircraft (Klein 1973; Ward et al. 1986; White and Sherrod 1973; Awbry and Bowles 1990;). Andersen and others (1889, 1990) studied the effects of selected military activities and helicopter overflights at the Fort Carson Military Reservation (FCMR) and Piñon Canyon Maneuver Site (PCMS) in Colorado. They found that in general, raptors tended to shift the centers of their home ranges in response to, and away from military activities (Andersen, Rongstad, and Mytton 1986, 1990). Furthermore, 8 percent of nesting RTHAs on FCMR flushed in response to direct approaches by helicopters, while 53 percent of the nesting RTHAs at PCMS flushed (Andersen, Rongstad, and Mytton 1989). Andersen and others attributed this significant discrepancy in helicopter tolerance to unique land use histories. More specifically, low-level aircraft training has occurred regularly on the FCMR since the late 1950s, while the PCMS experienced little human activity and no low-level aircraft training prior to the Army acquiring the land in 1983. The results of their studies suggest that raptor habituation to certain military activities and helicopter disturbance is influenced by season, with nesting raptors exhibiting a greater tendency than nonnesting to habituate. Their results further suggest breeding RTHAs on the PCMS could, after several more decades of consistent use, habituate to helicopter disturbance to comparable levels exhibited at the FCMR.

On Fort Sill, approaching nesting GHOWs and RTHAs via helicopter or on foot was minimal, but when attempted generally did not elicit a noticeable response from the bird. Nest #150 (Figure B12), for example, was just 6.9 m off the ground in a small eastern cottonwood located directly between two small arms ranges and within an impact area buffer zone. The GHOW female occupying this nest allowed the author and an associate to approach the nest and sit directly under her to get an accurate location reading from a GPS unit. The female sat relatively motionless during the entire event that lasted 5 or 6 minutes. At least two young, and possibly a third, subsequently fledged from this nest. Andersen (1984), in contrast, believed that while wintering raptors on Fort Carson seemed to habituate to military activities, breeding raptors probably did not.

Lynch and Speake (1978) reported that neither real nor simulated sonic booms produced adverse effects on nesting behavior or productivity in the eastern wild turkey (*Meleagris gallopavo silvestris*). Holthuijzen (1989) concluded that construction activities (including blasting), in general, had no detectable adverse effects on nesting prairie falcons (*Falco mexicanus*) in the Swan Falls area of Idaho. He further concluded that the vacancy rate did not significantly differ between prairie falcon nesting territories exposed to blasting and those that were not. Fraser, Frenzel, and Mathisen (1985) found the proportions of bald eagle nests that were successful or failed were not associated with nest proximity to vehicles, machinery, or roads. White and Thurow (1985) found that while 38 percent of Ferruginous hawk nests failed after 6 to 8 vehicle disturbances, successful nests incurred 24 to 28 vehicle disturbances. In investigating the effects of vehicular traffic on nesting burrowing owls (*Speotyto* [*Athene*] *cunicularia*) in eastern Colorado, Plumpton and Lutz (1993) found few negative impacts on owl behavior or productivity. Burrowing owls on Fort Sill appear to be most abundant within the heavily used West Range impact area, although little is known regarding their productivity.

Researchers (Jackson et al. 1977) in Mississippi observed a northern harrier (NOHA) on a U.S. Navy bombing range while jet aircraft flew approximately 500 m away (noise levels of 80 to 87 dB) dropping 25-lb exploding bombs. They suggested the harrier was opportunistically hunting small mammals flushed from cover by the explosions. While this specific behavior was not observed on Fort Sill, Tennesen (1993) did report NOHAs and wild turkey frequently and successfully roosting adjacent to an Air Force strafing area in Quanah Range (Figure 2). Additionally, the impact area buffer zone on the north side of the South Arbuckle Impact Area on Fort Sill (Figure 2) contains consistently high numbers of NOHAs on their winter roosts (mean=482 individuals) annually. Empirical evidence collected to date suggests fluctuations in the winter harrier population appear to be influenced more by landscape-level factors such as prey abundance (Orr, 2 February 1992) and weather patterns than by military activities or other site-specific influences.

Field observations at Fort Sill indicate that species and individuals often respond to the same types of disturbances differently. The maturity and current reproductive stage of each adult at the time of disturbance are likely important yet unquantified factors in determining the level of that response. During the 1991 nesting season, an adult RTHA remained on nest #124 (Figure B5) as 155 mm howitzers were firing just 15 to 20 m and frequent troop activity occurred almost directly under the tree. Two young birds subsequently were banded and fledged from this particular nest. As another example, nest #143 (Figure B3) is located in the Beef Creek drainage, and was occupied by a RTHA in 1988 that successfully fledged two young. In 1990, it was occupied by a GHOW, but unfortunately it could not be determined if the owl nest was successful or not. Interestingly though, this nest was immediately downrange of a frequently used small arms firing complex, and is bordered on the opposite side by the North Arbuckle impact area. The trunk of this cottonwood was riddled with bullet holes to a height of about 5 m, and the nest itself was 9 m off the ground. Just 200 m to the south of #143 and also in the beef creek drainage at the periphery of the small arms range was nest #144, which blew down in 1990. This nest was located just west of the small arms range, received somewhat less damage from small arms fire, and was never occupied by a breeding pair during the study period. This nest could have been an alternate nest constructed by the same individuals who built nest #143, or possibly by a nonbreeding pair.

It is sometimes tempting to extrapolate conclusions reached in other studies to the raptors on Fort Sill, but few if any of the researchers used comparable approaches and experimental designs, making it difficult to draw valid inferences about the effects of disturbance in different environments. More specifically, variables such as recreational use, precipitation, topography, vegetation, soils, land-use, and training intensity and frequency are site-specific, further highlighting the need for conservative data interpretation. However, because of the consistent types of training activities occurring in the same areas year after year, it is likely that some of the nesting raptors on Fort Sill have become habituated to certain military disturbances. More simply, many of the nesting raptors appear to tolerate most of the loud military noises and activities around their nest sites.

Impacts to nesting raptors, in spite of apparent habituation to many military disturbances, still have the potential to be detrimental, especially if the disturbance occurs during a critical period in the nesting cycle. In 1991, a RTHA pair occupied nest #29, located just east of the eastern border of the Quanah Range Impact Area (Figure B5). An accidental fire attributed to a military training exercise burned much of the immediate area, including the base of the post oak tree supporting the nest. Because of the fire, the nest was abandoned for much of the day by the female and it subsequently failed. It was impossible to monitor each nest during training activities, and Army activities have undoubtedly directly and indirectly contributed to other raptor nests failing. Nest #29 represents one of just two known cases of RTHA nest failure directly as a result of military activity documented during this study. The second nest failure, nest #162 (Figure B5), was located adjacent to a small arms firing range and appeared to fail in 1991 because of firing activities. The same or another pair of RTHAs reoccupied this nest in 1992, failing again after it completely blew out of the tree from high winds.

7 Conclusions and Recommendations

Conclusions

A total of 217 raptor-constructed nests were located and mapped over the 6-year study period. Approximately 153 structurally-intact raptor nests were identified and monitored for occupancy annually, with approximately one-third of them subsequently found to be occupied by breeding pairs in any one nesting season.

Great Horned Owls were without exception the earliest nesters on Fort Sill, occasionally laying eggs in mid-January. RTHAs and RSHAs generally began laying eggs 4 to 6 weeks after the GHOWs.

Expectedly, RSHA densities were substantially lower than those reported in the literature, as Fort Sill is located within the extreme western margin of this species' geographic range and as such does not contain optimal habitat. In contrast, installation-wide RTHA and GHOW nest densities compare favorably with those reported from other regions. Within their preferred habitats, RTHA and GHOW densities on Fort Sill equal or exceed many of the published values for other regions.

On average, RTHAs and GHOWs comprised 68 percent and 27 percent of the documented nesting raptors, respectively, each year. Because of their secretive behavior and tendency to nest in cavities, BAOWs are believed to have nested in significantly greater numbers than documented. Other raptor species (e.g., Barn Owls, Northern Harriers, and Mississippi Kites) were known to nest on the installation but were not a research priority in this study. Not known to nest on Fort Sill or anywhere in the county prior to 1989, RSHAs appear to have established a small but persistent breeding presence on the installation. Red-shouldered Hawks, BAOWs and NOHAs collectively comprised the remaining 5 percent of the documented nesting pair annually.

Red-tailed Hawks nested in 13 species of native trees, but nearly one-half (48 percent) of their occupied nests were in cottonwood (Table 8). Great Horned Owls did not construct their own nests but instead relied on the RTHA or other species for nest-structures. Great Horned Owls clearly did not select nest structures randomly, and occupied nests in 11 species of trees. Post oak (31 percent), cottonwood (25 percent) and American elm (15 percent) were the three most common nest-tree species for the GHOW. Red-shouldered Hawks were less predictable than GHOWs and RTHAs with respect to their choice of nest-tree. The seven RSHA nests were constructed in five tree species, none of which were cottonwood.

The physical structure of a tree and its size relative to adjacent trees was clearly more important to nesting raptors than what species it was. Of the 33 species of potential nest trees occurring on Fort Sill, raptor nests were identified in nearly one-half (45 percent) of them. However, approximately 95 percent of the nests were constructed in trees with their crowns classified as dominant or codominant. Few nests were found in trees with intermediate crowns and none in suppressed crowns. The number of nest supporting branches varied slightly among tree species, but did not appear to be strongly correlated with nest longevity, success, or failure.

Red-tailed Hawks were more likely to occupy the same nest two or more times than any other species. Several RTHA nests were occupied in 5 or 6 of the study years, while it was uncommon for GHOWs to occupy the same nest for even 3 consecutive years. Based on the number of nests lost to adverse weather or other causes and the number of newly constructed nests each year, nest turnover on Fort Sill is estimated at 8 to 10 years.

Woody understory and overstory stem densities at the nest-site were highly variable, and in general were not reliable predictors of the occupying species. Red-tailed Hawks and GHOWs occupied nests in isolated trees as often as those surrounded by numerous woody plants of varying size classes. Red-shouldered Hawks were never in isolated trees, and tended to be surrounded by a relatively diverse over and understory. The one consistent characteristic that was shared among raptors was that nest-trees were taller and bigger (DBH) than adjacent trees in the immediate area.

There was highly significant interaction between plant community and overall raptor nest distribution (X^2=376.8; df=15, $p<0.005$) and also with individual species. Red-tailed Hawks were strongly associated with Elm-Ash forest, nesting in disproportionally high numbers (55 percent of nests) relative to the total available area (13 percent of the installation). Red-shouldered Hawks nested exclusively in Elm-Ash forest, with 100 percent of their nests occurring there. Great Horned Owls were more evenly distributed over the installation, but appeared to favor available nests occurring in one of the two upland forest types (Mesquite Savanna and Cross Timbers) over bottomland (Elm-Ash) forest.

Particularly with regards to the RTHA, raptors generally did not select a nest-tree species in proportion to its abundance in the plant community. Within Elm-Ash habitat, RTHAs and RSHAs preferred a few, relatively infrequently occurring tree species over the far more abundant species (in terms of frequency). Similarly, within Cross Timbers plant communities, nest abundance (largely GHOWs) was strongly biased towards post oak although it was less abundant than blackjack oak. Western soapberry and mesquite, both dominant trees in terms of density (# trees/ha) in their respective habitat types, are clearly selected against by the larger raptors as nest trees. The reason mesquite and soapberry are avoided could be largely due to undesirable growth-form characteristics. More simply, the typical branch structure for these two species at 6 m above the ground (minimum recorded nest height) simply does not appear adequate to support a moderately sized nest.

Including both occupied and unoccupied nests, overall raptor nest distribution was not statistically significant with respect to military land-use as defined in this study (X^2=12.2; df=6). Great Horned Owls, RTHAs, and RSHAs nested in the Cantonment, Impact, and Maneuver areas in numbers closely approximating what would be expected in a random distribution.

The mean distances from the nests to a stream or pond tended to be more variable within species than between, although species-specific trends became evident. Red-shouldered Hawks' nests were consistently the closest to water (mean=54 m). The average RTHA nest was three times farther away (mean=160 m), and GHOW nest nearly four times farther (mean=204 m) from water than the RSHAs.

Based on the number of nests in which nesting success or failure could be confirmed (60 percent), habitat appeared to be a contributing factor in determining overall raptor nesting success. Nests within the Mesquite Savanna plant community exhibited the lowest success rate (58 percent) and Elm-Ash forest the highest (82 percent), with the other habitats being intermediate. The differing nesting success rates are likely biased by small sample sizes, site accessibility, and monitoring frequency, warranting a conservative interpretation. In contrast to nesting success, overall productivity did not appear to vary appreciably with respect to land-use or habitat (including Mesquite Savannah).

Competition was identified as being a major factor not only in influencing raptor nest distribution but also in determining the upper density limit. Based on intraspecific and interspecific nest distances, RTHA territories appeared to be considerably smaller than GHOW territories. Red-tailed hawk territories were found to be inversely correlated (r=-0.85) with nesting abundance to a greater degree than for the GHOW (r=-0.65), contributing to the greater potential of RTHAs to achieve higher densities. As expected, RTHAs and GHOWs were more tolerant of another species nesting in close proximity than they were of a conspecific pair.

The overall nesting success rate for the RTHA (75 percent), RSHA (75 percent) and GHOWs (70 percent) in general compare favorably when compared to published reports. Based on values reported in the literature, Andersen (1984) calculated a mean (unweighted) RTHA success rate of 69 percent. Henny (1972) reported the mean success rate for GHOWs, RTHAs and RSHAs across North America as 78 percent, 73 percent and 82 percent respectively. Other investigators have reported success rates for the RTHA, RSHA, and GHOW in other areas ranging from 50 to 93 percent (Hagar 1952; Gates 1972; Henny et al. 1973; Peterson 1979; Andersen 1984).

The number of young fledged per successful nest (productivity) was 1.86 for RTHAs, 1.82 for GHOWs, and 2.7 for RSHAs. Combining successful and failed nesting attempts, the number of young per nest averaged 1.67 for RTHA, 1.12 for GHOW and 2.7 for RSHA (none were confirmed to have failed but it was possible). In general, these figures are comparable to published reports in other regions, which generally range from 0.9 to 2.8 young per nest (Hagar 1952; Gates 1972; Henny et al. 1973; Peterson 1979; Andersen 1984).

