THE HABITAT, DIET, AND FORAGING BEHAVIOR OF THE APLOMADO FALCON, *FALCO FEMORALIS* (TEMMINCK)

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DEAN PURDY HECTOR

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THE HABITAT, DIET, AND FORAGING BEHAVIOR

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FEMORALIS (TEMMINCK)

Thesis Approved:

Stanley F. Fox
Thesis Adviser

A. Bissonette

James H. Shaw

Norman N. Durham
Dean of the Graduate College

PREFACE

In the Spring of 1977, I began a field study of a little-known neotropical bird called the Aplomado Falcon (*Falco femoralis*). This species ranges into the southwestern United States where it once nested regularly. My original objectives were basically threefold, and as follows: (1) to describe the natural history of the aplomado; (2) to determine the extent to which this species is affected by pesticide use in Latin America; and (3) to help develop a plan for restoring the Aplomado Falcon to its former status north of Mexico. The chapters that make up this thesis attempt to describe and summarize my research as it relates to these three objectives.

It is my belief that the information presented in the following pages represents the first in-depth description of the natural history of the Aplomado Falcon. Still, there are many aspects of the species' biology that I have failed to discuss. Accordingly, data concerning reproductive and territorial behavior, time-activity budgeting, and nest site parasitism will be presented at some future date.

Chapters II-VI represent the body of this report, and treat, in order: the history of the Aplomado Falcon in the United States; the effects of pesticides on the species in eastern Mexico; the feeding behavior of this falcon; the species' habitat in eastern Mexico; and steps that might be taken to restore the Aplomado Falcon to its former status within the United States. Background information concerning the study animal and study area, along with the tables referenced in the text, have been included in the appendixes. I hope that this arrangement will facilitate the use of my thesis as a source of information on the biology of the Aplomado Falcon, at least until I am able to publish these data.

In the course of my research, I have received support from many sources. Accordingly, I would like to attempt a proper acknowledgment of such assistance, before presenting the results of the study. My work with the Aplomado Falcon actually began while I was a student of Joseph Murphy's at Brigham Young University. Dr. Murphy's guidance and encouragement motivated me to initiate and continue my studies of the aplomado. I am especially appreciative of the role he played in the conception of this project. At Oklahoma State University, Fritz Knopf initially supervised my program of research, and in this capacity, provided valuable assistance in the preparation of project grant proposals, and in the design of the habitat analysis methodology. In the Fall of 1979, when Dr. Knopf left the university for another position, Stanley Fox consented to act as my major advisor for the remainder of my career at OSU. Dr. Fox patiently, and meticulously edited initial drafts of the thesis, and has been a constant source of intellectual stimulation and good fellowship since the date of our first meeting. John Bissonnette served as the third member of my committee. Though on short notice, he, along with Jim Shaw (who agreed to substitute for Dr. Knopf at my thesis defense) edited the final draft of the thesis, and provided me with many useful suggestions concerning the preparation of the final manuscript.

Several individuals helped me in various ways during the stages of my research activities. I owe them my utmost gratitude for their assistance. In this regard, the following deserve special thanks. Sr. Prospero Duval graciously allowed me to use his Rancho La Lenera as a base camp in 1977, 1979, and 1980. David Latham and Leon Ashford, both volunteers, competently and enthusiastically helped conduct the habitat analysis work in 1979. Bill Warde offered valuable advise concerning the use of SAS, and the application of various statistical techniques to problems of data analysis. I take full responsibility, however, for the manner in which my data were finally analyzed. Keith Arnold permitted me to use the Texas A & M Cooperative Wildlife Collections during the process of identifying falcon prey remains. Don Karr of Brigham Young University, and Judy Gray of the Oklahoma Cooperative Wildlife Research Unit both were instrumental in helping me to secure equipment needed to conduct the field work. In this regard, I would also like to thank Paul Vohs, former Unit Leader of the Oklahoma Cooperative Wildlife Research Unit.

For suggestions concerning the design and orientation of this project I thank: John Hubbard, Grainger Hunt, Ian Newton, Helen and Noel Snyder, George Miksch Sutton, Roland Wauer, and Scott Ward. In addition, from John O'Neill, Bill Mader, David Ellis, and Rich Glinski, I received valuable information concerning the behavior and ecology of the Aplomado Falcon in other parts of Latin America.

During 1976, I conducted a survey of museum collections to obtain tag data for aplomado specimens. A number of collections responded, and I would like to thank the appropriate curators and curatorial assistants for their cooperation in this regard. In particular, I wish to acknowledge responses made by: John Farrand, Jr. of the American Museum of Natural History; Lloyd Kiff of the Western Foundation of Vertebrate Zoology; Milton Trautman of Ohio State University's Museum of Zoology; Richard Zusi of the National Museum of Natural History; and Dianne Maurer of the Field Museum of Natural History.

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During the typing of the final copy of this thesis I enjoyed the hospitality of Lloyd, Julie, Kaleena and Hiram Kiff while staying at their home in West Los Angeles. Space and equipment required during preparation of the final manuscript were provided by the Western Foundation of Vertebrate Zoology. In this regard, I am especially grateful to Ed Harrison, and Lloyd and Julie Kiff.

James Lish, a friend and office mate since 1976, deserves special thanks and sympathy for patiently listening to my incessant babble about the Aplomado Falcon.

My parents, Neil and Pat Hector, have indirectly supported this

research in many ways, perhaps most significantly by encouraging my interest in animal ecology and behavior long before my infatuation with the Aplomado Falcon. Written words of thanks are inadequate to express my appreciation for the role they have played in my development as a biologist.

And finally, to Mary, I owe my love, respect, and admiration for her patience and understanding in dealing with (or tolerating) an often distracted and absent-minded cohabitant.

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CHAPTER I

INTRODUCTION

The Aplomado Falcon (<u>Falco femoralis</u>) is an inhabitant of the savanna and desert grassland communities of the neotropics (Brown and Amadon 1972, Ligon 1961, Johnson 1965, Peterson and Chalif 1973, Howell 1972, and others). Within this region (Figure 1), the species occupies a broad range in terms of both latitude and elevation. Aplomado Falcons have been collected or observed at localities from 53 degrees South Latitude (Humphrey et al. 1970) to 33 degrees North Latitude (Ligon 1961) or, in other words, from Tierra del Fuego to south-central New Mexico, and from coastal lowlands to 3500 m above sea level in the Peruvian altiplano (Howell 1972; and John O'Neill, personal communication). The species occurs in suitable habitat in many parts of Latin America (David Ellis and Rich Glinski, personal communication). This extensive geographical distribution suggests that the Aplomado Falcon may be somewhat adaptable in terms of its sensitivity to climatic conditions and habitat variability. In the early twentieth century, however, the species decreased in abundance in the northern parts of its range.

The Aplomado Falcon once nested regularly at a number of localities in Texas, New Mexico, and Arizona, yet today is rarely and sporadically observed north of Mexico. The most recent documented nesting by <u>Falco femoralis</u> in the United States was discovered during

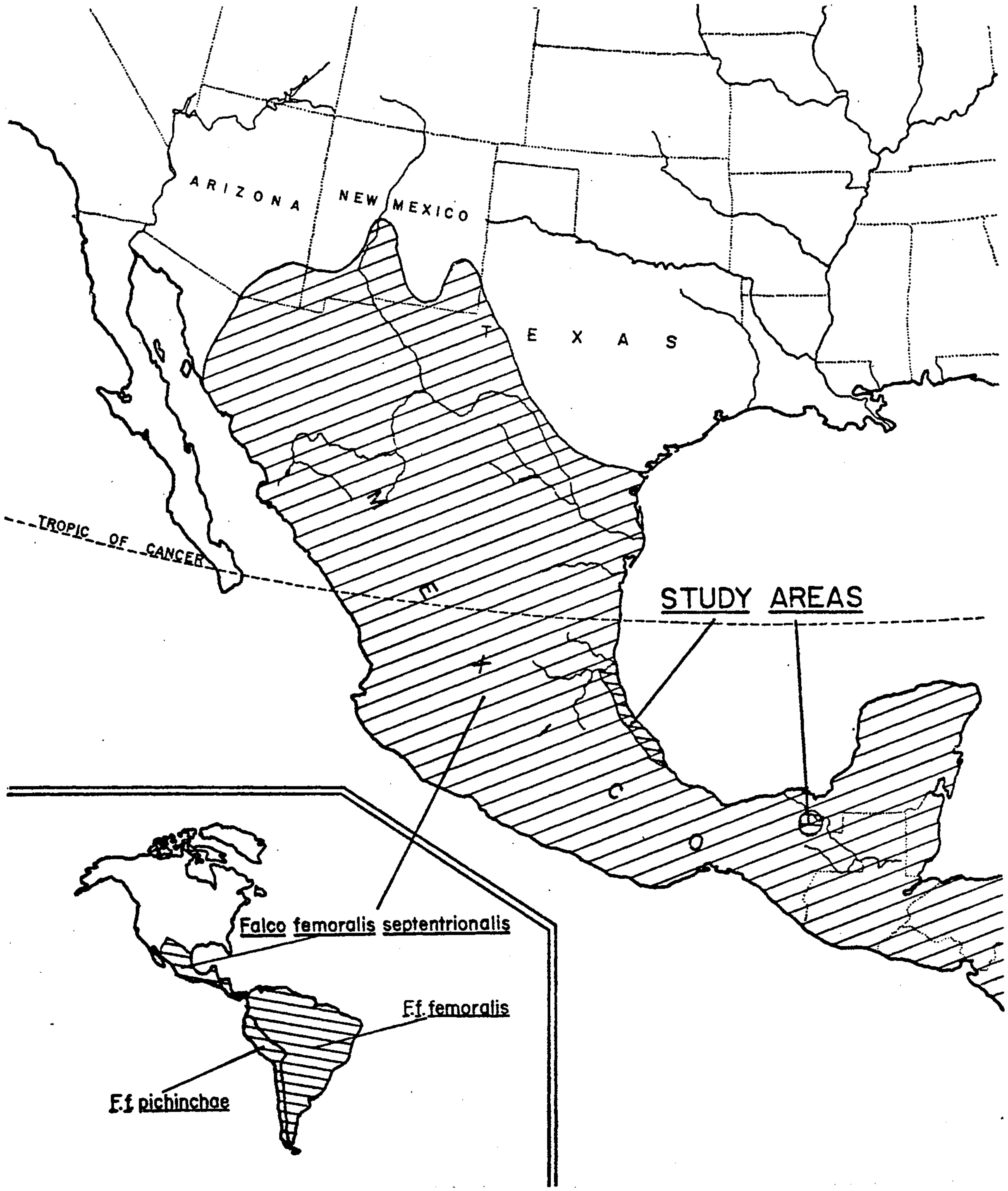

Figure 1. Geographic Distribution of the Aplomado Falcon, and Locations of Study Areas Examined in 1977-1979. The Northern Limit of this Distribution is Very Approximate and May Now Lie Farther South.

1952 (Ligon 1961). Of greater concern than the decline of this falcon in a limited portion of its range is recent evidence that the species is suceptible to the effects of contamination by organochlorine insecticides (Kiff et al. 1977). This suggests that the Aplomado Falcon may be exposed to the threat of pesticide-induced reproductive failure within parts of Latin America where insecticides such as DDT continue to be heavily applied on croplands.

It is difficult to understand fully the reasons for the decline of the species in the United States, or its sensitivity to pesticide contamination, without basic information concerning this falcon's habitat, diet, and behavior. Unfortunately, it appears that only three published reports have dealt exclusively with the Aplomado Falcon (Housse 1937, Snelling and Leuck 1976, and Hector 1980). Numerous annotated lists of species observed and/or collected in the neotropics offer brief descriptions of the Aplomado Falcon. However, the results of a comprehensive study of this animal's ecology have yet to be published.

The past declines of the Aplomado Falcon in North America, evidence that the species is contaminated by pesticides in eastern Mexico, and the fact that very little is known about the species, suggested that there was sufficient justification for carrying out a thorough examination of the current status and natural history of the Aplomado Falcon in North America. In March of 1977 I attempted to locate a group of active nest sites of this falcon in eastern Mexico. My hope was to find birds nesting close enough to the United States so that an examination of their behavioral ecology might improve our understanding of the ecology of the Aplomado Falcon within the United States. The paucity of recent observations of the aplomado in the United States suggested that an attempt to locate a study population north of Mexico would be risky. Oological records indicated that the gulf-coastal plain of Mexico might be a promising area to search for nesting falcons. Accordingly, surveys were carried out in that region. Seventeen active home ranges were located and nesting activities were observed within 11. Eight new sites were located in 1978-79. All the sites are within 425-1125 km of the southern tip of Texas in the Mexican states of Veracruz, Chiapas, Tabasco, and Campeche.

To produce a quantitative description of the structure of suitable nesting habitat of the Aplomado Falcon, an analysis of the floral and faunal communities associated with these home ranges was conducted during the spring of 1979. Behavioral studies have been aimed at learning how the habitat and behavior of the species are interrelated.

This report presents results of my studies of the habitat and hunting behavior of the Aplomado Falcon in eastern Mexico. An attempt is also made to relate my conclusions to the former status and ecology of the Aplomado Falcon in the United States. Final remarks deal with procedures needed to improve the status of the species north of Mexico.

CHAPTER II

HISTORY OF THE APLOMADO FALCON IN THE UNITED STATES

Introduction

In 1852, an Aplomado Falcon was collected in southwestern New Mexico by Heerman (1854). This was the first record of the species in North America (Brewer 1856). Within the next 20 years, a second specimen was collected in Texas on the Pecos River by Anderson (Baird et al. 1905). Not until 1878, however, when Merrill located two active nests near Fort Brown, Texas (now Brownsville), was the Aplomado Falcon proven to breed within the United States (Merrill 1878). In 1887, five additional nests were located by Benson near Fort Huachucha, Arizona (Bendire 1892). A number of additional egg sets and specimens were collected during the final decade of the nineteenth century and during the first twenty years of the twentieth century (Table VI, Appendix C).

The present chapter is devoted to a description of the spatial and temporal distribution of the Aplomado Falcon within the United States. Speculations concerning reasons for the decline of the species are also presented along with data that should dispel the notion that the Aplomado Falcon was always rare within the United States or that the species declined during the nineteenth century.

Methods

The "tag data" associated with North American skins and eggs of the Aplomado Falcon were solicited from a sample of 57 bird collections. Specifically, the following information was requested for each specimen: (1) date and place of collection; (2) age and sex of specimen; (3) clutch size and nest site descriptions for collected sets of eggs; and (4) the identity of the collector. The data that were gathered as a result of this survey were summarized and analyzed statistically using the FREQ and GLM procedures of the Statistical Analysis System, SAS (Barr, et al. 1979).

Results and Discussion

Former Distribution of the Aplomado Falcon in the United States

Of the 57 collections to which letters of inquiry were sent, 43 responded and 29 (50.8%) contained material from the Aplomado Falcon. These collections provided information on 436 eggs (a minimum of 133 clutches) and 89 skins. All were collected within the United States or Mexico. The locality data derived from this sample were used to create Figure 2. In the western half of the species' United States range -- that is, the portion west of the Pecos River -- the distribution of the bird seems to have coincided fairly closely with the distribution of the soaptree yucca (*Yucca elata*). This plant provides sites for the stick nests of species such as the White-necked Raven (*Corvus cryptoleucus*) and Swainson's Hawk (*Buteo swainsoni*). Stick platforms constructed by these birds served as nest sites for

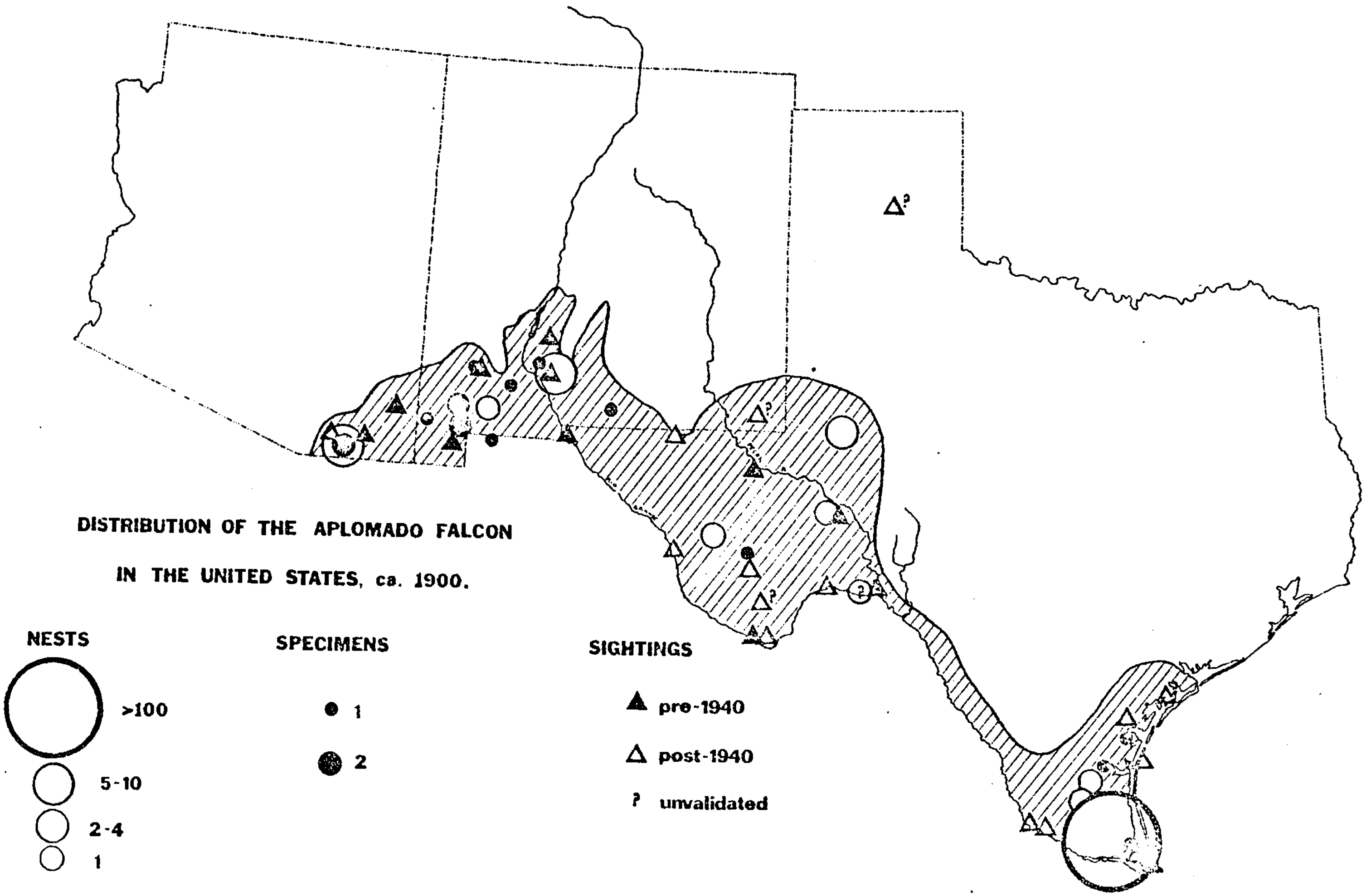

Figure 2. Historical Distribution of the Aplomado Falcon (Falco femoralis septentrionalis) in the United States. Cross-hatching Demarcates a Possible Breeding Distribution for the Year, 1900.

Aplomado Falcons (see Chapter V, and Strecker 1933, and Bendire 1892). In addition, the flowering stalks of Yucca elata were also used as perch sites by aplomados (Ligon 1961).

To the east of the Pecos River, the falcon occurred in prairie containing an open overstory of mesquite (Prosopis pubescens), yucca (Yucca treculeana), and in some areas, scattered mottes of live oaks (Quercus virginiana)(Johnston 1963, Smith 1910, and Merrill 1878). Since aplomados nest in oak savanna in eastern Mexico, it is tempting to suggest that the species may have inhabited the oak grasslands of Arizona, the Edward's Plateau of central Texas, or the coastal plain of Texas farther north than indicated by collection localities alone. At least in Texas, and probably also in New Mexico, and Arizona, the activities of collectors were so unevenly distributed that it is likely that the range of the Aplomado Falcon was more extensive than depicted in Figure 2.

The Decline of the Aplomado Falcon in the United States

Aplomado Falcons once nested regularly within the United States (Tables VI, VII, VIII, and IX). The highest densities of collection sites were in Cameron County, Texas (Table VII), and south-central and southwestern New Mexico (Table VIII). Between 1910 and 1950, however, the species disappeared from many localities where it had formerly been collected. During this period the aplomado became extremely rare in the United States.

The obvious explanation for the decline of the species is the proliferation and encroachment of woody vegetation that began in the latter part of the nineteenth century and that continues today in many parts of the southwestern United States (Hastings and Turner 1964). Other open country birds such as Botteri's Sparrow (Aimophila botterii), the Masked Bobwhite (Colinus virginianus ridgwayi), Scaled Quail (Callipepla squamata), White-tailed Hawk (Buteo albicaudatus), and White-tailed Kite (Elanus leucurus) also declined during this same period (Brown 1900 and 1904, and Oberholser 1974). Factors besides brush encroachment that may have affected the Aplomado Falcon, and to varying degrees, these other species, include: (1) overcollecting; (2) reduced nest availability due to declines of certain stick nest constructors; (3) conversion of prairie land to farmland in some areas; and (4) declining annual rainfall coupled with increasing annual average temperatures (Hastings and Turner 1964, Harris 1966, and Humphrey 1958).

The initial period of overgrazing may have temporarily improved many areas for Aplomado Falcons (John Hubbard, personal communication). As a result of my observations of the hunting behavior of the Aplomado Falcon in eastern Mexico, it seems reasonable to expect that decreasing ground cover density may have increased the hunting efficiency of the falcons by reducing the effectiveness of ground cover as a refuge for prey animals. In Mexico, aplomados are adept at hunting in semi-open areas where prey can be trapped in, and extracted from, hiding places on the ground or in isolated patches of vegetation (Chapter IV). As prairie lands became more congested with woody vegetation, however, these areas surely became less suitable as habitat for Falco femoralis.

Most eggs of the Aplomado Falcon collected within the United

States were found between 1900-1910 (Table VI). Although Table VI suggests that the Aplomado Falcon declined in abundance after 1910, it may only reflect the periods during which various collectors were active.

The majority of eggs represented in Table VI were collected by Frank B. Armstrong. He is responsible for 320 eggs (allegedly 88 clutches) or 76.19% of the total sample of 436 eggs. Armstrong began his collecting in about 1888 and continued until his death in 1915 (Oberholser 1974). His activities affected areas on both sides of the Rio Grande River in northeastern Mexico and in Texas on the southern part of the coastal plain and in the lower Rio Grande valley. There has been some speculation about the validity of Armstrong's records (Oberholser 1974). Suspicion raised by his associates suggests that specimens actually collected in Mexico were recorded as having come from Texas. Also, sets of eggs that Armstrong provided for his clients may not have been true clutches but instead eggs from more than one clutch that were artificially grouped together (Quillen 1922, in a letter to Pemberton). This may have been a function of Armstrong's method of storing eggs (perhaps en masse), or due to some hesitancy he may have had in providing clients with clutches of only one or two eggs.

