FINAL REPORT

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Project 68: Biology of the Cactus Ferruginous Pygmy-Owl (Glaucidium brasilanum cactorum) in Texas

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Objective: Develop information on specific habitat use, territory size, population density, distribution, food habits, and potential management strategies for the Cactus Ferruginous Pygmy Owl (Glaucidium brasilianum cactorum) in Texas.

PREFACE

The attached thesis entitled "Natural History of the Cactus Ferruginous Pygmy-Owl" by Glen Arthur Proudfoot resulted directly from this objective and is submitted in fulfillment of the Final Report requirement.

Prepared by: Lee Elliot
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Date: November 6, 1996

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Federal Aid Coordinator
Date: December 31, 1996

NATURAL HISTORY OF THE CACTUS FERRUGINOUS PYGMY-OWL

A THESIS

by

GLENN ARTHUR PROUDFOOT

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August 1996

NATURAL HISTORY OF THE CACTUS FERRUGINOUS PYGMY-OWL

A THESIS

by

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Submitted to the College of Graduate Studies
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ABSTRACT

Natural History of the Cactus Ferruginous Pygmy-Owl

(August 1996)

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Co-Chairman of Advisory Committee: Drs. Samual L. Beasom and

Felipe Chavez-Ramirez

I collected data on cactus ferruginous pygmy-owl (Glaucidium brasilianum cactorum) habitat use and developed a natural history profile with descriptive accounts of the ecology and ethology of this species in southern Texas. Based on my results cactus ferruginous pygmy-owls use artificial nest structures in areas that lack natural cavities if moderate to dense understory exists. Based on observation of active artificial nest structures and natural nest cavities, 1) egg laying was asynchronous, 2) mean clutch size was 4.7 eggs, 3) incubation lasted 21-23 days, and 4) fledging occurred 26-28 days after the hatching of the first egg. Cactus ferruginous pygmy-owls were generalistic predators, feeding on at least 30 different prey species from 5 Classes. I discovered 4 natural nest cavities. Owls showed preferential habitat use, seasonal variations in individual home range size, and responded to broadcast conspecific calls to a distance of 700 m. Information on natural history may aid conservation of

cactus ferruginous pygmy-owls by providing some of the necessary data for development of a viable management plan.
Key words: ferruginous pygmy-owl, food habits, Glaucidium brasilianum cactorum, habitat, natural history, nest box, physical characteristics, pygmy-owl.

DEDICATION

This thesis is dedicated to Patricia Proudfoot and Samual L. Beasom (deceased).

ACKNOWLEDGEMENTS

A project of this nature would not be possible without the assistance of numerous individuals. It would be difficult to extend full credit to all those involved, however, I would like to extend sincere thanks to several key players.

To my committee members, Drs. S. Beasom, F. Chavez-Ramirez, T. Fulbright, and S. Henke my deepest appreciation for their guidance and insight. I would be remiss if I did not mention Dr. Michael E. Tewes, who graciously accepted the advisory position on an interim basis when Sam passed away.

Dr. Ralph Bingham and Jenny Walter used their computer expertise to assist in statistical analysis and areal use determinations. Dr. Jerry Underbrink and the staff of the Animal Medical Clinic at Kingsville, Texas served as medical consultants. Administrative assistance was provided by Becky Trant.

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I am very grateful to all who reside on the Norias Division of the King Ranch whose friendship will not be forgotten. I would be remiss if I did not thank Johnny and Cindy Gonzales, Roberto and Norma Garcia, Ramiro and Jannie Lerma, Joe Gonzales, and Ricardo Lopez. Finally, and certainly not least, I extend my deepest appreciation to Gus and Janis Puente, who have unselfishly given their friendship and support throughout my stay on Norias.

Loan of ferruginous pygmy-owl study skins were courtesy of the American Museum of Natural History, Chicago Field Museum of Natural History, Louisiana State University Museum of Natural History, Oklahoma Museum of Natural History, Smithsonian Institution, University of California Museum of Vertebrate Zoology, and the University of Kansas Museum of Natural History.

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INTRODUCTION

Cactus ferruginous pygmy-owls (hereafter referred to as pygmy-owl) are 1 of 3 geographically separated subspecies of ferruginous pygmy-owl (*Glaucidium brasilianum* [Gmelin 1788]). Historically occurring in mesquite (*Prosopis* spp.) woodlands and cottonwood (*Populus* spp.) forests on the Salt, Verde, and Gila Rivers of Arizona, pygmy-owls were thought to be fairly numerous during 1870-1920 (Gilman 1909, Millsap 1987). Prior to 1920, pygmy-owls were considered common residents of mesquite brush, ebony (*Pithecellobium* spp.), and riparian areas in the Lower Rio Grande Valley of Texas (Oberholser 1974). By the early 1970's over 90% of this habitat was cleared for urban and agricultural expansion, drastically reducing the population size of pygmy-owls (Monson and Phillips 1981).

In recent years, reports of pygmy-owl sightings have been infrequent (Monson and Phillips 1981). In Arizona, less than 20 documented sightings have been reported since 1970. Arizona has no known persistent population and has formally listed the pygmy-owl as endangered. Similarly, the Texas Parks and Wildlife Department has listed the pygmy-owl as threatened. The present federal status of the pygmy-owl is unclear. The U.S. Fish and Wildlife Service (USFWS) has proposed listing the species as endangered in Arizona and threatened in Texas (USFWS 1994). However, federal listing

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This thesis follows the *Journal of Wildlife Management* style.

has not been authorized at this time. Regardless, biologists need specific ecological information about pygmy-owls before a viable management plan can be designed (Greene 1994).

Nest Boxes

Over the past 30 years, artificial nest structures have been used as a management tool to augment various avian populations. Recent use of such structures has invoked economic and ethological research as well (Korpimaki 1985, Brawn and Balda 1988, Hayward et al. 1992). It is assumed that secondary cavity nesters (e.g., pygmy-owls) are limited solely by the availability of nest cavities and that populations can be augmented by adding nest boxes to areas lacking cavities (Waters et al. 1990). However, few researchers have conducted controlled experiments in relatively undisturbed habitat to test these hypotheses (Brush 1983). By manipulating only 1 factor (i.e., availability of nest cavities), Brush (1983) recorded an increase in breeding populations of secondary cavity nesting passerines after nest boxes were established in areas containing few natural cavities. After cavity entrances were blocked, breeding populations of secondary cavity nesters were reduced in an area containing many natural cavities (Brush 1983).

Plumage and Morphology

Johnsgard (1988) describes pygmy-owls as grayish brown with cinnamon-rufous tail-bands. Although color differences may occur among regions, pygmy-owls are not regarded as sexually dichromic (Johnsgard 1988). The upper-body is more cinnamon-rufous in pygmy-owls from the Texas population than individuals from Arizona and Arizona pygmy-owls are more rufous than those from Mexico. Juveniles generally display adult plumage but lack the pale streaks that occur on the crown of adults. Bill, cere, and toes are greenish yellow to grayish yellow and irises are lemon yellow (Johnsgard 1988).

Ridgway (1914) reported wing measurements of males as $\bar{X}$ = 92.10 mm (range 87-97 mm, n = 32), females $\bar{X}$ = 97.1 mm (range 93-103 mm, n = 21); tail lengths of males were $\bar{X}$ = 59.7 mm (range 53-66 mm, n = 32), and females $\bar{X}$ = 62.5 mm (range 56-70 mm, n = 21). Weights of males were $\bar{X}$ = 61.4 g (range 46-74 g, n = 29), and females $\bar{X}$ = 75.1 g (range 64-87 g, n = 16). Estimated egg weight was 8 g (Earhart and Johnson 1970).

Vocalization

Stillwell and Stillwell (1954) described the vocalization of pygmy-owls in southern Texas as "a clear and mellow series of notes, sounding something like 'whah', similar to the sound made by blowing across the opening of a partially filled bottle of water, and at the approximate pitch of 1400 hertz". Each series contained 10-45 repetitions of this singular note uttered at a rate of 1/0.4 sec with about a 10 sec pause between songs. Calling was most frequent at dawn and dusk, but also occurred during daylight and at night (Johnsgard 1988).

Nests and Nesting

Pygmy-owls nest in natural or pre-excavated cavities of trees, stumps, snags, and forks or depressions. One pygmy-owl nest site was located in a hole in a sand bank (Johnsgard 1988). Clutch sizes range from 2-5 eggs with 3 and 4 eggs most common. Egg laying has been recorded 28 March-17 June (Bent 1938). A captive female with a clutch of 5 eggs laid a second clutch 20 days after the first 1 was removed (Scherzinger 1977). Scherzinger (1977) noted an incubation period of 30 days and initial fledging occurred 28 days after the hatching of the first egg.

Food Habits

Pygmy-owls are diurnal predators that attack prey as large or larger than themselves. Anecdotal accounts characterize pygmy-owls as generalistic predators taking small mammals, birds, lizards, large insects, and scorpions (Jonsgard 1988). An early account notes pygmy-owls attacking and killing young domestic fowl, as well as captive guans (*Penelope*, [Jonsgard 1988]). Captive pygmy-owls prefered small birds, particularily house sparrows (*Passer domesticus*, [Gilman 1909]).

Although anecdotal accounts provide useful information regarding pygmy-owl natural history they lack rigor, an essential factor for the development of a viable management plan. I incorporated artificial nest structures, radio telemetry, fiber optics, and audio-visual equipment to develop a detailed natural history profile with descriptive accounts of pygmy-owl ecology and ethology.

The objectives of this study were to determine: 1) if the availability of nest cavities alone controlled pygmy-owl habitat selection, 2) nest box placement criteria of pygmy-owls, and 3) physical characteristics, habitat use, food habits, and nesting biology of pygmy-owls. Information generated from this project will aid population enhancement of this species by providing necessary management data.

METHODS

Research was primarily conducted within a 29,000-ha live oak (Quercus virginiana)-honey mesquite (Prosopis glandulosa) forest on the Norias Division of the King Ranch, Kenedy County, Texas (26° 37'30" and 26° 51'30"N, 97° 27'30" and 97° 43'30"W). Secondary study areas (El Canelo Ranch, Runnels Ranch, and Knapp Ranch) were located within 32 km of the Norias Division. Secondary study areas encompassed 700-1,400 ha of >80-year-old honey mesquite thicket. The climate is subtropical with 68 cm mean annual precipitation and 24 C mean annual temperature.

Availability of Cavities

To estimate the number of natural or excavated cavities on the primary study area I established 104 transects (400 x 6 m) and 556 box plots (100 x 100 m) at 400 m intervals perpendicular to roads that intersect the study area. Compasses were used to orient transects (i.e., north-south directions), and lines were laid with a tonometric hip-chain (Forestry Suppliers, Inc., Jackson, MS) to establish boundaries. Trees within transect boundaries were checked for the presence of natural and excavated cavities by circling each tree and visually inspecting its surface. To avoid inspecting the same tree twice, trees were temporarily marked with a chalk tree marker (Forestry Suppliers, Inc., Jackson, MS).

To obtain information on possible interspecific competition for nest cavities, studies were conducted 16

March-14 June, 1995. Cavities >3.8 cm in diameter were inspected for occupancy with a miniature video system designed to inspect pygmy-owl nest boxes (Proudfoot, in press). Cavity entrance diameters were estimated by placing the camera in or adjacent to the cavity and comparing the size of the entrance hole to the size of the camera housing (3.6 x 2.2 cm). The above ground height of cavity entrances were estimated (± 15 cm) from markings placed on the telescoping pole that supported the video camera. Trees containing cavities were identified according to species and diameters measured at breast height (dbh) (i.e., 130-145 cm above ground level). The number of cavities/ha on the study area was estimated by multiplying the number of cavities/ha in the area sampled (24.96 ha) by the size (ha) of the study area.

In conducting box plots, markers were placed in 4 cardinal directions and 100 m from predetermined road sites. The 4 closest trees (N,S,E,W) to the point center of the box plot marker were checked for natural and excavated cavities. Cavity inspection in box plots also followed transect format. In the box plot study, the number of cavities/ha was estimated by multiplying the number of cavities/tree sampled by the mean number of trees/ha found on the study area (228). The number of trees/ha on the study area was determined from data obtained in a systematic-random sample of 217 0.04 ha circular plots.