Approximately 167 RTHA, 53 GHOW, and 8 RSHA young were known to have fledged on Fort Sill during the study period. Of this total, approximately 70 percent were banded with USFWS leg bands. Productivity estimates were based on those nests known to have been successful or failed. A significant but unknown number of RTHA, GHOW and RSHA young are believed to have fledged from the relatively large number of nests with unknown dispositions as well.

The majority of nest failures were most frequently attributed to weather (e.g., high winds) when the cause could be discerned. Direct military impacts are those that directly cause mortality, destroy occupied nests, or alter habitat or a raptors typical daily activity pattern. At least two nest failures over the 6-year period were the result of military activities (6.9 percent). Direct impacts can be difficult to observe and although this figure should be considered conservative, it is doubtful it approached failures from adverse weather (27.6 percent). Indirect impacts from military activities undoubtedly occurred but were difficult at best to observe and even more difficult to quantify, highlighting the need for additional research in this area.

The distance of a nest from a stream or pond was not a reliable predictor of nesting success. Successful RTHA nests were not significantly closer to a stream or pond than were failed nests. Likewise, successful GHOW nests were not significantly closer to a stream or pond than failed nests.

Nesting densities on Fort Sill did not appear to be limited significantly by the quantity of existing nests or potential nest-trees. Reasons to support this include: (1) on average, 70 percent of structurally-intact raptor nests in any 1 year were unoccupied, (2) although preferences were clearly evident, most species showed a broad tolerance to many tree species, tree sizes, and plant communities, and (3) just one nest was constructed in a nontree during the entire study period.

Prey availability was believed to be the single most important factor in determining raptor nesting abundance. Trends in nesting abundance paralleled perceived trends in hispid cotton rat abundance, a small mammal species preferred as a prey item and sometimes subject to extreme weather-induced population fluctuations. Based on incidental food habit observations in occupied nests, rabbits appeared to be an important staple prey item in all years as well.

Because raptor mortality, dispersal, and immigration data were not collected, the stability of the raptor populations on the installation was not assessed directly. It is therefore not known whether raptor productivity on Fort Sill is great enough to exceed the additive effects of mortality and emigration (loosely termed an ecological "source") or whether immigration is critical to maintain a persistent population (loosely termed an ecological "sink").

The cumulative impacts of military and civilian activities were not assessed during this study. However, nesting raptors appeared tolerant of many military activities, and in numerous instances, occupied nests were located in extremely close proximity to firing ranges, artillery firing points, and impact areas with no apparent impact on productivity or nest success is provided as empirical evidence of habituation. Moreover, overall RTHA and GHOW densities, success, and productivity rates are comparable and often exceed values reported from other regions. In general, evidence collected during this study suggests the direction of any cumulative impacts from military activities has been either neutral or leaning toward the positive side of the scale.

Recommendations

General

It is recommended that identifying, mapping and monitoring RTHA-, RSHA-, and GHOW-occupied nests on an annual basis be continued if possible. A long-term data set is essential in definitively assessing the stability of the raptor population, and to discriminate perceived trend from natural variability. Based on the estimated nest-turnover rate, if nest location data were no longer collected, the utility of the data base would be greatly reduced in just a few years, and antiquated by the year 2000.

Censusing the NOHA winter roost on the East Range should continue each winter. This range is thought to be the worlds largest for this species so monitoring this roost represents an unprecedented research opportunity for installation personnel. Combining the census with prey studies is suggested to help elucidate the importance of Fort Sill as a migratory habitat to this species.

Management aimed at improving game populations will generally benefit raptors so long as adjacent nesting habitat continues to be maintained. Fort Sill's restrictions on the cutting of standing timber, a 4-decade moratorium on livestock grazing, and emphasis on a proactive wildlife management program have undoubtedly been contributing factors in encouraging and maintaining the high levels of raptor wintering and nesting use of the installation.

A number of researchers (Thomas et al. 1979; Glinski et al. 1983; Bohall and Collopy 1984) have emphasized the great importance of snags as perching and hunting sites to raptors. Fager and others (1984) report that a minimum of 11 snags of 50 cm DBH or greater be provided per 40 ha (or 1 per 0.3 ha). The RTHA, GHOW, and RSHA are species that require standing timber to perch on or hunt from. And although available data suggests a sufficient number of snags exist on Fort Sill, monitoring this structural and functional component of their habitat should help assure an adequate quantity and equitable distribution in the future.

Data collected to date suggests the use of artificial platforms by nesting raptors would be low. However, erecting nesting platforms in areas where suitable nest-trees are noticeably lacking could *potentially* increase, albeit slightly, overall raptor nesting densities under the proper conditions. Specifically, the relatively large area of rocky hills between Blue Beaver Creek and the Quannah Range impact area is consistently and conspicuously sparse with respect to nests, and might benefit from this management option only if: (1) sufficient prey populations exist and are readily accessible, (2) there is a surplus of breeding adults in the area, and (3) platforms are strategically located on hillsides, drainages, or other areas somewhat protected from high winds associated with higher elevations.

Minimizing Disturbance to Nesting Raptors

Spatial access restrictions to portions of Fort Sill are an intrinsic by-product of past and present military weapons-firing activities. These restrictions, some permanent and some temporary, have undoubtedly helped to minimize disturbances to raptors often associated with human recreational activities (e.g., boating, hiking, off-road driving, birding) than experienced on nonmilitary public lands. Continued access restrictions are likely to maintain a similar level of protection into the next century.

A recommendation to restrict all military or civilian activities in close proximity to nesting raptors is not supported by qualitative observations and limited quantitative data collected to date. However, in spite of apparent habituation to many military activities, it is reasonable to believe the *potential* of these activities to disturb nesting raptors remains. The period of greatest nesting activity on Fort Sill is generally from February through June. If flexibility in a military mission exists, encouraging vehicle operators not to park within 25 m of the base of trees with raptor nests during this time period is recommended. This distance is somewhat arbitrary, but represents a distance that should prevent direct damage to and reduce soil compaction around nest trees, and was a distance that seemed to be well tolerated by the majority of females sitting on their nests.

Not all raptors on Fort Sill are able to habituate to military-related disturbances, and this attribute should not be assumed. To minimize negative impacts to eggs or young birds, occupied nests should not be closely approached during periods of extreme weather conditions. If close contact with an occupied nest is unavoidable, civilians and military personnel should be encouraged to approach the nest tangentially rather than directly. While numerous individuals remained on their nests regardless of the approach used, this method has been shown to be less threatening to raptors in general and is therefore encouraged.

Fire is a natural and required component of grassland ecosystems, but excessive fire frequency can reduce some small mammal populations and potentially impact those raptor species dependent on them. Fire frequency approximating what was historically experienced in the region should be maintained, and attempts should be made to extinguish excessive accidental fires caused by military and/or civilian activities when possible.

Reducing disturbance requires both education and law enforcement components. Raptors continue to be protected under federal and state law, and any willful persecution or molestation of the birds or their nests is illegal. Arrests made by Fort Sill Game Wardens for endangering or killing raptors have resulted in successful convictions in the past (Kevin McCurdy, U.S. Army Field Artillery Center and Fort Sill, Fort Sill, OK, Game Warden, professional discussion, 10 December 1988). Continued law enforcement by Fort Sill natural resources personnel in concert with educational briefings of these and other environmental regulations for incoming military personnel and civilian sportsman should help minimize the risk to raptors considerably.

Suggested Areas of Future Research

Additional research should establish one or more long-term, on and off-post study site(s) as controls to more clearly define and quantify short-term and cumulative Army impacts on nesting raptors. Controlled experiments are essential to definitively measure and assess military or any other reasonably foreseeable impacts. Concurrent monitoring of raptor and prey populations within the Wichita Mountains Wildlife Refuge should also be considered.

Seasonal raptor surveys (e.g., systematic roadside counts) should be inititated on Fort Sill to quantify and monitor the nonbreeding as well as the breeding individuals. Although this study focused on the nesting population, the importance of Fort Sill to raptors in the region is clearly not restricted to the nesting season.

Little is known on the population dynamics of raptors in the region. Tracking adult and, to a lesser extent, juvenile birds via radio telemetry would be extremely valuable in: (1) documenting the responses of individual birds to concurrent military activities (direct impacts), (2) clearly defining seasonal raptor home ranges and territories, (3) assessing the importance of each habitat type to each species, (4) quantifying mortality and dispersal, and (5) assessing population stability.

Since prey abundance and importance to a predators diet are not always highly correlated (Korschgen and Stuart 1972; Steenhof and Kochert 1988), initiating a general food-habits study on Fort Sill is recommended to quantify the important prey items actually consumed by each raptor species. LCTA methodologies could be augmented to provide density estimates (# per ha) for the appropriate small mammal species within each of the major plant communities identified. Monitoring the prey base would also be helpful in understanding and predicting trends in raptor abundance.

Barred owls, Northern Harriers, and other non-buteos are believed to have nested in numbers greatly exceeding those recorded. Additional research efforts, which recognize activity patterns and nesting tendencies of the more secretive and uncommon nesting species, are recommended to more adequately address issues related to abundance, competition, habitat, and prey requirements, and compatibility with military training activities.

References

Ames, P.L., and G.S. Mersereau, "Some Factors in the Decline of the Osprey in Connecticut," *Auk*, vol 81 (1964), pp 173-185.

Andersen, D.E. *Military Training and the Ecology of Raptor Populations at Fort Carson, Colorado*, M.S. Thesis (University of Wisconsin-Madison, 1984).

Andersen, D.E., O.J. Rongstad, and W.R. Mytton, "The Behavioral Response of a Red-tailed Hawk to Military Training Activity," *Journal of Raptor Research*, vol 20 (1986), pp 65-68.

Andersen, D.E., O.J. Rongstad, and W.R. Mytton, "Response of Nesting Red-tailed Hawks to Helicopter Overflights," *Condor 91* (1989), pp 296-299.

Andersen, D.E., O.J. Rongstad, and W.R. Mytton, "Home-Range Changes in Raptors Exposed to Increased Human Activity Levels in Southeastern Colorado," *Wildlife Society Bulletin*, vol 18 (1989), pp 134-142.

Andrew, J.M., C.P. Boydstun, and A.R. Pfister, "Black-Shouldered Kite in Commanche County, Oklahoma," *Bulletin of the Oklahoma Ornithological Society*, vol 16 (1983), pp 30-31.

Armstrong, E., and D. Euler, "Habitat Usage of Two Woodland *Buteo* Species in Central Ontario," *Canadian Field Naturalist*, vol 97 (1982), pp 200-207.

Austin, O.L., Jr., W.B. Robertson, Jr., and G.E. Woolfenden, "Mass Hatching Failure in Dry Tortugas Sooty Terns (*Sterna Fuscata*), in K.H. Voous, ed., *Proceedings: 15th International Ornithological Congress* (The Hague, Netherlands, 1970), p 627.

Awbrey, F.T., and A.E. Bowles, *The Effects of Aircraft Noise and Sonic Booms on Raptors*, NSBIT Technical Operating Report No. 12 (Sea World Research Institute, Hubbs Marine Research Center, San Diego, CA, 1990).

Banta, J. K., and J. McMahon, "Harris' Hawks in Oklahoma During Fall and Winter, 1986-87," *Bulletin of the Oklahoma Ornithological Society*, vol 20 (1987), pp 29-31.

Baumgartner, A., and F.M. Baumgartner, "Hawks and Owls in Oklahoma 1939-1942: Food Habits and Population Changes," *Wilson Bulletin*, vol 56 (1944), pp 209-215.

Bednarz, J.C., and J.J. Dinsmore, "Status, Habitat Use and Management of Red-shouldered Hawks in Iowa," *Journal of Wildlife Management*, vol 45 (1981), pp 236-241.

Bednarz, J.C., and J.J. Dinsmore, "Nest-Sites and Habitat of Red-shouldered and Red-tailed Hawks in Iowa," *Wilson Bulletin*, vol 94 (1982), pp 31-45.

Beebe, F.L., "Field Studies of the Falconiformes of British Columbia," *British Columbia Provincial Museum Occasional Papers*, No. 17 (Victoria, BC, Canada, 1974).

Bent, A.C., *Life Histories of North American Birds of Prey: Part One* (Dover Publications, Inc., New York, NY, 1961).

Bent, A.C., *Life Histories of North American Birds of Prey: Part Two* (Dover Publications, Inc., NY, 1961b).

Boeker, E.L., and T.D. Ray, "Golden Eagle Population Studies in the Southwest," *Condor*, vol 73 (1971), pp 463-467.

Bohall, G.B., and M.W. Collopy, "Seasonal Abundance, Habitat Use, and Perch Sites of Four Raptor Species in North-Central Florida," *Journal of Field Ornithology*, vol 55 (1984), pp 181-189.

Boice, L.P., "The Department of Defense's Natural Resources Management Program: Integrating Stewardship and Mission Requirements," *The Environmental Professional*, vol 14 (1992), pp 84-87.

Bosakowski, T., D.G. Smith, and R. Speiser, "Status, Nesting Density, and Microhabitat Selection of Red-shouldered Hawks in Northern New Jersey," *Wilson Bulletin*, vol 104 (1992), pp 434-446.

Brimley, H.H., "An Unusual Gathering of Marsh Hawks in Central North Carolina," *Auk*, vol 52 (1935), pp 445-446.

Brittingham, M.C., "The Nature and Management of Source and Sink Populations," *First Annual Conference Abstracts* (The Wildlife Society, Albuquerque, NM, 1994).

Bryant, A.A., "Influence of Logging on Red-shouldered Hawks, *Buteo lineatus*, in Waterloo Region, Ontario, 1953-78," *Canadian Field Naturalist*, vol 100 (1986), pp 520-525.

Carrier, W.D., and W.E. Melquist., "The Use of Rotor-Winged Aircraft in Conducting Nesting Surveys of Ospreys in Northern Idaho," *Journal of Raptor Research*, vol 10 (1976), pp 77-83.

Choate, L.L., *Natural History Study of a Relictual Population of Pitymys Ochrogaster in Southwest Oklahoma*, M.S. Thesis (Midwestern State University, OK, 1988).

Craighead, J.J., and F.C. Craighead, Jr., *Hawks, Owls and Wildlife* (Dover Publications, Inc., New York, NY, 1969).