Although Oberholser (1974) attempts to dispel doubts about the validity of Armstrong's records, an analysis of variance that I conducted, suggested strongly that clutch size was "affected" by the identity of the collector (Table X, Appendix C). This analysis employed a two factor design into which eggs were arranged according to two criteria. The first criterion was the identity of the collector. One group contained only eggs collected by Armstrong, while the other group contained eggs collected by other individuals. Eggs were then further subdivided depending on whether they were collected North or South of the Tropic of Cancer. Eighty-eight of Armstrong's sets average over one egg larger than the average size of the 45 clutches collected by other individuals (Table XI, Appendix C). Considering that the maximum clutch size was only four eggs, a difference of a single egg seems rather large. Furthermore, the size of clutches collected by Armstrong is less than half as variable as the size of clutches collected by other oologists ($F=4.57$, $p<0.005$). Contributing to the smaller amount of variability present in the sample of clutches collected by Armstrong is the lack of any single-egg clutches among his egg sets. The clutches taken by other individuals contained 12 single egg clutches (26.7% of 45 clutches). These characteristics of the sets collected by Armstrong could be the result of an intentional creation of fake clutches or could also stem from a tendency of the collector or his assistants to take only large clutches.

The validity of Frank Armstrong's records has relevance to a consideration of the former abundance of the Aplomado Falcon in the United States because the majority of aplomado eggs in my sample were collected by Armstrong. The statistical techniques were used to examine the Armstrong sets for any aberrancies. This seemed prudent in view of the controversy surrounding specimens collected by this individual. My analysis suggests that information derived from Armstrong's specimens should be used cautiously.

Regardless of where Armstrong collected his aplomado specimens, it is likely that his aplomado eggs represent more clutches than the number of sets would indicate. If 2.58 eggs represents the true mean clutch size for northern Aplomado Falcons, then the sample of 320 eggs collected by Armstrong actually contains 124 clutches instead of 88 (41% more).

Oberholser (1974) believed that the locality data for Armstrong's eggs were accurate. If so, then eggs supposedly collected in Texas were actually collected there. Enough sets were collected near Brownsville and north of the Rio Grande by collectors working independently of Armstrong to support the contention that the Aplomado Falcon was once a regular nesting species on the prairies of the lower Rio Grande valley and southern Texas coast (Merrill 1878, and Smith 1910). Furthermore, Johnston (1963) indicates that northeastern Mexico was covered with mesquite brush during the nineteenth century. The closest prairie in Mexico was located about 193 km south of Brownsville. Therefore, the former distribution of prairie along the gulf-coastal plain suggests that the most likely areas to search for Aplomado Falcons existed north of the Rio Grande.

After Armstrong's death, R.D. Camp continued to collect in the vicinity of Brownsville, and is responsible for four clutches collected during the 1920's (Tables VI and VII, Appendix C). To the west, other individuals were active during this same period and slightly earlier (Tables VIII and IX, Appendix C). For some reason, however, few eggs were collected outside of southern Texas.

Unlike the eggs, the number of aplomado skins collected in the United States decreases between 1920 and 1930 (Table XII, Appendix C). The peak between 1910 and 1920 corresponds to the period of time when Camp and collectors such as J. Stokley Ligon and Ralph Kellogg (the principal aplomado collectors in New Mexico) were active (Table XII, Appendix C).

Ligon located several nest sites and collected several birds during the period between 1917 and 1928 (Table XII), but remained in the field after the date of his last aplomado specimen (J. Hubbard, personal communication, and Ligon 1961). He documented a successful 1952 nesting attempt located by Arnold Bayne near Deming, New Mexico. Similarly, several individuals continued to collect birds in southern Texas after the period in which aplomados nested regularly on the Texas coast. Val Lehman collected the last skin from the United States in 1949 on the King Ranch, and the last reported nesting attempt in Texas was discovered in 1941 by Nyc and Peterson (Table VII). These discoveries suggest that, following its earlier decline, the Aplomado Falcon at least still survived within parts of the United States.

The Effect of Pesticide Contamination

If the aplomado persisted as a United States nesting species into the 1950's then pairs nesting north of Mexico were probably exposed to the effects of pesticide contamination during the 1950's and 1960's. Lehman (personal communication) believes that the species disappeared from one part of the King Ranch several years before brush encroachment appreciably affected the area. He speculates that their disappearance was due to pesticide contamination or disturbance resulting from oil exploration activities. My experiences with the species in eastern Mexico suggest that Aplomado Falcons are generally tolerant of human-caused disturbance, yet are definitely affected by pesticides (see Chapter III, and Kiff et al. 1977). During the late 1950's and early 1960's, Aplomado Falcons in eastern Mexico were laying thin-shelled eggs that were heavily contaminated with residues of DDE (the principal metabolite of DDT) (Kiff et al. 1977). Perhaps within the United States, falcons still nesting after 1947 were further decimated by the effects of pesticide contamination during the 1950's and 1960's.

CHAPTER III

PESTICIDES AND THE APLOMADO FALCON

Bond (1972) stated that the Aplomado Falcon should not be sensitive to the effects of pesticide contamination due to characteristics of the species' diet. Formerly, the aplomado was thought to feed primarily on insects, small mammals, and reptiles (Brooks 1933, Ligon 1961, and Bailey 1928). Birds such as the American Kestrel (*Falco sparverius*) that have a similar diet have not generally been adversely affected by pesticide contamination (Henny 1977).

In 1976, David Peakall and Lloyd Kiff examined shell thickness and pesticide residue levels in shell membranes of a sample of 88 eggs of the Aplomado Falcon collected in southern Texas and eastern Mexico (Kiff et al. 1977). Fifty-six eggs (at least 15 clutches) had been collected between 1891 and 1929, while the remainder of the sample (13 clutches) were collected between 1956 and 1967. The post-DDT (post 1947) eggs averaged 25.4% thinner than the pre-DDT eggs and contained 110-530 ppm DDE ($\overline{X}$=297 ppm wet weight) in their shell membranes.

During 1977, I collected 10 samples of eggshell fragments from nine nest sites of the Aplomado Falcon in eastern Mexico. These fragments were 24.0% thinner than the pre-DDT eggs analyzed by Kiff and Peakall. The DDE content of shell membranes associated with these fragments averaged 296.8 ppm wet weight and ranged from 52-364 ppm.

One side-effect of contamination by pesticides could have been a decrease in the ability of nesting falcons to colonize available habitat with their offspring. Although parts of the southwestern United States have been cleared of woody vegetation and returned to some semblance of openness, this change by itself would not have had much effect on the Aplomado Falcon in the United States if the productivity of nesting falcons was, at the same time, being reduced by the effects of pesticide contamination.

Dependence on DDT as an insecticide has decreased considerably within the northern hemisphere, yet many Third-World nations still use this compound for control of mosquitos and crop pests (Goldberg 1975). Despite restrictions on the use of organochlorines in the industrialized nations, worldwide use of DDT is actually increasing (Newton 1979). Newton has pointed out that whenever a population of birds of prey produced eggs at least 16-18% thinner than pre-DDT eggs over several years, its numbers began to decline. Aplomado Falcons in eastern Mexico have been laying eggs that exceed this rate of thinning by about 7%, and have been doing so since the mid-1950's. This raises the obvious question of whether the Aplomado Falcon might be undergoing a general, pesticide-induced decline throughout its range.

CHAPTER IV

DIET AND HUNTING BEHAVIOR

Introduction

Presumably, Aplomado Falcons, like other animals, concentrate residues of organochlorine insecticides through the ingestion of contaminated prey. In eastern Mexico, Aplomado Falcons are contaminated with residues of DDE (see Chapter III), suggesting that the species occupies a trophic level like that occupied by other birds that have declined because of pesticide contamination. Accordingly, this chapter describes the feeding niche of the Aplomado Falcon in eastern Mexico, and provides some explanation of why the species has shown signs of pesticide-induced eggshell thinning.

During the pursuit of prey the foraging efficiency of the Aplomado and other predatory species is perhaps most obviously affected by the structure of habitat. An understanding of the diet and foraging ecology of a predator provides a means for learning which subset of habitat components actually constitutes the most significant niche dimensions of the species. This is necessary before conclusions concerning the ecology of a species in a localized portion of its range can be applied to the ecology of the species as a whole. One objective of my research was to develop an appreciation for the behavioral ecology of the study animal that generalizes beyond eastern

Mexico. Therefore, interpretations of relationships between habitat structure and behavior broadly relate to the full range of habitats inhabited by the Aplomado Falcon. The conclusions that have been reached should improve our understanding of the general ecology of the Aplomado Falcon, and provide a basis for increasing the abundance of the species in the United States and for protecting its status in other parts of the species' range.

Methods

Prey remains were collected from beneath perches where falcons plucked and/or fed on prey. Remains contained mostly feathers, but also heads, mandibles, hind limbs, and sterna of avian prey, as well as the hind legs of locusts; wings of moths, butterflies and wasps; and the elytra of beetles. During each visit to a plucking perch, remains were collected and placed in plastic "zip-loc" bags to which a few naphthalene crystals had been added as protection against insects. Each bag was then labeled with the date and place of collection. Feeding pellets were also collected and stored but comprised only a small proportion of the total sample.

Identification of prey remains was accomplished using reference material collected in the field or by comparing remains with study skins housed in the Texas Cooperative Wildlife Collections at Texas A & M University (College Station, Texas, Keith Arnold, Curator).

Weights of prey animals were estimated using weights taken from freshly-killed specimens now housed at the collection mentioned in the previous paragraph. When possible, the weights of several conspecifics were averaged. Weights of specimens not available at Texas A & M were obtained from the literature (for example, Johnson 1968). Prey lengths were extracted from Peterson and Chalif (1973) and Blake (1953, 1977). All insect prey were assumed to weigh one gram. This value overestimates the weight of most insects eaten by aplomados. Even large noctuid moths seldom weigh over half a gram. Accordingly, the weight of insect prey has in most cases been estimated within a gram or less of the actual weights of these prey.

On the initial visit to a well-used plucking perch, the ground beneath the perch was cleared of all old prey remains. This procedure pooled remains from more than a single prey animal. To estimate the number of individuals in these groups of remains, feathers were first separated into apparent species categories and then further separated by feather type (i.e. right remiges, left remiges, retrices, and contour feathers). Feathers from a single species were then examined for slight differences in size and coloration and further separated into putative individuals. Finally, the number of feathers in each group (excluding the contour feathers) was divided by the number of that type of feather characteristically found in individuals of that species. This procedure produced an estimate of the number of prey -- in some cases, a different estimate for each type of flight feather. The largest of these estimates was selected as the final estimate of the number of individuals contained in the sample.

Observed Hunting and Feeding Behavior

The openness of the savanna and pastureland areas inhabited by aplomados in eastern Mexico facilitates visual observation of hunting and feeding behavior. Nesting Aplomado Falcons usually hunt close to their nest sites (within 500 m), and are quite tolerant of nearby people. Consequently, it has been possible to observe and describe many successful and unsuccessful hunting flights and observe both caching and feeding behavior. Blinds were unnecessary; observers watched nests from exposed positions within 50-100 m of nest trees. Even with an observer nearby, falcons would participate in hunts, territorial encounters, incubation switches, copulatory behavior, and other forms of behavior. This suggested that the birds were minimally affected by the presence of observers.

Movements made by falcons were described in written accounts and then plotted on maps of the appropriate nest site. These maps contained locations of nest trees and perch sites. Flights in which fleeing prey were observed were definite hunting flights. Often, however, putative hunting flights took place in which the prey animal could not be seen. To avoid confusing these flights with non-hunting behavior, some objective criteria were used to determine when a hunt had taken place. In situations in which no territorial vocalizations were heard, prey pursuits were assumed to have taken place when one or both adult falcons left a perch and proceeded on a more or less straight path without immediately beginning to soar, or without flying directly to a new perch or cache site. In many cases, a falcon would suddenly fly rapidly from a perch, then abruptly slow and return. These flights were scored as aborted hunts. It is likely that some behavior was misinterpreted, but this method was conservative in that actual success rates would be underestimated (at least somewhat consistently) owing to the possibility of including some "non-hunts" in the sample of unsuccessful hunts.

When successful hunts were observed, an attempt was made to identify the prey animal and collect its remains. Since these remains were added to the sample of collected prey remains, there is broad overlap between the sample of prey remains and the sample of prey that were observed being captured, eaten, and/or cached at aplomado nest sites. When it was impossible to determine the identity of a captured or pursued prey animal, the animal was assigned to one of several size categories, each based on prey weight (Table XLIV, Appendix D). Details concerning prey habitat and diet were extracted from Blake (1953) or Peterson and Chalif (1973).

For each pursuit, the following details were recorded: sex of pursuer(s); stage of the nesting period during which the pursuit occurred; hunting strategy employed; number of prey pursued; location of the prey when the chase began; and distance covered by the pursuit.

Data Analysis

Data summarization and statistical analyses were carried out using the 1979 edition of the Statistical Analysis System, SAS (Barr et al. 1979).

Results and Discussion

Prey of the Aplomado Falcon

Introduction. Available descriptions of the hunting behavior and diet of the aplomado contrast sharply (Table XIII, Appendix C). Sclater and Hudson (1889, p. 69) state that in Argentina, Aplomado Falcons (*F. femoralis*) ". . . never boldly and openly attack any bird, except of the smallest species . . ." On the other hand, Johnson (1965, p.271) writes that, in Chile:

> This falcon preys on tinamou ("perdices"), young chickens and other smaller birds, paying comparatively little attention to mammals or reptiles. Its flight is usually low, direct and very fast, disconcerting its victims by the very rapidity of its movements . . .

Without quantitative information concerning the relative importance of individual prey species, or broad categories of prey (e.g. insects versus birds) in the diet of the Aplomado Falcon, generalizations about the feeding niche of the species are somewhat difficult to make. No published study has adequately covered this basic aspect of the aplomado's natural history. In response to this deficiency, the remainder of this chapter contains the first extensive description of the diet and foraging behavior of the Aplomado Falcon.

Sampling Effort at Nest Sites. Prey remains were collected and observations made of feeding behavior at 21 home ranges of the Aplomado Falcon (Table XIV, Appendix C). One hundred sixty-eight (65.6%) prey contained in the sample of prey remains (256 total prey), and 218 (93.2%) prey in the sample of observed feeding behavior (234 total prey) were eaten by falcons at only seven sites.

Resident falcons failed to nest at seven sites during my field work; eighteen prey (7.0%) in the sample of prey remains, and six prey (2.6%) in the sample of observed feedings were collected at these sites. At eight sites falcons were incubating eggs during my field seasons; these territories contributed 46 prey (18.0%) to the sample of prey remains, and 52 prey (22.2%) to the sample of observed behavior. The remainder, and majority of observations and collected prey remains, were gathered at nests where young were present. Feeding rates and hunting rates were greatest when young were being raised. In addition, adult birds were most easily watched at this time since they tended to remain near the young for most of the day. Feeding rates were much lower at sites where falcons were not nesting or incubating. When not nesting, falcons were relatively difficult to watch for extended periods because they are not as restricted to a particular area and wander more. These factors contributed to the unequal distribution of dietary data among categories of nest sites.

Prey Species. Forty-three species of birds are represented in the sample of prey remains (Table XV). Forty birds (17.1% of 240 total avian prey) could not be identified to species, and instead were placed into appropriate size classes. Unidentified birds contributed only 7.6% of total prey biomass. The five species contributing most prey biomass were the Mourning Dove (*Zenaida macroura*), White-winged Dove (*Z. asiatica*), Groove-billed Ani (*Crotophaga sulcirostris*), female Great-tailed Grackle (*Quiscalus mexicanus*), and Yellow-billed Cuckoo (*Coccyzus americanus*).

Prey remains are rather insensitive to the presence of small prey items (Errington 1932; and Snyder and Wiley 1976). Consequently, they may often provide dietary information that is strongly biased. On the other hand, prey remains survive for some time after the death of the prey animal and can be collected rather easily. As a result, per unit effort by the researcher, the collection of prey remains may be the most efficient means for examining the diet of a raptorial bird. Under conditions in which it is possible to collect a high proportion of the remains of captured prey, prey remains can be used to detect the capture of rare or infrequently eaten prey and provide a more comprehensive look at prey species composition. In a single, brief visit to a nest site, it may be possible to gather evidence of hunting flights taking place over the previous days or weeks. Eight to nine hours of observations per day would be required to achieve the same degree of coverage using only direct observations. Furthermore, each additional day of observational work adds 8-9 hours to the total time expended, while daily visits to collect prey remains may take only 1-2 hours per site per day.

The contention that prey remains are relatively insensitive to small prey items is supported by a comparison of the sample of observed hunting behavior and sample of prey remains (Table XVI, Appendix C). Considering total prey (n=256), the prey remains contained only 15 insects (5.9% of the total sample). However, 152 insects (65.0% of 234 prey animals) are represented in the sample of observed feeding behavior (Table XVI).

Table XVI emphasizes the discrepancy that exists between the frequency with which insects are captured and the proportion of total prey biomass they comprise. The proportion of insects in the sample of observed feeding behavior is greater than the proportion of total prey weight contributed by insects. The opposite is true for avian prey. The relationship between percentage of total prey weight and percentage of total prey individuals contributed by a certain category of prey may reflect the energetic cost-benefit ratio associated with the capture of each prey category. Although insects are very small compared to typical avian prey, they seem to be easily captured and abundant enough to be worthwhile to capture in numbers that greatly exceed the proportion of biomass they contribute.

In the sample of observed feeding behavior (Table XVII, Appendix C), the top five categories of avian prey include two size classes of unidentified birds and White-winged Doves, Mourning Doves, and female Great-tailed Grackles. This set is similar to the top-ranked species in the sample of prey remains (Table XV) except that the Groove-billed Ani and Yellow-billed Cuckoo do not appear until ranks eight and nine, respectively, in the sample of observed behavior. The insect categories fall at the lower end of the array of prey animals (ranks 14, 21, 23, and 25-29). These categories are ordered as follows by their contribution to total prey biomass: unidentified insects, moths, beetles, locusts, butterflies or moths, butterflies only, wasps, and dragonflies.

Prey Size. The weight of prey animals in the sample of prey remains averaged 82.2 g, while the average weight of prey represented in the sample of observed feedings and captures was 23.8 g. Average weight of avian prey was 82.3 g for the sample of prey remains and 71.1 g for the sample of observed behavior. The difference between mean prey weights of the two samples provides additional evidence concerning the biased nature of prey remains.

The largest prey animal detected in either sample was a Chachalaca (*Ortalis vetula*). This species was represented by a single tarso-metatarsus and foot collected at an active nest site in northern Veracruz. The weights of six reference Chachalacas averaged 829.9 g and ranged from 741.5 g (female) to 934.0 g (male). While the remains were definitely those of an adult bird, the condition and precise weight of this bird at the time of capture is unknown. This species may lie near the upper size limit of prey taken by Aplomado Falcons.

Diet of the Nestlings. Observations of prey animals fed to young aplomados provide information only about the diet of the nestlings; the diet of the adults may not be the same. As mentioned previously, avian prey seem to contribute most prey biomass to the diet of Aplomado Falcons within eastern Mexico, while insects make up the numerical majority of captured prey animals. The last half of the preceding statement, however, seems to apply only to adults since nestlings at the sites I have observed (Table XVIII, Appendix C) were fed 46 birds (63.0%) and only 25 insects (34.2%).

Many diet studies of birds of prey fail to mention the possibility that adults may not have the same diet as their young. The implicit assumption is often that the diet of the adults and nestlings is the same (for example, see Porter and White 1973, Cade 1960, Meng 1959, Ogden 1974, and others). There exists no easy technique for unbiased study of feeding habits short of making continuous observations of adults and young, or by examining the stomach contents from a large sample of collected specimens (Snyder and Wiley 1976). My study (utilizing both prey remains and direct observations) suggests that Aplomado Falcons actually feed more on insects than observations made only of the young would have indicated. Both adults and young, however, certainly subsist primarily on avian prey. Furthermore, an adequate supply of birds may be particularly important when young are on the nest.

Diet of Prey. Birds of prey that feed mainly on insectivorous or piscivorous birds should contain higher levels of organochlorine residues than species feeding mainly on granivorous birds. The former category of predator occupies a higher trophic level and is more susceptible to the effects of bioaccumulation (Newton 1979). This generalization seems to apply accurately on a worldwide basis (Newton 1979, and Peakall and Kiff 1979).

Slightly over half (51.1%) of prey biomass represented in the sample of observed feedings is contributed by insectivorous birds (Table XIX, Appendix C). A single piscivore, the Green Kingfisher (Chloroceryle americana) contributes less than 1% of prey biomass. Insectivorous species listed in Table XIX belong to the families: Cuculidae, Tyrannidae, Picidae, or Icteridae. The preponderance of prey biomass contributed by insectivorous species helps to explain further the tendency of the Aplomado Falcon to concentrate pesticide residues.

Prey Habitat. Perhaps to a limited degree, the habitat of prey gives some idea about the type of habitat in which the falcons hunt. The mobility of birds is such, however, that some species contained in the list of prey animals (Tables XV, XVII, and XX) may have been captured while enroute across atypical habitat -- perhaps habitat that for one reason or another increased the vulnerability of these animals to capture by Aplomado Falcons.

It is reasonable to suppose that aplomados would be most likely to capture species that occur in savanna habitats. Accordingly, the majority (55.0%) of prey biomass was contributed by species that have extremely variable habitat preferences -- species that occur in savanna as well as other types of plant associations. Species that frequent brushy areas are next in importance (24.3% by weight), followed by true savanna species (10.0%) and woodland species (6.3%).

Prey animals that inhabit woods or brushy areas may be captured when Aplomado Falcons pursue birds that are attempting to cross open areas. Woodland and brushland species could be vulnerable to capture when moving from dense brush and woods into or across more open terrain. In several instances I have observed single birds and flocks being pursued by aplomados as the prey attempted to fly over active falcon territories. I have also watched small birds trapped by pairs of falcons in isolated trees in open fields.

Hunting Behavior

Spatial Distribution of Hunts. The spatial distribution of hunting activities is a result of the type of foraging strategy used by a particular avian predator. A bird that hunts at points distant from the nesting area may preferentially utilize hunting areas unlike the habitat within which the nest is situated. This may be particularly evident in species that do not construct their own nesting platforms. For example, Peregrine Falcons nesting in the mountains surrounding Utah Lake and the Great Salt Lake of north-central Utah actually seemed to forage in the marsh habitat associated with these lakes (Porter and White 1973). Peregrine Falcons usually nest on cliffs and do not build stick nests (Brown and Amadon 1972). Like the peregrine, the Aplomado Falcon does not construct its own nest sites, yet aplomados in eastern Mexico usually hunt very close to their nest sites (Figure 3).