Nest Box Study

In October 1992, Beasom et al. (1993) established 40 nest boxes varying in box depth, entrance hole size, and placement height in areas of the Norias Division known to be occupied by pygmy-owls. This initial set of 40 nest boxes were incorporated into the study to ascertain additional information on characteristics of nest boxes preferred by pygmy-owls.

In January 1994, 40 more nest boxes were constructed (14 x 14 x 46 cm with a 5.13 cm entrance hole placed 31 cm above the box bottom) and established in 4 different habitat types to determine if the availability of nest cavities affected pygmy-owl habitat selection. Sixteen nest boxes were placed in undisturbed live oak stands dominated by 20-30 cm dbh trees with >600 trees/ha that lacked natural cavities and had minimal (0-25%) to sparse (25-50%) understory cover. Sixteen nest boxes were placed in undisturbed old-growth live oak stands (>51 cm dbh trees) with <400 trees/ha that contained natural cavities and had minimal to sparse understory cover.

Thinning of 4 forested areas on the primary study area provided an opportunity to ascertain the effect nest box placement may have on these sites. In January 1994, 4 nest boxes were placed in live oak stands dominated by 8-13 cm dbh trees that lacked natural cavities, had minimal understory, and had been thinned from >2000 trees/ha to 118 trees/ha.

Access to secondary study areas provided the opportunity to establish nest boxes in undisturbed sites void of live oak. In January 1994, 4 nest boxes were placed in undisturbed mesquite stands dominated by >20 cm dbh trees which contained natural cavities and had moderate (50-75%) to dense (75-100%) understory cover.

Nest box placement height varied from 3.8-7.0 m above ground level. Nest boxes placed in the 20-30 cm dbh undisturbed live oak stands and in the undisturbed old-growth live oak stands were placed in convergent converse sets of 2 <100 m apart to allow equal opportunity for occupancy.

In January 1995, 32 additional nest boxes were constructed (14 x 14 x 46 cm with a 5.13 cm entrance hole placed 31 cm above the box bottom) and placed in >20 cm dbh undisturbed honey-mesquite stands which contained natural cavities and had moderate to dense understory cover. Expanding habitat criteria studies, 20 previously established nest boxes were removed (4 from disturbed sites, 8 from undisturbed areas dominated 20-30 cm dbh trees, and 8 from undisturbed old-growth stands) and relocated. Ten of these nest boxes were placed in live oak-mesquite habitat dominated by 20-30 cm dbh trees with >600 trees/ha that lacked natural cavities and had moderate to dense understory. The other 10 nest boxes were established in old-growth forest habitat with <400 trees/ha that contained natural cavities and had moderate to dense understory cover.

Placement of nest boxes followed 1994 format (i.e., 1 nest-box in old-growth and 1 in a 20-30 cm dbh stand <100 m apart).

During 1994, an 8-m ladder was used to inspect nest boxes bimonthly 25 January-7 March, weekly 8 March-11 April, on alternating days 11 April-9 May, and weekly 10 May-30 June. Once occupancies (i.e., pygmy-owl) were determined, nest boxes were inspected almost daily to obtain information on pygmy-owl laying sequence, clutch size, incubation period, and hatching sequence. Although efficient, use of a ladder may stress the observer and the nest box occupant and possibly injure the tree. Therefore, in 1995 a nest box monitoring system (i.e., a miniature video board camera mounted on top of a telescoping pole, Proudfoot in press) was employed to inspect nest boxes from the ground. Nest box inspections were conducted weekly 15 March-13 April, on alternating days 14 April-9 May, and weekly 10 May-5 June, 1995.

Two active pygmy-owl nest boxes (1 in 1994, 1 in 1995) were monitored visually from an elevated blind and by placing miniature external lens video cameras (Chugai Boyeki Corp., N.Y.) inside the top of the nest box to record nestling activities. To aid pygmy-owl age determination, stages of nestling development (i.e., feather growth) were recorded on slide film at 4, 12, and 20 days post hatch.

Natural Nest Cavities

Radio telemetry was used to locate 4 active pygmy-owl nest cavities during Spring 1995 (Belthoff and Ritchison 1989, 1990). Radio-tagged pygmy-owls were tracked to their nest sites using a hand-held receiver (Model F/L, L. L. Electronics, Mahomet, Ill) and a 3-element yagi antenna (L. L. Electronics, Mahomet, Ill). At each nest site, a 0.04-ha circular plot was established to determine habitat composition (Stoddard and Stoddard 1987). Trees >2 m in height and ≥2.5 cm in dbh that occurred within the 0.04-ha plot were counted, identified according to species, and measured for dbh. Density board values were estimated to determine understory cover. A single board measuring 205 x 8.9 x 1.9 cm, with 8 equal-sized panels of alternating colors (white, orange), was placed at the center of each plot and observed from the outer edge of the plot from 4 cardinal directions. Each panel was rated between 0 and 6 for percentage of the panel covered by vegetation (0 = 0%, 1 = >0-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-95%, 6 = 96-100%). As with active nest boxes, elevated blinds were established at active natural nest sites to observe nesting biology. Internal nest cavity observations were made with a FS-490X108 flexible fiber optic stratascope (Schott Fiber Optics Inc., Southbridge, MA) or with a telescoping miniature video system designed to inspect pygmy-owl nest boxes (Proudfoot, in press). Observations of natural cavities provided information similar to that obtained from active nest boxes (i.e., clutch size, incubation period, hatching sequence, nestling development, and prey items consumed).

An extensive literature search failed to produce information on recruitment standards (i.e., number of fledged young/nest attempt needed to maintain a stable population) of pygmy-owls. Gehlbach (1994) established a recruitment standard of 1.8 for eastern screech owls, a similar species. However, the mean clutch size of pygmy-owls exceeds that of eastern screech owls, suggesting higher mortality. Therefore, to acquire information regarding the stability of the Norias Division pygmy-owl population, I compared the fecundity (i.e., number of nestlings fledged/nest attempt) of pygmy-owls on the Norias Division to an expanded eastern screech owl standard (2.25) (Gehlbach pers. comm., see results and discussion).

Sexual Dimorphism

Examination of 10 live adult pygmy-owls (5 male, 5 female) captured on the Norias Division showed distinct sexual dimorphic plumage characteristics. Therefore, I examined 571 museum specimens for sexually dimorphic plumage characteristics. Initially, I secured museums' loans of 660 pygmy-owl study skins for examination, of which 571 were labeled according to sex and suitable for color phase analysis. Specimens remained anonymous (i.e., tags containing capture location and sex identification were not viewed) until sex was determined through analysis of plumage characteristics. Specimens that displayed homogenous cinnamon-rufous color tone on coverts, remiges, occipitals, scapulars, and rufous tail bands were classified as females. Specimens that displayed homogenous dark brown color tones on coverts, remiges, occipitals, and scapulars that contrasted with the rufous tail bands were classified as males.

Pygmy-owls that displayed white tail bands (198) were sexed by comparing continuity in color tones of coverts, remiges, occipitals, scapulars, and the dark brown tail bands. Those specimens that maintained continuity were recorded as males, and those that displayed distinct differences were recorded as females. The validity of this technique was tested by comparing sex determinations made from analysis of plumage characteristics and determinations made by museums' preparators (i.e., specimen tags).

Sex determination comparisons were conducted on specimens throughout the range of pygmy-owls. Specimens were separated according to capture location (i.e., Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, San Salvador, Trinidad, United States of America, and Venezuela) to obtain information on possible geographic variations in plumage sexual dimorphism.

Color phase difference of adult male (left) and adult female (right) cactus ferruginous pygmy-owl, Kenedy County, Texas, 1995.

Physical Characteristics

Nylon mist nets (Item No. CTX, Avinet, Inc., Dryden, N.Y.) and baited bow nets (Bird Traps, Czechoslovakia) were used to capture adult pygmy-owls March 1994-June 1995. Bow nets were baited with live white laboratory mice and placed in proximity (<5 m) to mist nets. To avoid injury or loss of mice to predation, mice were placed in cages (4.5 x 13.5 x 49.4 cm) constructed of 0.64 cm mesh hardware cloth; bow nets (25 x 25 cm) were then placed on top of the cages. Trigger systems similar to those found on common leg-hold traps activated the bow net. Anything that landed on top of the cage would trigger the bow net.

Mist nets were set in varying configurations (e.g., 2 nets placed on opposite sides of a small mesquite tree, 3 nets enclosing a small mesquite tree in a triangular fashion) in proximity (<100 m) to known pygmy-owl locations. A portable tape recorder (i.e., MS512MR Johnny Stewart Bird and Animal Caller) was placed inside the mist net configuration to broadcast conspecific calls and lure pygmy-owls into the nets (Ritchison et al. 1988). Implementing 2 capture techniques was done because some pygmy-owls may not display enough aggressive territorial behavior (i.e., assaulting the recorder) to enter the mist nets, but may attempt to capture mice.

Captured pygmy-owls were weighed with 300 g ± 3% pesola scales (Pesola Precision Scales, Switzerland). Measurements of wing chord, tail length, and total body length were made using a flexible ruler. Tarsus length was measured with a 505-101 Milutoyo caliper. Similar measurements were taken from 12 pygmy-owl nestlings 4-7 days before fledging. Tarsus lengths were recorded from 16 individuals (9 adults, 7 nestlings). Nest box occupants (i.e., pygmy-owls and eastern screech owl (Otus asio)) were captured with elevated mist nets, measured for wing chord, tail, and total body length, weighed, fit with a U.S. Fish and Wildlife Service aluminum leg band, and released. To determine molt patterns, feather growth analyses were conducted on all adults captured (Evans and Rosenfield 1987).

Measurements of pygmy-owl eggs (i.e., mean weight, external dimensions, and shell thickness) were obtained from 2 clutches (5 eggs each) in active nest boxes. To minimize the possible adverse effect of clutch examination (nest abandonment), mean egg weight was determined by dividing the combined egg weights by the clutch size. Clutches were weighed with 300 g ± 3% pesola scales. External egg measurements were taken with a 505-101 Milutoyo caliper (Milutoyo Co., Japan), accurate to within 0.003 cm. Shell thickness was estimated with caliper measurements of shell remnants.

Regional Differences.--

Physical measurements of museum specimens provided information on regional differences in pygmy-owl morphology. Pygmy-owl study skins were measured (i.e., wing chord, tail and culmen), separated according to collection location (i.e., Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Peru, Trinidad, United States of America, and Venezuela), and compared (1 tailed t-test) to the Norias Division population. Statistical analysis was not conducted on areas with <10 specimens taken (i.e., Bolivia, El Salvador, Guyana, Nicaragua, Panama, Paraguay, and San Salvador).

Hematozoa Study

Blood samples were collected from 49 pygmy-owls to obtain information on possible hematozoa presence. To avoid injury and reduce stress, pygmy-owls were secured in 3.8 cm diameter tubes 13 cm in length and partially open on both ends. One toe-nail of each pygmy-owl sampled was clipped to the pulp to obtain enough blood to make 4 smears (Bennett 1970). Slides were labeled according to pygmy-owl band numbers. Kwik-stop (Gimborn-Rich Health, Atlanta, Ga.) was applied to stop the bleeding. Pygmy-owls were fit with U.S. Fish and Wildlife Service aluminum leg bands and released.

Blood smears were air dried and fixed in 100% methanol. Fixed blood smears were separated into 2 sets of 98 slides. Each set contained 2 slides from each individual sampled. Slides were stained with 1:9 (10%) dilution of Giemsa's stain (stock solution) in distilled water buffered to a pH of 7.2 for 30 minutes. They were then rinsed in slightly acidic water (pH 6.5) and air dried. Smears were examined under a Zeiss Ultraphot microscope with a total magnification of 625X. Approximately 100 fields (which approximates 15-20,000 erythrocytes) were examined. One set of slides was examined by Andrew Radomski at Caesar Kleberg Wildlife Research Institute and 1 set was sent to Dr. Gordon Bennett of the International Reference Center for Avian Haematozoa for verification.