Crocoll, S.T., and J.W. Parker, "The Breeding Biology of Broad-winged and Red-shouldered Hawks in Western New York," *Journal of Raptor Research*, vol 23 (1989), pp 125-139.

Davis, J.W. "Snags Are for Wildlife," in J.W. Davis, G.A. Goodwin, and R.A Ockenfels, eds., *Snag Habitat Management: Proceedings of a Symposium*, USDA Forest Service Technical Report RM-99 (1983), pp 4-9.

Diersing, V.E., and W.D. Severinghaus, *The Effects of Tactical Vehicle Training on the Lands of Fort Carson, Colorado—An Ecological Assessment*, Technical Report (TR) N-85/03/ADA152142 (U.S. Army Construction Engineering Research Laboratories [USACERL], December 1984).

Diersing, V.E., and W.D. Severinghaus, *Wildlife as an Indicator of Site Quality and Site Trafficability During Army Training Maneuvers*, TR N-86/03/ADA163560 (USACERL, December 1985).

Ellis, D.H., *Responses of Raptorial Birds to Low-Level Military Jets and Sonic Booms: Results of the 1980-1981 Joint USAF-USFWS Study*, ADA108-778 (National Technical Information Service, Springfield, VA, 1981).

Fager, L.F., J.C. Capp, and J.L. Sheppard, "Wildlife Requirements and Uses of Snags and Dead/Down Trees on Forested Land in Colorado," in R.L. Hoover and D.L. Wills, eds., *Managing Forested Lands for Wildlife* (Colorado Division of Wildlife, Denver, CO, 1984), pp 413-417.

Fernandez, C., and P. Azkona., "Human Disturbance Affects Parental Care of Marsh Harriers and Nutritional Status of Nestlings," *Journal of Wildlife Management*, vol 57 (1993), pp 602-608.

Fitch, H.S., "Home Ranges, Territories, and Seasonal Movements of Vertebrates of the National History Reservation," *University of Kansas Publications, Museum of Natural History*, vol 11 (1958), pp 63-326.

Fitch, H.S., F. Swenson, and D.F. Tillotson, "Behavior and Food Habits of the Red-tailed Hawk," *Condor*, vol 48 (1946), pp 205-237.

Fleischner, T.L., and S. Weisberg, *Effects of Jet Aircraft Activity on Bald Eagles in the Vicinity of Bellingham International Airport*, Unpublished Report (DEVCO Aviation Consultants, Bellingham, WA, 1986).

Fort Sill Military Reservation Natural Resources Conservation Plan (USDA Soil Conservation Service, 1970).

Fraser, J.D., L.D. Frenzel, and J.E. Mathisen, "The Impact of Human Activities on Breeding Bald Eagles in North-central Minnesota," *Journal of Wildlife Management*, vol 49 (1985), pp 585-592.

Fyfe, R.W., and R.R. Olendorff, "Minimizing the Dangers of Nesting Studies to Raptors and Other Sensitive Species," *Canadian Wildlife Service Occasional Papers*, No. 3 (1976).

Galli, A.E., C.F. Leck, and R.T. Foreman, "Avian Distribution Patterns in Forest Islands of Different Sizes in New Jersey," *Auk*, vol 93 (1976), pp 356-364.

Galushin, V.M, "Synchronous Fluctuations in Populations of Some Raptors and Their Prey," *Ibis*, vol 116 (1974), pp 127-134.

Garber, D.P., *Osprey Nesting Ecology in Lassen and Plumas Counties, California*, M.S. Thesis (Humboldt State University, Arcata, CA, 1972).

Gates, J.M., "Red-tailed Hawk Populations and Ecology in East-Central Wisconsin," *Wilson Bulletin*, vol 84 (1972), pp 421-433.

Geese, E.M., O.R. Rongstad, and W.R. Mytton, "Changes in Coyote Movements Due to Military Activity," *Journal of Wildlife Management*, vol 53 (1989), pp 334-339.

Glinski, R.L., T.G. Grubb, and L.A. Forbis, "Snag Use by Selected Raptors," in J.W. Davis, G.A. Goodwin, and R.A. Ockenfels, technical coordinators, *Snag Habitat Management: Proceedings of the Symposium*, TR RM-99 (USDA Forest Service, 1989), pp 130-133.

GRASS Version 4.1 User's Reference Manual (USACERL, 1993).

Grier, J.W, "Bald Eagle Behavior and Productivity Responses to Climbing to Nests," *Journal of Wildlife Management*, vol 33 (1969), pp 961-966.

Grier, J.W., and Fyfe, "Preventing Research and Management Disturbance," in B.A. Giron Pendleton, B.A. Milsap, K.W. Cline, and D.M. Bird, eds., *Raptor Management Techniques Manual* (National Wildlife Federation, Washington, DC, 1987), pp 173-182.

Hagar, D.C., Jr, "Nesting Populations of Red-tailed Hawks and Horned Owls in Central New York State," *Wilson Bulletin*, vol 69 (1957), pp 263-272.

Hardin, G., "The Competitive Exclusion Principle," *Science*, vol 131 (1960), pp 1292-1297.

Heintzelman, D.S., *Hawks and Owls of North America* (Universe Books, NY, 1979).

Henny, C.J, *An Analysis of the Population Dynamics of Selected Avian Species With Special Reference to Changes During the Modern Pesticide Era*, Wildife Research Report No. 1 (U.S. Department of the Interior, Bureau of Sport Fishing and Wildlife, 1972), pp 1-99.

Henny, C.J., and H.M. Wight, "Population Ecology and Environmental Pollution: Red-tailed and Cooper's Hawks," in *Population Ecology of Migratory Birds: A Symposium*, Wildlife Research Report Number 2 (U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife, 1972), pp 229-250.

Henny, C.J., F.C. Schmid, E.M. Martin, and L.L. Hood, "Territorial Behavior, Pesticides, and the Population Ecology of Red-shouldered Hawks in Central Maryland, 1943–1971," *Ecology*, vol 54 (1973), pp 545-554.

Herren, H., "The Status of the Peregrine Falcon in Switzerland," in J.J. Hickey, ed., *Peregrine Falcon Populations: Their Biology and Decline* (University of Wisconsin Press, Madison, WS, 1969), pp 231-238.

Holthuijzen, A.M.A., *Behavior and Productivity of Nesting Prairie Falcons in Relation to Construction Activities at Swan Falls Dam*, Final Report submitted to the Idaho Power Company, Boise, ID (1989).

Howell, J., B. Smith, J.B. Holt, Jr., and D.R. Osborne, "Habitat Structure and Productivity in Red-tailed Hawks," *Bird Banding*, vol 49 (1978), pp 162-171.

Houston, C.S, "Close Proximity of Red-tailed Hawk and Great Horned Owl Nests," *Auk*, vol 92 (1975), pp 612-614.

Hunt, C.B., *Natural Regions of the United States and Canada* (W.H. Freeman Co., 1974).

Jackson, J.A., B.J. Schardien, and T.H. McDaniel, "Opportunistic Hunting of a Marsh Hawk on a Bombing Range," *Journal of Raptor Research*, vol 11 (1977), pp 86.

Johnson, M.K, "Endangered Species Act Amendments 1979 and 1982," *Wildlife Society Bulletin*, vol 12 (1984), pp 304-311.

Johnson, F.L., R.A. Thompson, R. Rudman, J.R. Estes, G.D. Schnell, and K.D. Harris, *Floral Inventory of Fort Sill, Oklahoma*, Final Report submitted to USACERL (Oklahoma Biological Survey, University of Oklahoma, Norman, 1990).

Kirkley, J.S., and M.A. Springer, "Nesting Populations of Red-tailed Hawks and Great Horned Owls in Central Ohio," *Journal of Raptor Research*, vol 14 (1980), pp 22-28.

Klein, D.R., "The Reaction of Some Northern Mammals to Aircraft Disturbance," in *Proceedings: 11th International Congress of Game Biology* (National Swedish Environmental Protection Board, Stockholm, Sweden, 1973), pp 377-383.

Korschgen, L.J., and H.B. Stuart, "Twenty Years of Avian Predator-Small Mammal Relationships in Missouri," *Journal of Wildlife Management*, vol 36 (1972), pp 269-282.

Krzysik, A.J., *Birds in Human Modified Environments and Bird Damage Control: Social, Economic, and Health Implications*, TR N-90/03/ADA218043 (USACERL, December 1989).

Kuchler, A.W., *Potential Natural Vegetation of the Conterminous United States*, Special Publication No. 36 (American Geographic Society, 1964).

Lee, J.A., "Habituation to Human Disturbance in Nesting Accipiters," *Journal of Raptor Research*, vol 15 (1981), pp 48-52.

Lipske, M., "From War Games to Wildlife Gains," *National Wildlife*, vol 33 (1995), pp 46-51.

Lynch, T.E., and D.W. Speake, "Eastern Wild Turkey Behavioral Responses Induced by Sonic Boom," in J.L. Fletcher and R.G. Busnel, eds., *Effects of Noise on Wildlife* (Academic Press, New York, NY, 1978), pp 47-61.

Mathisen, J.E, "Effects of Human Disturbance on Nesting of Bald Eagles," *Journal of Wildlife Management*, vol 31 (1968), pp 1-6.

McGarigal, K., R.G. Anthony, and F.B. Isaacs, *Interactions of Humans and Bald Eagles on the Columbia River Estuary*, Wildlife Monograph No. 115 (1991), pp 1-47.

McInvaille, W.B., and L.B. Keith, "Predator-Prey Relations and Breeding Biology of the Great Horned Owl and Red-tailed Hawk in Central Alberta," *Canadian Field-Nature,* vol 88 (1974), pp 1-20.

McKay, W.D., *Nesting Density and Distribution of Red-tailed Hawks and Great Horned Owls on a Quadrangle in Unglaciated Ohio*, M.S. Thesis (Ohio State University, Columbus, 1976).

Miller, H.W., and D.H. Johnson, "Interpreting the Results of Nesting Studies," *Journal of Wildlife Management,* vol 42 (1978), pp 471-476.

Montapero, T, "First Northern Harrier Nest in Southwestern Oklahoma," *Bulletin of the Oklahoma Ornithological Society,* vol 21 (1988), pp 12-13.

Morris, M.M.J., B.L. Penak, R.E. Lemon, and D.M. Bird, "Characteristics of Red-shouldered Hawk, *Buteo Lineatus*, Nest Sites in Southwestern Quebec," *Canadian Field-Nature,* vol 96 (1981), pp 139-142.

Morris, M.M.J., and R.E. Lemon, "Characteristics of Vegetation and Topography Near Red-shouldered Hawk Nests in Southwestern Quebec," *Journal of Wildlife Management*, vol 47 (1983), pp 138-145.

Mosher, J.A., K. Titus, and M.R. Fuller., "Habitat Sampling, Measurement and Evaluation," in B.A. Giron Pendleton, B.A. Milsap, K.W. Cline, and D.M. Bird, eds., *Raptor Management Techniques Manual* (National Wildlife Federation, Washington, DC, 1987), pp 81-97.

Nelson, M.W, "Human Impacts on Golden Eagles: A Positive Outlook for the 1980s and 1990s," *Journal of Raptor Research,* vol 16 (1982), pp 97-103.

Newton, I., *Population Ecology of Raptors* (Buteo Books, SD, 1979).

Olendorff, R.R., and J.W. Stoddard, "The Potential for Management of Raptor Populations in Western Grasslands," in F.N. Hamerstrom, Jr., et al., eds., *Management of Raptors*, Raptor Research Report No. 2 (1974), pp 47-88.

Orians, G., and F. Kuhlman, "Red-tailed Hawk and Great Horned Owl Populations in Wisconsin," *Condor,* vol 58 (1956), pp 371-385.

Orr, S.J., and P.B. Tirrell, *Examination of Red-tailed Hawk (Buteo Jamaicencis) for the Presence of Myiasis by Protocalliphora Spp. (Diptera) in Oklahoma*, Unpublished Report (1988).

Palmer, R.S., *Handbook of North American Birds, Vol. 4* (Yale University Press, New Haven, CT, 1988).

Palmer, R.S., *Handbook of North American Birds, Vol. 5* (Yale University Press, New Haven, CT, 1988).

Peterson, L., *Ecology of Great Horned Owls and Red-tailed Hawks in Southeastern Wisconsin,* Wisconsin Department of Natural Research Technical Bulletin No. 111 (Madison, WI, 1979).

Pilcher, B.K., and G.E. Wampler, "Hunting Season Movements of White-tailed Deer on Fort Sill Military Reservation, Oklahoma," in *Proceedings: Annual Conference of the Southeastern Association of Fish and Wildlife Agencies*, vol 35 (1982), pp 142-148.

Plumpton, D.L., and R.S. Lutz, "Influence of Vehicular Traffic on Time Budgets of Nesting Burrowing Owls," *Journal of Wildlife Management,* vol 57 (1993), pp 612-616.

Preston, C.R., C.S. Harger, and H.E. Harger, "Habitat Use and Nest-Site Selection by Red-shouldered Hawks in Arkansas," *Southwest Nature,* vol 34 (1989), pp 72-78.

Regosin, J.V., S.J. Orr, and J. Sarnat, "Recent Breeding Records for the Northern Harrier in Southwestern Oklahoma," *Bulletin of the Oklahoma Ornithological Society,* vol 24 (1991), pp 29-30.

Schroeder, G.J., *Results of a 2-year Investigation of the Ospreys of Northern Idaho,* M.S. Thesis (University of Idaho, Moscow, 1972).

Severinghaus, W.D., and W.D. Goran, *Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Lewis, Washington,* TR N-116/ADA111201 (USACERL, September 1981).

Severinghaus, W.D., and M.C. Severinghaus, "Effects of Tracked Vehicle Activity on Bird Populations," *Environmental Management,* vol 6 (1982), pp 163-169.

Severinghaus, W.D., R.E. Riggins, and W.D. Goran, *Effects of Tracked Vehicles on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY,* Special Report (SR) N-77/ADA073782 (USACERL, July 1979).

Severinghaus, W.D., R.E. Riggins, and W.D. Goran, "Effects of Tracked Vehicles on Terrestrial Mammals and Birds at Fort Knox, KY," *Transactions of the Kentucky Academy of Sciences,* vol 41 (1980), pp 15-26.

Severinghaus, W.D., W.D. Goran, G.D. Schnell, and F.L. Johnson, *Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX,* TR N-113/ADA109646 (USACERL, September 1981).