One nest site was examined intensively in June of 1979, in an attempt to quantify the frequency with which hunts occur a different distances from nest sites. Six days (about 62 hours) of observations

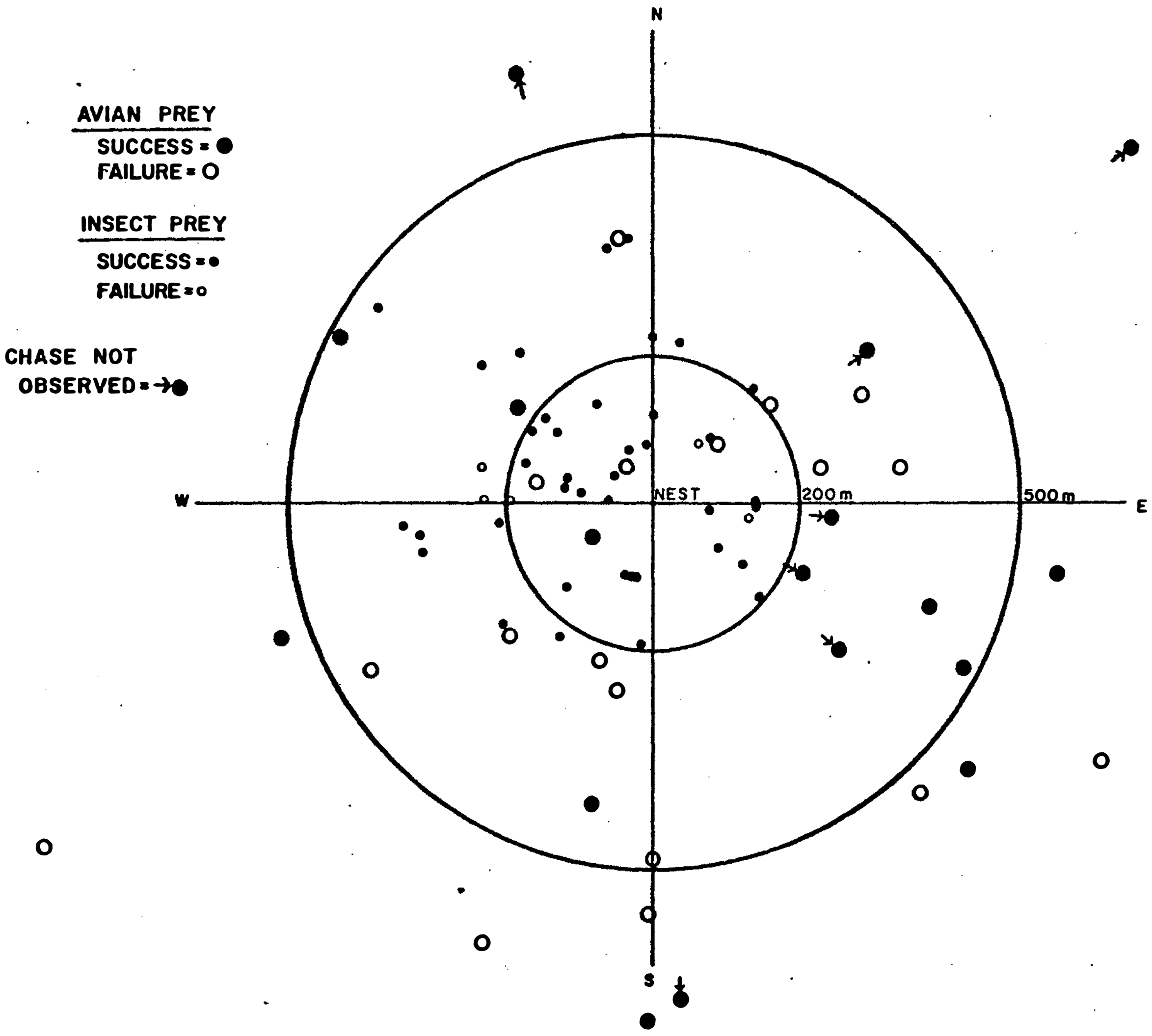

Figure 3. Spatial Distribution of Hunts Made by Aplomado Falcons During Six Days at a Northern Veracruz Nest Site.

were gathered at the site. During this period, the nest contained two, three-to-four week old young. Since the nest tree was situated in a plowed cornfield containing scattered acacias, observation conditions were nearly ideal. Few chases taking place within 600 m of the nest tree could escape detection.

Of 78 observed chases, 34 (43%) involved avian prey while 44 (57%) involved insect prey (Figure 3). Thirty-nine (86%) of the insects were captured and 17 (50%) of the birds were captured. A Chi-square test did not provide much evidence of real differences in success rates between flights occurring within 200 m of the nest and those beyond this distance ($0.25 > p > 0.10$, $X^2=1.6$, d.f.=1). However, significant differences were detected between the proportion of insect prey captured in these two zones ($p < 0.001$, $X^2=21.33$, d.f.=1).

Insects are rarely attacked or pursued at great distances from perches or nest sites (most hunts begin from the vicinity of the nest site regardless of the type of prey being pursued). The estimated geometric mean of flight distances involving avian prey for all hunts observed over the three years of this study is 178.9 m greater than the geometric mean of flights at insect prey (Figure 4). This difference is highly significant when examined using a parametric t-test applied to the common logarithms of flight distances ($p < 0.001$, $t=13.4$, d.f.=149). Pursuit and/or attack distance is probably a function of the relative energetic benefits of prey that vary in size, abundance, or difficulty of capture. Insects are captured easily, but are small compared to avian prey. Accordingly, it may be profitable to capture insects only when they are abundant and concentrated close to falcon hunting perches. As mentioned in the section on diet com-

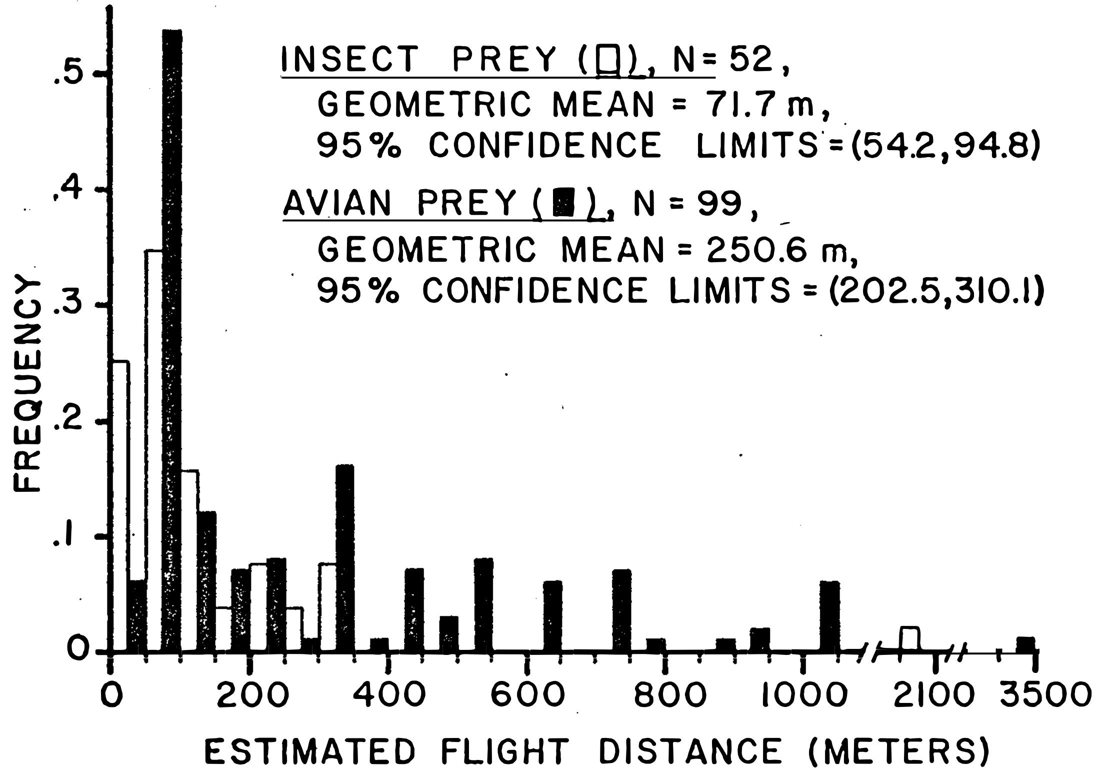

Figure 4. Frequency Distribution of Flight Distances for Hunts Involving Avian and Insect Prey.

position, however, avian prey comprise the major portion of dietary biomass, and may be consistently more profitable to hunt than insects.

Besides these considerations of foraging energetics, pursuit distance and attack distance (since it is difficult to mark accurately the location of prey when the attack begins, the two distances are nearly inseparable) could simply correspond with the distance at which prey of various sizes can be visually detected. In other words, larger prey can probably be detected by falcons at greater distances than smaller prey. This, by itself, might explain the difference between avian and insect flight distances. However, the relationship between prey size, prey detectability and flight distance is perhaps inextricably confounded with considerations of the cost-benefit ratios associated with various prey types.

Prey Selection and Pair Hunting. In a sample of 360 observed hunts, 106 (29.2%) involved two falcons simultaneously chasing the same prey animal(s). I term this type of chase a "pair hunt" or "pair chase". Neither term implies that a chase engaged in by two birds was a cooperative endeavor. To uniformly label such flights as "ccooperative flights" would be improper since such a label suggests that pair hunting always leads to mutual benefits for the pursuers, or at least that the participants work together for mutual benefits. In the case of the Aplomado Falcon, benefits do accrue to both participants in a dual pursuit as a result of the sharing of captured prey or the feeding of prey to the offspring of the adults. It is unwise, however, to use a descriptive label implying that all pair hunts or group pursuits are forms of cooperative behavior, and not simply simultaneous and fortuitous pursuit of the same prey by more than one predator.

With regard to the 106 pair hunts mentioned above, 34 (32.4%) were successful. Surprisingly, of 254 solo pursuits, 149 (58.7%) were successful. It would seem intuitively reasonable to expect that pair hunts should be more successful than solo hunts. The sample on which these statistics are based, however, contains flights involving both insects and avian prey. Pair hunts are nearly exclusively directed at avian prey. In only a single instance have I witnessed two aplomados chasing the same insect. Of the total sample of 360 hunts, 174 (48.3%) involved insects. In this subset, insects were captured 82.2% of the time. The total success rate for flights at avian prey was much lower (35.8%). When only avian prey are considered, the advantage of the pair hunting strategy becomes apparent. Sixty-eight (64.1%) of the sample of 106 bird chases were pair hunts and 30 (44.1%) were successful. Only 7 (18.9%) of 37 solo pursuits were successful. These differences were found to be statistically significant (0.025 $p<0.01$, $X^2=5.95$, d.f.=1). This suggests, first, that pair hunting improves the success with which avian prey are captured, and second, that pair hunting may be an adaptation for capturing larger, more maneuverable prey.

The tendency to hunt in pairs is not limited to Aplomado Falcons in my study area, to aplomados during the breeding season, or to Aplomado Falcons in general. In the early part of this century, Cherrie (1917) observed pairs of aplomados hunting together on the Orinoco River in Venezuela. During the 1920's, Ligon (1961) watched pairs of Aplomado Falcons hunting bats on the Jornada del Muerto in south-central New Mexico. Several home ranges in eastern Mexico contained pairs of falcons that were not nesting at the time that my field studies took place. These birds conducted early morning and late evening pair hunts just like the nesting falcons. At one site the two resident aplomados captured a White-winged Dove. In another instance two recently-fledged aplomados were observed chasing grassquits (*Volatina* sp.), or Variable Seedeaters (*Sporophila aurita*) on the fringes of a tidal marsh.

The Red-headed Merlin (*Falco chicquera*) of southern Africa and western India and Pakistan is behaviorally and ecologically very similar to the Aplomado Falcon (Ali and Ripley 1968). It nests in habitats ranging from palm savanna to dry desert scrub and, like the Aplomado Falcon, frequently hunts in pairs. In fact, the description of the behavioral ecology of this eastern hemisphere species provided by Brown and Amadon (1972), could just as well have been written about the Aplomado Falcon. Other raptors that consistently hunt in pairs or in larger groups include Eleonora's Falcon (*Falco eleonorae*), the Bay-winged Hawk (*Parabuteo unicinctus*), and Lanner Falcon (*F. biarmicus*)(Walter 1979, Mader 1975, Mebs 1959).

In addition to affecting hunting success, pair hunting also has an effect on the size of prey captured by Aplomado Falcons. In a sample of 96 observed captures, the geometric mean of estimated prey length was 107 mm (Table XXI). Of these prey, 21 were captured by pairs of falcons. The estimated geometric mean of lengths of prey in these flights was 224 mm as opposed to only 87 mm for 75 solo captures. Using the common logarithms of prey length, an analysis of variance was conducted to examine the relative effect of number of pursuers and sex of captor on size of captured prey (Table XXII). The number of pursuers had a significant effect on prey length, while the effect of the sex of captor was judged to be not significant. Interaction between the effect of the number of pursuers and the sex of the captor, however, is highly significant.

One possible interpretation of these results considers differences in the roles assumed by male and female Aplomado Falcons during the nesting period. Normally, during all stages of the nesting period, the female remains within view of the nest. Female falcons participate in most of the interspecific territorial encounters taking place at nest sites. The larger size of the females (relative to the size of the males) may enhance the ability of the female to intimidate intruders. Males, on the other hand, occasionally disappear on solitary hunting forays. At the nesting territory, males participate in most intra-specific territorial encounters, and may continue attacking intruding conspecifics (of both sexes) long after the resident female has returned to the nest. In other words, females take a greater role in nest defense activities while males play a more important role in defending the nesting territory from other Aplomado Falcons. This dichotomy is perhaps best appreciated when the adult falcons are subjected to disturbance as a result of certain research activities (for example, handling of the young, examination of cache sites, collection of prey remains from beneath the nest tree, etc.). At some nest sites, the male falcons fail to respond to this sort of disturbance. Usually, however, they at least vocalize and fly about above the researchers then intermittently return to a nearby perch. The females, on the other hand, vocalize steadily and dive on the intruders, especially when nest trees are climbed.

In at least three instances, female falcons struck researchers who were working close to (within 50 m) or in nest trees. Female Aplomado Falcons may continue to vocalize and attack intruding humans long after the male has silently retired to a distant tree. Interestingly, field workers and fence riders are usually ignored by aplomados, suggesting that the birds are somewhat sensitive to differences that distinguish the native from the meddlesome researcher.

With this division of labor, female falcons apparently are limited to hunting near the nest tree. Their hunting territory may therefore coincide fairly closely with the nesting territory. At one site, when incubation was in progress, I watched the female begin a hunting flight while the male was taking his turn on the nest. Almost immediately, the male left the nest and joined the female. Both birds flew rapidly about 500 m then the female suddenly reduced speed, wheeled and began a steady flight back to the nest tree. Meanwhile, the male flew into a pasture located a kilometer from the nest and began chasing some Mourning Doves. This suggests that the females are motivated to hunt, but that their hunting behavior is constrained by a stronger motivation to protect or maintain the contents of the nest. Since males are able to wander more freely than their mates, they may be less inhibited than females in the selection of prey. Alternatively, males may be motivated to capture larger prey so that the female and young can be adequately fed. Females capture many insects when hunting alone at nest sites. This may be because insects can be quickly captured and eaten, and, therefore, provide only brief distractions from the task of nest defense. The tendency of females to capture small prey when hunting alone may explain why the average length of prey captured by females in solo hunts is 54.9 mm (49.3%) less than the geometric mean of prey captured by male falcons hunting alone.

When both sexes hunt together, they are exposed to nearly the same set of potential prey. In pair hunts, the effect of differences in the roles assumed by males and females should be controlled somewhat. The geometric mean of lengths of prey captured by females in pair hunts is 80.7 mm (45.5%) larger than the geometric mean length of prey captured by males in pair hunts. Females should be expected to capture larger prey than males since females are larger than males. As I will discuss in the next section, male and female aplomados do not, however, use the same strategies (or assume the same roles) during pair hunts. Differences between the behavior of the sexes during pair hunts could enhance or nullify the physical attributes of the respective sexes, and further affect prey size.

At nest sites of the Aplomado Falcons studied in eastern Mexico, both male and female falcons were at least partially committed to responsibilities of feeding the other adult and the young; and of inter- and intraspecific territorial defense. Time must be adequately allocated among these responsibilities if the falcons are to produce successfully offspring and maintain their occupancy of a nesting territory. A system in which only one sex hunts assures that the nest site will be protected at all times. Consequently, pair hunting might distract both members of a pair of falcons from duties of nest defense. As suggested above, this is perhaps the most obvious reason that pair hunting is a behavioral phenomenon limited to the vicinity of active nests. It is to the advantage of the falcons to participate in pair hunts, despite the behavioral and concomitant spatial limitations mentioned above, because: (1) the success rate of pair hunts involving avian prey is more than double the success rate for solo pursuits involving avian prey; (2) the average size of prey captured in pair hunts is nearly triple the average size of prey captured in solo hunts; (3) pair hunts improve the efficiency with which highly maneuverable prey (birds) are captured and may increase the ability of falcons to capture prey under conditions that would thwart single falcons; and (4) pair hunting may reduce the risk of injury to which hunting falcons are exposed.

The first two points have already been discussed. Concerning the third advantage, it is valid to say that pair hunting improves the efficiency with which more maneuverable prey are captured, since insects are more easily captured than birds, and since the success rate of pair hunts directed at birds is so much greater than for solitary hunts. This also applies to various types of birds (the Columbidae in particular) that seem to be inherently more difficult to capture than relatively weak-flying species such as the Groove-billed Ani (*Crotophaga sulcirostris*). When falcons hunt in pairs, they seem to chase the more difficult-to-capture prey in situations in which capture is difficult, much more persistently than falcons hunting alone. Hunts involving two falcons are more costly (energetically) than hunts involving only one falcon, however, it may be advantageous to continue pair flights over longer distances and periods of time than solo flights since the average success rate is higher in pair hunts, and the size of prey captured in pair hunts is much greater on the average.

The best example, with which I am familiar, concerning the efficacy of pair hunting as a means of capturing highly maneuverable prey, involves a predatory species other than the Aplomado Falcon. Falxa and Wehmeyer (personal communication) witnessed a pair of Bat Falcons (Falco rufigularis) hunting hummingbirds on the shores of a lake in the highlands of Chiapas. The male would begin the encounters by flying out from the edge of the lake to meet hummingbirds attempting to cross the open body of water. The male falcon would begin repeatedly and unsuccessfully stooping at the rapidly maneuvering prey, until the female would finally assist. In several flights, the hummingbirds were unable to cope with the threat of an additional pursuer and were almost immediately captured by the female. Similarly, male Aplomado Falcons often force prey into cover near nest sites then produce a high-pitched "cheeping" vocalization that seems to attract the attention of the female. She then assists in driving the prey from cover and thereby helps to expand the range of situations in which the falcons are able to capture prey.

With regard to the fourth point, at the conclusion of successful pair hunts, females often secure larger and better-armed prey animals. Female falcons most likely captured the larger prey animals (Chachalacas, Great-tailed Grackles, etc.) listed in Tables XV and XVII. During the observational work summarized in Figure 3, the female aplomado captured two female grackles, and a Bobwhite in pursuits in which the male also participated. At another site, I watched the female capture a Squirrel Cuckoo (Piaya cayana)(107 g) at the end of a brief pair hunt. Even when the males do capture larger prey such as Mourning Doves (126 g) or White-winged Doves (168 g), the female often takes the prey from the male almost immediately, then carries it back to the nearest plucking perch. Male falcons seem to have difficulty carrying these larger prey. The effect on the females of carrying large prey is much less noticeable. This is not to imply, however, that females assist the males in carrying prey, but only that the transfer of prey to the female (which may occur at any time prior to the feeding of the young) at times happens immediately after a kill is made, and may at least fortuitously improve the efficiency with which prey are transported back to the nest.

In addition to participating in the capture of larger prey, females often enter ground cover and the crowns of trees to drive out hidden prey. Both tasks would seem to expose females to greater risk of injury than males -- at least during pair hunts. The act of hunting together, however, may by itself reduce the risk to which both members of a pair are exposed. If two birds hunt together, and in the process, improve their individual hunting success, and also increase the average size of prey captured per pursuer, then they also effectively reduce the number of hunts required to capture a given unit of food. Consequently, the risk to which both falcons are exposed is reduced. This may be a very important factor in considerations of the longevity and associated reproductive fitness of both male and female Aplomado Falcons. At at least two nest sites, male falcons showed signs of wing injuries. In both birds, one wing drooped slightly when folded, and also affected the wing beat. In captive birds, this condition is associated with wing sprains and often results from collisions with immovable objects such as barbed wire fences, telephone wires, woody vegetation, etc. It is likely that the act of chasing prey animals is not without some risk. Factors such as pair hunting that may reduce this risk, should be beneficial to Aplomado Falcons as well as other predators.

The Effect of Habitat Quality on Pair Hunting. Many raptors forage at some distance from the nest site (Newton 1976, Marquiss and Newton 1979, Dementiev and Gladkov 1954, and others). European Sparrowhawks (Accipiter nisus) forage up to 9 km from active nest sites (Marquiss and Newton 1979), and Peregrine Falcons have been reported as foraging 20-27 km from nests (Kumari 1974, Porter and White 1973). As mentioned previously, Aplomado Falcons usually hunt within 500 m of nests in eastern Mexico. Even non-nesting falcons consistently hunt from only a few perches within their home ranges. This tendency to forage from a central place may be a function of prey abundance or due to some dependence on pair hunting for efficiently capturing larger and/or more maneuverable prey. Female aplomados stay near active nests, and as a result, hunts made by pairs of falcons take place near nests. If the male and female aplomados are unable to capture prey in a pair hunt within 1-2 hours, the male will finally leave on a solitary hunt. These solitary forays occur infrequently at nest sites in eastern Mexico, but could take place more often at nest sites where prey are more patchily distributed, less abundant, or less vulnerable to predation. At suboptimal nest sites, males may capture a greater proportion of prey on their own or else the females might leave the vicinity of the nest more frequently to forage solitarily or in company with their mates. Marquiss and Newton (1979) have shown that there is a tendency for both members of nesting pairs of Sparrowhawks to forage farther from nest sites in poorer habitat. Perhaps Aplomado Falcons are able to make the same adjustments in their foraging patterns. It seems reasonable to suppose, however, that the optimum situation is one in which pairs of falcons capture most prey near the nest. This suggests that one measure of habitat quality might be the proportion of dietary biomass contributed by prey captured in pair hunts and/or hunts taking place close to nest sites.

Hunting Strategies and Habitat Structure. When insect prey are attacked, falcons slowly flap or glide towards the prey animal over distances that are usually less than 200 m (Figure 4). Insects such as locusts and moths are often flushed from the ground then captured in short flights. Flying beetles and wasps are easily captured at the end of short glides, and seem to be nearly incapable of out-maneuvering the falcons.

Birds in flight, are usually pursued in rapid horizontal dashes. When avian prey are trapped in ground cover, or among the branches of trees, however, the approach by the falcons is, in most cases, fairly slow (Figure 5, Hover Chase). In these situations, one falcon (usually the male) precedes the other to the prey animal then climbs and hovers until the second aplomado (usually the female) arrives. The second falcon then attempts to flush the prey animal from its refuge. The first aplomado descends, attacking in a slanting dive or stoop, while the second bird gives chase along a low, horizontal path. At the end of each dive, the male rebounds upward then stoops again. This sequence may be repeated so that the male follows an undulating path. In a variation of this strategy, both falcons fly directly into cover and together flush hidden prey, then pursue on the same path as the prey animal (Figure 6, Horizontal Pair Chase).