Habitat Use

To determine habitat use of pygmy-owls, 10 adults and 5 fledglings equipped with backpack-style radio transmitters (L. L. Electronics, Mahomet, Ill) were monitored (Nicholls and Fuller 1987). Three pygmy-owls (1 ad, 2 fledglings) were monitored during 17 June 1994-14 July 1994. Three adults were monitored during 16 September 1994-26 November 1994. Nine pygmy-owls (6 ad, 3 fledglings) were monitored 3 April 1995-24 September 1995. Portable radio-receivers (Model F/L, L. L. Electronics, Mahomet, Il), directional antennas (Model F150-5FB, AF Antronics Inc., White Heath, Il), compass bearings, and pacing were used to estimate Universal Transverse Mercator (UTM) coordinates of radio-tagged pygmy-owls. Observers started tracking radio-tagged individuals from established UTM locations and used compass bearings and pacing to calculate the geographic location of each pygmy-owl visual sighting.

Pygmy-owl locations were recorded almost daily during the lives of the transmitters (30-90 days). Following procedures described from nest site locations, 0.04-ha circular plots were established at the location of each pygmy-owl visual sighting to determine habitat composition of areas used by pygmy-owls. Mean cover values, number of trees/ha, and dbh of trees within circular plots were compared to study area composition data obtained in a systematic-random sample of 219 0.04-ha plots to determine pygmy-owl habitat selection (Stoddard and Stoddard 1987).

To calculate pygmy-owl areal use, UTM coordinates were analyzed for 95 and 100% minimum convex polygons with the TELEM88 home range analysis program (Dept. of Fish and Wildlife, Virginia Polytechnic Institute and University, Blackburg, VA.). It is assumed that 95% minimum convex polygons reduce outlier bias by eliminating an individual's radical movement outside its normal home range. However, I hypothesized the probability of obtaining an outlier with a sample of <30 points (69% in this study) is immeasurable, and therefore I calculated 100% minimum convex polygons as well as 95% to obtain an accurate representation of pygmy-owl areal use.

Response Testing

I tested the responsiveness of pygmy-owls to broadcasted conspecific calls at varying distances (400, 500, 600, and 700 m) to establish criteria on appropriate spacing of vocalization survey points. Four male pygmy-owls were trapped, banded, and fit with radio-transmitters 3-17 April 1995. I monitored movements daily and charted their locations throughout the season. Once 7-10 locations were recorded, I began sampling.

Equipped with portable radio-receivers and 2-way radios

(Radius P110 Motorola, Mt. Pleasant, IA), 1 observer tracked a targeted pygmy-owl, obtained visual contact, and relayed its location to a second observer. The second observer calculated the distance to the target individual by relating its present position to previously established locations. Compass and pace-factor adjustments were then made to obtain the response distance desired for testing. At the desired distance, the second observer broadcast conspecific calls toward the targeted individual. Any movement and vocalization response that occurred as a result of the broadcast was substantiated with radio-telemetry, and recorded. I did not sample during precipitation or when winds exceeded 19-24 kmh.

Food Habits

Pygmy-owl food habits were determined by identification of prey remains, regurgitated pellets, direct observation, and analysis of video footage recorded inside active nest boxes. Prey remains were removed from 5 pygmy-owl nest sites (2 in 1994, 3 in 1995), postfledging, and analyzed for identifiable prey species. Identification of prey remains was made using dichotomous keys, university reference collections, and by consulting the university's mammalogists, herpetologists, ornithologists, and entomologists. To estimate numbers of prey items in remains, the number of grasshopper (Acrididae and Tettigoniidae) hind legs and the number of click beetle (Elaterdae) wings were divided by 2. Numbers of cone-nose blood sucker (Reduviidae) were estimated by counting thorax exoskeleton. Other insects were identified and counted from complete exoskeletons. Mammal and reptile remains were identified and numbers estimated from corresponding upper and lower mandibles. Bird remains were identified from beak and feather remnants and numbers were estimated from corresponding sets of upper and lower beaks.

Although biased toward larger species, prey remain analysis provides valuable information to qualify food habit studies (Errington 1938, Craighead and Craighead 1956, Rosenberg and Cooper 1990). My inability to distinguish many insect remains (e.g., wing scales) limited this study. To avoid distorting the results, speculations on numbers of unidentifiable insect remains were not recorded. From observation blinds erected at 2 natural nests and 2 nest boxes an observer recorded species and number of prey brought to the nest cavity by adults. Observations were made daily over irregular time intervals between sunrise and sunset postincubation-fledging.

Video footage obtained from inside active pygmy-owl nest boxes was used to enhance food habit studies. Two replacement nest box covers were constructed to house miniature video cameras and a light source. In 1 replacement cover (19 x 20 x 2 cm), I drilled a 1.9 cm diameter hole through the center and hollowed a 6.0 x 5.5 x 1.9 cm depression around the hole to house a color video camera (XC-42 Computar, Chugai Boyeki Corp., New York, N.Y.). Two 12 V DC miniature lamps (Archer, Radio Shack, Kingsville, Texas) were then similarly installed 3.9 cm on opposite sides of the camera lens. The second replacement cover (19 x 20 x 2 cm) was also drilled in the center (1.9 cm in diameter) and hollowed (3.2 x 3.2 x 1.9 cm) to house a smaller black and white video camera (EM200L38 Computar, Chugai Boyeki Corp., New York, N.Y.). One 12 V DC miniature lamp was similarly installed in the second replacement cover to provide a light source.

During 1994, infrared phototransistors (Archer, Radio Shack, Kingsville, Texas) powered by a 1.5 V DC battery replaced the miniature lamps as a light source to record night nest box activities. Replacement covers containing light source and video camera were protected from weather by sealing the edge of the depression with silicon and attaching another 19 x 20 x 2 cm board over the depression. Video patch cables (Radio Shack, Kingsville, Texas) transferred the video image to Canon A1 Digital cam-corders (Canon Inc., Japan) placed in the blind. The power source was a 12 V car battery. Replacement covers were installed on active pygmy-owl nest boxes (1 in 1994, 1 in 1995) 7-10 days before nestlings fledged. Video recordings were analyzed for identifiable prey items and compared to visual observations from the blind and prey remain data acquired from nest boxes.

Statistics

Physical characteristics of pygmy-owls captured on the study area were compared to those obtained from museum study skins using Multivariate Analysis (MANOVA, [SAS Inst. Inc. 1985]). When differences occurred in the MANOVA, I used Fisher's Least Significant Differences (LSD) procedure to test for differences among pygmy-owl collection locations. I compared the forest composition of the primary study area to forest composition data obtained at pygmy-owl visual sighting points using Wilcoxon Signed Ranks (1 tailed-test, [SAS Inst. Inc. 1985]). Chi-squre goodness-of-fit was used to compare the use of four habitat types (i.e., live oak-mesquite, live oak, mesquite, and open grassland) by pygmy-owls to their availability on the primary study area (SAS Inst. Inc. 1985).

RESULTS

Availability of Cavities

Transects encompassed 24.96 ha (approximately 13,995 trees) and contained 261 natural or excavated cavities (10.5/ha), 221 (84%) of which occurred in live oak and 40 (16%) in mesquite. Sixty-eight (26%) (2.7/ha) were of the entrance hole diameters preferred by pygmy-owls (i.e., 4.5-5.8 cm, Beasom et al. 1993) (Table 1). However, only 9 (3%) (0.4/ha) cavities (7 in live oak, 2 in mesquite) of suitable entrance size were in trees ≥30 cm dbh, the smallest tree found to contain active pygmy-owl nests. Estimates (i.e., 0.4 x 29,000) indicate 11,600 preferred pygmy-owl nest cavities (i.e., cavities of suitable size in suitable age trees, [Beasom et al. 1993]) could occur throughout the study area. In box plots, examination of 2,224 trees located 42 (4.3/ha) natural or excavated cavities, 30 (71%) in live oak and 12 (29%) in mesquite. Twenty-two (62%) (2.7/ha) were within the preferred entrance size limits proposed by Beasom et al. (1993) (Table 2). However, only 2 (0.2/ha) cavities of suitable entrance hole size were in suitable aged trees. Occurrence of excavated and natural cavities in live oak and mesquite stands were disproportionate to the occurrence of these tree species throughout the study area (i.e., 75% live oak, 35% mesquite, Table 3). No natural or excavated cavities inspected contained avian occupants.

Table 1. Distribution and size of cavities in live oak and mesquite trees on the Norias Division of the King Ranch, as determined from 104 400 x 6 m systematically established line transects, Norias, Texas, 1995.

		Diameter of cavities in live oak (± 1.3 cm)						Diameter of cavities in mesquite (± 1.3 cm)					
dbh[a]	n[b]	3	5	8	10	13	≥15	3	5	8	10	13	≥15
		(Number of Cavities)						(Number of Cavities)					
10	11	10	0	1	0	0	0	0	0	0	0	0	0
15	49	14	21	5	2	1	0	0	3	1	2	2	0
20	63	7	14	14	8	2	1	1	2	4	3	2	1
25	52	4	14	8	14	3	2	0	5	2	1	0	0
30	33	0	3	4	11	3	5	0	0	1	3	0	0
35	25	0	3	7	7	2	3	0	2	0	1	0	1

Table 1. (continued)

		Diameter of cavities in live oak (± 1.3 cm)						Diameter of cavities in mesquite (± 1.3 cm)					
dbh[a]	n[b]	3	5	8	10	13	≥15	3	5	8	10	13	≥15
		(Number of Cavities)						(Number of Cavities)					
40	11	0	0	4	2	1	3	0	0	0	0	1	0
45	6	0	1	0	0	1	4	0	0	0	0	1	0
50	3	0	0	0	2	0	0	0	0	0	0	0	0
55	1	0	0	0	0	1	0	0	0	0	0	0	1
60	3	0	0	0	0	2	1	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
70	1	0	0	1	1	0	1	0	0	0	0	0	0

Table 1. (continued)

dbh[a]	n[b]	Diameter of cavities in live oak (± 1.3 cm) 3	5	8	10	13	≥15	Diameter of cavities in mesquite (± 1.3 cm) 3	5	8	10	13	≥15
		(Number of Cavities)						(Number of Cavities)					
75	1	0	0	0	0	0	1	0	0	0	0	0	0
Total	259	35	56	44	48	16	22	1	12	8	10	6	3

[a]dbh = Diameter at breast height of trees containing cavities, ± 1.3 cm.

[b]n = number of trees containing cavities.

Table 2. Distribution and size of cavities in live oak and mesquite trees on the Norias Division of the King Ranch, as determined from 506 systematically established box plots, Norias, Texas, 1995.

		Diameter of cavities in live oak (± 1.3 cm)						Diameter of cavities in mesquite (± 1.3 cm)					
dbh[a]	n[b]	3	5	8	10	13	≥15	3	5	8	10	13	≥15
		(Number of Cavities)						(Number of Cavities)					
15	8	0	5	0	0	0	0	2	1	0	0	0	0
20	9	0	5	0	1	0	0	3	0	0	0	0	0
25	6	0	2	1	0	0	0	3	0	0	0	0	0
30	4	0	1	2	0	0	0	1	0	0	0	0	0
35	3	0	0	2	0	0	0	1	0	0	0	0	0
40	3	0	0	1	0	0	2	0	0	0	0	0	0
45	5	0	1	1	1	1	0	1	0	0	0	0	0

Table 2. (continued)

		Diameter of cavities in live oak (± 1.3 cm)						Diameter of cavities in mesquite (± 1.3 cm)					
dbh[a]	n[b]	3	5	8	10	13	≥15	3	5	8	10	13	≥15
		(Number of Cavities)						(Number of Cavities)					
50	1	0	0	0	1	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0
60	1	0	1	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
70	1	0	0	0	0	0	1	0	0	0	0	0	0
>70	1	0	0	0	0	0	1	0	0	0	0	0	0
Total	42	0	15	7	3	1	4	11	1	0	0	0	0

[a]dbh = Diameter at breast height of trees containing cavities, ± 1.3 cm.