Shaw, E.W., *California Condor,* Library of Congress Report Number SK351 (Washington, DC, 1970).

Smith, D.G., and J.R. Murphy, *Breeding Ecology of Raptors in the Eastern Great Basin of Utah,* Brigham Young University Science Bulletin No. 18 (1973).

Snyder, N.F.R., H.W. Kale, and P.W. Sykes, Jr., *An Evaluation of Some Potential Impacts of the Proposed Dade County Training Jetport on the Endangered Everglade Kite,* Florida Audubon Society Unpublished Report (Maitland, FL, 1978).

Spurr, S.H., and B.V. Barnes, *Forest Ecology* (John Wiley and Sons, Inc., 1980).

Stalmaster, M.V., and J.R. Newman, "Behavioral Responses of Wintering Bald Eagles to Human Activity," *Journal of Wildlife Management,* vol 42 (1978), pp 506-513.

Steenhof, K., "Assessing Raptor Reproductive Success and Productivity," in B.A. Giron Pendleton, B.A. Milsap, K.W. Cline, and D.M. Bird, eds., *Raptor Management Techniques Manual* (National Wildlife Federation, Washington, DC, 1987), pp 157-170.

Steenhof, K., and M.N. Kochert, "Dietary Responses of Three Raptor Species to Changing Prey Densities in a Natural Environment," *Journal of Animal Ecology*, vol 57 (1988), pp 37-48.

Steenhof, K., and M.N. Kochert, "An Evaluation of Methods Used To Estimate Raptor Nesting Success," *Journal of Wildlife Management*, vol 46 (1982), pp 885-893.

Stephenson, T.R., *Mule Deer Response to Military Activity in Southeast Colorado*, M.S. Thesis (Virginia Polytechnic Institute and State University, 1989).

Stewart, R.E, "Ecology of a Nesting Red-shouldered Hawk Population," *Wilson Bulletin*, vol 51 (1949), pp 26-35.

Sutton, G.M., *Oklahoma Birds* (University of Oklahoma Press, Norman, 1967).

Swenson, J.E, "Factors Affecting Status and Reproduction of Ospreys in Yellowstone National Park," *Journal of Wildlife Management*, vol 43 (1979), pp 595-601.

Tazik, D.J., W.D. Severinghaus, and V.E. Diersing, *Annual Variation in Populations of Birds and Small Mammals on an Army Installation*, Interim Report (IR) N-86/02/ADA164631 (USACERL, 1985).

Tazik, D.J., S.D. Warren, V.E. Diersing, R.B. Shaw, R.J. Brozka, C.A. Bagley, and W.R. Whitworth, *U.S. Army Land Condition-Trend Analysis (LCTA) Plot Inventory Field Methods*, TR N-92/03/ADA-247931 (USACERL, February 1992).

Teer, J.G., and J.C. Truett, *Studies of the Effects of Sonic Boom on Birds*, Report No. FAA-RD (U.S. Department of Transportation, 1973).

Tennesen, M., "Birds on Base," *American Birds*, vol 47 (1993), pp 210-215.

Thomas, J.W., R.G. Anderson, C. Maser, and E.L. Bull, "Snags," in J.W. Thomas, ed., *Wildlife Habitats in Managed Forests: The Blue Mountains of Oregon and Washington*, U.S. Department of Agriculture, Forest Service Handbook No. 533, pp 60-77.

Tirrell, P.B., "*Protocalliphora avium* (DIPTERA) Myiasis in Great Horned Owls, Red-tailed Hawks, and Swainson's Hawks in North Dakota," *Journal of Raptor Research*, vol 12 (1978), pp 21-27.

Titus, K., and J.A. Mosher, "Nest Site Habitat Selected by Woodland Hawks in the Central Appalachians," *Auk*, vol 98 (1981), pp 270-281.

Tyler, J.D., and J.F. Jensen, "Notes on Foods of Great Horned Owls (*Bubo Virginianus*) in Jackson County, Oklahoma," *Oklahoma Academy of Science*, vol 62 (1981), pp 28-31.

Tyler, J.D., S.J. Orr, and J.R. Banta, "The Red-shouldered Hawk in Southwestern Oklahoma," *Bulletin of the Oklahoma Ornithological Society*, vol 22 (1989), pp 17-21.

Van Horne, B., "Density as a Misleading Indicator of Habitat Quality," *Journal of Wildlife Management*, vol 47 (1983), pp 893-901.

Verbeek, N.A.M., "Egg Predation by Northwestern Crows: Its Association With Human and Bald Eagle Activity," *Auk,* vol 99 (1982), pp 347-352.

Ward, D.H., R.A. Stehn, D.V. Derksen, C.J. Lensink, and A.J. Loranger, *Behavior of Pacific Black Brant and Other Geese in Response to Aircraft Overflights and Other Disturbances at Izembek Lagoon, Alaska,* Unpublished Report (U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center, 1986).

Weller, M.W., I.C. Adams, and B.J. Rose, "Winter Roosts of Marsh Hawks and Short-eared Owls in Central Missouri," *Wilson Bulletin,* vol 67 (1955), pp 189-193.

White, C.M., and S.K. Sherrod, "Advantages and Disadvantages of the Use of Rotor-winged Aircraft in Raptor Surveys," *Journal of Raptor Research,* vol 7 (1973), pp 97-104.

White, C.M., and T.L. Thurow, "Reproduction of Ferruginous Hawks Exposed to Controlled Disturbance," *Condor,* vol 87 (1985), pp 14-22.

Wilkinson, L., *SYSTAT: The System for Statistics* (SYSTAT, Inc., 1986).

Wiley, J.W, "The Nesting and Reproductive Success of Red-tailed and Red-shouldered Hawks in Orange County, California: 1973," *Condor,* vol 77 (1975), pp 133-139.

Wilson, P.W., and E.M. Grigsby, "Red-tailed Hawks Attack Great Horned Owl," *Inland Bird Banding,* vol 52 (1980), p 35.

Windsor, J., *The Response of Peregrine Falcons (Falco Peregrinus) to Aircraft and Human Disturbance* (Canadian Wildlife Service, Edmonton 1975).

Appendix A: Nest Occupancy History

Nest	Tree Species	Year					
		1987*	1988	1989	1990	1991	1992
1	E. Cottonwood	RTHA	RTHA	-	x	x	x
2	E. Cottonwood	-	-	-	-	x	x
3	Pecan	-	GHOW	-	RTHA	GHOW	-
4	Post oak	-	-	-	-	-	x
5	Shumard's oak	x	x	x	-	-	-
6	E. Cottonwood	-	-	-	x	x	x
7	Pecan	-	-	-	-	-	-
8	Pecan	-	-	RTHA	-	-	-
9	Post oak	-	-	-	RSHA	GHOW	-
10	Pecan	x	x	RSHA	-	-	-
11	Pecan	-	GHOW	-	-	RTHA	-
12	Post oak	GHOW	GHOW	-	-	GHOW	-
13	Post oak	-	RTHA	-	-	-	-
14	Pecan	-	-	RTHA	-	-	-
15	Blackjack oak	x	x	x	-	-	-
16	Post oak	-	GHOW	GHOW	x	x	x
17	Pecan	-	-	-	-	-	-
18	Black walnut	-	GHOW	x	x	x	x
19	Post oak	-	-	-	-	GHOW	-
20	Unknown	-	-	-	x	x	x
21	American elm	x	x	RTHA	RTHA	RTHA	GHOW
22	Unknown	-	-	-	-	-	x
23	Post oak	-	-	-	-	x	x
24	Post oak	-	RTHA	-	-	-	-
25	Blackjack oak	-	-	-	-	-	-
26	E. Cottonwood	-	GHOW	-	RTHA	x	x
27	Pecan	x	x	x	RTHA	RTHA	-
28	Post oak	x	-	-	-	-	-

*Note:

- = Not occupied by a breeding pair.
x = Nest had not been built yet or no longer exists.

Nest	Tree Species	Year					
		1987*	1988	1989	1990	1991	1992
29	Pecan	-	RTHA	-	-	RTHA	
30	Post oak	-	-	x	x	x	x
31	Pecan	-	GHOW	-	GHOW	-	x
32	Woolly buckthorn	-	-	-	-	-	x
33	Post oak	-	-	-	GHOW	GHOW	-
34	American elm	-	-	-	-	BAOW	-
35	Pecan	-	-	-	-	-	-
36	Post oak	-	-	x	x	x	x
37	Pecan	RTHA	-	-	RTHA	RTHA	-
38	Post oak	-	-	RTHA	-	-	x
39	Post oak	-	-	-	-	-	x
40	American elm	-	GHOW	-	-	-	x
41	Post oak	-	-	-	-	-	-
42	Post oak	-	RTHA	-	RTHA	-	-
43	Post oak	-	RTHA	GHOW	GHOW	-	x
44	American elm	RTHA	GHOW	-	-	-	-
45	Blackjack oak	-	-	-	-	x	x
46	Black walnut	-	RTHA	-	x	x	x
47	Black walnut	-	GHOW	-	-	x	x
48	Black walnut	RTHA	RTHA	-	GHOW	-	-
49	Red elm	-	GHOW	-	-	-	-
50	American elm	-	RTHA	-	-	-	-
51	Red elm	-	-	-	-	x	x
52	Woolly buckthorn	-	-	-	-	-	-
53	Pecan	-	-	GHOW	x	x	x
54	Pecan	-	-	-	-	-	x
55	Pecan	x	x	x	RTHA	-	-
56	Post oak	-	-	-	-	-	-
57	American elm	x	-	-	-	x	x
58	Black walnut	RTHA	GHOW	-	-	-	-
59	American elm	-	-	-	-	-	-
60	Post oak	-	RTHA	-	-	-	x
61	Post oak	-	GHOW	GHOW	-	x	x
62	American elm	-	-	GHOW	GHOW	GHOW	-
63	Hackberry	-	-	GHOW	-	x	x
64	Red elm	-	-	-	-	x	x

*Note:

- = Not occupied by a breeding pair.
x = Nest had not been built yet or no longer exists.

Nest	Tree Species	Year					
		1987*	1988	1989	1990	1991	1992
65	American elm	-	GHOW	-	GHOW	-	-
66	E. cottonwood	-	RTHA	-	-	-	x
67	W. soapberry	-	-	-	-	x	x
68	American elm	-	-	-	-	-	x
69	Red elm	x	x	x	-	-	x
70	Sugarberry	-	-	-	-	x	x
71	American elm	-	RTHA	-	-	GHOW	GHOW
72	E. Cottonwood	-	GHOW	-	-	RTHA	RTHA
73	Post oak	-	-	RTHA	RTHA	-	-
74	Post oak	-	RTHA	-	x	x	x
75	Post oak	-	-	-	RTHA	-	-
76	Post oak	-	-	-	GHOW	GHOW	-
77	American elm	-	-	-	-	-	-
78	Hackberry	-	-	-	-	RTHA	-
79	Powerline pole	x	RTHA	-	x	x	x
80	Post oak	-	-	-	-	-	-
81	Post oak	-	-	x	x	x	x
82	Post oak	-	-	-	-	-	-
83	American elm	x	x	x	GHOW	-	-
84	Blackjack oak	-	-	-	-	-	-
85	Post oak	-	-	-	-	-	-
86	Black willow	RTHA	RTHA	x	x	x	x
87	Post oak	-	GHOW	-	-	-	-
88	Post oak	-	RTHA	RTHA	x	GHOW	RTHA
89	American elm	-	-	-	-	-	x
90	Blackjack oak	-	RTHA	GHOW	-	-	RTHA
91	American elm	-	RTHA	-	-	x	x
92	Post oak	-	GHOW	x	x	x	x
93	Post oak	x	x	RTHA	x	x	x
94	Post oak	-	RTHA	RTHA	BAOW	GHOW	BAOW
95	Bur oak	-	-	-	RTHA	-	x
96	Post oak	x	x	x	RTHA	RTHA	GHOW
97	Green ash	RTHA	GHOW	-	RTHA	-	-
98	American elm	-	-	-	-	-	x
99	American elm	-	RTHA	-	GHOW	GHOW	-
100	E. cottonwood	x	RTHA	x	x	x	RTHA

*Note:

- = Not occupied by a breeding pair.
x = Nest had not been built yet or no longer exists.

Nest	Tree Species	Year					
		1987*	1988	1989	1990	1991	1992
101	Shumard's oak	x	-	-	-	-	x
102	E. cottonwood	-	RTHA	-	RTHA	RTHA	-
103	Bur oak	-	GHOW	-	GHOW	x	x
104	Bur oak	-	RTHA	x	x	x	x
105	Black walnut	x	x	x	x	RTHA	GHOW
106	Post oak	-	GHOW	-	RTHA	GHOW	RTHA
107	E. cottonwood	RTHA	-	RTHA	x	x	RTHA
108	Sugarberry	RTHA	-	-	-	x	x
109	E. cottonwood	-	RTHA	-	-	RTHA	RTHA
110	Sugarberry	-	-	-	-	GHOW	-
111	E. cottonwood	-	RTHA	RTHA	RTHA	RTHA	RTHA
112	Shumard's oak	-	-	RTHA	-	x	x
113	Shumard's oak	-	RTHA	RTHA	RTHA	RTHA	RTHA
114	E. cottonwood	x	x	-	RTHA	RTHA	RTHA
115	Shumard's oak	-	-	-	RSHA	-	-
116	E. cottonwood	RTHA	x	x	x	x	x
117	Shumard's oak	-	-	-	RSHA	-	-
118	Post oak	-	-	-	-	x	x
119	Pecan	-	-	-	-	-	-
120	E. cottonwood	x	x	x	GHOW	-	-
121	E. cottonwood	x	x	-	RTHA	-	-
122	Pecan	x	x	-	RTHA	RTHA	RTHA
123	E. cottonwood	-	-	-	-	RTHA	-
124	E. Cottonwood	RTHA	RTHA	x	x	x	x
125	Pecan	RTHA	-	-	x	x	x
126	E. cottonwood	-	-	-	-	RTHA	-
127	Pecan	-	RTHA	-	RTHA	RTHA	x
128	E. cottonwood	x	x	x	RTHA	RTHA	RTHA
129	E. cottonwood	RTHA	-	-	-	-	x
130	E. cottonwood	-	RTHA	-	GHOW	GHOW	-
131	E. cottonwood	RTHA	-	-	-	RTHA	RTHA
132	E. cottonwood	RTHA	RTHA	RTHA	RTHA	RTHA	RTHA
133	W. soapberry	RTHA	RTHA	-	-	-	x
134	E. cottonwood	RTHA	RTHA	-	-	-	-
135	E. cottonwood	-	RTHA	-	GHOW	-	-
136	American elm	-	RTHA	-	-	-	-

*Note:
- = Not occupied by a breeding pair.
x = Nest had not been built yet or no longer exists.