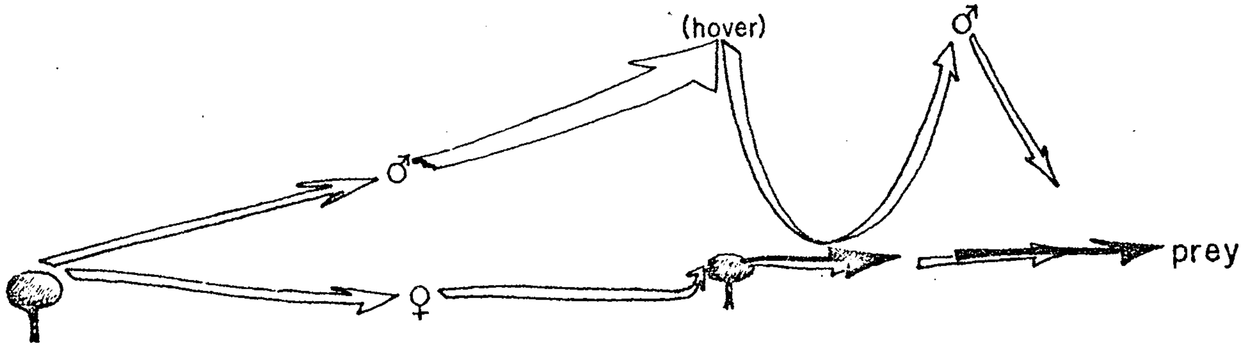

Figure 5. Hover Chase. Solid Arrows are the Flight Path Taken by the Prey Animal.

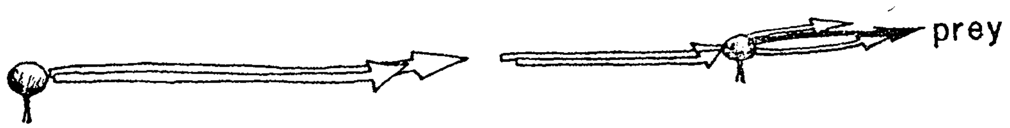

Figure 6. Horizontal Pair Chase.

High-flying flocks of birds are encountered head-on or obliquely by pairs of falcons rapidly ascending from the vicinity of the nesting territory (Figure 7, Pair Ascending Flight). The flock members are then forced to outfly the falcons or reach secure hiding places. The strategy shown in Figure 8 (Bilevel Ascending Flight) is used when a single falcon (usually the male) has singled out one member of a flock of birds and has forced this individual to descend to cover. The female then flies low before rising to meet the descending prey animal.

Aplomado Falcons possess the speed needed to overhaul most avian prey in level flight. In many instances, I have observed falcons steadily gaining on fleeing Mourning Doves and White-winged Doves under circumstances in which the pursuers had no prior advantage of altitude; both of these prey species are capable of rather swift flight. This advantage in speed forces avian prey to out-maneuver aplomados in mid-air or seek refuge in available cover. If prey animals reach cover (ground cover or the crowns of trees), Aplomado Falcons attempt to extract these prey from their refuges or force them from cover and into flight. Aplomados are agile on their feet and able to move rapidly through branches of trees and fairly dense underbrush while searching for, or pursuing prey. If hiding places are secure enough, and present in sufficient densities, then avian prey may lead the falcons through a series of refuges, avoiding capture until the aplomados finally give up.

Since Aplomado Falcons can outfly typical prey in level flight, obstacles such as trees could to some extent nullify this advantage in speed by keeping falcons from ever achieving or maintaining

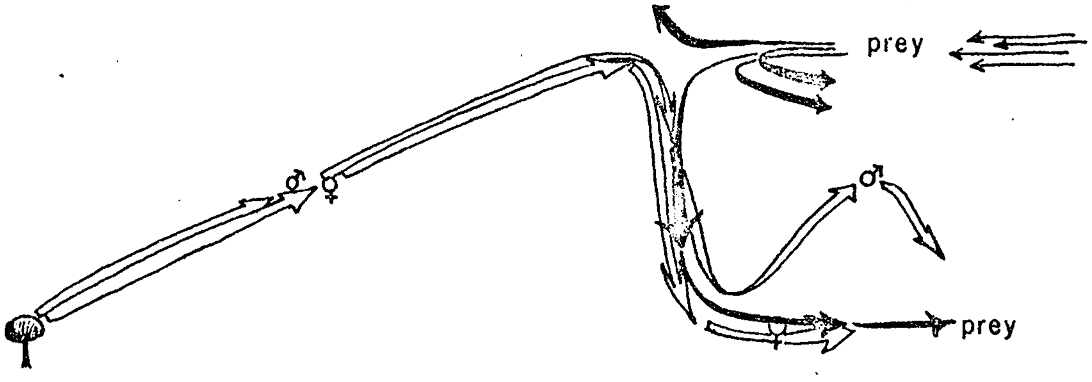

Figure 7. Pair Ascending Flight. Solid Arrows are the Flight Path Taken by the Prey Animal.

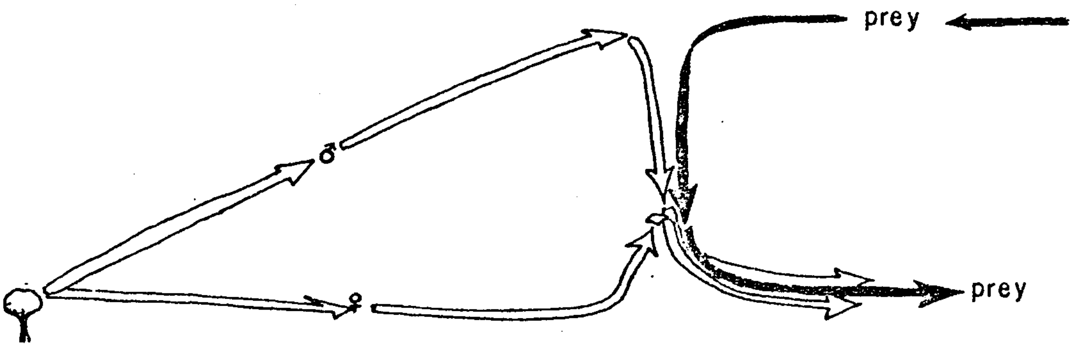

Figure 8. Bilevel Ascending Flight.

maximum flight speed. Certain species may be capable of escaping aplomados by effectively taking advantage of woody vegetation. When pursued, these prey may maneuver among scattered trees while flying at a speed that the falcons cannot achieve under the same conditions. For example, a male Aplomado Falcon was observed chasing a White-winged Dove low across a pasture containing scattered acacias. Every time the dove made a rapid turn around a tree, the gap between pursuer and prey would increase 2-3 m. When the chase briefly straightened between trees, the falcon rapidly gained then lost ground again as the dove twisted around the next obstacle. Finally both birds dashed into an adjacent pasture and out of sight. The falcon soon returned without prey. At other times small birds such as Bronzed Cowbirds (Tangavius aeneus) and White-collared Seedeaters (Sporophila torqueola) have been observed to successfully evade pairs of falcons in a series of hiding places within the crowns of closely spaced trees.

These observations suggest that the spacing of woody vegetation and ground cover depth (and density) may affect the efficiency with which Aplomado Falcons capture prey. In plant associations in which trees are closely spaced or the ground cover is relatively impenetrable, falcons may have difficulty in efficiently capturing prey.

CHAPTER V

THE HABITAT OF THE APLOMADO FALCON IN EASTERN MEXICO

Introduction

Aplomado Falcons inhabit a diverse assortment of neotropical habitats. At 3,000 m above sea level, the species survives in the grasslands of the Peruvian altiplano(J. O'Neill and D. Ellis, personal communications), while at sea level, aplomados nest in the dry thornscrub of Chile's Atacama Desert (Johnson 1965) and in moist palm and oak savannas of Mexico's eastern coast. On the central plateau of Mexico, the species inhabits pine-oak woodland, and grasslands dominated by mesquite and yucca. In Nicaragua, Howell (1972) collected the species in lowland pine savanna (Pinus caribaea). From the standpoint of climate, elevation, and biotic species composition, these areas are very dissimilar. From the standpoint of habitat structure or physiognomy, however, habitats inhabited by Aplomado Falcons are all semi-open associations containing rather widely scattered woody vegetation and relatively little ground cover.

It has been suggested that habitat structure may provide so-called "sign stimuli" used by birds and other animals to select suitable habitat (Lack 1933, 1937; Hildén 1965; and MacArthur and MacArthur 1961). Recognizable physiognomic features may enable an animal to remain within the environmental conditions to which it is best adapted

(Wiens 1969). Physiognomic features that provide an organism with cues concerning habitat quality, however, should not be thought of as being only indirectly or fortuitously correlated with habitat quality. Structural elements could directly affect the quality of certain areas with respect to habitation by a species (Wiens 1969). Considering the Aplomado Falcon, for example, availability of this species' prey is probably governed by structural components such as ground cover density, tree spacing and tree size, that affect both the abundance and vulnerability of prey animals. In addition, characteristics of woody vegetation would certainly affect the availability of the nest platforms required by aplomados. In short, physiognomic elements of habitat that serve as sign stimuli, may also directly influence habitat quality.

Information about habitat physiognomy may provide a basis for facilitating the recovery of the aplomado within the United States. To a large extent this is because physiognomy is not defined by species composition. With a quantitative description of the structure of habitat used by the Aplomado Falcon in eastern Mexico, it becomes easier to recognize areas within the United States where the species might still nest; or alternatively, to locate areas which can be most easily managed to promote reoccupation by aplomados. In this regard, the present chapter presents a detailed description of the physiognomy of habitat used by the Aplomado Falcon in eastern Mexico, and discusses components of habitat that have the greatest effect on habitat quality.

Methods

Vegetational Structure

Spatial Distribution, Size and Shape of Woody Vegetation. Structure of woody vegetation was sampled and described using the Quarter Method (Cottam and Curtis 1956). At falcon nesting territories, three straight transects were established, each radiating 200 m outward from the nest tree or most frequently used perch tree (the transect origin). To position these transects, one compass coordinate was randomly selected. The first transect followed this coordinate away from the nest or perch tree. Remaining transects were then placed 120 degrees to either side of the initial transect. Along each transect route, woody vegetation was sampled at points located 100 and 200 m from the transect origins. Consequently, woody vegetation was measured in the vicinity of six sampling points at each home range. At each point, "sampling quarters" were then formed using an imaginary line placed perpendicular to transects and intersecting them at each sampling point.

For the purposes of this study "trees" were assumed to be any woody plant having a diameter at breast height of two centimeters or more. The tree within each quarter nearest the sampling point was then described using the following measurements: point-plant distances; total height; trunk diameter at breast height (dbh); crown height (vertical diameter of the crown); and crown width (horizontal diameter of the crown). Point-plant distances were measured directly by stepping off the distance between each sampling point and nearest trees. Since three persons participated in this work, individual correction factors were used to convert average stride lengths to meters. My subsequent analysis allowed observer differences in the measurements to be separated from effects due to other factors (differnces in nest sites, and in habitat quality). The remaining measures were taken using a modified version of the Biltmore Cruising Stick (Forbes 1955; James and Shugart 1970) to give estimates of tree dimensions at various viewing distances.

Ground Cover. Ground cover profiles were described using a variation of the Vegetation Profile Pole (Nudds 1977). Three aluminum poles (1.25 cm in diameter; 185 cm tall) were wrapped in alternating 0.25 m segments with black tape. This created seven sampling units per pole. Poles were then sharpened at one end to that when in use they could be sunk into the ground until the first tape mark was flush with the ground.

During Quarter Method transects, ground cover was measured at sampling points located 50, 100, 150, and 200 m along each transect from the origin. At each sampling point, the profile pole was placed in the ground and then examined from a point located 20 m from the pole toward the transect origin and 1 m to either side of the transect itself. The lateral displacement was intended to reduce bias caused by examining vegetation recently trampled by an observer. Obscurence indices were then recorded by estimating, to the nearest tenth, the proportion of each sampling unit obscured by vegetation. Values for these indices could range from 0 to 1.0. Seven index values were derived at every sampling point. These indices were used to create additional values for larger sampling units by averaging the indices for adjacent sampling intervals. In this way additional index values were created for sampling units of 0.5, 0.875, and 1.5 m.

Bird and Insect Abundance

The transect method proposed by Emlen (1971 and 1977) was used to estimate densities of birds and insects. Transects extended at least one kilometer and covered areas within one kilometer of nest sites. Shapes of transect routes were usually rectangular and followed existing fence lines. At a few sites, however, paths were followed that crossed nesting territories and extended equal distances to either side of the nest site. Birds were counted along transect routes in mornings, excluding days of inclement weather. When a bird or insect was detected (either visually or aurally) along the transect route, the animal was identified and its location described by visually estimating the distance perpendicular from the transect to the spot at which the animal was first noticed. The precision of distance estimates was improved using a knowledge of the measured spatial arrangement of landmarks such as trees and fencelines located adjacent to transect routes.

Transect-organism distances were later categorized into "strips" -- ten between 0-100 m; eight between 100-500 m; and a single strip extending from 500-1000 m. Density estimates were then derived using what Emlen (1971) called the "specific strip width" of each category of organism. Specific strips were determined by finding the strip containing the greatest number of sightings of a particular taxon. Density estimates were then derived for the entire transect route using the number of individuals per taxon-specific strip as an estimate of the density of that taxon in the area sampled. This assumes that within each species-specific or taxon-specific strip, all members of the appropriate species are detected by the observer.

Nest Trees and Perch Trees

Perch and nest trees and their neighboring trees were also measured. This was accomplished using the methods described in the section concerning the analysis of woody vegetation. In this case, however, the nest or perch trees were the sampling points, and accordingly, four trees were measured in the vicinity of each nest or perch tree. These were the four trees situated closest to the sampling points within sampling quarters that were positioned in a random fashion.

Nest Platforms

A small sample of aplomado stick nest platforms was also measured. The dimensions measured were: maximum external diameter of the nest, maximum external depth, maximum diameter of the nest cup, and maximum depth of the nest cup.

Levels of Habitat Quality

Habitat quality could have been indexed by measuring feeding rates at nest sites or by examining hunting success rates. Ultimately, however, habitat quality should be judged by the average number of young fledged per nesting attempt in different types of habitat and for a sufficiently large sample of nest attempts. Unfortunately, due to limitations of size and financial support, habitat quality in this study has been indirectly indexed using criteria based on the reproductive and occupancy status of individual nest sites. Two variables were constructed to describe these two kinds of status. The variable describing reproductive status contained the levels: nesting (aplomados engaged in nesting activities); and non-nesting (aplomados either present or absent from a site, but not nesting). The variable describing occupancy status also contained two classes: occupied (falcons present); and unoccupied (falcons absent or at least not observed).

If nesting and occupied sites are assumed to be better in quality (on the average) than non-nesting and unoccupied sites, respectively, then the variables for reproductive status and occupancy status can be converted to an ordinal scale containing not just classes of site status but levels of habitat quality. Furthermore, since habitat quality is obviously a continuous variable and not a discrete one, it is possible to argue that the discrete nature of these two habitat quality variables is simply a result of my inability to measure habitat quality with greater precision. Limits of precision essentially force all continuous variables to be measured in discrete ways. Consequently, it is possible to use these sorts of habitat quality variables as dependent variables in the regression models that are discussed later in this chapter.

It was easier to prove that a site definitely contained falcons than to prove that falcons were not present. Once aplomados were located, it became relatively easy to determine whether or not the birds were nesting by simply monitoring the behavior of the birds over a sufficient period of time. The initial location of a pair of falcons was usually difficult since aplomados can be very secretive. Non-nesting falcons were even more difficult to locate since they are not as limited in their movements as nesting falcons. The status of some sites may therefore be misclassified. Errors of this sort would weaken the assumptions required to convert categories of nest site status into levels of habitat quality, and blur any correlations of measured habitat variables with habitat quality.

Data Analysis

Measurements collected in the field were recorded on data forms, then coded and placed on computer cards. Statistical analyses and data summarization were carried out using the 1979 edition of the Statistical Analysis System, SAS (Barr et al. 1979).

In most cases, appropriate parametric statistical methods were used after transformation of the data into a scale of measurement in which they did not deviate significantly from a normal distribution. Measurements derived using the quarter method were transformed to common logarithms ($\log_{10}(x+1)$), while vegetation profile measurements were transformed to the arcsin distribution (Snedecor and Cochran 1967). Density estimates derived in the faunal transect work were not transformed. Deviations from normality were examined statistically with measures of skewness and kurtosis available in the MEANS Procedure of SAS. Prior to Discriminant Analysis and Stepwise Multiple Regression Analysis, all independent variables were standardized and centered using the STANDARD Procedure of SAS.

Univariate analysis of variance (General Linear Models Procedure) was used to compare relative effects of observer, nest site, and habitat quality on variability in habitat measurements. Data collected with the Quarter Method, Vegetation Profile Pole, and Emlen Method were analyzed separately because of differences in the way data were collected in each method. In these analyses, nest sites were arranged within levels of both habitat quality variables, and the analysis of variance procedure was conducted separately for each of these variables. Observer and habitat quality were arranged factorialy, as were observer and nest sites. That is, each observer measured vegetation along one transect at each nest site. An attempt was made to allow more than one person to carry out the faunal surveys at each site. As a result, each observer analyzed habitat structure (all habitat variables but only along one transect) at each site, and therefore, within each level of habitat quality. On the other hand, nest sites could be placed into only a single level of habitat quality within each habitat quality variable. By carrying out these analyses once for each habitat quality variable, it was possible to examine the degree to which each method of categorizing nest sites affected the structural variables.

To complete the statistical analysis, an improved form of Stepwise Multiple Regression (Maximum R-Square, MAXR, Barr et al. 1979), and Discriminant Analysis were used to complete the description of habitat structure. Stepwise Multiple Regression provides a means for building a model from a large array of potentially highly intercorrelated variables. Since the dependent variable should be continuous in regression analysis, numeric dummy variables were substituted for the levels in each status variable (the dependent variable). This produces a statistical technique that is similar to discriminant analysis, but which provides more information than

than discriminant analysis (in the form of the regression coefficients and multiple correlation coefficients) about the relative effects and direction of effects of each independent variable included in a model. In addition, the overall fit of each model can be examined using the multiple correlation coefficient (R^2). Since habitat quality is actually a continuous variable, regression analysis can be interpreted as producing a model of habitat quality if it is assumed that categories within each nest site status variable are actually equivalent to levels of habitat quality.

Stepwise model building techniques can deal effectively with sets of intercorrelated variables because the effect of each independent variable is examined individually. Once one member of an array of intercorrelated variables enters the model, this variable accounts for some variability accounted for by other members of the array. It then becomes more difficult for remaining intercorrelated variables to provide much increase in the fit of the model. This feature of stepwise regression allowed two, five variable habitat quality models to be constructed from the 25 habitat variables that were measured, and thereby produced a meaningful subset of variables to be used in the discriminant analysis. In the description of the results on the model-building procedures, however, only the independent variables producing a significant partial F-test have been retained and discussed except in one case in which a variable verged on producing a significant F-ratio.

The following independent variables were used in constructing the regression models: density of birds and insects; density of corvids and raptors (nest providers/predators); density of all birds;

insect density; density of non-prey, non-corvid, and non-raptorial birds; prey species density; level one vegetation profile index (0-0.25 m); level two vegetation profile index (0.25-0.50 m); level three vegetation profile index (0.50-0.75 m); level four vegetation profile index (0.75-1.00 m); level five vegetation profile index (1.00-1.25 m); level six vegetation profile index (1.25-1.50 m); level seven index (1.50-1.75 m); low level index (0-0.5 m); middle level index (0.5-1.0 m); high level index (1.0-1.5 m); ground level index (0-0.875 m); upper level index (0.875-1.75 m); overall vegetation profile index (0-1.75 m); distance to nearest road; point-plant distances; tree diameter at breast height; vertical crown diameter; horizontal diameter of tree crowns; and tree height.

Discriminant Analysis utilizes a "calibration data set" (the data on habitat structure collected in Mexico) for which class identities are known, to build a model that maximally discriminates between classes. In this study, for example, the two nest site status variables were the classification variables. Consequently, different discriminant functions were created for each status variable. The same variables selected using the SAS Stepwise Multiple Regression routine (STEPWISE) were used as the independent variables in the discriminant analysis procedure. Discriminant analysis detects differences between populations of observations that would not be detected using only univariate statistical techniques. The use of discriminant analysis in this research corroborated the results of the regression analysis and enabled me to examine the degree to which nest sites of known status could be separated using measured elements of habitat structure.

Results

Vegetation Structure

Tree Spacing and Tree Shape. A cursory examination of Tables XXIII-XXVII (Appendix C) should suggest that the trees at "better" sites (nesting and occupied sites) are larger than trees at "poorer" sites (non-nesting or unoccupied). In addition, it seems that trees are more sparsely distributed at the "better" sites.

Point-plant distances provide a quantitative definition for terms such as "semi-open" and "open overstory". Average point-plant distances ranged from 40.8-45.7 m. These values convert to estimates of 18.9-25.0 trees/40 ha. For purposes of comparison, Beasom and Haucke (1975) derived density estimates of 1,295-4,382 trees/40 ha for southern Texas live oak mottes. A patch of oak-hickory forest sampled by James and Shugart (1970) contained an estimated density of 22,600 trees/40 ha.

The relative effect of observer differences, nest site differences and nest site quality on individual habitat variables was examined using univariate analysis of variance. In seven of ten analyses, site status had a significant effect ($p<0.05$) on habitat structure (Tables XXVIII-XXIX, Appendix C). Variability due to nest sites and observers was great, yet effects due to differences in habitat quality were still detected. Site reproductive status had a significant effect on: diameter at breast height, crown height, crown diameter, and tree height. Site occupancy status had a significant effect on: point-plant distances, diameter at breast height, and tree height.

Average distances separating trees might be positively correlated with hunting success rates. In view of the information presented in Chapter IV, optimal habitat would be expected to contain trees more widely scattered than trees in sub-optimal habitat. Limits to this relationship should exist, however, because trees serve not only as refuges for prey or obstacles to the pursuit of prey, but also as observation posts and supports for nest platforms.

The other measurements are more difficult to interpret. Taller trees may provide better vantage points from which falcons can survey nesting territories for edible or potentially harmful intruders. Crown height and crown diameter were hightly correlated with tree height as is dbh (p=0.0001). Intercorrelation among these variables may explain differences in crown height and crown diameter between levels of habitat quality. Crown shape, by itself, however, could be important to aplomados because of its effect on the quality of plucking perches and roost sites. Large crowns may provide secure plucking perches or roost sites. In addition, crown shape may affect the ability of Aplomado Falcons to capture prey items within tree crowns. Presumably, however, prey should be easier to extract from smaller crowns -- not larger ones, but this generalization could easily be disrupted by differences in branch or leaf density that are independent of crown size or shape.

Ground Cover. Ground cover at different classes of nest sites was relatively similar. As in the analysis of woody vegetation, univariate analysis of variance was used to determine the relative effect of observer, nest site and nest site quality on profile indices. The responses used in this analysis were the following profile indices: low level; middle level; and high level. Only the level between

0.5 and 1.0 m showed differences that were close to being significant (Table XXX, Appendix C).

It was suggested in Chapter IV that hunting success might be reduced in areas where ground cover is too dense. Ground cover at sites containing nest falcons has a lower average profile index for levels below 1.25 m than other sites, but this is not a significant difference. No attempt has been made to examine the effect of ground cover density on foraging efficiency, however. The differences in profile indices are as would be expected if better home ranges were those in which prey could be located, pursued and extracted most efficiently. Further observational and experimental work dealing with the relationship between actual hunting success and ground cover density needs to be conducted.