[b]n = number of trees containing cavities.

Table 3. Size distribution of live oak and mesquite trees on the Norias Division of the King Ranch, as determined from 217 systematically-random established 0.04/ha circular plots, May-Jun 1994 and 1995.

	Live oak		Mesquite	
dbh[a]	n	% of total[b]	n	% of total
5	263	8.1	1085	62.4
10	807	24.9	231	13.3
15	986	30.4	174	10.0
20	607	18.7	86	4.9
25	301	9.3	74	4.3
30	138	4.3	53	3.0
35	66	2.0	20	1.1
40	24	0.7	6	0.3
45	14	0.4	4	0.2

Table 3. (continued)

	Live oak		Mesquite	
dbh[a]	n	% of total	n	% of total
50	10	0.3	3	0.2
55	10	0.3	3	0.2
60	8	0.2	0	0.0
65	5	0.2	1	tr.
70	1	tr.		
75	1	tr.		

[a]dbh = Diameter at breast height (i.e., 130-145 cm above ground level) ± 1.3 cm of trees examined on the study area.

[b]tr. = trace.

Nest Box Study

Nest box placement provided 192 nesting opportunities. Three nest boxes (1.6%) (2 in 1994, 1 in 1995) were used as nest sites by pygmy-owls, and 2 were successful in fledging young. Fecundity of pygmy-owls using nest boxes was 3.0, 0.5 young/nest attempt higher than the estimated 2.5 recruitment standard. Occupied nest boxes were in areas dominated by 20-30 cm dbh live oak that lacked cavities (1), >51 cm dbh live oak containing cavities (1), and in >20 cm dbh mesquite with few cavities (1). Two active pygmy-owl nest boxes were in areas with moderate (50-75%) understory and 1 was in an area with dense (75-100%) understory. Entrance hole heights were 5.9, 6.4, and 7.0 m above ground level. Nest tree dbh were 26, 31, and 63 cm. Active pygmy-owl nest box configurations were 13 X 13 X 31 cm with a 4.5 cm diameter entrance hole, 13 X 13 X 44 cm with a 4.5 cm diameter entrance hole, and 13 x 13 x 46 cm with a 5.8 cm diameter entrance hole.

Several other species utilized the nest boxes including brown-crested flycatchers (Myiarchus tyrannulus) (20), golden-fronted woodpeckers (Melanerpes aurifrons) (6), eastern screech owl (Otus asio) (1), and European starling (Sturnus vulgaris) (1). Although only 1 pair of eastern screech owls was found nesting in boxes, 17 different individuals (9 in 1994, 8 in 1995) were recorded as using nest boxes for daily roost sites. An additional 7 (4%) boxes containing nest material were listed as abandoned or lost to predation. Unidentified spider and wasp species occupied 21 nest boxes (4 and 5 respectively in 1994, 1 and 11 in 1995).

Eggs of 2 pygmy-owls were laid on the bare wooden surface of the nest box bottom. The third pygmy-owl laid eggs on 5-8 cm of Spanish moss (*Tillandisa usneoides*). Clutch sizes were 4 and 5 eggs with only 1 box containing 4 eggs. In periodic nest box inspections, I determined pygmy-owls laid 1 egg every 32-39 hr until the clutches were complete. Laying of the first egg in a clutch was recorded as early as 17 April 1994, and as late as 26 April 1995. Incubations were conducted solely by females, were initiated upon completion of the clutch, and continued for 21-23 days. Hatchings were asynchronous with 1 egg hatching every 20-26 hr. Of 10 eggs examined, mean egg weight, egg diameter, and shell thickness were 7.8 g, 2.95 x 2.36 cm (range 2.79-3.26 x 2.31-2.39), and 0.023 cm respectively. Fledging occurred 26-28 days after hatching was complete.

At 4 days posthatch, pygmy-owls were covered in white down and absent of visible feather sheaths. Their eyes had not yet opened and they were unable to hold their heads erect.

At 12 days posthatch pygmy-owls held their heads erect and responded to movement. Remiges had erupted from sheaths approximately 0.2 cm with neossoptiles still attached. Auricular, occipital, covert, and scapular sheaths were exposed and intact. Rectrice sheaths were not exposed.

Cactus ferruginous pygmy-owl 4 days posthatch, Norias, Texas, 1994.

Cactus ferruginous pygmy-owl 12 days posthatch, Norias, Texas, 1994.

At 20 days posthatch pygmy-owl auriculars, occipitals, coverts, and scapulars were fully feathered except for attachment of neossoptiles on approximately 10% of auriculars and coronals. Primaries were unsheathed about 3.1 cm and secondaries had erupted approximately 2.0 cm. Rectrices were approximately 0.2 cm beyond their sheaths. At this age plumage coloration was dark brown, which resembled adult males.

Natural Nest Cavities

Through tracking of radio-tagged pygmy-owls, 4 active nest cavities (presumably excavated by golden-fronted woodpecker) were located during Spring 1995 and 1 was successful in fledging 4 young. One was predated 22 days after the clutch (5 eggs) was complete. The other 2 succumbed to predation 11 and 21 days posthatch. Fecundity of pygmy-owls nesting in excavated cavities was 1.0, far below the 2.5 recruitment standard established. All 4 pygmy-owl nest cavities were in live oaks. The closest distance between active nest sites was 845 m. Characteristics of pygmy-owl nest cavities (i.e., height of entrance hole above ground level, entrance hole diameter, internal cavity diameter, depth of cavity, and nest tree dbh) differed slightly (Table 4). All active pygmy-owl nest cavities were on the underside of upward and outward sloping limbs. Clutch size and laying sequence of pygmy-owls nesting in excavated cavities were similar to those using nest boxes (i.e., 4-5 eggs with only 1 nest containing 4

Cactus ferruginous pygmy-owl 20 days posthatch, Norias, Texas, 1994.

Table 4. Characteristics of 4 active pygmy-owl nest sites established in live oak trees located on the Norias Division of the King Ranch, April, 1995.

Characteristics*	Nest Site 1	Nest Site 2	Nest Site 3	Nest Site 4
DBHNT (cm)	30.8	51.3	41.0	46.2
CEHAG (cm)	410.3	356.4	484.6	242.0
CEHD (cm)	5.1	5.9	4.9	5.0
NCD (cm)	8.3	14.7	8.3	12.2
DNC (cm)	4.6	4.4	4.4	3.6
UV	111	163	140	93
ET/Ha	80	270	160	120

*DBHNT = diameter at breast height (130-145 cm above ground level) of nest tree; CEHAG = cavity entrance height above ground; CEHD = cavity entrance hole diameter; NCD = nest cavity depth; DNC = nest cavity diameter; UV = understory value (0-192, 0 = 0% 192 = 100% cover); ET/Ha = estimated trees/ha.

eggs and 1 egg being laid every 32-39 hr). The earliest laying date (i.e., laying of the first egg in a clutch) recorded was 12 April and the latest 19 April 1995. Fledging occurred 26-28 days after hatchings were complete.

Sexual Dimorphism

Sexual determinations made through color phase analysis concurred with museums' preparators on 387 (68%) of the 571 specimens studied (Table 5). Specimens collected from El Salvador, Guyana, Nicaragua, and San Salvador had the highest correlation (100%) and specimens collected from Costa Rica the least (47%). Sexual determinations of Glaucidium brasilianum cactorum (i.e., the subspecies on the study area) specimens had a correlation of 82% between plumage characters and museum tag identifications (Table 6).

Physical Characteristics

Mean wing chord, tail, tarsus, and total body lengths of adult pygmy-owls trapped on the study area were 94.5, 64.3, 10.7, and 159.9 mm respectivly. Mean weight was 70.5 g (Table 7).

Variations in physical characteristics of museum specimens exceeded those of pygmy-owls trapped on the study area (Table 8). Significant differences ($F = 8.12$, 15 df, $P = 0.0001$) in wing chord lengths were recorded between pygmy-owls trapped on the study area and museum specimens. Differences (LSD test, 672 df, $P < 0.05$) in wing chord lengths occurred between pygmy-owls trapped on the study area and museum specimens collected from Argentina, Brazil,

Table 5. Comparative results of sex determinations made through analysis of ferruginous pygmy-owl plumage characteristics (i.e., color phase differences) and sex identifications displayed on museum tags, December 1995.

Capture location	n	Concur[a]	Differ[b]
Argentina	70	47	23
Bolivia	4	2	2
Brazil	48	28	20
Chile	21	18	3
Colombia	6	4	2
Costa Rica	15	7	8
Ecuador	45	32	13
El Salvador	1	1	0
Guatemala	25	15	10
Guiana	3	3	0
Honduras	12	11	1
Mexico	161	119	42
Nicaragua	2	2	0
Panama	5	4	1
Paraguay	11	7	4
Peru	37	23	14
San Salvador	4	4	0
Trinidad	28	14	14

Table 5. (continued)

Capture location	n	Concur	Differ
United States	35	28	7
Venezuela	28	18	10
Total	571	387	184

[a]Number of pygmy-owl museum specimens sampled in which sexual determinations made from analysis of plumage characteristics concurred with sex identifications recorded on museums' study skin tags.

[b]Number of pygmy-owl museum specimens sampled in which sex determinations made from analysis of plumage characteristics differed from sex identifications recorded on museums' study skin tags.

Table 6. Comparative results of sex determinations made through analysis of cactus ferruginous pygmy-owl plumage characteristics and sex identification displayed on museum tags.

Capture location	n	Concur[a]	Differ[b]
Colima, Mexico	10	8	2
Jalisco, Mexico	8	7	1
Mazatlan, Mexico	3	2	1
Nayarit, Mexico	3	2	1
San Luis, Mexico	3	3	0
Sinaloa, Mexico	14	12	2
Sonora, Mexico	20	19	1
Tamaulipas, Mexico	24	17	7
United States	35	28	7
Total	120	98	22

[a]Number of pygmy-owls sampled in which sex determinations made from analysis of plumage characteristics concurred with sex identifications recorded by museums.

[b]Number of pygmy-owls sampled in which sex determinations made from analysis of plumage characteristics differed from sex identifications recorded by museums.

Table 7. Physical characteristics of pygmy-owls live trapped on the Norias Division of the King Ranch, Kenedy County, Texas, 1994 and 1995. (Length-mm, weight-g)

	n	x̄	STD	Min	Max
		(Adults)			
Tail length	57	64.3	3.7	48	70
Wing chord	57	94.5	3.1	87	103
Total length	56	159.9	6.2	141	171
Weight	57	70.5	9.3	57	102
Tarsus	16	10.7	1.6	9.6	14.0
		(Nestlings 4-7 days before fledging)			
Tail	12	19.7	4.16	12	26
Wing chord	12	65.67	5.25	55	74
Total length	12	105.17	4.62	98	117
Weight	12	61.67	4.29	56	70
Tarsus	6	9.70	0.30	9.1	10.0

Table 8. Physical characteristics obtained from ferruginous pygmy-owl (FEPO) museum study skins (1995). (Length-mm, weight-g)

	n	$\bar{x}$	SE	Min	Max
		(Throughout FEPO Range)			
Wing chord	549	96.2	4.9	71	120
Tail	533	61.8	4.1	52	84
Culmen	527	11.1	0.8	8.5	13.7
Weight	27	68.1	7.3	54	84
		(Male FEPO)			
Wing chord	304	94.4	3.7	81	108
Tail	299	60.6	3.4	52	78
Culmen	291	11.0	0.8	8.5	13.1
Weight	20	66.3	6.3	54	77
		(Female FEPO)			
Wing chord	194	98.7	4.4	89	113
Tail	188	63.6	4.0	52	79
Culmen	186	11.4	0.8	8.5	13.7
Weight	7	73.0	7.9	62	84
		(Argentina FEPO)			
Wing chord	68	96.0	3.7	89	113
Tail	68	63.5	3.2	58	77
Culmen	67	11.0	0.8	9.4	13.4
Weight	0	0.0	0.0	0	0