Nest	Tree Species	Year					
		1987*	1988	1989	1990	1991	1992
137	E. cottonwood	-	RTHA	-	x	x	RTHA
138	E. cottonwwod	RTHA	RTHA	x	-	RTHA	RTHA
139	E. cottonwood	RTHA	RTHA	-	-	-	-
140	E. cottonwood	-	GHOW	x	x	x	x
141	E. cottonwood	-	-	-	GHOW	GHOW	RTHA
142	E. cottonwood	GHOW	-	x	x	x	x
143	E. cottonwood	-	RTHA	GHOW	-	-	-
144	E. cottonwood	-	-	-	-	-	x
145	Hackberry	RTHA	-	-	-	-	-
146	Pecan	-	-	-	-	-	x
147	E. cottonwood	x	-	-	-	x	x
148	E. cottonwood	x	-	-	-	-	x
149	E. cottonwood	-	-	-	-	-	-
150	E. cottonwood	RTHA	-	-	-	-	GHOW
151	E. cottonwood	x	x	-	RTHA	-	-
152	E. cottonwood	-	GHOW	x	x	x	x
153	E. cottonwood	x	-	-	-	x	x
154	E. cottonwood	-	-	-	-	-	-
155	E. cottonwood	RTHA	RTHA	RTHA	RTHA	RTHA	GHOW
156	E. cottonwood	RTHA	GHOW	-	-	RTHA	RTHA
157	Sugarberry	x	-	-	-	RTHA	-
158	E. cottonwood	x	-	-	GHOW	RTHA	-
159	Red elm	RTHA	-	-	-	x	-
160	Pecan	x	x	x	x	x	RTHA
161	Pecan	x	x	x	x	x	-
162	E. cottonwood	x	x	x	x	RTHA	RTHA
163	E. cottonwood	RTHA	-	-	-	-	-
164	E. cottonwood	x	-	-	-	-	x
165	Shumard's oak	-	-	-	-	-	-
166	E. cottonwood	-	RTHA	-	-	-	RTHA
167	E. cottonwood	x	x	-	-	-	-
168	Sugarberry	x	x	x	x	x	-
169	Pecan	x	RTHA	-	-	RTHA	RTHA
170	E. cottonwood	x	x	x	x	x	RTHA
171	Shumard's oak	x	x	x	x	RTHA	RTHA
172	Post oak	x	-	-	-	-	GHOW

*Note:

- = Not occupied by a breeding pair.

x = Nest had not been built yet or no longer exists.

Nest	Tree Species	Year					
		1987*	1988	1989	1990	1991	1992
173	Pecan	x	-	-	-	-	-
174	Pecan	x	x	x	x	x	-
175	American elm	x	x	x	-	RTHA	-
176	E. cottonwood	x	x	x	x	x	-
177	E. cottonwood	RTHA	GHOW	-	-	-	-
178	Black willow	RTHA	-	-	-	-	-
179	Post oak	RTHA	-	-	-	x	x
180	E. cottonwood	RTHA	x	x	x	x	x
181	E. cottonwood	RTHA	-	x	x	x	RTHA
182	Unknown	RTHA	-	-	-	-	-
183	American elm	BAOW	-	-	-	-	-
184	E. cottonwood	x	x	x	-	RTHA	RTHA
185	Unknown	x	x	x	x	RTHA	RTHA
186	E. cottonwood	x	-	-	-	RTHA	RTHA
187	American elm	x	x	x	x	RTHA	RTHA
188	American elm	x	x	x	x	RTHA	x
189	Unknown	x	x	x	x	RTHA	-
190	Ground nest	x	x	x	x	NOHA	-
191	Ground nest	x	x	x	x	NOHA	-
192	Unknown	x	x	x	x	GHOW	-
193	Sugarberry	x	x	x	x	GHOW	GHOW
194	Unknown	x	-	-	-	-	RTHA
195	Bur oak	x	x	x	x	-	RSHA
196	E. cottonwood	x	x	-	-	-	BAOW
197	Bur oak	x	x	x	x	-	RSHA
198	E. cottonwood	x	x	x	x	x	x
199	Hackberry	x	-	-	-	-	RTHA
200	E. cottonwood	x	x	x	x	-	RTHA
201	Unknown	x	x	x	x	x	RTHA
202	Black willow	x	x	x	x	x	RTHA
203	American elm	x	x	x	x	-	RTHA
204	American elm	x	-	-	-	-	GHOW
205	Red elm	x	x	x	-	-	-
206	Unknown	x	-	-	-	-	RTHA
207	Unknown	x	x	x	x	x	-
208	Pecan	x	x	x	x	-	RTHA

*Note:

- = Not occupied by a breeding pair.
x = Nest had not been built yet or no longer exists.

Nest	Tree Species	Year					
		1987*	1988	1989	1990	1991	1992
209	Post oak	x	x	x	x	x	RTHA
210	Pecan	x	x	x	x	x	RTHA
211	Sugarberry	x	x	x	x	x	RTHA
212	E. cottonwood	x	x	x	-	-	RTHA
213	Unknown	x	x	x	-	-	RTHA
214	E. cottonwood	x	x	x	-	-	GHOW
215	Green ash	x	x	x	x	x	RTHA
216	Sugarberry	x	-	-	-	x	RSHA
217	Black willow	x	RTHA	-	x	x	x
		141	160	155	156	155	147

*Note:

- = Not occupied by a breeding pair.
x = Nest had not been built yet or no longer exists.

Appendix B: Fort Sill Raptor Nest Distribution Maps by Species and Year

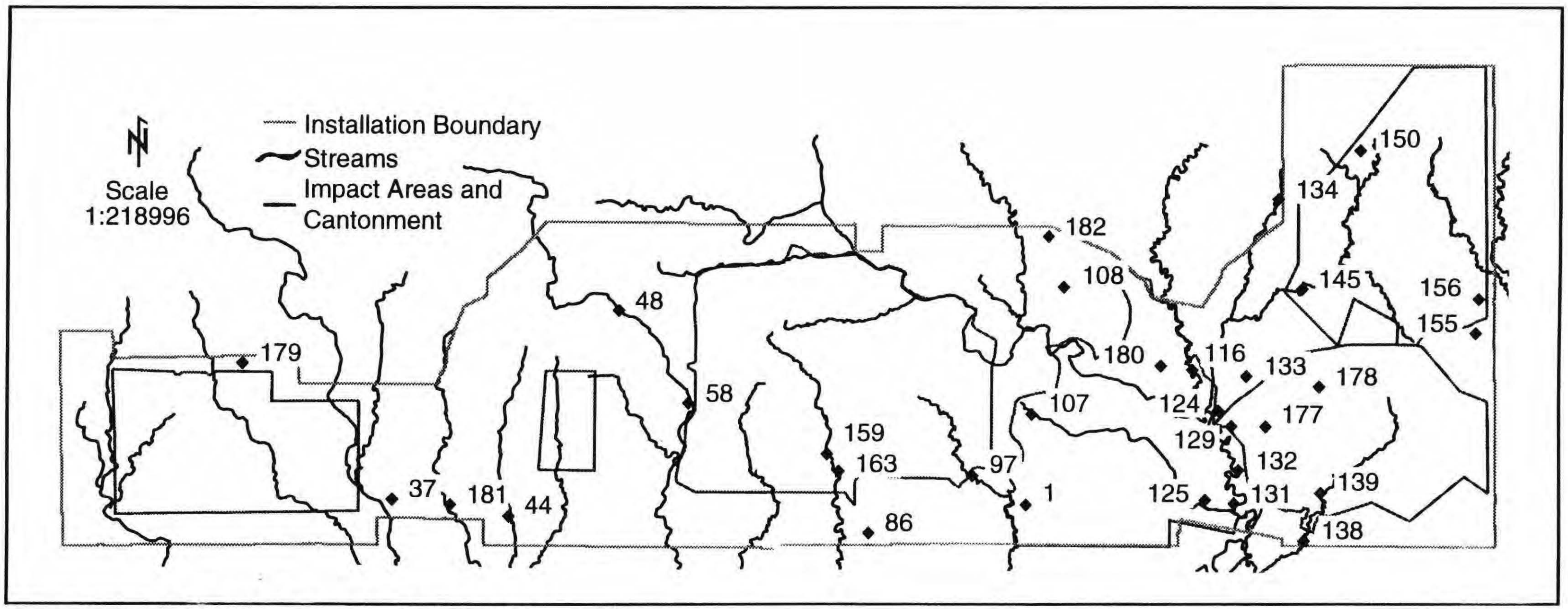


Figure B1. Red-tailed Hawk nest distribution, 1987.

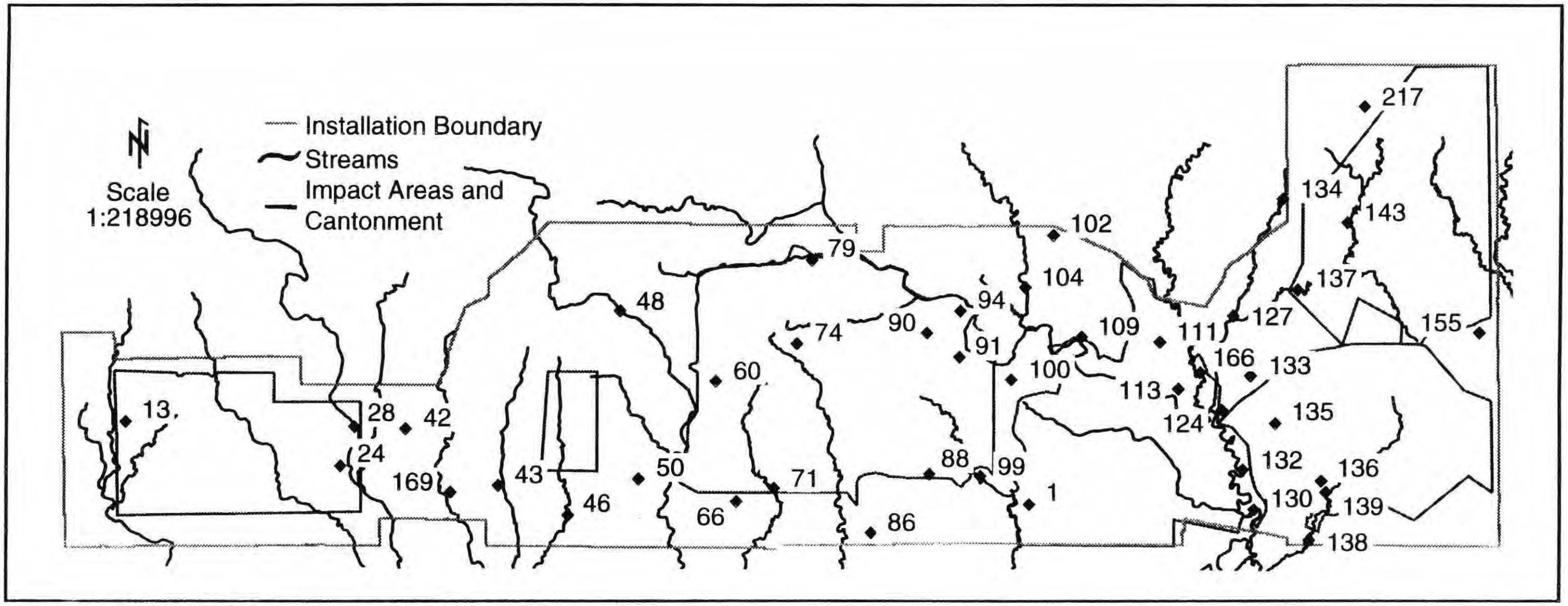


Figure B2. Red-tailed Hawk nest distribution, 1988.

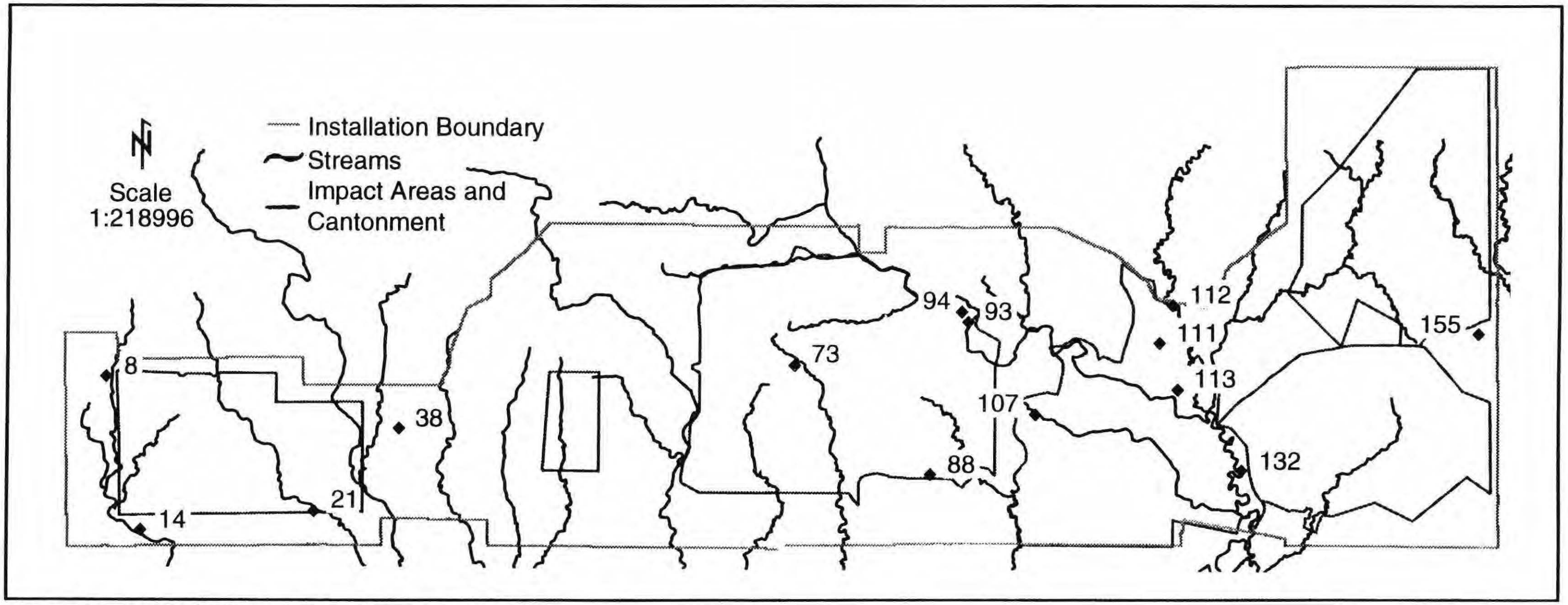


Figure B3. Red-tailed Hawk nest distribution, 1989.