Bird and Insect Abundance

Seventy-six bird species and six insect orders were encountered during faunal transects (Table XXXI, Appendix C). At sites containing nesting falcons, highest density estimates were derived for butterflies (500.76/40 ha); dragonflies (389.01/40 ha); Groove-billed Anis (52.63/40 ha); Brown Jays (59.01/40 ha); Great-tailed Grackles (105.73/40 ha); and White-collared Seedeaters (51.61/40 ha). This list contains two birds, the Great-tailed Grackle and Groove-billed Ani, that are frequently taken as prey by Aplomado Falcons. Densities for other common prey species are: White-winged Dove - 0.16/40 ha; Mourning Dove - 0.16/40 ha; Yellow-billed Cuckoo - 0.64/40 ha; and Bobwhite - 17.54/40 ha. Estimated densities for the Roadside Hawk (4.78/40 ha) and Crested Caracara (also 4.78/40 ha) were the highest for falconiform birds.

Several other species occasionally encountered near nesting areas were not recorded during the faunal transects. These included: the Gray Hawk (Buteo nitidus), White-tailed Hawk (Buteo albicaudatus), Barn Owl (Tyto alba), Bay-winged Hawk (Parabuteo unicinctus), Common Black Hawk (Buteogallus anthracinus), Short-tailed Hawk (Buteo brachyurus), Bat Falcon (Falco rufigularis), Snail Kite (Rhostramus sociabilis), Montezuma's Oropendula (Gymnostinops montezuma), Ringed Kingfisher (Ceryle torquata), Green Kingfisher (Chloroceryle americana), Turquoise-browed Motmot (Eumomota superciliosa), and Pauraque (Nyctidromus albicollis).

Mean densities of birds at nest sites ranged from 307.65/40 ha at non-nesting sites to 423,30/40 ha at nesting sites (Table XXXII, Appendix C). Unoccupied sites contained the greatest densities of insects (504.22/40 ha), while nesting sites contained the lowest densities (376.37/40 ha).

Differences in densities of insects and birds were examined with univariate analysis of variance, but in all cases observed differences in the abundance of insects and birds among categories of nests were not statistically significant ($p>0.05$). This is surprising in view of the large differences between mean densities for each category. Variability among sites, however, was sufficiently large to obscure differences between nest site groups.

Comparisons were also made of estimated densities of corvids, raptors, potential prey species, and birds falling into none of these categories (Table XXXIII). Occupied and nesting sites supported greater densities than either unoccupied or non-nesting sites, respectively, but these differences were not statistically significant.

It is of interest to compare bird densities between the tropical and subtropical areas formerly or presently occupied by Aplomado Falcons. At four study sites on the lower Texas coast, Roth (1977) derived estimates of total avian abundance that ranged from 294-542 birds/40 ha. These estimates were derived in relatively brushy areas using the modified spot-mapping technique (Kendeigh 1956). In other studies, Dixon (1959), and Raitt and Maze (1968) produced estimates of 42 birds/40 ha for study sites located in western Texas and south central New Mexico, respectively. Both sites were located in shrub desert. The New Mexico site was on the Jornada del Muerto, the broad valley where aplomados nested during the 1920's.

Three additional studies conducted in desert shrub habitat provide some information on the extremes of avian abundance that may exist in desert grassland situations. At a site in Durango, Mexico, Davis and Fowler (1959) derived an estimate of 44 birds/40 ha, while in Zacatecas, a site examined by Webster (1977) contained approximately 330 birds/40 ha. Wauer (1977) found desert shrub and thornscrub associations in Sonora to contain 250-432 birds/40 ha. In general, the tropical savanna communities seem to support higher densities of birds than desert grassland communities. At least one desert site (Zacatecas), however, contained an estimated density of birds comparable to densities derived in eastern Mexico.

The abundance of prey species within a nesting area should affect the ability of falcons to efficiently forage in the vicinity of nest sites. Surely the optimal situation is one in which prey are super-abundant. Density estimates presented above, suggest that avian abundance is lower in parts of the Chihuahuan Desert than in eastern Mexico. Perhaps desert grassland areas provide nesting habitat of poorer quality than tropical savanna associations, unless falcons can capture prey easily enough in desert grassland associations to compensate for lower prey abundance.

These statements, however, ignore indirect effects of non-prey species on Aplomado Falcons. Other birds of prey and larger corvids likely have both beneficial and detrimental effects on habitat quality. These birds build stick platforms that aplomados use as nest sites, but may also eat the eggs and young of the falcons. Although I have never observed any sign of predation at an aplomado nest site, most raptors as well as Brown Jays are vigorously harassed at nest sites.

Characteristics of Nest, Perch, and Cache Sites

Nest Platforms. Within the United States, Aplomado Falcons apparently nested in stick platforms constructed by White-necked Ravens (*Corvus cryptoleucus*), Swainson's Hawks (*Buteo swainsoni*), and Crested Caracaras (*Polyborus plancus*) (Bendire 1892, Strecker 1930, and oological records). Stick platforms constructed by White tailed Kites (*Elanus leucurus*), and White-tailed Hawks (*Buteo albicaudatus*) may have been used by Aplomado Falcons in southern Texas.

At 15 sites in eastern Mexico, Aplomado Falcons nested in stick platforms. Three of these platforms were constructed by Crested Caracaras, three by White-tailed Kites, eight by either Roadside Hawks (*Buteo magnirostris*) or Brown Jays, and at least one was constructed by a Grey Hawk (Buteo nitidus). Since there is no reliable indication that falcons are capable of building their own nests (Brown and Amadon 1972, and Newton 1979), considerations of the effect of non-prey bird species on falcon productivity must acknowledge that in many areas Aplomado Falcons are probably dependent on these birds for nest sites.

Nest platforms used by Aplomado Falcons are quite variable in size. For a sample of five nest platforms measured in eastern Mexico, the maximum outside diameter ranged from 28 to 100 cm (Table XXXIV). Nest cup diameter ranged from 6 to 18 cm. The largest nest included in this sample was constructed by Crested Caracaras, while the smaller nests were built by either White-tailed Kites or Brown Jays.

Since 1977, I have observed 15 nesting attempts in which young were successfully fledged and qualitative characteristics of the nest platforms were recorded. An average of 2.2 young per nest were produced. Mean brood size for the sample of five "large nests" (outside diameter greater than 50 cm) was 2.4 young/nest, while the brood size for the sample of ten "small nests" (outside diameter less than 50 cm) was 2.1 young/nest. This suggests that in terms of short-term productivity larger nest may be better than smaller nests. However, the difference between the mean brood sizes for the two categories of nests was not judged to be significant (Mann-Whitney Test: $T=17.5$, $p>0.1$).

At four sites, arboreal bromeliads were used as nest platforms. The nest cups of these platforms were simply slight depressions in the crowns of large plants or situated in a hollow between several smaller plants. These plants could have been used without modification, but the nests I have examined seemed to have been enlarged slightly. At one home range, two different bromeliads in the same tree were used in consecutive years.

The option of using bromeliads as nest sites would not be available to falcons inhabiting the southwestern United States, or northern Mexico. In eastern Mexico, bromeliads are extremely abundant as are birds whose nests can be used by Aplomado Falcons. Suitable nest sites may be relatively easy for falcons to locate in this area. In the Chihuahuan Desert and on the lower Texas coast, however, raptors do not seem to be as common as they are on the east coast of Mexico. At territories in Mexico where falcons nested in 1977, the density of White-tailed Kites was estimated as being 3.99 birds/40 ha (Table XXXI). Roadside Hawk densities were about 4.78 birds/40 ha, and the density of Brown Jays at these sites was about 59.01 birds/40 ha. In studies of avian abundance carried out in the Chihuahuan Desert, densities of over 2 birds/40 ha were not detected for any raptor or corvid with the exception of the Turkey Vulture (Cathartes aura). Like the falcons, however, the Cathartid Vultures do not construct stick nests. In the shrub desert areas, raptor and corvid densities were neglible (less than 0.5/40 ha). Due to the paucity of nest constructing species, and an absence of bromeliads, it may be much more difficult for Aplomado Falcons to procure suitable nesting platforms in the dryer parts of North America than in eastern Mexico.

Nest site availability has been shown to be a factor limiting the abundance of several raptor species (Cavé 1968, Hamerstrom et al. 1973, Reese 1970, and Rhodes 1972). Since the Aplomado Falcon used the stick platforms of other birds in the United States, then decreases in the abundance of these stick nest constructors may have, in turn, adversely affected the abundance of the Aplomado Falcon.

Perch Sites. Trees are used by Aplomado Falcons as stations from which to detect prey, predators and territorial intruders. To some extent, they may also provide protection from wind and sun, and serve as sites where maintenance activities such as preening and sleeping can be safely carried out. Falcons also dismember and eat prey animals at certain trees -- so-called "plucking perches".

One important characteristic of the typical perch may be its height relative to the height of the surrounding vegetation. Twenty six perch trees at home ranges of the Aplomado Falcon in eastern Mexico were found to be significantly taller than neighboring trees (Table XXXV).

Depending on the time of day, weather conditions and perhaps the motivational state of the birds, aplomados may perch nearly anywhere within a perch tree. Still, specific regions of perch trees are used by aplomados under characteristic circumstances. When hunting, for example, aplomados often perch in the upper branches of trees. Higher perch sites are also selected on overcast days and/or during the cooler parts of the day (early morning and late evening). Typically, however, the cooler parts of the day coincide with times of greatest hunting activity. Consequently, it is difficult to separate the effect of temperature and weather-related phenomena from effects associated with hunting behavior. When not actively searching for prey, and in fact, during the majority of days that I have observed sites in eastern Mexico, Aplomado Falcons perch on the inner branches of trees. Like the accipiters, a group of woodland hawks, Aplomado Falcons will begin opportunistic chases from the inner branches of trees, but more typically, hunt from higher perches or at least from perches near the edge of tree crowns.

Trees used as plucking perches usually contain only a few relatively large, horizontally-oriented branches within the central portion of the crown. These trees provide secluded open areas than contain broad, level platforms (the branches) on which the falcons can pluck and dismember prey. The crowns of such trees may be densely congested with leaves or branches or contain little foliage. In trees with dense crowns, the plucking perch will usually be slightly below the crown, while in trees with only a few branches, the perch may be on nearly any level. This suggests that the falcons prefer a position from which they can easily survey their surroundings while feeding or preparing food.

In most cases, avian prey are partially plucked at the site of capture, then carried to the nearest plucking perch where most of the remaining flight and contour feathers are removed. Small prey, however, may be eaten almost anywhere, and are often dismembered and eaten while the falcons are in flight.

During the nestling period, favorite plucking perches may be used as many as five to six times a day, and double as hunting or resting perches. Accordingly, such multi-purpose trees may contain aplomados for much of the day.

It has been difficult for me to ascertain exactly where the falcons roost. At nest sites, the adult falcons remain active in the evening until light levels are too low for falcon movements to be detected by the human observer. Likewise, in morning hours, the falcons are already hunting when it becomes just light enough to see them. Based on the orientation of late evening activity, my impression is that Aplomado Falcons roost in favorite plucking perch trees or in multi-purpose trees in the vicinity of the nest.

As a result of my experiences in eastern Mexico, and due to comments present in the literature, I would speculate that in mesquite/grassland associations, mesquite trees would have provided adequate plucking perches, resting sites, and hunting perches. Even small mesquite trees (between 3-5 m tall) would seemingly provide the larger inner branches and well-formed crown typical of many trees used as plucking and hunting perches in eastern Mexico. Huisaches (*Acacia farnesiana*) are somewhat like mesquites in shape and size and seem to provide adequate perch sites both on their inner and uppermost branches. This tree species dominates the woody vegetation at savanna nest sites in northern Veracruz (Appendix B). It also occurs in southern Texas in associations containing mesquite, and *Yucca treculeana*.

The long, often decumbent flowering stalks of yuccas (both *Yucca elata* and *Y. treculeana*) might also provide adequate hunting perches for the falcons. Several observers noted this use of yuccas by aplomados in the United States during the early twentieth century (Ligon 1961, May 1935). Yuccas, however, may not provide sufficiently sheltered sites where aplomados can feed and roost. Bendire (1892) indicates that Aplomado Falcons in Arizona often perched on the ground. Perhaps in terrain containing few trees, the falcons might perch on the ground in the shade of small shrubs on low hills or hillsides so that the birds might still have an adequate view of their surroundings. In the

Peruvian altiplano, Aplomado Falcons have been observed to use low perches such as fenceposts, small outcrops, or piles of dirt, in terrain that was essentially treeless (J. O'Neill and H. Snyder, personal communications).

Cache Sites. Uneaten or partially consumed prey are usually cached by Aplomado Falcons. Cache sites in trees are nearly always in clumps of bromeliads. Food is also frequently cached near the ground in clumps of grass, wedged amongst the branches of small shrubs, or else simply placed on bare ground. Cache sites may be used repeatedly or rarely, and often are vigorously defended by the falcons even when no cached food is present.

Certain situations -- for example, arboreal sites -- are probably better cache sites because they provide secure hiding places for uneaten food. It does seem, however, that aplomados are flexible with regard to selection of cache sites, and, in the dryer parts of their range, would be able to use yuccas, old stick nests, clumps of cacti and other thorny vegetation, and of course a variety of ground sites.

Habitat Components -- A Multivariate Synthesis

Habitat Quality Models. Only tree height and the seventh level profile index were retained in the model of site reproductive status (Table XXXVI). Both independent variables were positively correlated with habitat quality. This model accounted for 53.1% of the variability in the data. The best three-variable model of site reproductive status accounted for 70.9% of total variation in the data. This model added the third level vegetation profile index and substituted the sixth level profile index for the seventh level profile index. The third level profile index was associated with a negative regression coefficient (Table XXXVII) and verged on producing a significant F-ratio (p=0.0561).

When site occupancy status was used as the dependent variable, the best model contained three variables: the fifth level profile index; tree height; and tree crown vertical diameter (Table XXXVIII). Tree crown vertical diameter shows a negative correlation coefficient, while the other two variables show positive coefficients. This model explained 69.0% of the variability in the data.

One additional model was constructed using a third habitat quality variable. This variable is a "hybrid" version of the occupancy and reproductive status variables and contains the levels: nesting (birds nesting), non-nesting (birds present but not nesting), and deserted (birds not present). As in the previous models this variable was converted to a numeric dummy variable after arranging the three categories of nest sites in order of increasing habitat quality (with "nesting" the best, and "deserted" the poorest categories). This model accounted for 73.6% of variability in the data and included three independent variables: overall vegetation profile index, vegetation profile below 0.875 m (ground level index), and tree height. Overall vegetation profile index and tree height were judged to be positively correlated with habitat quality while the ground level vegetation profile index was negatively correlated with habitat quality.

Interpretations

Tree Height. In each of the models, tree height was found to be positively correlated with habitat quality. Perhaps the simplest explanation for the direction of this correlation might be the better view available to a predator sitting atop a tall perch. Taller perches should provide a more extensive view of the surrounding area than lower perches. In addition, taller observation posts may enable falcons to more efficiently detect prey in ground cover. Mock (1980) has demonstrated that Goliath Herons (*Ardea goliath*) probably enhance their ability to detect distant prey and prey beneath the surface of water by using a more erect feeding posture. In some ways ground cover, like water, seems to be visually penetrated to a greater depth when viewed from higher observation posts. In addition, taller perch sites may improve the speed and acceleration of hunting falcons, or at least reduce the amounts of energy expended in active flight. Often, falcons simply glide toward prey on set wings using momentum developed when the flight began.

Aplomado Falcons use many trees situated near their nest sites as perches. Accordingly, the best nesting sites may be those that contain a high frequency of suitable perch sites near the nest. The best situation may be one in which prey and territorial intruders are unable to predict adequately the whereabouts of an aplomado because the falcon is able to monitor adequately its surroundings from a number of different perch sites while still protecting the nest.

Tree Crown Shape. Crown diameter of trees in the vicinity of aplomado nests shows a negative regression coefficient (Table XXXVIII). If tree crowns are smaller, then they may provide rather poor refuges for prey animals. Crown shape could also affect the quality of perch sites used by Aplomado Falcons. Many perch trees seem to have rather tall, narrow crowns containing few branches. Aplomado Falcons often sit within the crowns of trees and seem to be able to monitor their surroundings for prey and intruders while remaining somewhat concealed.

Ground Cover. Vegetation profile variables appear in all three models. The description of hunting behavior (Chapter IV) implied that ground cover density might affect hunting success. Dense ground cover may reduce hunting success by providing secure refuges for prey. If this is the case then ground cover should be less dense at the better sites.

The model created using the last-mentioned variable for habitat quality (the variable containing the levels: nesting, non-nesting, and deserted), indicated that vegetation density below 0.875 m has a negative effect on habitat quality. But overall vegetation profile index (also included in this model) has a positive regression coefficient. Areas containing dense ground cover may support greater densities of prey animals than areas covered by sparse ground cover. Lush ground cover may provide prey animals with better supplies of food, cover and nesting sites. It seems reasonable to suppose that the best situation for a predatory animal is one that provides nearly optimal conditions for its prey. Prey animals, however, must for one reason or another, be vulnerable to capture by the predator -- sufficiently so that the predator can feed itself and produce offspring.

Ground cover density at better sites differed most from the poorer sites between 0.5 and 0.75 m above the ground. At better sites, prey may be vulnerable to capture by aplomados due to low vegetation density near ground level, yet be abundant because their habitat is otherwise ideal.

Regardless of the cause of the relationships between ground cover density and habitat quality, trends in the ground cover data fit expectations resulting from an examination of the pattern of vegetational change in the southwestern United States, and its relationship to the decline of the Aplomado Falcon. During the late nineteenth century, much of the rangelands of the southwestern United States were denuded as a result of intense overgrazing. This process probably decreased vegetation density at all levels. Following this period of intense grazing pressure, woody vegetation proliferated in many formerly open areas. The growth and spread of woody plants would have brought about an increase in vegetation density at progressively higher levels above the ground. Within certain limits, therefore, this process of vegetational change may have benefitted the Aplomado Falcon. Decrease or increase of ground cover density at various levels beyond some extreme may have been detrimental to the falcon. Obviously, areas now dominated by brush no longer bear any resemblance to areas typically inhabited by aplomados in eastern Mexico. Since lower level vegetation density is negatively correlated with habitat quality, brush encroachment would be expected to decrease the quality of nest sites. On the other hand, denudation of rangeland could also decrease habitat quality because overall vegetation density of ground cover was positively correlated with habitat quality.

Discriminant Analysis Results

Discriminant analysis was used to emphasize the fact that there were recognizable differences between categories of nest sites and also to suggest that the habitat analysis measurements can be employed to evaluate potential nesting habitat of the Aplomado Falcon.

For both nest site status variables, the reclassification of the calibration data was flawless (Tables XL and XLI). This indicates that complete separation of nest sites into correct status categories is possible. To test the usefulness of these classification criteria as means for identifying suitable nesting habitat, a group of new nest sites in eastern Mexico (for which individual site statuses are known) should be measured and then classified using the discriminant functions derived from the calibration data. The final step would be to use the classification criteria to locate suitable habitat within the United States. The primary objective of the habitat study was to generate measures of habitat quality that would be general enough to compensate for gross differences in plant and animal species composition among the biotic associations inhabited by Aplomado Falcons. Such a general model could then be applied to the objective of determining whether the southwestern United States contains suitable nesting habitat for the Aplomado Falcon.

On the coastal prairies of southern Texas, many oak and mesquite savanna communities appear to be structurally similar to communities inhabited by Aplomado Falcons in eastern Mexico. This is especially true of the terrain between Raymondville and Kingsville, Texas. The average height of trees in this area is probably between 5 and 10 m. Intertree distances would average over 50 m, and the ground cover in many pastures is similar to ground cover at nest sites in Mexico. In western Texas, Arizona, and New Mexico, however, ground cover in open yucca and mesquite grassland associations is generally much less than ground cover in eastern Mexico or southern Texas. Also, in these dryer parts of the Aplomado Falcon's former United States range, average tree height would be much less than at Mexican nest sites. In homogeneous yucca-grassland areas the shape of woody vegetation differs radically from the shape of vegetation in habitat dominated by oaks, huisaches, palms, and other trees. Extensive forests of soaptree yucca dominate many parts of southwestern New Mexico where aplomados formerly occurred. It would definitely be of interest to measure the structure of vegetation in yucca grassland communities, and other desert and subtropical communities in the United States, and then evaluate these communities in terms of their abilities to support nesting Aplomado Falcons. The use of standardized variables (as in this study) might reflect relative habitat measures at different sites within a biome and minimize the importance of absolute differences in vegetational aspects between eastern Mexico and southwestern United States.

The ultimate test of the discriminant predictions would have to involve some sort of program in which aplomados were actually reintroduced to putative suitable habitat. Of course, a reintroduction program would also be one direct approach towards the improvement of the status of the Aplomado Falcon within the United States. Consequently, the models of Aplomado Falcon habitat quality along with the discriminant functions could serve as tools for locating Aplomado Falcon management areas and perhaps eventually lead to the reestablishment of the species in parts of its former United States range.

Biological Significance versus Statistical Significance

Variability caused by factors such as observer error and nest site differences may have obscured all except the most profound differences attributable to levels of site status or site quality. Falcons are surely affected by factors other than those included in the regression models. Some important variables may not have been measured, or else the wrong index may have been used. For example, perhaps distance to the nearest road is a too indirect way of measuring the degree to which sites are disturbed by humans. A better index might have been the rate of automobile and/or pedestrian traffic along roads and trails near nest sites. In addition, because sites examined in this study were used at least once (and recently used) by aplomados, the magnitudes of some variables affecting aplomado habitat quality may have been similar enough among sites so that these variables showed no correlation with habitat quality. In a larger sample of nest sites or in a sample of sites from another part of the range of the Aplomado Falcon, these same variables might turn out to be highly correlated with the quality of nest sites. Also, in other areas, if a larger set of variables were measured, an entirely different set might appear in habitat quality models because of effects due to interaction of floral and faunal associations different from those inhabited by aplomados in eastern Mexico, with the behavioral ecology of the falcon.

To reduce the impact of these types of limitations, it would be necessary to examine nest sites in ecologically diverse parts of the species' range, and measure, at all sites, a great variety of factors thought to affect the quality of habitat used by the aplomado. Only in this way would there be some likelihood of actually erecting a truly comprehensive model containing variables of major biological significance to the species throughout its range.

Finally, it should be remembered that just because a particular variable is not judged to have a significant effect on habitat quality, it does not mean that that variable has no biological importance to the falcon. As mentioned above, sampling error may obscure real patterns in the data. In addition, however, variation due to individual differences among falcons (as this applies to habitat selection) may further obscure patterns that are not due to chance. Fairly large sample sizes may be needed to surmount variation due to factors other than habitat quality. In short, therefore, it is not sufficient to depend solely on the results of statistical techniques when examining Aplomado Falcon habitat requirements and other biological phenomena. It is necessary and natural to apply subjective but pragmatic judgements to considerations of components of habitat of the falcon. In this regard, to conclude this chapter I present the following qualitative assessment of general factors that should be associated with good habitat of the Aplomado Falcon: (1) an adequate supply of suitable nesting platforms; (2) an adequate supply of sufficiently vulnerable prey animals; (3) prey that are not overly contaminated with pesticide residues (particularly DDE); and (4) an area in which prey can be efficiently captured. This hunting area should spatially coincide as much as possible with the location of the nesting area, and should contain: (a) scattered trees that provide perch sites from which sufficient prey can be spotted so that the falcons can capture enough prey to feed themselves and their young; (b) a density of woody vegetation that is low enough so that aplomados can either trap prey in isolated trees or in high-speed aerial pursuits; and (c) ground cover vegetation that is sufficiently sparse so as to not provide perfect refuges to prey of Aplomado Falcons. Obviously these components would interact to some degree. However, for an area to support falcons, interaction between pertinent habitat variables must produce a situation in which the falcons can find food, cover and, at certain times of the year, nest sites. The quantitative data presented in this chapter describe at least one combination of habitat components that "works" for the Aplomado Falcon (at least the northern race). Different combinations could be satisfactory in other parts of the range of the species. At present, however, my data from eastern Mexico must provide the basis for any consideration of the status of the species in the United States since no other information of this sort is presently available.