Table 8. (continued)

	n	$\bar{X}$	SE	Min	Max
(Brazil FEPO)					
Wing chord	52	98.2	4.3	91	112
Tail	50	63.2	4.3	59	74
Culmen	52	11.2	1.0	9.7	13.4
Weight	0	0.0	0.0	0	0
(Chile FEPO)					
Wing chord	21	101.0	6.3	93	118
Tail	20	68.1	5.1	62	84
Culmen	20	11.5	0.9	8.7	12.9
Weight	0	0.0	0.0	0	0
(Colombia FEPO)					
Wing chord	11	97.2	3.5	94	105
Tail	11	61.8	2.5	59	66
Culmen	9	11.6	0.5	11.0	12.5
Weight	0	0.0	0.0	0	0
(Costa Rica FEPO)					
Wing chord	13	98.5	3.4	93	104
Tail	13	59.3	2.6	55	66
Culmen	13	11.2	0.7	9.7	12.6
Weight	0	0.0	0.0	0	0
(Ecuador FEPO)					
Wing chord	48	97.2	5.5	88	110

Table 8. (continued)

	n	$\bar{X}$	SE	Min	Max
Tail	47	60.5	3.2	54	67
Culmen	48	11.4	0.7	9.9	13.2
Weight	0	0.0	0.0	0	0
		(Guatemala FEPO)			
Wing chord	22	96.0	6.3	71	104
Tail	20	61.4	3.3	53	66
Culmen	22	11.2	0.7	10.3	12.8
Weight	3	63.3	5.7	58.8	71.3
		(Honduras FEPO)			
Wing chord	10	96.3	3.4	91	102
Tail	10	60.0	2.8	54	63
Culmen	10	10.7	0.5	9.9	11.3
Weight	0	0.0	0.0	0	0
		(Mexico FEPO)			
Wing chord	141	93.5	4.2	79	106
Tail	135	61.1	2.8	53	71
Culmen	124	10.9	0.8	8.5	13.6
Weight	24	68.6	7.3	54	84
		(Peru FEPO)			
Wing chord	37	96.6	4.7	88	110
Tail	34	61.9	4.4	54	79
Culmen	37	10.9	0.9	9.1	13.7

Table 8. (continued)

	n	$\bar{X}$	SE	Min	Max
Weight	0	0.0	0.0	0	0
(Trinidad FEPO)					
Wing chord	29	96.4	2.1	93	103
Tail	28	58.4	2.6	55	63
Culmen	29	11.4	0.6	10.3	12.7
Weight	0	0.0	0.0	0	0
(United States FEPO)					
Wing chord	33	94.8	3.3	87	102
Tail	33	63.2	2.2	60	68
Culmen	33	10.8	0.8	8.5	12.4
Weight	0	0.0	0.0	0	0
(Venezuela FEPO)					
Wing chord	29	96.6	3.1	89	103
Tail	27	59.4	3.0	54	66
Culmen	33	11.5	0.8	9.8	13.0
Weight	0	0.0	0.0	0	0
(Areas with <10 FEPO collected)					
Wing chord	35	98.2	6.6	87	120
Tail	35	62.0	6.4	52	79
Culmen	34	11.1	0.8	9.5	12.9
Weight	0	0.0	0.0	0	0

Chile, Costa Rica, Ecuador, and Peru, (Table 8). Significant differences ($F = 13.61$, 15 df, $P = 0.0001$) in tail lengths were recorded between pygmy-owls trapped on the study area and museum specimens. Differences (LSD test, 653 df, $P < 0.05$) in tail lengths occurred between pygmy-owls trapped on the study area and museum specimens collected from Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Peru, Trinidad, and Venezuela. Significant differences ($F = 4.46$, 14 df, $P = 0.0001$) in culmen lengths were recorded between museum specimens collected from the United States and specimens collected from Mexico, Central and South America. Differences (LSD test, 594 df, $P < 0.05$) in culmen lengths occurred between pygmy-owls museum specimens collected in the United States and those collected from Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Trinidad, and Venezuela.

No significant differences ($F = 1.38$; 26, 51 df, $P = 0.32$) were recorded between weights of pygmy-owls on the study area and museum specimens from Mexico, the only area with comparative data. Information gathered on adult and nestling pygmy-owl tarsus lengths lack comparative data. The variability in wing chord, tail lengths, and weights of pygmy-owls sampled (i.e., live trapped and museum specimens) exceeded measurements reported by Ridgway (1914) and Earhart and Johnson (1970). Nine of 13 adult pygmy-owls captured between 29 July-31 October 1994, and 1 1994 hatchling captured 15 Febuary 1995 displayed evidence of full tail molt.

Hematozoa Study

Results received from Gordon Bennett at the International Reference Center for Avian Hematozoa concurred with those received from Andrew Radomski at Caesar Kleberg Wildlife Research Institute. No hematozoa parasites were seen in the blood samples.

Habitat Use

Forest composition of areas used by radio-tagged pygmy-owls were disproportionate to their availability on the study area (Table 9). Areas used by pygmy-owls contained a significantly ($Z = 6.66$, $P = 0.0001$) more trees >26 cm dbh than occurred throughout the study area. Areas used by pygmy-owls contained significantly ($Z = 14.55$, $P = 0.0001$) more understory than occurred throughout the study area (Table 10). Comparisons showed that expected use of 4 habitat categories (i.e., live oak-mesquite, live oak, mesquite, and open grassland) by pygmy-owls differed significantly from observed use ($\chi^2 = 81.18$; 3 df, $P < 0.005$, Table 11). Comparisons of 4 understory categories (minimal <25%, sparse 25-50%, moderate 50-75%, and dense 75-100% cover) differed significantly between availability and use by pygmy-owls ($\chi^2 = 431.31$; 3 df, $P < 0.005$, (Table 12]). Sample size restricted chi-square analysis of individual differences in habitat selection. Therefore, I compared individual habitat selection graphically (Thomas and Taylor 1990, Figure 1). Areal use varied among

Table 9. Comparison of size distributions of live oak and mesquite trees on the Norias Division of the King Ranch, as determined from 298-0.04/ha circular plots established at pygmy-owl visual sighting points, and from 217-0.04/ha systematic-random points established throughout the study area 1994 and 1995.

	Live oak (%)		Mesquite (%)	
dbh*	Visual points	Random points	Visual points	Random points
5	0.7	8.1	42.9	62.4
10	2.4	24.9	31.3	13.3
15	9.9	30.4	16.3	10.0
20	22.9	18.7	3.7	4.9
25	24.1	9.3	2.4	4.3
30	20.3	4.3	2.2	3.0
35	9.7	2.0	1.0	1.1
40	5.2	0.7	tr.	0.3

Table 9. (continued)

dbh*	Live oak (%)		Mesquite (%)	
	Visual point	Random point	Visual point	Random point
45	2.5	0.4	tr.	0.2
50	1.3	0.3		0.2
55	0.8	0.3		0.2
60	tr.	0.2		0.0
65	tr.	0.2		tr.
70	tr.	tr.		
75	tr.	tr.		

*dbh = Diameter at breast height (i.e., 130-145 cm above ground level) ± 1.3 cm of trees examined on the study area.

Table 10. Comparison of study area forest composition and habitat used by pygmy-owls as determined from 298-0.04 ha circular plots established at pygmy-owl visual sightings and 217-0.04 ha systematic-random points on the study area, Norias, Texas, Jun 1994-Sept 1995.

		Diameter at breast height 130-145 cm above ground level[b]							
Habitat[a]	N	2	4	6	8	10	12	>13	MUV[c]
Fore.	217	6.21	4.78	5.34	3.19	1.72	0.88	0.81	67
Visu.	298	3.86	3.03	2.55	2.89	2.90	2.46	2.29	128
P =		0.88	0.78	0.0001	0.83	0.0001	0.0001	0.0001	0.0001

[a]Fore. = forest composition of the study area; Visu. = forest composition of areas used by pygmy-owls on the study area; P = Probabilities as determined by Wilcoxon Sum Ranks.

[b]Size categories (2 = 3-8 cm, 4 = 8-13 cm, 6 = 13-18 cm, 8 = 18-23 cm, 10 = 23-28 cm, 12 = 28-33 cm, and 14 = >33 cm) of trees at breast height that occurred within 0.04 ha circular plots.

[c]Mean understory values (0 = 0%, 192 = 100% cover) of areas studied.

Table 11. Occurrence of pygmy-owls in mixed live oak-mesquite (LOM), exclusive live oak (ELO), exclusive mesquite (EM), and open grassland (OGL) habitat as recorded by tracking radio-tagged pygmy-owls on the Norias Division of the King Ranch, Spring 1994-Fall 1995.

Habitat	Proportion[a] of study area	Number of pygmy-owl observations	Expected[b] number of pygmy-owl observations	Chi-square calculations
LOM	0.43	197	129	35.84
ELO	0.26	32	78	27.13
EM	0.25	71	75	0.21
OGL	0.06	0	18	18.00
Total	100	300	300	81.18

[a]Proportions of total study area represents expected pygmy-owl observations as if pygmy-owls occurred in each habitat in exact proportion to availability.

[b]Calculated by multiplying proportion expected by n; i.e., 0.43 X 300 = 129.

Table 12. Occurrence of pygmy-owls in habitat with minimal (<25%), sparse (25-50%) moderate (50-75%), and dense (75-100%) understory as recorded by tracking radio-tagged individuals on the Norias Division of the King Ranch, Spring 1994-Fall 1995.

Understory	Proportion[a] of study area	Number of pygmy-owls observed	Expected[b] number of pygmy-owls observed	Chi-square calculations
Minimal	0.44	13	132	107.28
Sparse	0.30	66	90	6.40
Moderate	0.16	104	48	65.33
Dense	0.10	117	30	252.30
Total	1.00	300	300	431.31

[a]Proportions of total study area represents expected pygmy-owl observations as if pygmy-owls occurred in each habitat in exact proportion to availability.

[b]Calculated by multiplying proportion expected by n; i.e., 0.44 X 300 = 132.