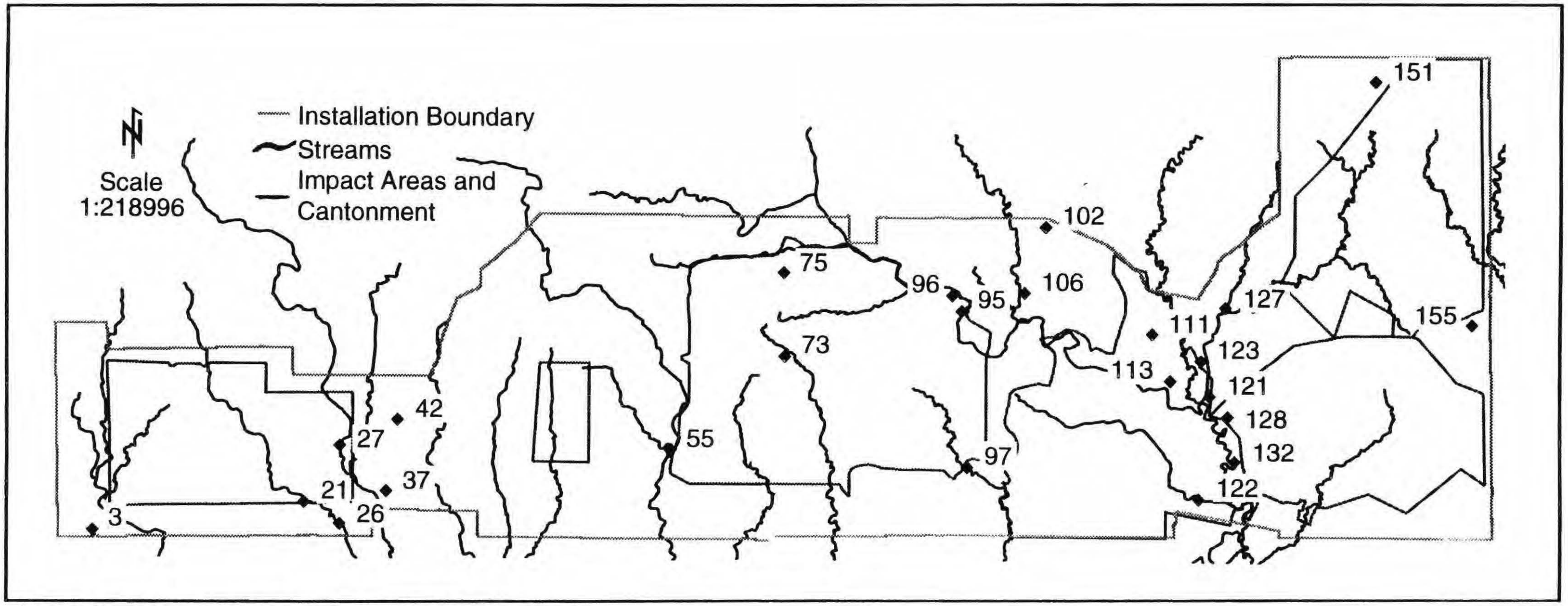


Figure B4. Red-tailed Hawk nest distribution, 1990.

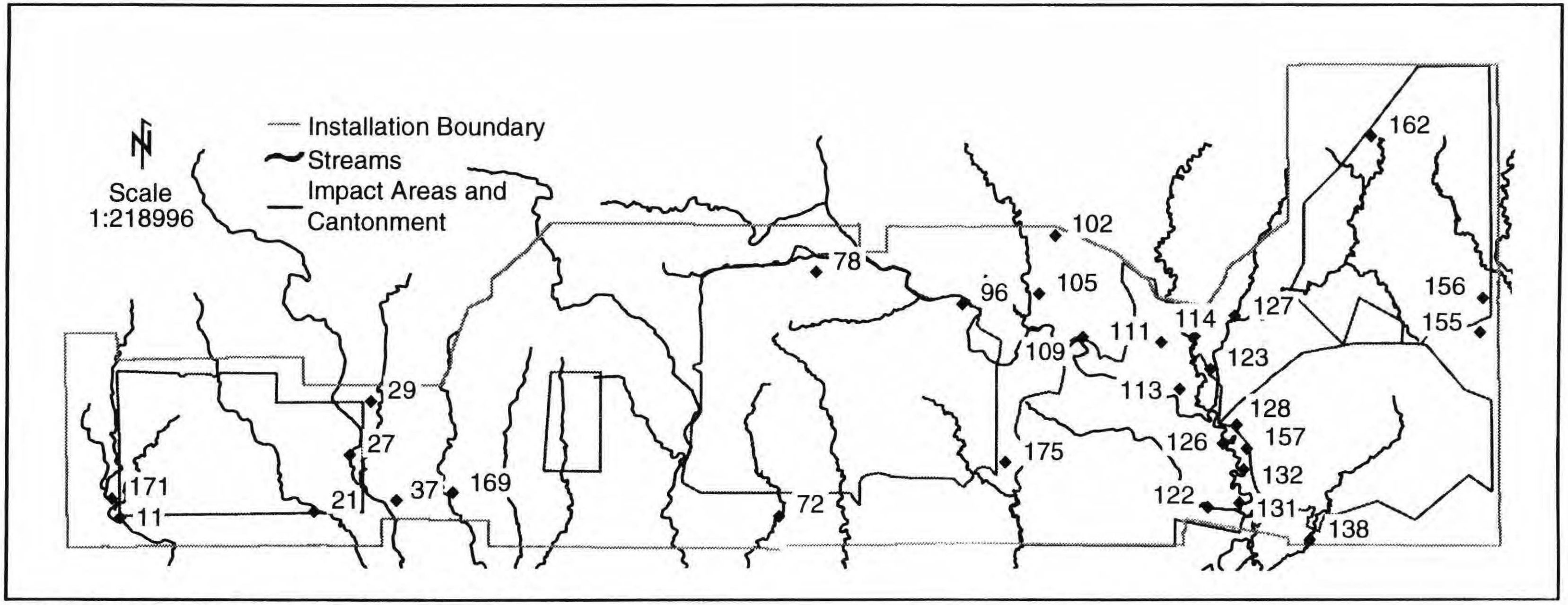


Figure B5. Red-tailed Hawk nest distribution, 1991.

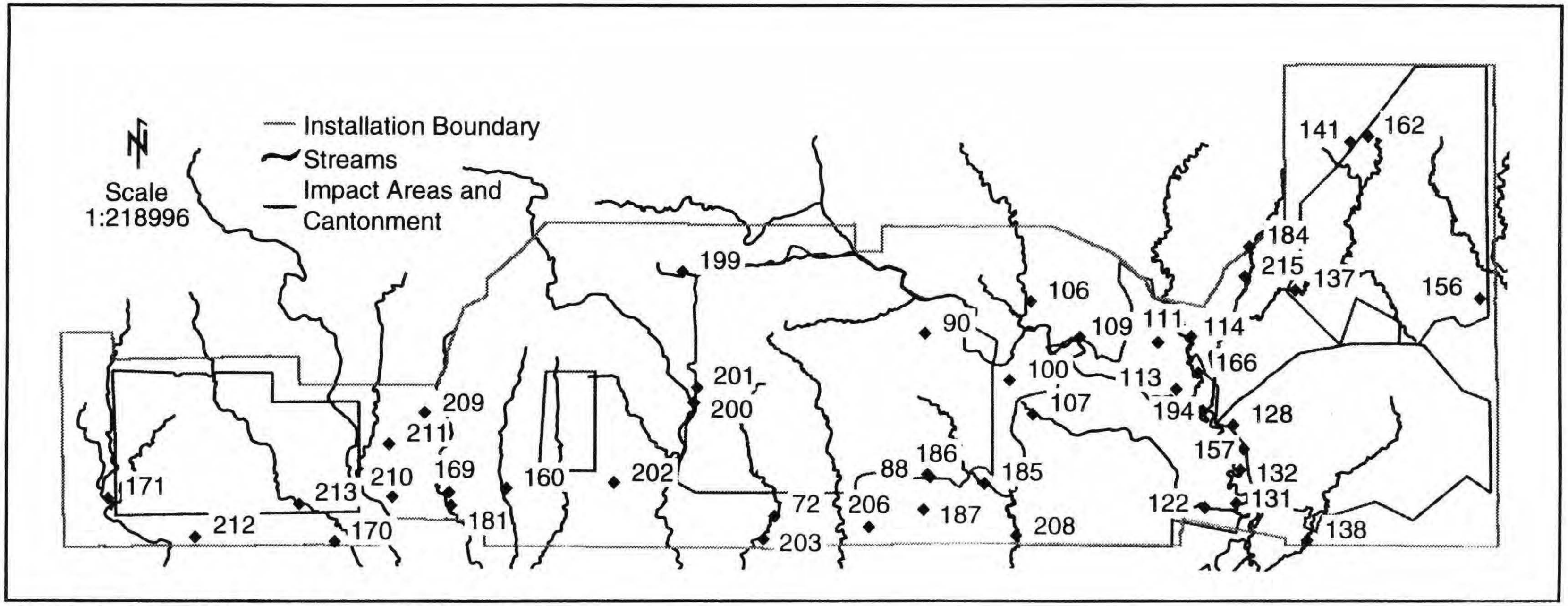


Figure B6. Red-tailed Hawk nest distribution, 1992.

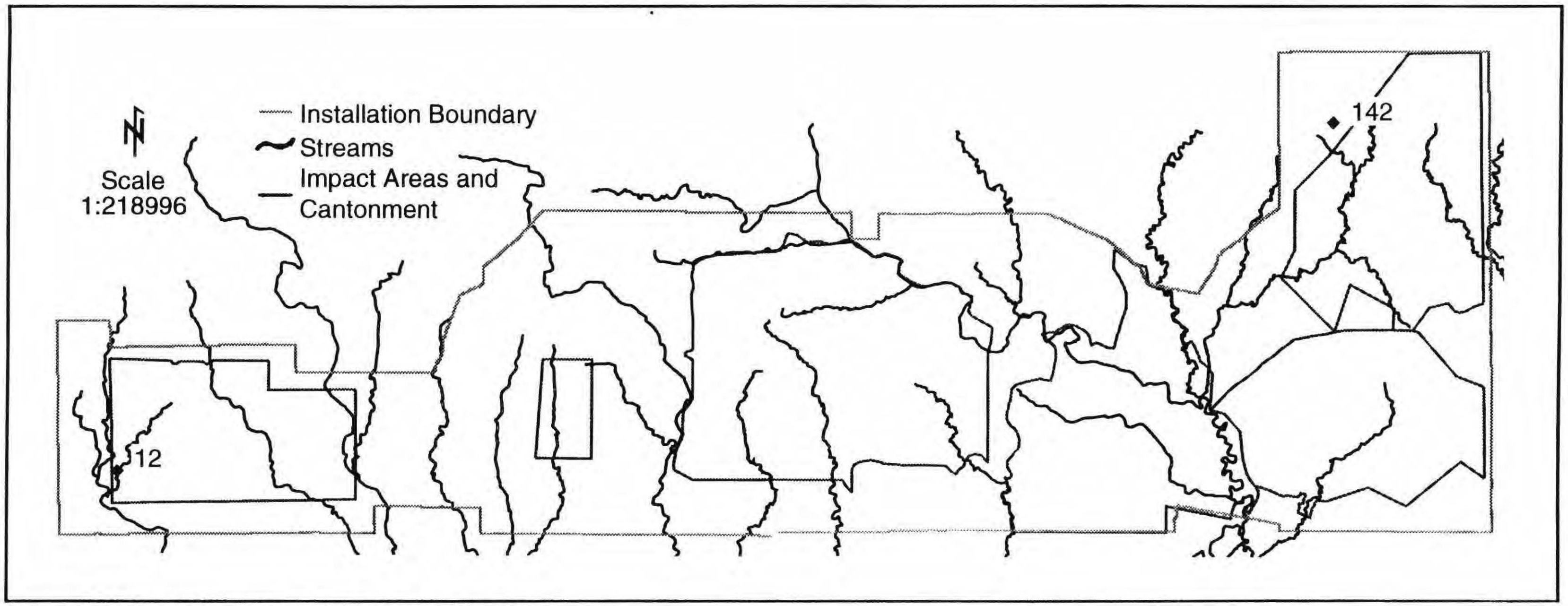


Figure B7. Great Horned Owl nest distribution, 1987.