CHAPTER VI

MANAGEMENT RECOMMENDATIONS

Introduction

From the beginning of my interest in this project, one of my objectives has been to provide a basis for improving the status of the Aplomado Falcon north of Mexico. When I began the present study, the basic ecology of the Aplomado Falcon had not been adequately described. This lack of information was a major obstacle to the development of any sort of comprehensive restoration and/or preservation program. After the last four seasons of field work, however, it is now at least possible to incorporate my familiarity with the behavioral ecology of the Aplomado Falcon into the beginnings of such a program. Presented below are my recommendations of procedures for restoring the species to at least some semblance of its former status in the United States. This is not a detailed management plan, but instead, is a preliminary sketch of programs that might improve habitat for the species in the United States and hasten recolonization of this habitat by the falcons.

Range Management Practices

The data presented in Chapter V quantitatively describe the open savanna in which aplomados nest in eastern Mexico. It would be possible (though time consuming and expensive) to take the data on vegetation structure and use them to create a patch of structurally authentic aplomado habitat. This would be an intensive approach to the restoration of the species in the United States, but could perhaps be instituted economically as part of brush control efforts already underway in many parts of the southwestern United States. An adequate density of properly-spaced trees should be left standing throughout an area that had been cleared of brush. The next step would be to retard the proliferation of woody vegetation and herbaceous vegetation among the ground cover. Periodic mowing or controlled burning might be carried out along with proper applications of grazing pressure to accomplish this objective and maintain vegetational diversity. These are exactly the steps taken (unintentionally) at at least one aplomado nest site in northern Veracruz. This nest site was created from a formerly dense woodland by clearing most of the trees to open up the land for dairy cattle (see Site #9, Table XLVI, Appendix F). Scattered acacias were left standing, however, to provide shade and food (in the form of the seeds of the acacias) for the cattle (Sr. Prospero Duval, personal communication). Not all patches of brush should be opened up, however. Riparian woodlands, and patches of woods and brush should be maintained in the vicinity of a potential nesting area to insure the availability of adequate nesting, and feeding areas for prey species of the Aplomado Falcon.

A less intensive approach to the same problem would require the institution of general guidelines for the protection of prairie lands from overgrazing and erosion, and the selective control of brush in areas once covered by semi-open prairie. Special attention should be given to retarding the proliferation of woody vegetation in grasslands that still remain. Measures should also be taken to protect permanent sources of water and associated vegetation, since watering areas may be of importance to prey of the falcon.

In eastern Mexico and other parts of Latin America, forested areas are rapidly being cleared and converted to pastures and farmland. This process seems to be creating habitat for savanna dwellers, but at the expense of woodland species. Consequently, human land use practices may actually be benefitting the Aplomado Falcon south of the United States. The pattern of vegetational change in the southwestern United States, however, suggests that grassland associations that are grazed heavily may deteriorate. This process could affect the Aplomado Falcon in other parts of its range, just as it probably did in the United States. Obviously, in considering the welfare of the Aplomado Falcon throughout its range, it seems wise to encourage the use of proper range management techniques wherever the birds occur.

Management of Prey

Suitable habitat for Aplomado Falcons must contain an adequate supply of vulnerable prey. Considering the prey species listed in Tables XIII, XV, and XVII, it seems that the aplomado is a generalist. Any program designed to improve the abundance of small birds, and insects, rodents or reptiles would probably improve habitat for Aplomado Falcons. Game birds such as the Mourning and White-winged Doves, and quail are already intensively managed in many areas. Other prey such as the Great-tailed Grackle, Bronzed Cowbird, and other icterids are extremely abundant around agricultural areas in the southwest and might provide a source of food for aplomados attempting to nest near farming areas. Small-scale plantings of sorghum and other plants used as food by granivorous and omnivorous prey, might further improve the quality of management sites not located near agricultural areas.

Nesting Platforms

In West Germany during the 1950's, members of a population of tree-nesting Peregrine Falcons (Falco peregrinus) occupied five or six of fifteen flat willow baskets that had been placed in trees near formerly-used but decrepit stick nests (Mebs 1969). Similarly, artificial nest boxes have been used to increase the density of pairs of nesting European and American Kestrels (Falco tinnunculus and F. sparverius, respectively) (Cave 1968, and Hamerstrom et al. 1973).

This suggests that artificial nesting platforms might be used to insure that adequate nest sites are available in otherwise suitable aplomado habitat. These platforms could be temporary structures such as wicker baskets, or more-or-less permanent. The dimensions of eastern Mexican nests might be used to design these platforms (Table XXXIV). To reduce competition with larger raptors such as the Great Horned Owl (Bubo virginianus), however, it might be advisable to make the platforms slightly smaller than the mean dimensions given in Table XXXIV. Nest dimensions of most importance would probably be maximum outside diameter, nest cup diameter, and nest cup depth. Another approach to the problem of nest site availability would involve considerations of the quality of habitat preferred by raptors like the Swainson's Hawk (*Buteo swainsoni*), White-tailed Hawk (*B. albicaudatus*), and White-tailed Kite (*Elanus leucurus*), that would probably build stick nests that would be used by the falcons. All three of these species, when not nesting in farming regions (this applies primarily to the White-tailed Kite), prefer semi-open grassland associations. The White-tailed Hawk, in fact, may serve as an indicator of suitable aplomado habitat since it nests in yucca and mesquite grassland associations similar to those once occupied by the Aplomado Falcon in southern Texas. Programs that improve habitat for these species might also indirectly benefit the aplomado.

Management Areas in the United States

Prior to beginning any restoration efforts, it would seem reasonable to first locate areas where the Aplomado Falcon may still exist in the United States and/or where its chances of survival are best. In addition, it is necessary to find areas where it is possible to carry out appropriate management procedures. Government-owned lands would seem to provide the best long-term security for this type of project. Alternatively, cooperative private landowners can at times provide a degree of protection not enjoyed by projects conducted on public lands. Privately-owned land may more efficiently restrict unauthorized intrusion by people. Control of access might be an overriding concern on public lands where hunting is permitted.

The areas listed in Table XLII (Appendix C) may presently contain or may have once contained appropriate habitat for the Aplomado Falcon, and all at least lie within my postulated former range of the species (Figure 2). The agencies or individuals responsible for these areas may at least wish to incorporate concerns of the Aplomado Falcon into their overall wildlife management progreams. In addition to the sites listed in Table XLII, several areas recently proposed as Unique Wildlife Ecosystems (USFWS 1979 a, b, and c) may also contain suitable habitat for the aplomado (Table XLIII). Sites mentioned in both these tables should first be surveyed to determine whether aplomados are present, then should be analyzed using the methods described in Chapter V and Appendix G to describe vegetation structure quantitatively. Data from these areas could then be compared with the summary statistics for sites analyzed in eastern Mexico, and finally evaluated with the regression models developed in Chapter V. Conceivably, once certain areas are deemed suitable for nesting Aplomado Falcons, then a remote sensing system such as LANDSAT could be used to search for other patches of suitable habitat.

Restoration of the Aplomado Falcon to the United States

As a result of efforts to improve parts of the southwestern United States for occupancy by Aplomado Falcons, the species might eventually begin a recovery on its own. This recovery could result from the dispersal of falcons from active nest sites in Mexico or the United States (if any still exist here). A quicker, though not necessarily better means for improving the status of the species in the United States would be to reintroduce aplomados to patches of suitable habitat. This could be accomplished by releasing young falcons that have been produced in captivity, or by removing young from nests in eastern Mexico and then introducing them to sites in the United States.

The Aplomado Falcon possesses some traits (flexibility with regard to nest site selection, somewhat social behavior, and a broad tolerance for climatic and habitat conditions) shared by several species that have already produced young in captivity. Accordingly, the species may be relatively easy to breed artificially. In this regard it would be advisable to establish a competently-run and adequately-funded project to produce aplomados for reintroduction to carefully selected release sites.

As a prerequisite for placing young birds in the wild, reintroduction sites should be located where the chances of the birds' survival are good. Potential reintroduction sites should therefore be evaluated using the models of habitat quality presented in Chapter V (also Appendix G). Another factor of concern in the location of reintroduction sites would be the abundance of potential predators (both human and non-human) of aplomados in the vicinity of the release site. Young falcons should not be released close to active nests of Golden Eagles (*Aquila chrysaetos*), Great Horned Owls, Red-tailed Hawks (*Buteo jamaicensis*) or the larger falcons such as the Peregrine or Prairie Falcon. Although adult aplomados are no doubt capable of out-maneuvering and out-flying these species in level flight, inexperienced young, without the protection of the adults, might be especially vulnerable to capture by larger raptors. Finally, release sites should not be located in areas where hunting activity is high. The actual release of birds should be carried out using techniques described by Newton (1979, p. 282).

CHAPTER VII

CONCLUSIONS

It is apparent that the Aplomado Falcon has failed to recover from its earlier decline in the United States. The species may, in fact, no longer nest north of Mexico. The failure of the Aplomado Falcon to return to its former status as a locally common peripheral species indicates that there exists some obstacle to the species' recovery (such as lack of habitat, or pesticide contamination) that may reduce the efficiency with which aplomados from Mexico or the United States can colonize suitable habitat. It therefore seems justified to initiate steps to speed recolonization of the former range of the Aplomado Falcon in the United States by instituting or encouraging measures that improve habiat or by actively reintroducing the species to the United States.

Collection and observation dates for aplomados in the United States suggest that at least some falcons overwintered in this country (Tables VII, VIII, and IX). This is not surprising considering the mild nature of winters in the southwestern United States. Pairs of Aplomado Falcons permanently residing in the United States might receive some protection from pesticide contamination. The presence of a relatively uncontaminated population of aplomados within the United States would be of special importance to the general welfare of the species if populations of Aplomado Falcons in Latin America begin to show signs of reproductive failure. This suggests that there is a need to monitor the reproductive health of aplomados and other bird-eating raptors in parts of Latin America in an effort to detect signs of widespread pesticide-induced reproductive failure.

The short-term goal of a program aimed at restoring and preserving the status of the Aplomado Falcon in the United States would be to establish the species at a few sites that could then serve as dispersal centers from which aplomados could colonize suitable habitat as it becomes available and/or is discovered by the birds. This would provide a basis for the eventual general recovery of the Aplomado Falcon in the United States.

CHAPTER VIII

SUMMARIES OF CHAPTERS II, III, IV, AND V

Chapter II

The Aplomado Falcon was first discovered in the United States during 1852. By the turn of the century, the species was known to nest regularly in parts of Arizona, New Mexico, and Texas. As is typical of the species throughout its range, Aplomado Falcons preferred semi-open grassland areas in the United States. Specimens were collected and nest sites located in the yucca and mesquite savannas of the northern Chihuahuan Desert (in western Texas, southern New Mexico, and southwestern Arizona), and in the Tamaulipan Biotic Province on the lower Texas coast. Aplomados declined in abundance north of Mexico after 1910 or 1920. This decline correlated with the beginnings of widespread brush encroachment. The near extirpation of the species from the United States, however, could have resulted from other factors such as overcollecting, lack of nesting platforms, conversion of prairie to farmland, and a climate that has become significantly warmer and dryer since the nineteenth century. The Aplomado Falcon is now very rare in the United States, but evidently nested in Texas and New Mexico during the late 1940's and early 1950's, and may still manage to nest, undetected, within remote parts of its former range.

Chapter III

Aplomado Falcons nesting in eastern Mexico have been laying thin-shelled eggs since the mid-1950's. Shell membranes of eggs collected in 1977 contained an average of 296.8 ppm DDE wet weight. Shell thickness of eggs collected between 1956 and 1967 averaged 25.4% thinner than eggs collected before 1947. A sample of shell fragments collected during 1977 averaged 24.0% thinner than pre-DDT eggs. If the Aplomado Falcon is similarly contaminated in other parts of its range, then this might explain the species' failure to recover from its early twentieth century declines in the United States. These data also suggest that the species could now be declining in other parts of its range in Latin America.

Chapter IV

As other authors have suggested, prey remains provide biased information about the diet of raptorial birds since they are not equally sensitive to the presence of small and large prey (Errington 1932, and Snyder and Wiley 1976). The mean weight of prey in the sample of prey remains is 23.8 g (40.7%) greater than the mean weight of prey in the sample of observed feeding behavior. Because of this probable bias, observed feeding behavior has been used as the basis for conclusions about the relative contribution of individual species and groups of species to the diet of the Aplomado Falcon in eastern Mexico. Prey most frequently captured by Aplomado Falcons are insects, yet birds comprise the majority of prey biomass. White-winged Doves, Mourning Doves, Groove-billed Anis, Yellow-billed Cuckoos, and Great-tailed Grackles contribute most prey biomass.

Moths, beetles, dragonflies, wasps, cicadas, and locusts are the most commonly eaten insects. Over half of avian prey are insectivorous species. This helps to explain why the Aplomado Falcon is heavily contaminated by pesticides in eastern Mexico. Most prey inhabit open country. Many woodland or brushland species, however, are also captured. Average prey weight for the sample of observed feeding behavior was 23.8 g. The average weight of avian prey was 71.1 g. The largest prey animal was a Chachalaca ($\bar{x}$=829.9 g for 6 specimens). Nestling aplomados eat fewer insects than adults. This suggests that diet studies based only on observations of the young may not accurately reflect the diet of the adults. Compared to other falconiform birds, the hunting activities of aplomados are concentrated close to nest sites (Figure 3). This generalization may not apply to areas where prey abundance or prey vulnerability is low. Insects are nearly always pursued by solo falcons, whereas pair hunting is a strategy applied nearly exclusively to avian prey. When only avian prey are considered, chases involving two pursuers are more successful than chases conducted by only one falcon. Also, pairs of falcons capture larger birds than single falcons. Females hunting with their mates capture larger prey than their partners, solo males, or solo females. Solo males, however, capture larger prey than solo females. These patterns are thought to result from interaction between the size of the two sexes and differences in the roles assumed by each sex during the nesting period. Pair hunting seems to benefit Aplomado Falcons by increasing hunting success, prey size and the efficiency with which highly maneuverable or otherwise difficult-to capture prey are captured; and by reducing the risk of injury to which hunting aplomados are exposed. During hunts, Aplomado Falcons use several hunting strategies. Insect flights are usually slow, short glides, while birds are pursued in rapid horizontal dashes. Factors such as ground cover density and the spacing of woody vegetation may affect the ability of aplomados to capture prey.

Chapter V

Twenty-five variables describing habitat structure were measured at a sample of 18 nesting sites of the Aplomado Falcon in eastern Mexico that were active in 1977, 1978, or 1979, to describe quantitatively the structure of the habitat that the birds used. The typical active nest site contained an average density of 18.9 trees/40 ha. The average inter-tree distance at these sites was 45.7 m. Average tree height for a sample of 228 trees measured at sites occupied by nesting falcons was 9.55 m. The average height for a sample of 376 trees measured at deserted sites was only 7.94 m. Vegetation profiles were similar for all categories of home ranges. Greatest differences in vegetation profiles were between 0.5 and 0.75 m above the ground. At this level, nesting sites contained a lower density of vegetation than poorer sites.

Home ranges were classified three different ways using: (1) site reproductive status; and (2) site occupancy status. Classes of nest sites were then examined to determine whether habitat structure affected site status. Using univariate analysis of variance, it was possible to show that both status variables were affected by some of the components of habitat structure. Vegetation profile measurements were so variable within classes of nest sites that it was not possible to provide support for the hypothesis that vegetation profiles influenced site status. The abundance of birds was highest at nesting sites, but not significantly so.

Nesting platforms used by Aplomado Falcons in eastern Mexico are usually stick platforms constructed by other raptors, and corvids. Platforms such as arboreal bromeliads, however, will also be used by the falcons. Due to the absence of large bromeliads in the northern and dryer parts of the aplomado's range (central Mexico and the United States), the species would be largely dependent upon other birds for nest sites in these areas. Perch trees of Aplomado Falcons are usually taller than surrounding trees. Trees used as plucking perches contain large, horizontally-oriented branches within the inner parts of the crown. Falcons may use the same tree both as an observation post, resting site, and plucking perch.

The habitat variables were selectively incorporated into models of habitat quality, using stepwise multiple regression. The dependent variable in each model was one of the nest site status variables. In all models, tree height was positively correlated with habitat quality. All models contained, in addition, an upper level or overall vegetation profile index that was positively related to habitat quality. In a third model containing a three level dependent variable (nesting, non-nesting, and deserted), vegetation density below 0.875 m showed a negative regression coefficient on habitat quality. Horizontal diameter of tree crowns had a negative coefficient on habitat quality in the model of site occupancy status. All of the models that were generated were interpreted primarily with regard to characteristics of the foraging ecology of the Aplomado Falcon.

Discriminant analysis was used to show that the variables included in the five-variable regression models could be employed to accurately classify nest sites into appropriate status categories. This statistical procedure was able to accurately classify a sample of 12 nest sites studied in 1979. Still, the effectiveness of such a classification regime when applied to dryer grassland associations is open to question. Undoubtedly, however, the use of the descriptive data and habitat models when searching for management areas for the Aplomado Falcon is much preferable to a process of only subjectively or politically designating areas as suitable habitat.

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APPENDIX A

DESCRIPTION OF THE STUDY ANIMAL

(TABLES I, II AND III)

DESCRIPTION OF THE STUDY ANIMAL

Size and Taxonomy

Due to geographic variation in size and coloration, *Falco femoralis* is currently divided into three subspecies (Blake 1977; and my Table I, and Figure 1). The northern race, *F. f. septentrionalis* (Todd), is the subject of this study. This is the palest and largest of the three races. The range of the northern race of the Aplomado Falcon extends south from the United States to Nicaragua (Howell 1972). The nominate race, *F. f. femoralis* (Temminck), occupies the remainder of Central America and most of South America east of the Andes. This subspecies is the smallest of the three races. *F. f. pichinchae* (Chapman) is the third race and inhabits the west coast of South America from Peru and Columbia to Tierra del Fuego, and ranges eastward from the Andes into Uruguay, Paraguay, and Patagonia. This is the darkest of the three forms (Blake 1977).

Northern Aplomado Falcons are intermediate in size between male Prairie Falcons (*F. mexicanus*) and female Merlins (*F. columbarius*) (Tables II and III). In terms of sexual dimorphism in weight (Table II), and wing length (Table III), the Aplomado Falcon is also intermediate between these two congenerics. Degree of sexual dimorphism in birds of prey has been shown to be correlated with the proportion of avian and/or agile prey in the diet (Snyder and Wiley 1976, and Newton 1979).

External Morphology

Proportions

Compared to the Prairie and Peregrine Falcons, the Aplomado Falcon is a rather long-tailed and long-legged species much slimmer than either of these larger falcons. In these respects, the aplomado is more like an accipiter (*Accipiter* sp.) or one of the forest falcons (*Micrastur* sp.) -- both essentially woodland-adapted genera.

Plumage

The Aplomado Falcon bears a distinctive, striped facial pattern made up of a dark streak extending from the posterior corner of each eye to the nape of the neck. Above this mark and separating it from the blackish crown of the head is a white superciliary stripe extending posteriorly to form an indistinct nuchal collar. Like other falcons, aplomados wear a thin, blackish malar stripe beneath each eye. The dorsal coloration is lead-colored, slate-grey, or bluish-grey.

On both adults and first-year birds, a dark abdominal band or cummerbund connects the axillary regions midventrally on the lower breast and upper abdomen. This irregular band contains scattered white barring in adult birds. In many members of the northern race, and in typical members of *F. f. pichinchae*, the cummerbund narrows midventrally and is incomplete in many birds.

The long tail is dark charcoal-grey or black and crossed by eight whitish or buff-colored bars that form a series of concentric arcs when the tail is spread.

The Aplomado Falcon in Flight

In flight and overhead, the Aplomado Falcon displays dark wing linings marked with many white or buff bars. The cummerbund forms an extensively dark axillary region reminiscent of the axillars of a very well-marked Prairie Falcon. Like the American Kestrel (*Falco sparverius*) and Mississippi Kite (*Ictinia mississippiensis*), aplomados have fairly long wings that are relatively narrow near the body. This narrowness proximal to the body accentuates the length of the tail. A white terminal line is present on the margins of the secondaries, and can be seen from behind and on about the same level as a perched or flying falcon. This same mark is also present on the Mississippi Kite.

First-Year Plumage

Nestlings begin life covered with white or pale grey down. At approximately two weeks of age the second down appears and is dark grey, much like the down of young Great Horned Owls (*Bubo virginianus*). This change to grey down also occurs in the Merlin, Saker (*Falco cherrug*), and New Zealand Falcon (*F. novaezeelandiae*) (Brown and Amadon 1972).

At fledging, about four to five weeks after hatching, aplomados are patterned similar to the adults, except that the upper breast, wing and tail barring, and margins of the contour feathers are usually cinnamon or buff-colored and occasionally white. The upper breast in fledglings is covered with broad, dark streaks that may obscure much of the ground color and form a continuous dark area on the central portion of the breast.

At the end of the first molt, light-colored barring appears on the abdominal band, then may increase slightly in density after each subsequent molt. Unlike the bars on the tail and wings, barring on the cummerbund is white or pale buff as soon as it first appears. While first-year falcons may be brownish-grey dorsally, older falcons are bluish-grey. The streaking on the upper breast seems to decrease in density with each molt until the upper breast is nearly immaculate. Birds over one year of age may be streaked on the upper breast, but these markings are not as broad or coalesced as in the first-year plumage. In adults, the cere and eyerings are a brilliant yellow-orange, while in recently-fledged falcons these structures are a light bluish shade. As the young grow older, this color changes to a pale yellow and eventually matches the color of the feet and tarsi. Feet and tarsi in first-year aplomados are pale yellow, not the bright orange-yellow color characteristic of the fleshy parts of adult falcons.

Summary

Falco femoralis is divided into three geographic races. The northern race, *F. f. septentrionalis* (Todd), is the subject of this study, and is the largest and palest of the three subspecies. With regard to overall size and sexual dimorphism, the northern Aplomado Falcon is intermediate between the Prairie Falcon and Merlin. Aplomados are distinctively marked and proportioned. Definitive field marks are: (1) striped facial pattern; (2) dark abdominal band; (3) wings relatively narrow close to the body; (4) long, barred tail; (5) long, accipiter-like tarsi; and (6) a white terminal band on the tips of the secondaries. Young falcons are first covered by a white natal down that is replaced by grey down at two weeks of age. Between their fledging date and the end of the first molt, aplomados are characterized by: (1) heavy streaking on the upper breast; (2) narrow cinnamon, buff, or whitish barring on the remiges and retrices; and (3) bluish cere and eyerings.

TABLE I

CHARACTERS THAT DISTINGUISH THE THREE SUBSPECIES OF THE APLOMADO FALCON (*FALCO FEMORALIS*). MEASUREMENTS WERE TAKEN FROM SPECIMENS AT THE FIELD MUSEUM OF NATURAL HISTORY.