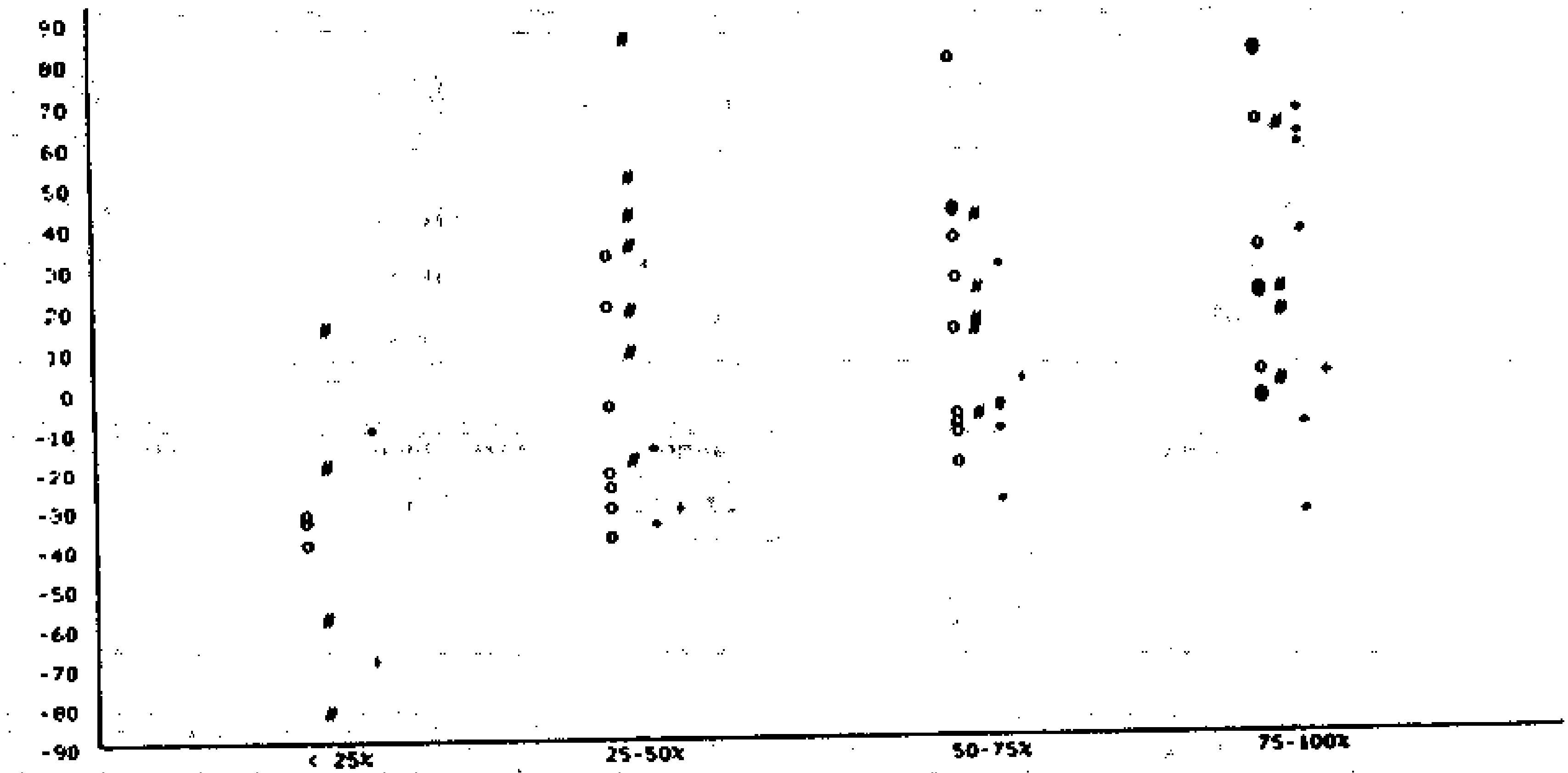

Figure 1. Percent available of 4 understory categories (i.e., <25, 25-50, 50-75, 75-100%) minus the percent use by 10 pygmy-owls as they occur in 4 habitat types (i.e., live oak-mesquite (o), live oak (#), mesquite (*), open grassland (+) on the Norias Division of the King Ranch, Norias, Texas, 1995.

individuals and increased with seasonal progression (Table 13). Adult males (40148AM, 40149AM, 40150AM) were recorded using 1.34-8.52 ha ($\bar{x}$ = 4.1, sd = 3.9, 100% minimum convex polygon) during incubation (9 Apr-22 May). Three pygmy-owls of undetermined sex (40134AUK, 40135AUK, 40137AUK) were recorded using 19.6-116.4 ha ($\bar{x}$ = 69.6, sd = 48.5, 100% minimum convex polygon) in late Fall. One adult female (40154AF) with 3 young postfledging (40151HY, 40152HY, 40153HY) used a larger area than adult males during incubation. Fledglings (40125HY, 40151HY, 40153HY) maintained proximity (<50 m) to adults (40150AM, 40154AF) until dispersal, about 63 $\pm$ 3 days after leaving the nest.

The only fledgling monitored throughout dispersal (40153HY) traversed 4 "known" pygmy-owl territories and established a residence about 6.5 km SW of its natal site. Its areal use after dispersal (29 Aug-9 Oct) was similar in size to pre-dispersal usage. Two fledglings fit with radio-transmitters succumbed to predation <7 days postfledging (1 in Spring 1994 and 1 in Spring 1995).

In 1995, after their nestlings succumbed to predation, 1 pair of pygmy-owls banded 6 June 1994 (40124AM, 40128AF) continued to maintain their pair bond (i.e., remained <50 m from each other) for the life of their transmitters 30 May-12 August (Figure 2). Two pygmy-owls (40134AUK, 40137AUK) of undetermined sex overlapped areas used in Fall 1994 (Figure 3). Another pair (40150AM, 40154AF) maintained their pair bond throughout dispersal of their young and remained together during the monitoring period (Figure 4).

Table 13. Areal use of radio-tagged pygmy-owls on the Norias Division of the King Ranch, Norias, Texas, Spring 1994-Fall 1995.

ID#	n Sightings	Monitoring Interval	95% Polygon (ha)	100% Polygon (ha)
40124AM	53	30 May-12 Aug 1995	6.05	7.88
40125HY	20	15 Jun-13 Jul 1994	6.72	7.14
40128AF	46	30 May-30 Jul 1995	9.23	9.29
40134AUK	27	17 Sep-07 Nov 1994	13.65	72.79
40135AUK	14	23 Sep-12 Oct 1994	115.54	116.39
40137AUK	10	02 Oct-19 Oct 1994	5.35	19.60
40148AM	15	09 Apr-03 May 1995	0.23	1.34
40149AM	27	12 Apr-22 May 1995	1.04	2.35
40150AM	22	12 Apr-16 May 1995	1.47	8.52
40151HY	29	15 Jun-20 Jul 1995	6.44	7.14
40152HY	4	15 Jun-20 Jun 1995	0.04	4.90
40153HY	46	15 Jun-16 Aug 1995	11.70	13.73
40154AF	58	15 Jun-02 Sep 1995	11.70	13.73

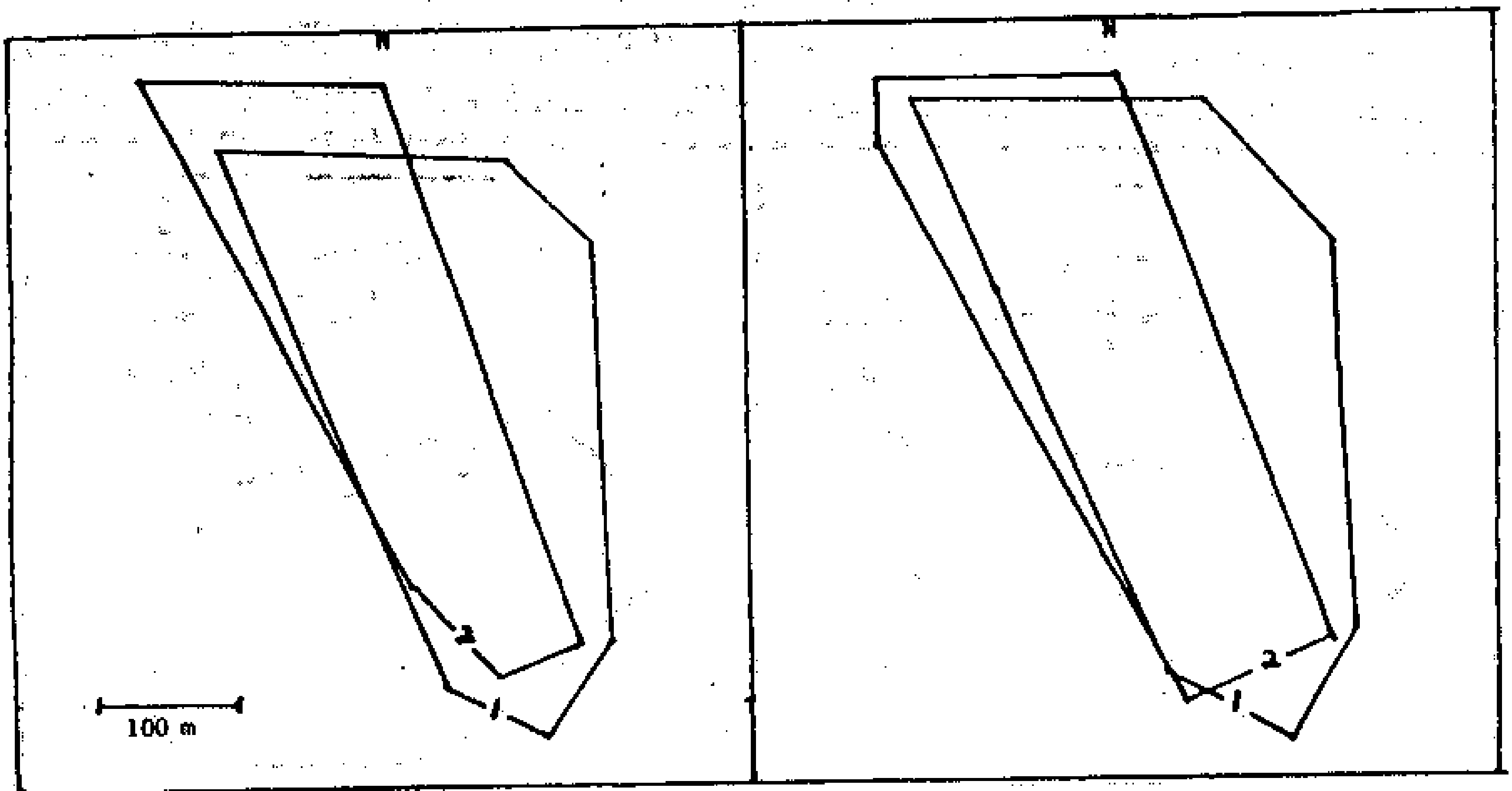

Figure 2. Area used by 2 mated pygmy-owls, Norias, Texas, 1995 (1 = 40124AM♂, 2 = 40128AF♀, Table 14). Coordinates were obtained from radio-tracking and calculated and plotted by TELEM88 home range analysis program, 95 (left) and 100% (right) minimum convex polygon.

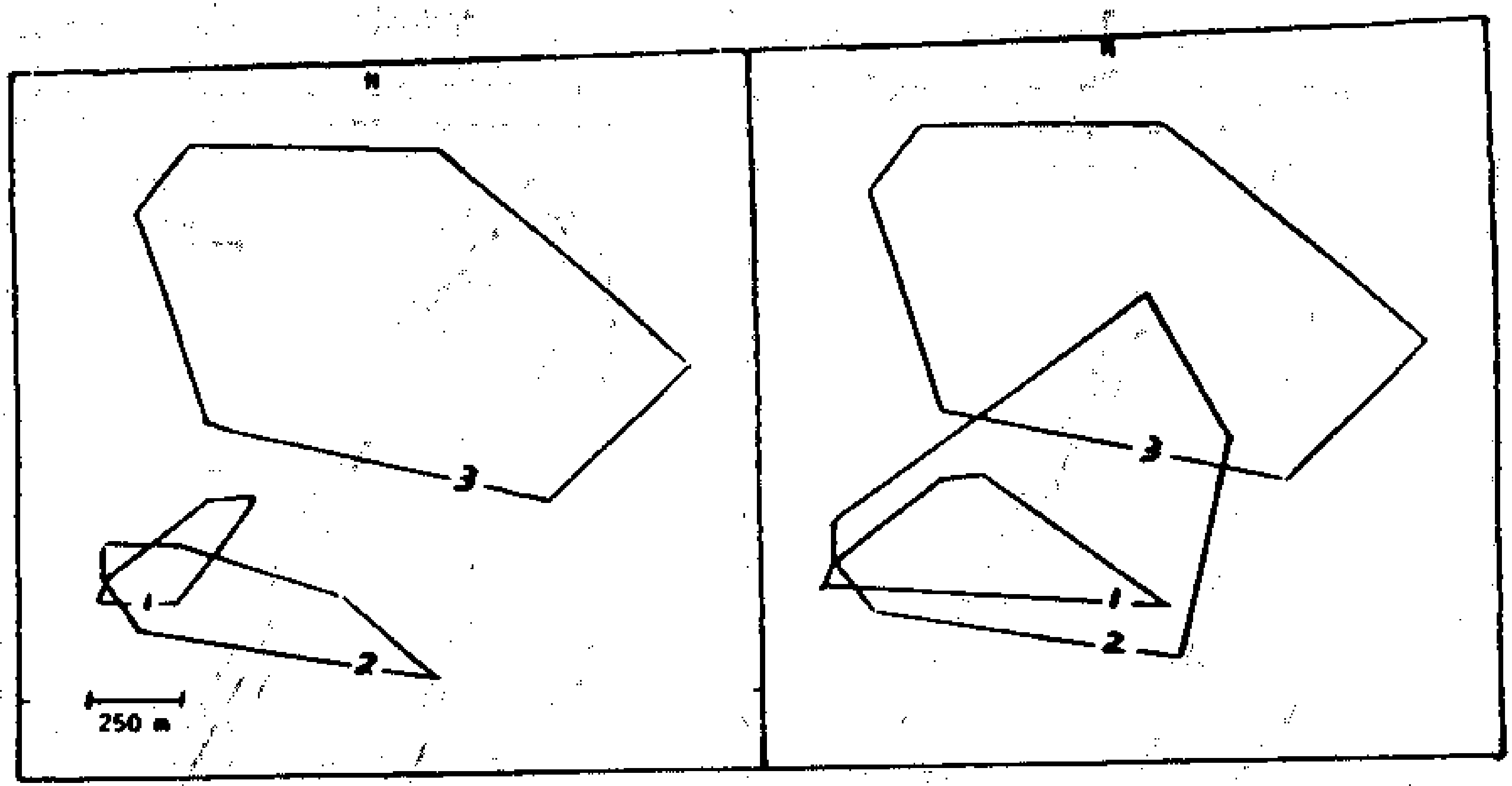

Figure 3. Area used by 3 adult pygmy-owls of undetermined sex, Norias, Texas, 1994 (1 = 40137AUK, 2 = 40134AUK, 3 = 40135AUK, Table 14). Coordinates were obtained from radio-tracking and calculated and plotted with TELEM88 home range analysis program, 95 (left) and 100% (right) minimum convex polygon. were made.