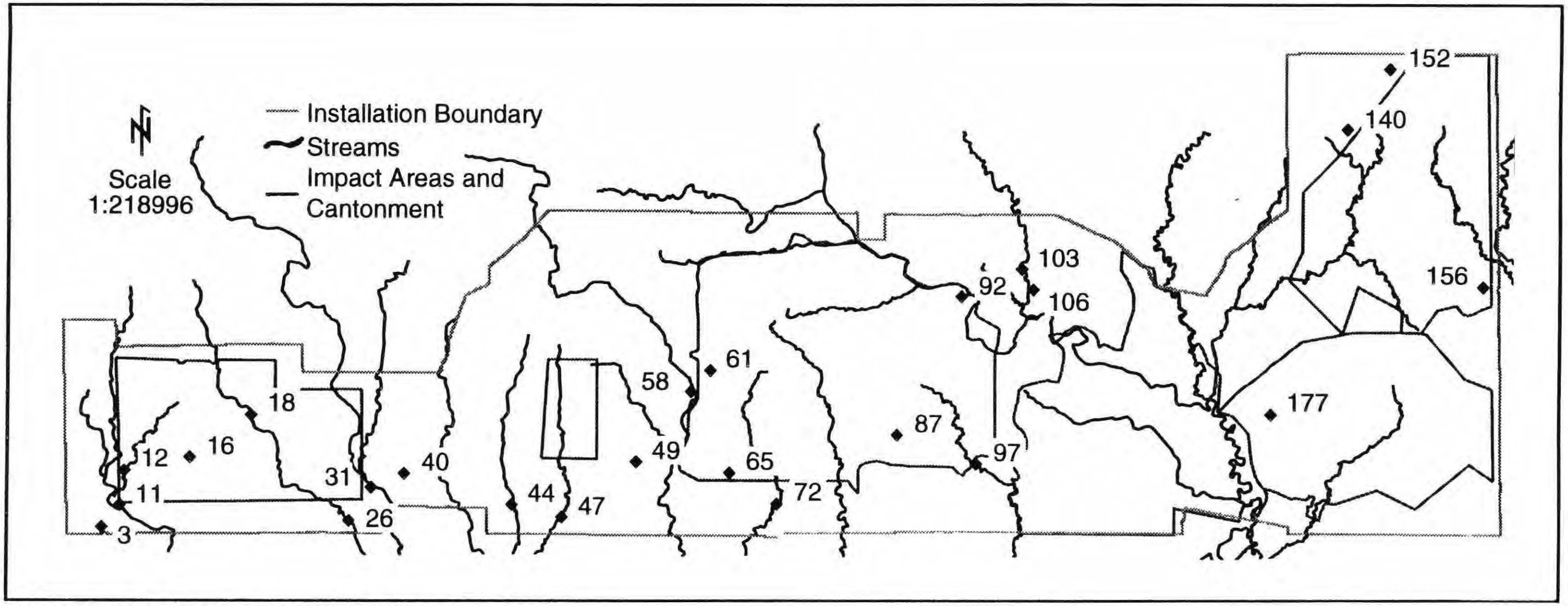


Figure B8. Great Horned Owl nest distribution, 1988.

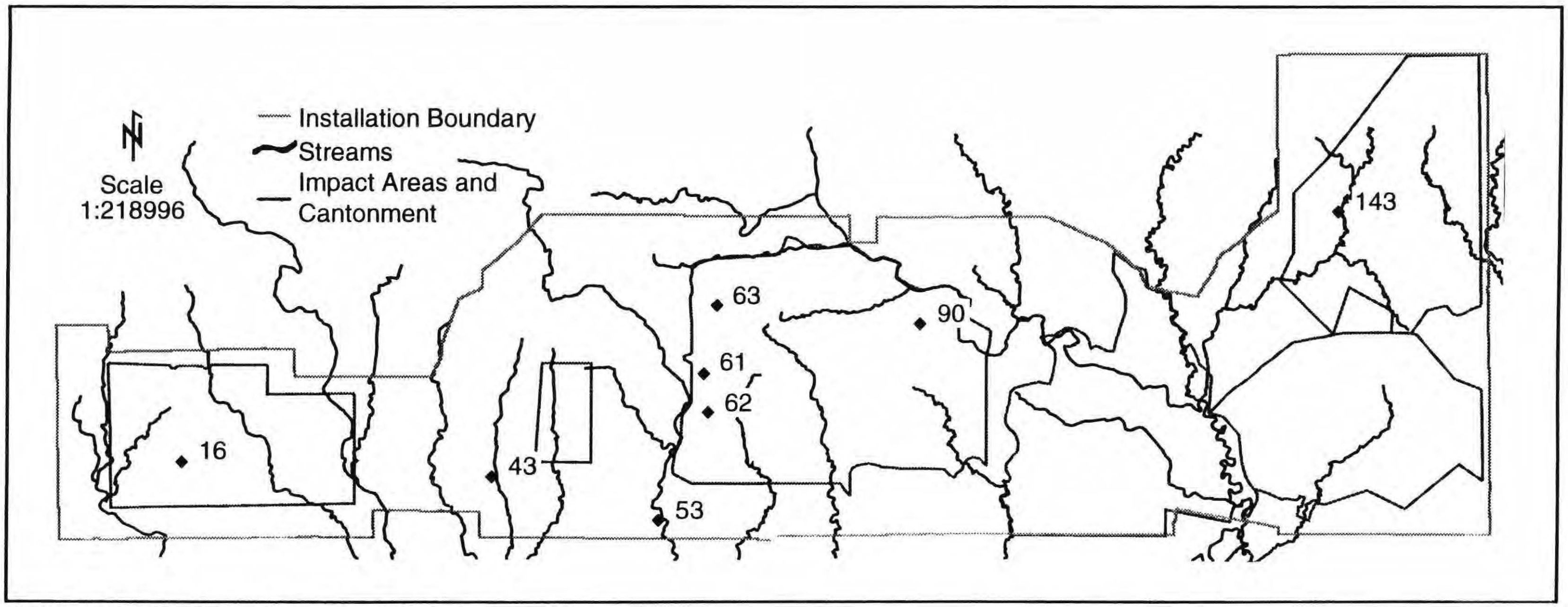


Figure B9. Great Horned Owl nest distribution, 1989.

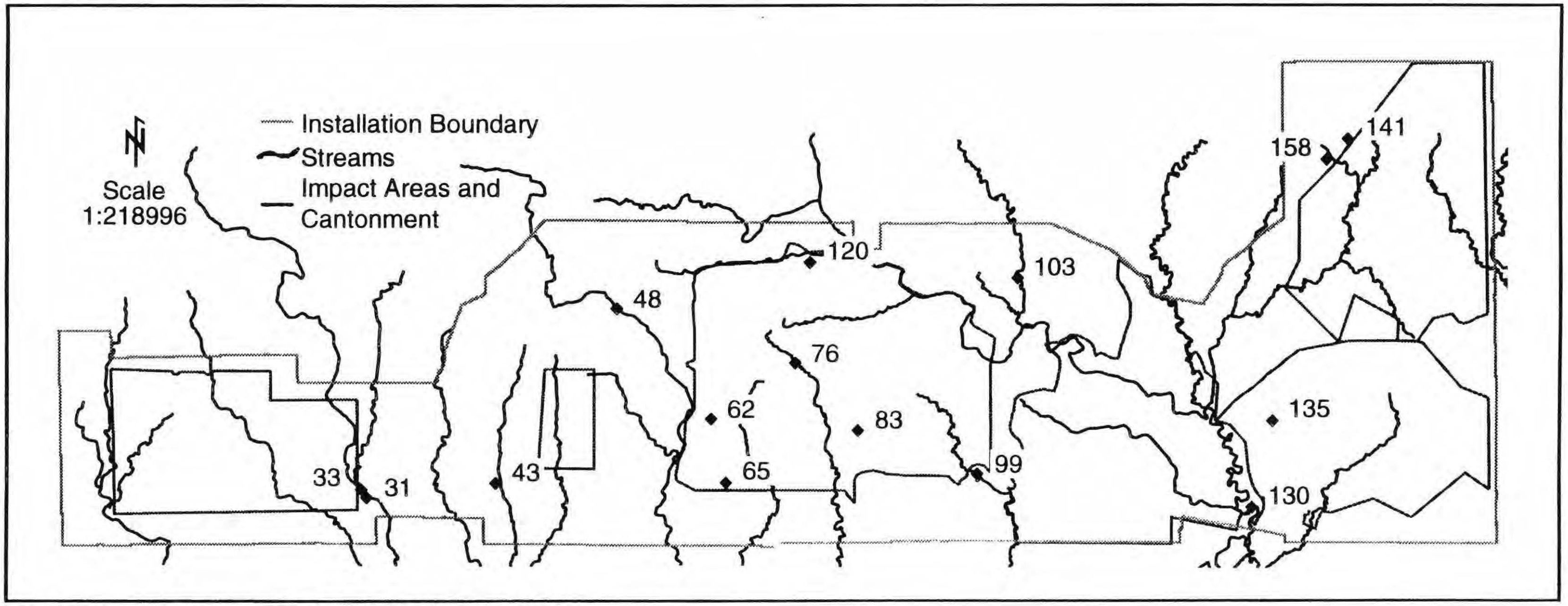


Figure B10. Great Horned Owl nest distribution, 1990.

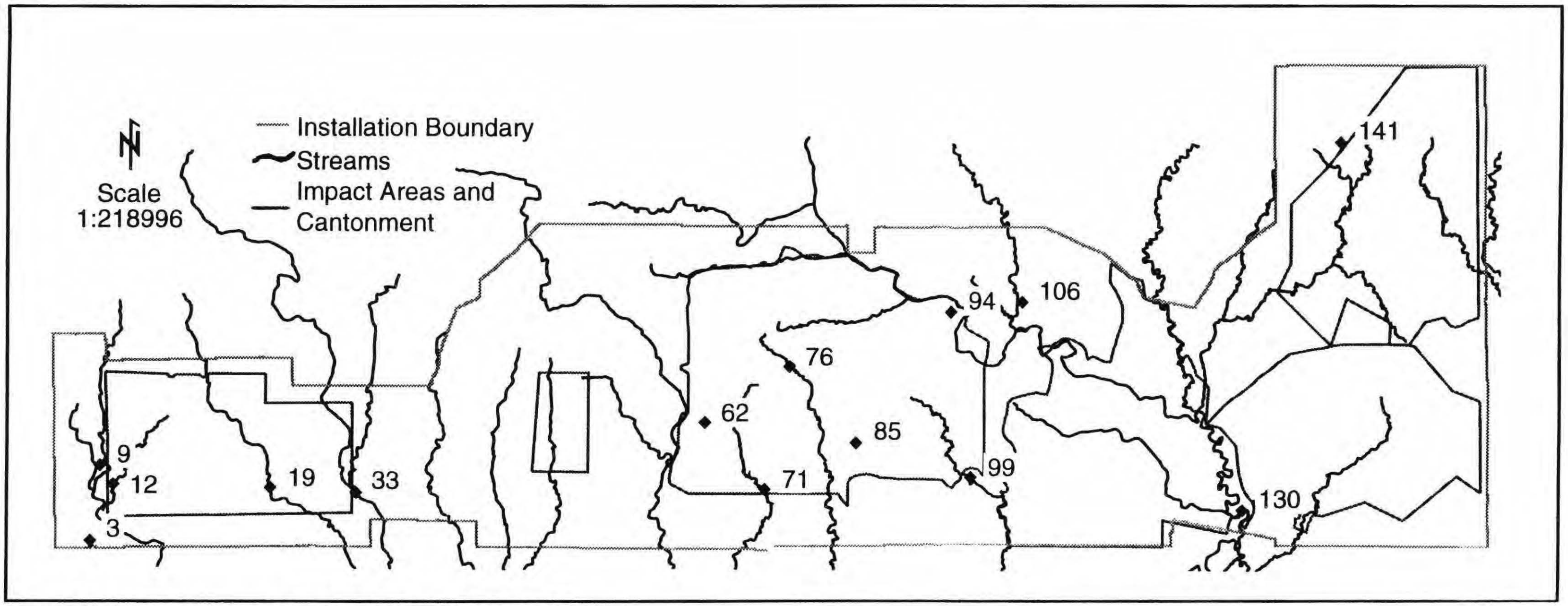


Figure B11. Great Horned Owl nest distribution, 1991.

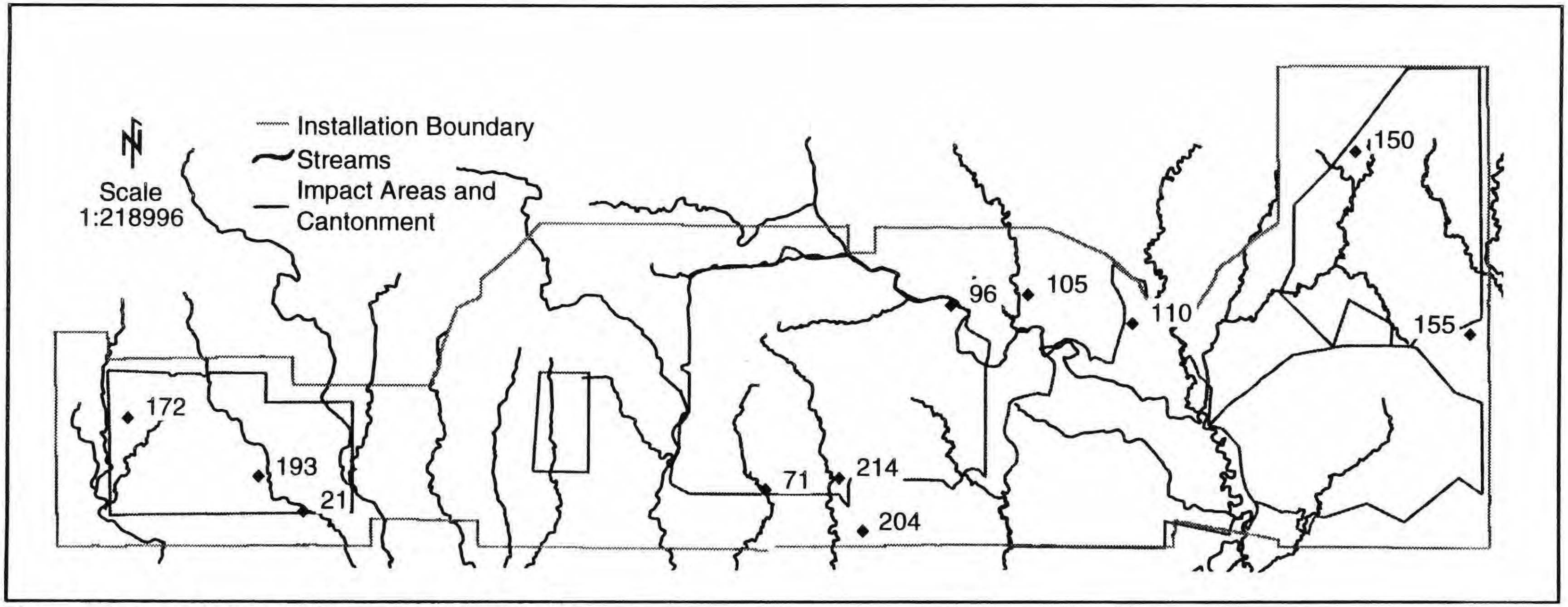


Figure B12. Great Horned Owl nest distribution, 1992.