Subspecies	N(males)/ N(females)	$\bar{X}$ Wing for Males (mm)	$\bar{X}$ Wing for Females (mm)	Color Pattern	
				Cummerbund	Dorsum
Falco femoralis femoralis	18/8	235.17 (223-250) s=7.12	263.12 (254-274) s=6.64	undivided	intermediate
F. f. pichinchae	7/8	268.00 (250-280) s=9.01	291.87 (275-318) s=14.01	usually divided	darkest
F. f. septentrionalis	5/6	257.50 (251-262) s=3.86	274.50 (255-290) s=14.72	narrows mid-ventrally	palest

TABLE II

WEIGHT SEXUAL DIMORPHISM IN NORTH AMERICAN FALCONS (EXCLUDING F. RUFIGULARIS AND F. DEIROLEUCUS). MEASUREMENTS ARE IN GRAMS. SPECIES RANKED BY SIZE. (AFTER SNYDER AND WILEY 1976).

Species	$\bar{X}$ (female)	$\bar{X}$ (male)	N(males)/ N(females)	Dimorphism Index*
Falco rusticolus	1,752.0	1,170.0	?/?	13.6
F. peregrinus tundrius	952.0	610.0	12/19	14.7
F. mexicanus	801.0	495.7	10/34	15.8
F. femoralis septentrionalis	406.7	260.5	7/6	14.8
F. c. columbarius	213.3	157.6	14/15	10.0
F. sparverius	119.0	109.0	50/67	2.9

*Dimorphism Index $=(2(\bar{X}(\text{female})^{1/3} - \bar{X}(\text{male})^{1/3})/(\bar{X}(\text{female})^{1/3} + \bar{X}(\text{male})^{1/3})) \times 100$ (Storer 1966).

TABLE III

WING SEXUAL DIMORPHISM IN NORTH AMERICAN FALCONS (EXCLUDING *F. RUFIGULARIS* AND *F. DEIROLEUCUS*). MEASUREMENTS ARE IN MILLIMETERS. SPECIES RANKED BY SIZE. (AFTER SNYDER AND WILEY 1976).

Species	$\bar{X}$ (female)	$\bar{X}$ (male)	N(males)/ N(females)	Dimorphism Index*
F. rusticolus	404.0	364.0	20/20	10.4
F. peregrinus tundrius	351.8	308.3	64/62	13.2
F. mexicanus	347.4	304.3	20/20	13.2
F. femoralis septentrionalis	284.7	257.5	6/4	10.0
F. columbarius columbarius	207.6	187.8	50/64	10.0
F. sparverius	193.8	185.3	87/65	4.5

*Dimorphism Index = $(2(\bar{X}(\text{female}) - \bar{X}(\text{male}))/(\bar{X}(\text{female}) + \bar{X}(\text{male}))) \times 100$ (Storer 1966).

APPENDIX B

DESCRIPTION OF THE STUDY AREA

(TABLES IV AND V)

DESCRIPTION OF THE STUDY AREA

Nesting areas of the Aplomado Falcon were located on the eastern coast of Mexico (Figure 1). Five home ranges were in northern Veracruz. An additional nine sites were scattered through parts of eastern Tabasco, northern Chiapas, and western Campeche. Nesting areas examined in this study are located between 17-23° N Latitude and 91-99° W Longitude.

Topography

All sites were below 150 m elevation on Mexico's gulf-coastal plain. The terrain is gently rolling but gradually slopes toward the gulf. Many sluggish, meandering streams dissect this area. In northern Veracruz, stock ponds are common in the vicinity of nest sites. Farther south, marshes are situated near a number of sites. Due to the seasonality and magnitude of rainfall in eastern Mexico, pastures studied during the dry season may be flooded at times during the rainy season.

Climate

Nest sites in southern Mexico and central Veracruz are exposed to a slightly hotter and wetter climate than the northern Veracruz sites (Tables IV and V). At Tampico, for example, the average annual mean temperature for a thirty year period (1941-1970) was 24.2°C. Annual precipitation for this same period averaged 985.0 mm. To the south, at Veracruz City, the average temperature was 25.4°C and average annual precipitation was 1,710 mm (Anguiano 1977).

The gulf-coastal plain of eastern Mexico shows distinct wet and dry seasons (Table V). At Tampico, total monthly precipitation increases from 41.8 mm in May to about 128.6 mm in June. Average monthly rainfall finally peaks at 286.5 mm for the month of September. Minimum monthly precipitation is received in March (13.6 mm). Generally, the dry season begins in November and continues into May. Rainfall increases in May then peaks sometime between June and October. My data were collected during the latter part of the dry season and early part of the rainy season in March, April, May, and June of 1977; April of 1978; and May and June of 1979.

Floral Components of Nesting Habitat

In eastern Mexico, I have found Aplomado Falcons in the following plant associations: palm savanna; oak savanna; acacia savanna; and cut-over rainforest. Pennington and Sarukhan (1968) provide detailed descriptions of the palm savanna ("palmares"); oak savanna ("encinares"); and crescentia savanna ("sabana"). Brief descriptions of these associations are presented below.

Oak Savanna

Three sites were in oak savanna (Appendix F, Sites 4, 10, and 13). This association is dominated by encino (Quercus oleoides). Other distinctive trees include: strangler figs such as Ficus glaucescens; chacah (Bursera simaruba); ceiba (Ceiba petandra); palo de rosa (Tabe-

buia rosea); *carnero* (*Coccoloba barbadensis*); and *guácima* (*Guazuma ulmifolia*).

Palm Savanna

Three sites were in palm savanna (Appendix F, Sites 2, 12, and 21). These areas are dominated by the mexican fan palm or *palma redonda* (*Sabal mexicana*). The vegetation at a few other sites is dominated by palms such as *coyol espinosa* (*Acrocomia mexicana*) or *coyol real* (*Scheelia liebmannii*). These sites, however, include elements of other plant associations such as the oak savanna and crescentia savanna.

Acacia Savanna

Huisache (*Acacia farnesiana*) dominates most sites in northern Veracruz (Appendix F, Sites 8, 9, 16, 17, and 22). This acacia also appears in savanna communities in Tamaulipas and southern Texas. One Veracruz site (No. 17) even contains a few spanish daggers (*Yucca treculeana*), the same species used as nest trees by Aplomado Falcons in southern Texas. Other plants found with *Acacia farnesiana* in northern Veracruz include: *ebano* (*Pithecellobium flexicaule*); *frijolillo* (*P. arboreum*); *guamúchil* (*P. dulce*); *guanacaste* (*Enterolobium cyclocarpum*); *palma redonda* (*Sabal mexicana*); and *guajilote* (*Parmentiera edulis*).

Crescentia Savanna

As my own term for this association implies, *jícaro* (*Crescentia cujete*) is the apparent dominant of what Pennington and Sarukhan (1968) term simply "*sabana*". Two pairs of Aplomado Falcons were discovered in this plant association at sites in western Campeche (Appendix F, Sites 19, and 23). These areas also contain White-tailed Hawks (*Buteo albicaudatus*), White-tailed Kites (*Elanus leucurus*), and Crested Caracaras (*Polyborus plancus*) -- essentially the same raptors found with the Aplomado Falcon in southern Texas during the early twentieth and late nineteenth centuries.

Jícaro is a small tree that rarely reaches four meters in height. It forms extensive savannas in western Campeche, northern Chiapas, western and eastern Tabasco, and southern Veracruz. Other trees found in the same association include: *nanche* (*Byrsonima crassifolia*), *carnero* (*Coccoloba barbadensis*), *tachicón* (*Curatella americana*), *Crescentia alata*, and *guarumbo* (*Cecropia obtusifolia*).

In western Campeche and northern Chiapas, crescentia savanna occurs in flat, seasonally flooded areas containing primarily a ground cover of short grass and sedges (less than half a meter in height). These areas contain scattered groves of mexican fan palms (*Sabal mexicana*) as well as scattered patches of rain forest.

Cut-over Rain Forest

Several sites in Chiapas, Campeche, and Tabasco are located in terrain once covered by tropical rain forest (Appendix F, Sites 20, 11, 3, and 1). Many of these areas contain stands of dead trees -- all killed by fire or girdling. Parts of northern Chiapas where aplomados nest, are covered by patches of surviving rain forest trees, stands of charred snags, extensive marshes, palm savanna, oak savanna, and crescentia savanna. The areas referred to as "cut-over rain forest" contain dead rain forest trees as well as surviving rain forest trees such as *Ceiba petandra* and *bellota* (*Sterculia apetala*). In these areas, a mixture of rain forest and savanna-adapted birds can be found living in close proximity to one another.

Similarities Among Plant Associations:

Vegetation Structure

Plant associations described above are structurally similar. All contain an open overstory of woody vegetation and a shallow understory of herbs and forbs. This characterization seems to fit most plant associations inhabited by the aplomado throughout its range. This suggests that the aplomado is probably more sensitive to details of habitat structure than to habitat species composition.

Human Land Use

The gulf-coast of eastern Mexico is densely populated with people and contains some of the country's most productive agricultural lands and mineral deposits. Slightly over four million people live in the state of Veracruz and this is the most heavily populated state in Mexico. Using 1970 estimates, the average population density for Veracruz is 56.59 individuals/km^2. A total of nearly seven million people live in the four states in which nests have been located. These states encompass 227,477 km^2 of land and contain an estimated human population density of 29.26 individuals/km^2 (Torres 1970a,b,c, and d).

Much of Mexico's petroleum deposits have been discovered off the east coast. Pumping stations and small storage facilities are commonplace in coastal pastures and farmlands, and large refineries have been established near most coastal cities. The ports of Tampico, Veracruz, and Minatitlán-Coatzacoalcos are the busiest in Mexico (West and Augelli 1966). The high commercial productivity of this region is reflected by heavy trucking traffic on the highways near many aplomado nest sites and by signs of rapid development throughout the area.

Ranching is the dominant land use in eastern Mexico, and is devoted both to the production of beef and dairy products. Farming is carried out on floodplains of streams in this region. Principal crops are sugarcane, corn, bananas, oranges, watermelons, cantaloupes, and coconuts. Papayas, mangos, avocados, coffee, and tobacco are also produced in this region. Several active nest sites were located adjacent to fields of sugarcane, melons, orange groves, and corn.

TABLE IV

CLIMATIC DATA FOR WEATHER STATIONS LOCATED NEAR NEST SITES OF THE APLOMADO FALCON (FALCO FEMORALIS). VALUES ARE ANNUAL AVERAGES FOR THE PERIOD 1941-1970.

Station	Latitude (N)	Longitude (W)	Elevation (m)	Temperature (°C)	Relative Humidity	Precipitation (mm)
Tampico, Tamaulipas	22°13'	97°51'	12	24.2 (20.1-27.9)	80	985.9
Veracruz City, Veracruz	19°12'	96°51'	16	25.4 (22.1-28.3)	79	1,710.0
Campeche City, Campeche	19°51'	90°33'	5	26.4 (22.4-30.1)	76	1,094.0

TABLE V

AVERAGE MONTHLY TEMPERATURES (°C) AND TOTAL MONTHLY PRECIPITATION (MM) FOR WEATHER STATIONS LOCATED NEAR NEST SITES OF THE APLOMADO FALCON FOR THE PERIOD 1941-1970 (ANGUIANO 1976).

Station	Average Monthly Temperatures and Precipitation											
	J	F	M	A	M	J	J	A	S	O	N	D
Tampico, Tamaulipas												
Temperature -	18.5	20.0	21.8	24.8	26.8	27.5	27.9	28.2	27.3	26.0	22.2	19.9
Precipitation -	28.5	15.6	13.6	20.7	40.8	128.6	122.0	123.9	286.5	132.3	47.6	24.8
Veracruz City, Veracruz												
Temperature -	21.5	22.1	23.4	25.8	27.4	28.0	27.8	28.2	27.7	26.5	24.3	22.6
Precipitation -	19.5	14.4	18.4	16.0	64.7	272.4	386.7	298.8	354.2	174.9	62.6	27.4
Campeche City, Campeche												
Temperature -	23.5	24.3	26.1	27.8	28.5	28.7	28.0	28.0	27.7	26.7	24.8	23.6
Precipitation -	17.2	12.5	13.2	10.1	60.5	152.4	206.0	201.0	221.0	119.0	53.9	26.6

APPENDIX C

TABLES VI–XLIV

TABLE VI

TEMPORAL DISTRIBUTION OF 420 EGGS OF THE APLOMADO FALCON (FALCO FEMORALIS) COLLECTED IN THE UNITED STATES AND MEXICO. THE NUMBER OF CLUTCHES IS EQUAL TO THE NUMBER OF SETS CLAIMED TO HAVE BEEN COLLECTED. THIS NUMBER MAY UNDERESTIMATE THE THE ACTUAL NUMBER OF CLUTCHES TAKEN BETWEEN 1890 AND 1910 (SEE CHAPTER II).

Decade	Mexico		United States		Totals	
	Eggs	Clutches	Eggs	Clutches	Eggs	Clutches
1880-1889	0	0	5	3	5	3
1890-1899	7	2	97	36	104	38
1900-1909	16	4	205	69	221	73
1910-1919	0	0	24	10	24	10
1920-1929	0	0	13	4	13	4
1930-1939	0	0	8	2	8	2
1940-1949	0	0	3	1	3	1
1950-1959	15	5	0	0	15	5
1960-1969	27	12	0	0	27	12
TOTALS	65	23	355	125	420	148

TABLE VII

A LISTING OF APLOMADO FALCONS (FALCO FEMORALIS) OR SPECIMENS OF THIS SPECIES (EGGS OR SKINS) COLLECTED OR OBSERVED WITHIN THE STATE OF TEXAS. (SEE APPENDIX E FOR AN EXPLANATION OF SPECIMEN ID NUMBERS).

Dates	Location	Evidence	Reference
Between 1853 and 1875(?)	Pecos River, County Unknown	Immature male collected by W. W. Anderson	NMNH 12497
1876	Cameron, County	Birds observed by J.C. Merrill	Merrill 1878
June 1877	Palo Alto Prairie, Cameron County	Three eggs collected by Merrill	Merrill 1878
May 1878	Palo Alto Prairie, Cameron County	Three eggs collected by Merrill	Merrill 1878
1877-1878(?)	Hidalgo County	One egg collected by Finley	Merrill 1878
February 1881	Pt. Isabel, Cameron County	Adult male and female collected by R.D. Camp	MCZ 206467, AMNH 80814
July 1890	Alpine, Brewster County	Immature female collected	NMNH 141151
1890-1910	Lower Rio Grande Valley primarily in Cameron County	Numerous skins and eggs collected by F.B. Armstrong and assistants	specimens in many museums and private collections
May 1900	Jeff Davis County	One egg collected by Jim and Jo Carroll	WCH 25662

TABLE VII (Continued)

Dates	Location	Evidence	Reference
December 1900	Bellville, Austin Co.	Adult male collected	VPSU
June 1904	Midland Co.	Three eggs collected by J.C. Burkett	AMNH 8377
April 1912	Falfurias, Brooks Co.	Three eggs collected by E.F. Pope	WFVZ
April 1923	11 mi. E of Brownsville, Cameron Co.	Three eggs collected by R.D. Camp	WFVZ
April 1924	Cameron Co.	Male collected by R.D. Camp	UMMZ 55683
May 1927	Cameron Co.	Three eggs collected by R.D. Camp	WFVZ
September 1927	Cameron Co.	Bird collected by R.D. Camp	CMNH 27776
April 1928	"near coast", Cameron Co.	Four eggs collected by R.D. Camp	WFVZ
May 1935	Johnson Ranch, Big Bend National Park, Brewster Co.	Bird observed by G.M. Sutton and J. van Tyne	Sutton and Van Tyne 1937
August 1935	Pt. Isabel, Cameron Co.	Bird collected by H.H. Kimball	Oberholser 1974

TABLE VII (Continued)

Date	Location	Evidence	Reference
December 1937	El Paso Co.	Bird observed by J.M. Kirksey	Oberholser 1974
December 1938	El Paso Co.	Bird observed by J.M. Kirksey	Oberholser 1974
April 1941	32.5 mi. N Edinburg, Brooks Co.	Three eggs collected by F. Nyc J. Peterson	WFVZ
December 1950	Presidio Co.	Pair of probable adults observed by A. Small, H. Clarke, and R. Pyle	A. Small (personal communication)
February 1952	Mariscal Mine, Big Bend National Park, Brewster Co.	Bird observed by K. Haller and P. Koch	Oberholser 1974, and Wauer 1973
July 1955	Welder Wildlife Refuge, San Patricio Co.	Bird observed by C. Cottam	Oberholser 1974
February 1957	Welder Wildlife Refuge, San Patricio Co.	Bird observed by C. Cottam	Oberholser 1974
July 1957	Welder Wildlife Refuge, San Patricio Co.	Bird observed by C. Cottam	Oberholser 1974
1950's	Laguna Atascosa Wildlife Refuge, Cameron Co.	At least one bird observed during the 1950's by L.C. Goldman	Oberholser 1974
January 1954	Cameron Co.	Bird observed by Col. Meredith	Field notes of Meredith

TABLE VII (Continued)

Date	Location	Evidence	Reference
1950's	S of Alpine, Brewster Co.	Adult observed on roadside by W.G. Hunt	W.G. Hunt (personal communication)
1950's	Alpine, Brewster Co.	Adult observed near town	W.G. Hunt (personal communication)
October 1963	North Padre Island, Kleberg Co.	Bird observed by K. Riddle	K. Riddle (personal communication)
September 1971	Roma, Starr Co.	Pair observed by A.D. Wood	Oberholser 1974
November 1971	Bullis Gap, Brewster Co.	Bird observed by E.C. Fritz	Oberholser 1974
April 1972	Boca Chica, Cameron Co.	Bird observed by E.T. Masthay and others	Webster 1972
April 1972	Mission, Hidalgo Co.	Bird observed by G. Donohue	Webster 1972
1973	Aransas Wildlife Refuge, Aransas Co.	Bird observed several times by L. Marlatt	Webster 1973

TABLE VIII

A LISTING OF APLOMADO FALCONS (FALCO FEMORALIS) OR SPECIMENS OF THIS SPECIES (EGGS OR SKINS) COLLECTED OR OBSERVED WITHIN THE STATE OF NEW MEXICO. (APPENDIX E FOR AN EXPLANATION OF SPECIMEN ID NUMBERS).

Date	Location	Evidence	Reference
March 1853	Hidalgo, Luna or Dona Ana Co.	Observations of birds and one specimen collected by A.L. Heerman	Heerman 1854
August 1875	Fort Bayard, Grant Co.	Adult Female collected by by F. Stephens	SDNH 361 and Bailey 1928
June 1886	Hachita, Grant Co.	Pair of falcons observed by Anthony	Anthony 1892 and Bailey 1928
April 1892	Lake Palomas (Just S New Mexico in Chihuahua, Mexico)	Adult male collected by Mearns	NMNH 126466, and Bailey 1928
June 1908	10 mi. E Rincon (Jornada del Muerto), Dona Ana Co.	Several active nests located by Ligon	Bailey 1928
July 1908	Hachita, Grant Co.	Adult collected by Goldman	USNM 204470
August 1908	Hatchet Ranch in the Playas Valley	Bird observed by Goldman	Bailey 1928
June 1909	10 mi. E Rincon (Jornada del Muerto), Dona Ana Co.	Several active nests located by Ligon	Bailey 1928

TABLE VIII (Continued)

Date	Location	Evidence	Reference
June 1917	45 mi. S. Alamogordo, Otero Co.	Adult female collected by Ligon	USNM 268932
August 1917	25 mi. N. Engle, Sierra Co.	Two birds observed by Ligon	Bailey 1928
September 1917	3 mi. SW Nutt, Luna Co.	Adult male and female collected collected by Ligon	USNM 268934 and USNM 268933
November 1918	N. of Engle, Sierra Co.	Male and female observed by Ligon and Fisher	Ligon 1961
December 1918	10 mi. NE Engle, Sierra Co.	One bird observed by Ligon	Bailey 1928
September 1918	20 mi. SE Silver City, Grant Co.	Bird observed by Ligon	Bailey 1928
May 1919	30 mi. SE Silver City, Luna Co.	Adult male collected by Ligon	CMNH 45
June 1924	Tadpole Ranch, 4 mi. N Separ, Grant Co.	Two adult males and one adult female collected by R.T. Kellogg	CMNH 46 & 47; and MVZ 99931
May 1924	15 mi. SE Cutter, Sierra Co.	Adult male collected by Ligon	YPM 70164
September 1928	Warm Springs, 20 mi. SE Silver City	Bird collected by J.S. Ligon	CMNH 48

TABLE VIII (Continued)

Date	Location	Evidence	Reference
October 1939	4 mi. S Animas, Hidalgo Co.	Immature male collected by A. Toomey	CMNH 124726
May 1952	Luna Co., and S of Hidalgo Co. in Chihuahua	Two nests discovered by A. Bayne	J. Hubbard (personal communication), and Ligon 1961
May 1962	Lea Co.	Two birds observed by Harris	Harris 1964
July 1968	100 mi. NE El Paso, Otero Co.	Bird observed by K. Riddle	Riddle (personal communication)
May 1975	W. El Paso in Dona Ana Co.	Bird observed by L.A. Nymeyer	J. Hubbard (personal communication)
March 1977	Hidalgo Co.	Bird observed by R.T. Scholes	J. Hubbard (personal communication)

TABLE IX

A LISTING OF APLOMADO FALCONS (FALCO FEMORALIS) OR SPECIMENS OF THIS SPECIES (EGGS OR SKINS) COLLECTED OR OBSERVED WITHIN THE STATE OF ARIZONA. (SEE APPENDIX E FOR AN EXPLANATION OF SPECIMEN ID NUMBERS).

Date	Location	Evidence	Reference
1874	SE near Fort Bowie, Cochise Co.	Aplomados observed on five separate occasions by Henshaw	Henshaw 1875
April 1887	Fort Huachuca, Cochise Co.	Two active nests located by Benson	Bendire 1887
May 1887	Fort Huachuca, Cochise Co.	Three active nests located by Benson	Bendire 1887
1910	Near Tucson, Pima Co.	Bird observed by Lusk	Visher 1910
February 1910	San Pedro River, near Fairbanks, Cochise Co.	bird observed by Willard	Willard 1910
November 1939	SE McNeal in Sulphur Springs Valley, Cochise Co.	adult observed by Monson	Monson 1942
October 1940	San Pedro River, near St. David, Cochise Co.	Bird observed by Huey	Phillips, et al. 1964
1970, 1971, and 1975	Cochise Co.	Several sightings made by Balch and others	Balch 1975

TABLE X

ANALYSIS OF VARIANCE TABLE. TEST OF EFFECT OF LATITUDE AND COLLECTOR ON THE SIZE OF APLOMADO FALCON (FALCO FEMORALIS) CLUTCHES COLLECTED IN NORTH AMERICA. A FACTORIAL DESIGN USED IN THIS ANALYSIS, WITH TWO LEVELS PER FACTOR (SEE CHAPTER II).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio	Probability of Greater F
Corrected Total	132	108.7067	-	-	-
Treatments	3	34.2334	11.4111	19.77	0.0001
Latitude	1	0.1222	0.2117	0.21	0.6463
Collector	1	17.6131	17.6131	30.51	0.0001
Interaction	1	0.8586	0.8586	1.49	0.2249
Error	129	74.4734	0.5773	-	-

TABLE XI

SUMMARY STATISTICS FOR DATA USED TO CREATE THE ANALYSIS OF VARIANCE TABLE PRESENTED IN TABLE X. DATA ARE NUMBERS OF CLUTCHES, AND MEAN AND STANDARD DEVIATION OF CLUTCH SIZE FOR 133 SETS OF EGGS OF THE APLOMADO FALCON COLLECTED WITHIN MEXICO OR THE UNITED STATES.