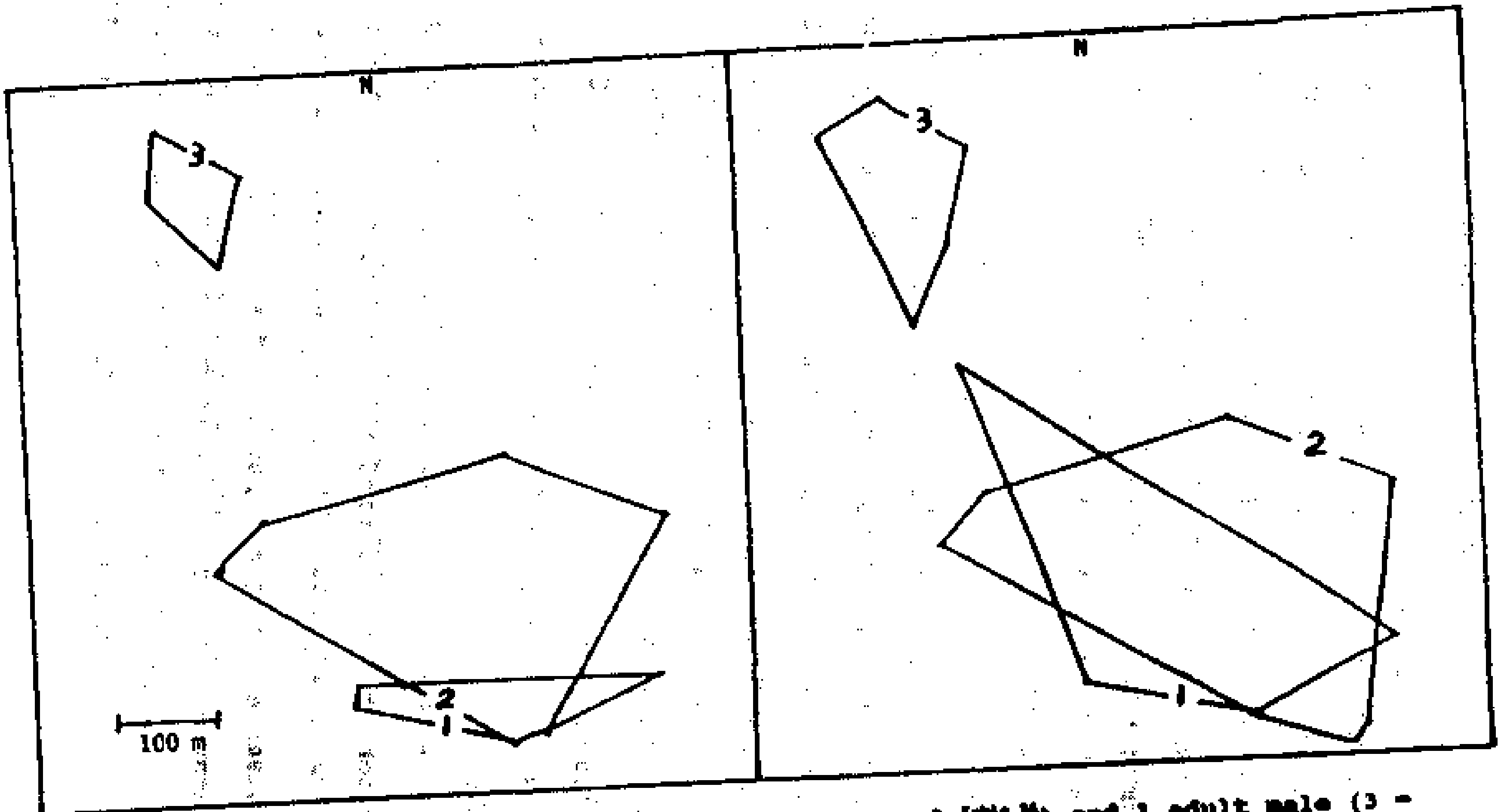

Figure 4. Area used by 2 mated (1 = 40150AM♂, 2 = 40154AF♀, Table 14) and 1 adult male (3 = 40149AM♂, Table 14) pygmy-owl, Norias, Texas, 1995. Coordinates were obtained from radio-tracking, and calculated and plotted with TELEM88 home range analysis program, 95 (left) and 100% (right) minimum convex polygon.

During Spring-Summer 1995, 2 pairs with nest sites established 845 m apart maintained territorial boundaries throughout the monitoring period (Figure 4).

Response Testing

Vocal and lateral responses (i.e., movement toward broadcast station) were obtained from all 4 individuals tested at 400 and 500 m. Three birds responded at 600 m with movement and vocalization, whereas the fourth only responded vocally. Only 1 bird was tested at 700 m and I received vocal and lateral response.

Food Habits

Thirty-three different prey species from 5 Classes (i.e. Insecta, Reptilia, Mammalia, Aves, and Amphibia) were identified during this study (Table 14). Prey remain analysis (4 nest sites) identified more individual prey items and prey species than analysis of video footage (2 nest sites) or visual observations (4 nest sites). Comparisons of the percentage of prey items identified/prey item brought to the nest site showed analysis of video footage exceeded visual observation in prey identification by 28%.

Throughout incubation, and for at least the first week posthatch, males collected all the food for females and young, during observation. At 3 weeks posthatch both adults were observed bringing prey into the nest site. On several occasions throughout the rearing of young, copulation was observed between males and females after food deliveries. During incubation most arrivals at the nest site followed

Table 14. Prey items found in the diet of pygmy-owls on the Norias Division of the King Ranch, Norias, Texas, Spring 1994-Summer 1995.

Prey Species	(Number of prey items identified by analysis of)[a] Prey Remains	Visual Observations	Video Recordings
Short and Long-horned grasshopper	94	15	77
True katydids (*Pseudophyllinae*)	0	5	7
Round-headed katydids (*Phaneropterinae*)	1	0	3
Dragonfly (*Aeshnidae*)	0	0	1
Click-beetle (*Elateridae*)	6	0	0
Lighting bug (*Lampyridae*)	3	0	0
Cicada (*Cicadidae*)	0	1	0
Walking stick (*Heteronemiidae*)	1	0	0
Cone-nose blood-sucker (*Reduviidae*)	9	0	2
Preying mantis (*Mantidae*)	0	0	1

Table 14. (continued)

Prey Species	(Number of prey items identified by analysis of) Prey Remains	Visual Observations	Video Recordings
Whip-tail lizard (*Cnemidophorus gularis*)	1	0	1
6-lined racerunner (*Cnemidophorus sexlineanius*)	1	0	0
Texas spiny lizard (*Sceloporus olivaceus*)	9	0	3
Rose-bellied lizard (*Sceloporus variabilis*)	4	1	0
Keeled earless lizard (*Holbrookia propinqua*)	2	0	0
Ground skink (*Scincella lateralis*)	5	8	4
Texas horned lizard (*Phrynosoma cornutum*)	2	0	0
Common evening bat (*Nycticeius humeralis*)	1	0	0
Mexican freetail bat (*Tadarida brasiliensis*)	1	0	0
Hispid pocket mouse (*Chaetodipus hispidus*)	0	2	0
Hispid cotton rat (*Sigmodon hispidus*)	2	2	0

Table 14. (continued)

Prey Species	Prey Remains	Visual Observations	Video Recordings
	(Number of prey items identified by analysis of)		
House mouse (*Mus musculus*)	1	0	0
Northern pygmy-mouse (*Baiomys taylori*)	7	0	0
Texas kangaroo rat (*Dipodomys compactus*)	3	2	1
Northern mocking bird (*Mimus polyglottos*)	1	0	0
Blue grosbeak (*Guiraca caerulea*)	1	0	0
Brown-crested flycatcher (*Myiarchus tyrannulus*)	4	0	0
Nashville warbler (*Vermivora ruficapilla*)	0	1	0
Eastern meadowlark (*Sturnella magna*)	1	1	0
Northern cardinal (*Cardinalis cardinalis*)	1	0	0
Paroluxea (*Cardinalis sinuatus*)	3	2	2
Narrow-mouth toad (*Gastrophryne olivarea*)	0	0	1

Table 14. (continued)

Prey Species	Prey Remains	Visual Observations	Video Recordings
	(Number of prey items identified by analysis of)		
Unidentified insects	NR	27	22
Unidentified reptiles	5	5	2
Unidentified mammals	3	2	0
Unidentified birds	6	3	1

*Prey remains were obtained from 2 active nest boxes and 2 natural cavities. Visual observations were recorded from 4 elevated blinds and included 105 hr 4 min of viewing. Video recordings obtained from inside 2 active nest-boxes provided 104 hr 3 min of footage.

ritualistic behavior: 1) on approach to the nest site males called with a short series of 2 or 3 notes, 2) after alighting on a branch near the nest site the male would repeat the 2 or 3 noted call, and 3) following the second set of calls the female would emerge from the nest cavity, join the male on his perch, appropriate the prey, and fly off (Table 14). During incubation, the only alteration observed in this feeding behavior entailed the male entering the cavity to deposit prey, after announcing its approach.

DISCUSSION

Availability of Cavities

Results obtained from box plot and transect studies suggest cavities suitable for pygmy-owl use occur at a rate of 0.2 or 0.4/ha respectively. Results from transects indicate an estimated 11,600 cavities of suitable size for pygmy-owls throughout the study area. However, assuming cavities are equally distributed, and based on information obtained from radio-tagged pygmy-owls (i.e., habitat types used by pygmy-owls during the nesting season only occur on about 10% of the study area), there were only 1,160 suitable cavities available to pygmy-owls. Territorial behavior of pygmy-owls would further limit access to cavities. However, information obtained from inspecting natural and excavated cavities (i.e., no avian occupants recorded during inspection) and nest boxes (i.e., only 48 nest boxes were used by 5 avian species during the study) suggests a substantial number of suitable nest cavities occur on the study area.

Nest Box Study

Results from the nest box study (i.e., given the opportunity, pygmy-owls used nest boxes established in areas with moderate to dense understory over those established in areas with minimal to sparse understory) suggest pygmy-owls are not influenced solely by the availability of cavities and may select nest sites based on habitat structure (e.g., the extent of understory available). Similarly, Brawn and Balda's (1988) recorded densities of 3 of 6 species of secondary cavity nesting birds studied were limited by habitat structure and not the availability of cavities. Waters et al. (1990) suggest factors such as territoriality and food abundance influence populations of secondary cavity-nesting birds (SCNB), and biologists should not assume that SCNB's are limited solely by nest site availability. Regional differences in habitat composition that alter selectivity may contradict this conclusion. However, habitat selection versus availability of cavities as a limiting factor should not be dismissed. Therefore, both the availability of cavities and the habitat structure should be evaluated before implementing future pygmy-owl nest box programs.