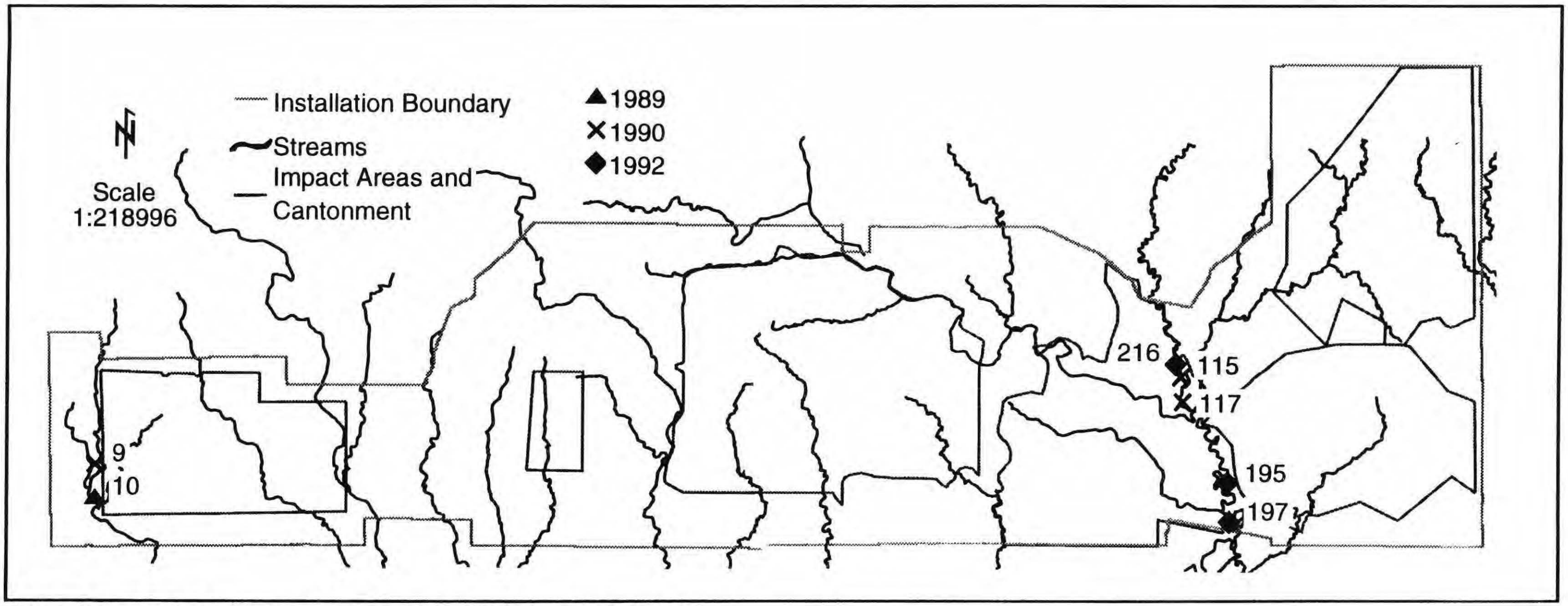


Figure B13. Red-shouldered Hawk nest distribution, 1987 to 1992.

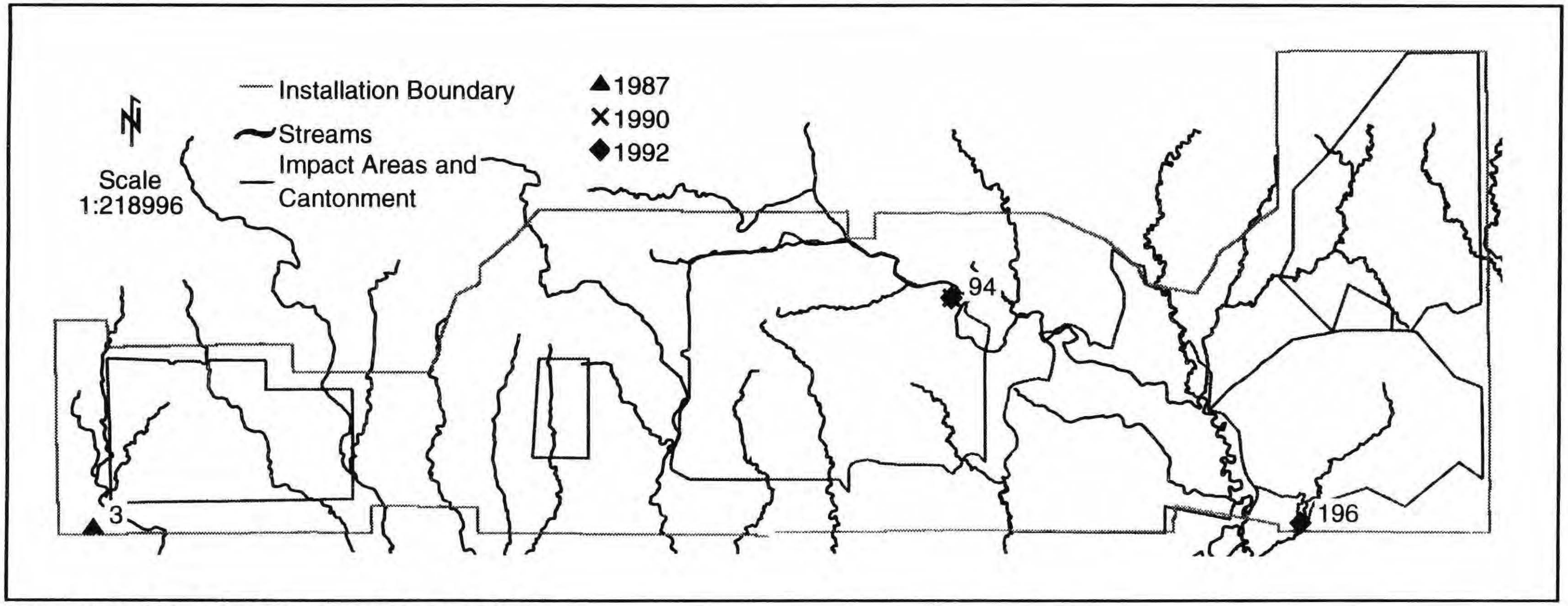


Figure B14. Barred Owl nest records, 1987 to 1992.

USACERL DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECC-R
ATTN: CERD-L
ATTN: DAIM-ED-N 20310-0600
ATTN: DAMO-TRO 20310-0400

US Army Europe
ATTN: AEAEN-ENVR 09114
ATTN: 100th Area Support Group

US Army Materiel Command (AMC)
ATTN: AMXEN-M 61299-7190
Dugway Proving Ground 84022
ATTN: STEDP-EPO-CP
Yuma Proving Ground 85365
ATTN: STEYP-ES-E
Aberdeen Proving Ground 21005
ATTN: STEAP-SH-ER
ATTN: STEAP-FE-G
White Sands Missile Range 88002
ATTN: STEWS-ES-E

FORSCOM
Fort McPherson 30330
ATTN: AFOP-TE
ATTN: AFOP-TSR
ATTN: AFPI-ENE
Installations:
Fort Indiantown Gap 17003-5000
ATTN: AFKA-ZQ-DEE
Fort AP Hill 22427-5000
ATTN: ANAP-PWE
ATTN: AFZM-FHE
Fort McPherson 30330-5000
ATTN: AFZK-EH-E
Fort Riley 66442-6000
ATTN: AFZN-DE-VN
Fort Polk 71459-5000
ATTN: AFZH-DE-EN
Fort Sam Houston 78234-5000
ATTN: AFZG-DE-EM
Fort Ord 93941-5000
ATTN: AFZW-DE
Fort Lewis 98433-5000
ATTN: AFZH-DEQ
Fort Carson 80913
ATTN: AFZC-ECM-NR (2)
Fort Bragg 28307-5000
ATTN: AFZA-PW-DW
Fort Campbell 42223-1291
ATTN: AFZB-DPW-E
Fort McCoy 54656-5000
ATTN: AFZR-DE-E
Fort Pickett 23824
ATTN: AFZA-FP-E
Fort Stewart 31314-5000
ATTN: AFZP-DEV
Fort Buchanan 00934
ATTN: AFZK-B-EHE
Fort Devens 01433-5000
ATTN: AFZD-DEM
Fort Drum 13602-5097
ATTN: AFZS-EH-E
Fort Irwin 92310-5000
ATTN: AFZJ-EHE-EN
Fort Hood 76544-5057
ATTN: AFZF-DE-ENV
Fort Hunter Liggett 93928
ATTN: AFZW-HE-DE
Yakima Tng Center 98901-5000
ATTN: AFZH-Y-ENR
Fort Dix 08640-5500
ATTN: ATZD-EHZ

TRADOC
Fort Monroe 23651
ATTN: ATBO-FE
ATTN: ATBO-HE
ATTN: ATZG-ISE
Installations:
Fort Lee 23801-5000
ATTN: ATZM-E-PE
Fort Jackson 29207-5660
ATTN: ATZJ-PWN
Fort Gordon 30905-5040
ATTN: ATZH-DIE
Fort McClellan 36205
ATTN: ATZN-EM
Fort Benning 31905-5122
ATTN: ATZB-PWN
Fort Rucker 36362-5135
ATTN: ATZQ-DPW-EN
Fort Leonard Wood 65473-5000
ATTN: ATZT-DPW-EE
Fort Leavenworth 66027-5020
ATTN: ATZL-GCE
Fort Bliss 79916-6100
ATTN: ATZC-DOE
Carlisle Barracks 17013-5002
ATTN: ATZE-DPW-E
Fort Eustis 23604-5306
ATTN: ATZF-PWE
Fort Chaffee 72905-5000
ATTN: ATZR-ZF
Fort Sill 73503
ATTN: ATZR-B (12)
Fort Huachuca 85613
ATTN: ATZS-EHB
Fort Knox 40121
ATTN: ATZK-PWE

US Air Force Command
ATTN: Envr/Natural Res Ofc
Andrews AFB 20031
Wright-Patterson AFB 45433
Randolph AFB 78150
Maxwell AFB 36112
Elmendorf AFB 99506
Scott AFB 62225
Hickam AFB 96853
Peterson AFB 80914
Bolling AFB 20332

US Air Force Air Combat Command
Avon Park AF Range, FL 33825-5700
ATTN: 6/CSS/CEN
Davis-Monthan AFB, AZ 85707-3920
ATTN: 355 CES/CEV
Dyess AFB, TX 79607-1670
ATTN: 7 CES/CEVA
Ellsworth AFB, SD 57706-5000
ATTN: 28 CES/CEV
Holloman AFB, NM 88330-8458
ATTN: 49 CES/CEV
Langley AFB, VA 23665-2377
ATTN: 1 CES/CEV
Little Rock AFB, AR 72099-5154
ATTN: 314 CES/CEV
Cannon AFB, NM 88103-5136
ATTN: 27 CES/CEV
Minot AFB, ND 58705-5006
ATTN: 5 CES/CEV
Moody AFB, GA 31699-1707
ATTN: 347 CES/CEV
Nellis AFB, NV 89191-6546
ATTN: WTC/EVR
Offutt AFB, NE 68113-4019
ATTN: 55 CES/CEV
Pope AFB, NC 28308-2890
ATTN: 23 CES/CEV
Mountain Home AFB, ID 83648-5442
ATTN: 366 CES/CEV
Seymour Johnson AFB, NC 27531-2355
ATTN: 4 CES/CEV
Shaw AFB, SC 29152-5123
ATTN: 20 CES/CEV
Whiteman AFB, MO 65305-5060
ATTN: 509 CES/CEV

USARPAC 96858
ATTN: APOP-TR
ATTN: APEN-EV
DCSENGR - ATTN: APEN-IV
Fort Shafter, HI 96858
Fort Richardson, AK 99505
Fort Wainright, AK 99703
Fort Greely, AK 98733

National Guard Bureau 20310
ATTN: NGB-ARE
ATTN: NGB-ARI

Army National Guard
Fort Richardson, AK 99505-5800
North Little Rock, AR 72118-2200
Phoenix, AZ 85008-3495
Sacramento, CA 95826-9101
Boise, ID 83707-4507
Jackson, MS 39209
Camp Shelby, MS 39407-5500
Oklahoma City, OK 73111-4389
Draper, UT 84020-1776
Braggs, OK 74423
Reading, MA 01867-1999
Camp Edwards, MA 02542-5003
Columbia, SC 29201
St. Augustine, FL 32085-1008
Starke, FL 32091-9703
Indianapolis, IN 46241-4839
Lansing, MI 48913-5101
Little Falls, MN 56345-0348
Jefferson City, MO 65101-9051
Los Alamitos, CA 90720

Honolulu, HI 96816-4495
Springfield, IL 62702-2399
Johnston, IA 50131-1902
Frankfort, KY 40601-6168
New Orleans, LA 70146-0330
Helena, MT 59604-4789
Carson City, NV 89701-5596
Sante Fe, NM 87502
Raleigh, NC 27607-6410
Bismark, ND 58502-5511
Salem, OR 97309-5047
Rapid City, SD 57702-8186
Austin, TX 78763-5218
Cheyenne, WY 82003

US Military Academy 10996-5000
ATTN: MAEN-EV
ATTN: Facilities Engineer

CEWES 39180
ATTN: Library

CECRL 03755
ATTN: Library

Headquarters, 7th ATC
ATTN: AEAGC-TD-MO

Headquarters, AEC
ATTN: SFIM-AEC-ECN

Headquarters, Army Tng Spt Ctr
ATTN: ATIC-CTS

Headquarters, EUSA
ATTN: EAGC-TD-RMD

Headquarters, USFK
ATTN: FKEN-EN

Headquarters, TECOM
ATTN: AMSTE-EQ

Headquarters, MDW
ATTN: ANOP

US Army Research Laboratory 20783-1145
ATTN: AMSRL-OP-SDFE

Military Dist of WASH
Fort McNair
ATTN: ANEN 20319

US Gov't Printing Office 20401
ATTN: Rec Sec/Deposit Sec (2)

Defense Tech Info Center 22304
ATTN: DTIC-FAB (2)

158
+20
9/95

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES
CORPS OF ENGINEERS
PO BOX 9005
CHAMPAIGN, ILLINOIS 61826-9005

OFFICIAL BUSINESS