The variations in placement height above ground level, entrance hole diameters, and configurations of nest boxes used by pygmy-owls indicates this species will tolerate a certain range of differences in each of these parameters. However, constructing nest boxes at the upper or lower end of tolerance limits obtained in this study may reduce their efficiency. Therefore, I suggest constructing nest boxes 13 x 13 x 44 cm with a 5.1 cm diameter entrance hole, midpoint of tolerances. To reduce inspection time and observer stress I suggest establishing nest boxes 3-4 m above ground level. The size (dbh) of trees containing nest boxes in which active pygmy-owl nests were later established showed variations in tree dbh. This suggests that if habitat criteria are met (e.g., availability of nest cavities and understory cover) pygmy-owls will nest in forests of varying age classes. Because 1 of the active pygmy-owl nest boxes that fledged young was located at the edge (<50 m from a house) of a permanently occupied hunt camp, it may be assumed a certain level of human activity is tolerated.

The occurrence of non-target species (e.g., brown-crested flycatcher, golden-fronted woodpecker, eastern screech owl, and European starling) in boxes designed for pygmy-owls, indicates potential interspecific competition, in areas where nest cavities are limited. Substantiating evidence (i.e., observation of competitive exclusion) on interspecific and intraspecific competition is lacking. However, 2 of 3 pygmy-owls in this study, and 3 of 3 pygmy-owls in Beasom et al.'s (1993) study placed their eggs on the bare wooden surface of the nest box bottom, while the third pygmy-owl in this study placed its eggs on 5-8 cm of nest material (spanish moss). Therefore, the possibility exists that the third pygmy-owl from this study appropriated the nest site from another avian occupant.

In 1994, both nest sites established by pygmy-owls were within 9 m of nest boxes used by eastern screech owls for daily roosts. Although this occurrence is not evidence of territorial overlap, and could easily be explained by temporal separation (i.e., eastern screech owls being predominantly nocturnal and pygmy-owls being predominantly diurnal), it suggests that if interspecific territoriality occurs between these 2 species it is not a crucial factor in habitat selection.

Because photographic records of pygmy-owl nestling development stages were obtained from a single brood, I suggest caution in assigning ages to chicks based solely on this guide, and do not recommend it for assessing nest productivity. However, it should provide information to assist investigators in timing nest visits for banding and marking, essential tools in avian management.

Natural Nest Cavities

Information obtained from pygmy-owl nest sites established in excavated cavities is in agreement with that collected from the nest box study (i.e., pygmy-owls show a selective preference for areas with moderate to dense understory). The composition of the study area may not represent pygmy-owl home range habitat, and pygmy-owls may actually be selecting areas in direct proportion to their availability within their home range. However, through dispersal an animal has already made an important choice by selecting its home range, and comparing habitat within its range may be misleading (Johnson 1980). According to Thomas and Taylor (1990), researchers studying habitat use within home ranges are actually studying a higher order of habitat selection and possibly not the most important one for management purposes. Therefore, I hypothesize that through dispersal pygmy-owls had the opportunity to choose habitat and cavities in direct proportion to their availability on the study area, and based on this research selected for areas with moderate to dense understory.

Variations in the height of entrance holes above ground level of pygmy-owl nests established in excavated cavities exceeded those of active nest boxes. This information may aid management by relaxing previously established nest box placement criteria.

Mean clutch size (4.7) exceeded that recorded by Johnsgard (1988) (3.3) and was below that recorded by Beasom et al. (1993) (5.3). This variation in clutch sizes may be explained by changes in prey availability. Solhiem (1984[a]) recorded an increase in clutch size of pygmy-owls (Glaucidium passerinum) nesting in boreal forests during peak vole years. Korpimaki (1985) examined variations in clutch size and breeding success in relation to nest box size in Tengmalm's owl (Aegolius funereus), and developed a correlation between clutch size, nest box size, and food availability.

Assuming the expanded eastern screech owl recruitment standard (2.25) is valid for pygmy-owls, the cumulative fecundity (i.e., fecundity of pygmy-owls in nest boxes + fecundity of pygmy-owls in excavated cavities) of pygmy-owls sampled from the Norias Division (1.86) indicates population instability. I hypothesize this possible instability is the effect of Allee's principal (i.e., the degree of aggregation, as well as the overall density, which results in optimum population growth and survival, varies with species and conditions; therefore, undercrowding [or lack of aggregation], as well as overcrowding may be limiting) of overcrowding (Allee et al. 1949). The rationale behind this hypothesis is that pygmy-owl's non-migratory behavior and affinity for forested areas has, over the past 150 years of agricultural expansion in southern Texas (Oberholser 1974), geographically isolated the Norias Division population. This isolation has restricted dispersal, and consequently saturated the area beyond optimum growth to a point of instability.

In the boreal regions of Norway, Solhiem (1984[b]) recorded increases in stoat and weasel numbers during peak vole cycles. This increase in vole numbers coincided with increasing pygmy-owl numbers, and predation on pygmy-owls by weasels and stoats. Although weasels do occur on the study area, evidence at the nest sites suggests (i.e., lack of egg shell remains and nest site disturbance) snakes are the main predator of pygmy-owls in this region. Using chemoreception, snakes cue in on the odors of fecal matter, and possibly prey remains, that eminate from the nest (Savidge 1987). In Guam, the brown tree snake (Boiga irregularis) has eliminated several bird species and drastically reduced others (Savidge 1987). In Tamaulipas, Mexico, Enkerlin-Hoeflich et al. (1993) recorded indigo snake (Drymarchon corais, a species prevalent on the study area) predation on cavity nesting green-cheeked Amazon parrots (Amazona viridigenalis). This information, along with personal observation of indigo snakes climbing trees on the study area lends validity to my assumptions.

Sexual Dimorphism

The cumulative correlation (68%) of sex determinations made through color phase analysis and sex identification recorded on museums' pygmy-owl study skin tags suggests color phase analysis of pygmy-owls is not a viable means of sexual identification. However, the museums' curators (pers. comm.) expressed apprehension regarding the validity and methodology used in making sex determinations of pygmy-owl study skins, thereby challenging this conclusion.

Results suggest there may be regional differences (i.e., sub-specific differences) in pygmy-owl morphology. This morphological variation was first addressed by Ridgway (1914). Categorizing pygmy-owl subspecies according to variations in tail band and mantle colors, Ridgway (1914) determined the differences found within the South American pygmy-owl population preclude categorizing them as specific subspecies or listing them as a different species. All pygmy-owl specimens collected from Texas displayed similar plumage morphology and fell into the same category. This variation between specimens collected from North and South America was also evident in my study. Therefore, taking into account the possible misidentification of some museum specimens, the high correlation (82%) of the northern population, and the regional variation in pygmy-owl morphology, I hypothesize sexual determinations made from analysis of pygmy-owl plumage characteristics could be valid in some regions of its range (e.g., United States and northern Mexico).

Physical Characteristics

Comparisons of physical measurements obtained from pygmy-owls captured on the study area and those acquired from museum specimens substantiates regional differences in pygmy-owl morphology. However, because there were no differences between physical characteristics of pygmy-owls on the study area and museum specimens collected from the United States, this information suggests if geographic separation of the Norias population exists it may not have influenced pygmy-owl morphology. Further analysis (e.g., discriminant analysis) of these data could authenticate or refute sub-specific scientific nomenclature of this species throughout its range.

Information obtained from radio tracking of 1 pygmy-owl family (2 adults, 3 young) showed the complete tail molt of adults coincided with the dispersal of young. Corroborating evidence of the seasonality of full tail molts was provided from 9 other adult pygmy-owls captured in Fall 1994. This information and behavioral observations noted while tracking radio-tagged adults (when in full tail molt adult pygmy-owls collided with branches and seemed awkward in flight when flushed) generates a presumptive hypothesis on pygmy-owl dispersal. I hypothesize that the complete tail molt of adult pygmy-owls reduces their maneuverability and consequently their foraging capabilities, reducing the amount of prey provided to the young. This reduction in feeding prompts an increase in independent foraging by young owls and hence, dispersal. Increased foraging brought by seasonal reductions in prey numbers may intensify, if not initiate, dispersal. Further study of this hypothesis could provide information regarding the evolutionary biology of pygmy-owls. In 25-28 days, adults seemed to have a full regrowth of tail feathers.

Hematozoa Study

Results from the hematozoa study suggests the Norias Division pygmy-owl population may not be affected by the presence of blood parasites (i.e., Haemogreian-Lankersterella, Haemoproteus, Leucocytozoon, microfilaria, Plasmodium, and Trypanosoma spp.). This information may aid pygmy-owl management by directing resources toward demographic studies and other areas of research including immunocompetence of species.

Habitat Use

Habitat use of radio-tagged pygmy-owls indicates a selection for older, uneven aged, mixed forest (i.e., live oak-mesquite) with moderate to dense understory cover. Although the overall importance of understory cover remains unclear, I hypothesize it may be a critical factor in protecting postfledged young from avian predators (e.g., great horned owls (Bubo virginianus) and Coopers hawks [Accipiter cooperii]). In addition, the multitude of insects that inhabit understory cover during the pygmy-owls nesting season may provide adult pygmy-owls with an ample food supply and naive young with a prey base that requires minimal foraging effort. With the immensity of the study area and the variety of habitat types that occur therein, I assume the areas selected by pygmy-owls are of optimal quality. Therefore minimal habitat requirements have not been addressed here and it is likely that pygmy-owls could be maintained in less desirable habitat.

I hypothesize seasonal variations in pygmy-owl areal use are due to variations in prey abundance. During the pygmy-owl nesting season, insect, reptile, bird, and small mammal numbers are on the rise. Lundberg (1981) recorded an increase in prey availablity during the ural owls (*Strix uralensis*) breeding season in Central Sweden. This increase in prey availability reduces foraging effort and thus reduces areal use. As Summer changes to Fall, insect, reptile, bird, and small mammal numbers decline, causing an increase in pygmy-owl foraging and thus an increase areal use.

Response Testing

Results from response testing indicates that although adult male pygmy-owls were found using only 1.3-8.5 ha during the nesting season, they would defend areas with at least a 600 m radius, approximately 113 ha. This information invalidates use of radio-telemetry as a means of determining territorial area of pygmy-owls during nesting. In addition, response testing provides a gauge for future pygmy-owl vocalization surveys. To minimize double counts I suggest establishing listening stations ≥1200 m apart.

Food Habits

Results from the food habit study suggests pygmy-owls are generalistic predators and are not restricted by the availability of a single prey species. This information is similar to results reported by Solheim (1984*), and supports anecdotal accounts of pygmy-owl feeding behavior (Johnsgard 1988). My results demonstrate the significance of prey remain analysis and the benefits video recordings may provide over visual observation. Some behavioral information, however, (e.g, prey exchange between adults) may only be aquired through visual observation. Solheim (1984[a]) recorded pygmy-owls in Norway caching prey in nest cavities during winter. Similarily, food caching by pygmy-owls on the Norias Division was observed on 3 occasions and ensued with copulation. To obtain information on the significance of individual prey species in the diet of pygmy-owls, a more intensive food habit study should be conducted. Only then could the impact of forest and resource management practices on this species be forecasted.

In conclusion, this multifaceted study has set the foundation for a comprehensive natural history profile of the ferruginous pygmy-owl. However, research limitations (time, funding) have precluded the degree of study nessasary to develop an unabridged natural history profile. Therefore, before conclusive decisions are made regarding pygmy-owl demographics, further research in each of the areas discussed should be conducted.

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Appendix A. MANOVA table for physical characteristic data of adult ferruginous pygmy-owls sampled on the study area and recorded from museum specimens.

Characteristic	D. F.	Sum of Squares	Mean Square	C. V.	F-Value	Pr>F
Wing chord	15	4140102.00	276006.80	53.51	8.12	0.0001
Tail length	15	5896811.85	393120.79	50.74	13.61	0.0001
Culmen length	14	1788172.21	127726.59	55.46	4.46	0.0001

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