Latitude	Collector								
	Armstrong			Others			Totals		
	n	$\bar{X}$	s	n	$\bar{X}$	s	n	$\bar{X}$	s
Tropical	4	4.00	0	17	2.47	0.87	21	2.76	0.99
Subtropical	84	3.62	0.51	28	2.64	1.22	112	3.37	0.86
Totals	88	3.64	0.51	45	2.58	1.09	133	3.28	0.91

TABLE XII

TEMPORAL DISTRIBUTION OF COLLECTION DATES OF SKINS OF THE APLOMADO FALCON (*FALCO FEMORALIS*) COLLECTED IN THE UNITED STATES AND MEXICO.

Decade	Mexico	United States	Total
1870–1879	0	1	1
1880–1889	2	10	12
1890–1899	4	9	13
1900–1909	6	9	15
1910–1919	0	17	17
1920–1929	1	8	9
1930–1939	3	1	4
1940–1949	4	1	5
1950–1959	8	0	8
1960–1969	5	0	5
Totals	33	56	89

TABLE XIII

PREY OF THE APLOMADO FALCON (*FALCO FEMORALIS*) AS PRESENTED IN THE LITERATURE.

Prey	Location	Race	Reference
Locusts	Southern Texas	*F.f. septentrionalis*	Brooks 1933
Dickcissels (*Spiza americana*) and bats	Trinidad and Tobago	*F.f. femoralis*	Ffrench 1973
Insects and small birds	Trinidad and Tobago	*F.f. femoralis*	Herklots 1961
Plovers, sandpipers, pigeons, doves, nighthawks, and humming-birds	Venezuela	*F.f. femoralis*	Friedmann and Smith 1950 and 1955
A wren (*Campylorhynchus* sp.), snipe (*Gallinago* sp.), and Antshrike (*Thamnophilus* sp.). Also beetles, a small fish, and a small mammal.	Venezuela	*F.f. femoralis*	Cherrie 1916
Lark Bunting (*Calamospiza melanocorys*), and a Lark Sparrow (*Chondestes grammacus*)	New Mexico	*F.f. septentrionalis*	Ligon, MS Notes 1909
Dragonflies, cricket and a Horned Lark (*Eremophila alpestris*)	New Mexico	*F.f. septentrionalis*	R.T. Kellogg in Bailey 1928
Small reptiles, mice and other rodents, grasshoppers, other insects and an occasional bird.	Texas	*F.f. septentrionalis*	Bendire 1887

TABLE XIII (Continued)

Prey	Location	Race	Reference
bats	New Mexico	*F.f. septentrionalis*	Ligon 1961
Quail, ground doves, "smaller species of ducks", pigeons, and sandpipers	Western Mexico	*F.f. septentrionalis*	Grayson in Lawrence 1874
"Aplomado Falcons are bird hunters, doves and quail being common food. They also take lizards and mice"(p. 228).	Panama	*F.f. femoralis*	Wetmore 1965
Plain-breasted Ground-dove (*Columba minuta*)	Nicaragua	*F.f. femoralis*	Howell 1972
Tinamou and smaller birds. ". . . paying comparatively little attention to mammals or reptiles"(p. 271).	Chile	*F.f. pichinchae*	Johnson 1965
Frogs, insects, butterflies, wasps, bees, beetles, and locusts	Surinam	*F.f. femoralis*	Haverschmidt 1968
beetles	Brazil	*F.f. femoralis*	Mitchell 1957
birds	Columbia	*F.f. femoralis*	Miller 1947

TABLE XIV

SAMPLING EFFORT AT APLOMADO FALCON NEST SITES. N = NUMBER OF PREY COLLECTED PER NEST SITE. SEE APPENDIX F, TABLE XLVI, FOR BACKGROUND INFORMATION ON NEST SITES.

Nest Site	Prey Remains		Observed Feeding Behavior	
	N	%	N	%
5	12	4.69	13	5.56
6	11	4.30	26	11.11
7	6	2.34	35	14.96
8	17	6.64	36	15.38
9	41	16.02	66	28.21
10	22	8.59	5	2.14
18	59	23.05	37	15.81
Remainder (14 sites)	88	34.37	16	6.84
Totals	256		234	

TABLE XV

SPECIES IN PREY REMAINS COLLECTED AT NEST SITES OF THE APLOMADO FALCON (*FALCO FEMORALIS*) IN EASTERN MEXICO. SPECIES ARE RANKED BY PERCENTAGE OF TOTAL PREY WEIGHT. NUMBER IN PARENTHESES IS RANK BY PERCENT OF TOTAL INDIVIDUALS.

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
1. Mourning Dove (*Zenaida macroura*)	126	27	10.55 (1)	16.16
2. White-winged Dove (*Z. asiatica*)	168	13	5.08 (6)	40.38
3. Groove-billed Ani (*Crotophaga sulcirostris*)	83	25	9.77 (2)	9.86
4. Female Great-tailed Grackle (*Quiscalus mexicanus*)	130	14	5.47 (5)	8.65
5. Yellow-billed Cuckoo (*Coccyzus americanus*)	57	19	7.42 (4)	5.15
6. Great-tailed Grackle (*Q. mexicanus*) sex unknown	190	5	1.95 (10)	4.51
7. Bobwhite (*Colinus virginianus*)	156	6	2.34 (9)	4.45
8. Meadowlark (*Sturnella* sp.)	101	9	3.52 (8)	4.32
9. Chachalaca (*Ortalis vetula*)	830	1	0.39 (40)	3.94
10. Male Great-tailed Grackle (*Q. mexicanus*)	251	3	1.17 (19)	3.58
11. Melodious Blackbird (*Dives dives*)	97	5	1.95 (11)	2.30

TABLE XV (Continued)

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
12. Unidentified *Zenaida* sp.	147	3	1.17 (20)	2.10
13. Unidentified *Columbina* sp.	40	11	4.30 (7)	2.09
14. Unidentified Passerines (20 g Size Class)	20	20	7.81 (3)	1.90
15. Golden-fronted Woodpecker (*Centurus aurifrons*)	75	5	1.95 (12)	1.78
16. Clay-colored Robin (*Turdus grayi*)	79	4	1.56 (15)	1.78
17. Great Kiskadee (*Pitangus sulphuratus*)	74	3	1.17 (21)	1.05
18. Squirrel Cuckoo (*Piaya cayana*)	107	2	0.78 (28)	1.02
19. Altamira Oriole (*Icterus gularis*)	69	3	1.17 (22)	0.98
20. Common Ground-dove (*Columbina passerina*)	40	5	1.95 (13)	0.95
21. Pale-vented Pigeon (*Columba cayennensis*)	200	1	0.39 (41)	0.95
22. Bronzed Cowbird (*Molothrus ater*)	60	3	1.17 (23)	0.86
23. Tropical Kingbird (*Tyrannus melancholicus*)	43	4	1.56 (16)	0.82
24. Pauraque (*Nyctidromus albicollis*)	55	3	1.17 (24)	0.78
25.American Robin (*Turdus migratorius*)	73	2	0.78 (29)	0.69
26. Aztec Parakeet (*Aratinga astec*)	62	2	0.78 (30)	0.59

TABLE XV (Continued)

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
27. Unidentified Tyrannidae	40	3	1.17 (25)	0.57
28. Grayish Saltator (*Saltator coerulescens*)	58	2	0.78 (31)	0.55
29. Whip-poor-will (*Caprimulgus vociferus*)	57	2	0.78 (32)	0.54
30. Common Flicker (*Colaptes auratus*)	113	1	0.39 (42)	0.54
31. Hooded Oriole (*Icterus cucullatus*)	27	4	1.56 (17)	0.51
32. Great-crested Flycatcher (*Myiarchus crinitus*)	34	3	1.17 (26)	0.48
33. Black-headed Saltator (*Saltator atriceps*)	83	1	0.39 (43)	0.39
34. Nighthawk (probably *Chordeiles acutipennis*)	80	1	0.39 (44)	0.38
35. Acorn Woodpecker (*Melanerpes formicivorous*)	76	1	0.39 (45)	0.36
36. Northern Oriole (*Icterus galbula*)	38	2	0.78 (33)	0.36
37. Citreoline Trogon (*Trogon citreolus*)	75	1	0.39 (46)	0.36
38. Unidentified Picidae	75	1	0.39 (47)	0.36
39. Eastern Kingbird (*Tyrannus tyrannus*)	37	2	0.78 (34)	0.35
40. Swainson's Thrush (*Catharus ustulatus*)	31	2	0.78 (35)	0.29
41. Killdeer (*Charadrius vociferus*)	60	1	0.39 (48)	0.29

TABLE XV (Continued)

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
42. Orchard Oriole (Icterus spurius)	20	3	1.17 (27)	0.29
43. Unidentified Coccyzus sp.	57	1	0.39 (49)	0.27
44. Mangrove Cuckoo (Coccyzus minor)	57	1	0.39 (50)	0.27
45. Black-billed Cuckoo (C. erythropthalmus)	57	1	0.39 (51)	0.27
46. Green Kingfisher (Chloroceryle americana)	40	1	0.39 (52)	0.19
47. Scissor-tailed Flycatcher (Muscivora forficata)	39	1	0.39 (53)	0.19
48. Unidentified Icterus sp.	38	1	0.39 (54)	0.18
49. Blue-grey Tanager (Thraupis episcopus)	37	1	0.39 (55)	0.18
50. Unidentified Catharus sp.	31	1	0.39 (56)	0.15
51. Southern House Wren (Troglodytes musculus)	13	2	0.78 (36)	0.12
52. Indigo Bunting (Passerina cyanea)	14	1	0.39 (57)	0.07
53. Tropical Parula (Parula pitiayumi)	8	1	0.39 (58)	0.04
54. Chiropterans	5	1	0.39 (59)	0.02
55. Lepidopterans (moths only)	1	5	1.95 (14)	0.02
56. Homopterans (Cicadidae)	1	4	1.56 (18)	0.02

TABLE XV (Continued)

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
57. Orthopterans	1	2	0.78 (37)	0.01
58. Hymenopterans (wasps only)	1	2	0.78 (38)	0.01
59. Coleopterans	1	2	0.78 (39)	0.01
TOTAL PREY		256		

TABLE XVI

RELATIVE CONTRIBUTION OF INSECTS AND BIRDS TO THE DIET OF THE APLOMADO FALCON (*FALCO FEMORALIS*). THIS TABLE COMPARES CONTENTS OF PREY REMAINS AND OBSERVED FEEDING BEHAVIOR.

Prey	Prey Remains				Observed Feeding Behavior			
	N	%	Grams	%	N	%	Grams	%
Birds	241	94.14	21,032	99.93	76	32.48	5,407	97.16
Insects	15	5.86	15	0.07	152	64.96	152	2.73
Unknown	–	–	–	–	6	2.56	6	0.11

TABLE XVII

SPECIES OF PREY OBSERVED CAPTURED, EATEN, AND/OR CACHED BY APLOMADO FALCONS (*FALCO FEMORALIS*) IN EASTERN MEXICO. SPECIES ARE RANKED BY PERCENTAGE OF TOTAL PREY WEIGHT. NUMBER IN PARENTHESES IS RANK BY PERCENTAGE OF TOTAL INDIVIDUALS.

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
1. Unidentified Small Birds (60 g Size Class)	60	20	8.55 (3)	21.56
2. White-winged Dove (*Zenaida asiatica*)	168	7	2.99 (6)	21.13
3. Mourning Dove (*Z. macroura*)	126	6	2.56 (7)	13.58
4. Unidentified Small Birds (20 g Size Class)	20	16	6.84 (5)	5.75
5. Female Great-tailed Grackle (*Quiscalus mexicanus*)	130	2	0.85 (14)	4.67
6. Common Ground-dove (*Columbina passerina*)	40	5	2.14 (9)	3.59
7. Great-tailed Grackle (*Q. mexicanus*) -- sex unknown	190	1	0.43 (17)	3.41
8. Yellow-billed Cuckoo (*Coccyzus americanus*)	57	3	1.28 (11)	3.07
9. Groove-billed Ani (*Crotophaga sulcirostris*)	83	2	0.85 (15)	2.98
10. Bobwhite (*Colinus virginianus*)	156	1	0.43 (18)	2.80
11. Altamira Oriole (*Icterus gularis*)	69	2	0.85 (16)	2.48
12. Unidentified Ground-doves (*Columbina* sp.)	40	3	1.28 (12)	2.16

TABLE XVII (Continued)

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
13. Squirrel Cuckoo (*Piaya cayana*)	107	1	0.43 (19)	1.92
14. Unidentified Insects	1	102	43.59 (1)	1.83
15. Meadowlark (*Sturnella* sp.)	101	1	0.43 (20)	1.81
16. Citreoline Trogon (*Trogon citreolus*)	75	1	0.43 (21)	1.35
17. Golden-fronted Woodpecker (*Centurus aurifrons*)	75	1	0.43 (22)	1.35
18. Great Kiskadee (*Pitangus sulphuratus*)	74	1	0.43 (23)	1.33
19. Aztec Parakeet (*Aratinga astec*)	62	1	0.43 (24)	1.11
20. Green Kingfisher (*Chloroceryle americana*)	40	1	0.43 (25)	0.72
21. Lepidopterans (Moths only)	1	21	8.97 (2)	0.38
22. Orchard Oriole (*Icterus spurius*)	20	1	0.43 (26)	0.36
23. Coleopterans	1	19	8.12 (4)	0.34
24. Unidentified Prey	20	6	2.56 (8)	0.11
25. Orthopterans	1	4	1.71 (10)	0.07
26. Lepidopterans (butterflies and moths)	1	3	1.28 (13)	0.05

TABLE XVII (Continued)

Prey	Weight (grams)	N	% Total Individuals	% Total Prey Weight
27. Lepidopterans (butterflies only)	1	1	0.43 (27)	0.02
28. Hymenopterans (wasps)	1	1	0.43 (28)	0.02
29. Odonatans (dragonflies)	1	1	0.43 (29)	0.02
TOTAL PREY		234		

TABLE XVIII

RELATIVE CONTRIBUTION OF INSECTS AND BIRDS TO THE DIET OF ADULT AND NESTLING APLOMADO FALCONS (FALCO FEMORALIS) IN EASTERN MEXICO.

Prey	Adult Diet				Nestling Diet			
	N	%	Grams	%	N	%	Grams	%
Birds	27	17.76	2,247	94.73	46	63.01	3,182	99.16
Insects	122	80.26	122	5.14	25	34.25	25	0.78
Unknown	3	1.98	3	0.13	2	2.74	2	0.06

TABLE XIX

PREY FEEDING NICHES. DATA DERIVED USING ONLY THE SAMPLE OF OBSERVED FEEDING BEHAVIOR. DIET PREFERENCES WERE BROADLY CHARACTERIZED USING DESCRIPTIONS IN PETERSON AND CHALIF (1973), AND BLAKE (1951).

Prey Diet Class	N	%	Grams	%
Insectivorous	30	12.82	2,846	51.14
Omnivorous	62	26.50	2,248	40.40
Granivorous	1	0.43	156	2.80
Frugivorous	3	1.28	138	2.48
Unknown	130	55.56	130	2.34
Piscivorous	1	0.43	40	0.72
Herbivorous	4	1.71	4	0.07
Nectarivorous	3	1.28	3	0.05
TOTALS	234		5,565	

TABLE XX

PREY HABITAT PREFERENCES. DATA DERIVED USING THE SAMPLE OF OBSERVED FEEDING BEHAVIOR. HABITAT PREFERENCES BROADLY CHARACTERIZED USING PETERSON AND CHALIF (1973) AND BLAKE (1951).

Prey Habitat Class	N	%	Grams	%
Variable Habitat	186	79.49	3,062	55.02
Brushy Areas	9	3.85	1,352	24.29
Savanna	7	2.99	554	9.96
Woods	5	2.14	353	6.34
Urban Areas, Villages	3	1.28	120	2.16
Marshes, Swamps	1	0.43	62	1.11
Riparian	1	0.43	40	0.72
Unknown	22	9.40	22	0.40
TOTALS	234		5,565	

TABLE XXI

GEOMETRIC MEANS OF ESTIMATED LENGTHS (MM) OF PREY ANIMALS CAPTURED BY MALE OR FEMALE APLOMADO FALCONS IN PAIR OR SOLO PURSUITS.

Sex of Captor	Number of Pursuers				TOTALS	
	Solo Hunt		Pair Hunt			
	N	Length	N	Length	N	Length
Male	48	111.23	8	177.23	56	118.88
Female	27	56.34	13	257.91	40	92.37
TOTALS	75	87.07	21	223.56	96	107.02

TABLE XXII

THE RELATIVE EFFECT OF NUMBER OF PURSUERS AND SEX OF CAPTOR ON VARIABILITY IN SIZE (LENGTH IN MM) OF CAPTURED PREY. DATA ANALYZED USING THE 1976 STATISTICAL ANALYSIS SYSTEM'S GENERAL LINEAR MODELS PROCEDURE (BARR, ET AL. 1979). ANALYSIS OF VARIANCE CONDUCTED USING COMMON LOGARITHMS OF PREY LENGTHS.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio	Probability of Greater F
Corrected Total	95	9.4896	-	-	-
Number of Pursuers	1	2.8666	2.8666	51.72	0.0001
Sex of Captor	1	0.0676	0.0676	1.22	0.2724
Interaction	1	0.8086	0.8086	14.59	0.0002
Error	92	5.0987	0.0554	-	-

TABLE XXIII

TREE DIAMETER AT BREAST HEIGHT (CM) FOR LEVELS OF NEST SITE QUALITY.

Status Variable	Level	N	$\bar{X}$	Min.-Max.	SD
Reproductive Status	Nesting	227	46.12	7.62-139.70	25.17
	Non-nesting	376	43.55	2.54-228.60	29.68
Occupancy Status	Occupied	303	47.89	5.08-228.60	31.33
	Unoccupied	300	41.11	2.54-205.74	23.93

TABLE XXIV

POINT-PLANT DISTANCES (M) FOR LEVELS OF NEST SITE QUALITY.

Status Variable	Level	N	$\bar{X}$	Min.-Max.	SD
Reproductive STatus	Nesting	232	45.68	0.00-326.89	46.72
	Non-nesting	376	41.55	0.00-353.78	42.13
Occupancy Status	Occupied	308	45.43	0.00-326.89	43.65
	Unoccupied	300	40.76	0.00-353.78	44.21

TABLE XXV

VERTICAL TREE CROWN DIAMETER (M) FOR LEVELS OF NEST SITE QUALITY.

Status Variable	Level	N	$\bar{X}$	Min.-Max.	SD
Reproductive Status	Nesting	228	3.29	0.00-16.00	2.05
	Non-nesting	374	2.86	0.00-13.00	1.98
Occupancy Status	Occupied	304	3.09	0.00-16.00	2.06
	Unoccupied	298	2.95	0.00-13.00	1.97

TABLE XXVI

HORIZONTAL CROWN DIAMETER (M) FOR LEVELS OF NEST SITE QUALITY.

Status Variable	Level	N	$\bar{X}$	Min.-Max.	SD
Reproductive Status	Nesting	228	8.94	0.00-32.00	4.99
	Non-nesting	376	7.24	0.00-25.00	4.12
Occupancy Status	Occupied	304	8.64	0.00-32.00	5.13
	Unoccupied	300	7.12	0.00-19.00	3.70

TABLE XXVII

TREE HEIGHT (M) FOR LEVELS OF NEST SITE QUALITY.

Status Variable	Level	N	$\bar{X}$	Min.-Max.	SD
Reproductive Status	Nesting	228	9.55	1.30-33.00	4.73
	Non-nesting	376	7.94	2.00-24.00	3.62
Occupancy Status	Occupied	304	9.10	1.30-33.00	4.76
	Unoccupied	300	7.99	2.00-21.00	3.32

TABLE XXVIII

UNIVARIATE ANALYSIS OF VARIANCE EXAMINING THE RELATIVE EFFECT OF OBSERVER, NEST SITE, AND NEST SITE QUALITY ON VARIABILITY IN MEASUREMENTS GATHERED USING THE QUARTER METHOD. OBSERVER AND NEST SITE WERE FACTORIALLY ARRANGED. NEST SITES WERE NESTED WITHIN LEVELS OF NEST SITE QUALITY.

Status Variable	Response Variable	Effect	Degrees of Freedom	Sum of Squares	F-ratio	Probability of Greater F
Reproductive Status with Levels:	Point-Plant Distance	Observer	2	11.94	26.89	0.0001
		Site Quality	1	0.38	1.70	0.1929
		Nest Site	16	19.68	5.54	0.0001
(1) nesting	Diameter at Breast Diameter	Observer	2	0.18	1.64	0.1947
(2) non-nesting		Site Quality	1	0.22	4.02	0.0454
		Nest Site	16	3.53	4.11	0.0001
	Vertical Crown Diameter	Observer	2	0.59	1.92	0.1481
		Site Quality	1	1.08	6.96	0.0086
		Nest Site	16	11.80	4.77	0.0001
	Horizontal Crown Height	Observer	2	0.01	0.05	0.9470
		Site Quality	1	1.10	9.85	0.0018
		Nest Site	16	8.74	4.88	0.0001
	Tree Height	Observer	2	0.84	11.12	0.0001
		Site Quality	1	0.72	19.22	0.0001
		Nest Site	16	2.88	4.76	0.0001

TABLE XXVIII (Continued)

Status Variable	Response Variable	Effect	Degrees of Freedom	Sum of Squares	F-ratio	Probability of Greater F
Occupancy Status with Levels:	Point-Plant Distance	Observer	2	12.94	29.22	0.0001
		Site Quality	1	0.96	4.32	0.0381
(1) occupied		Nest Site	16	19.38	5.47	0.0001
(2) unoccupied	Diameter at Breast Height	Observer	2	0.21	1.94	0.1442
		Site Quality	1	0.27	4.98	0.0260
		Nest Site	16	3.45	4.02	0.0001
	Vertical Crown Diameter	Observer	2	0.64	2.08	0.1258
		Site Quality	1	0.04	0.24	0.6231
		Nest Site	16	12.91	5.20	0.0001
	Horizontal Crown Diameter	Observer	2	0.002	0.01	0.9882
		Site Quality	1	0.39	3.54	0.0604
		Nest Site	16	9.47	5.32	0.0001
	Tree Height	Observer	2	0.84	11.12	0.0001
		Site Quality	1	0.19	5.13	0.0239
		Nest Site	16	3.45	5.71	0.0001

TABLE XXIX

THE EFFECT OF NEST SITE QUALITY ON VARIABILITY OF QUARTER METHOD MEASURES. OBSERVED SIGNIFICANCE LEVELS HAVE BEEN DERIVED FROM THE ANALYSIS OF VARIANCE TABLES (TABLE XXVIII). RESPONSE VARIABLES HAVE BEEN RANKED IN ORDER OF INCREASING PROBABILITY THAT OBSERVED VARIABILITY IS DUE TO CHANCE.

RANKED RESPONSE VARIABLES	
Reproductive Status (1) Nesting (2) Non-nesting	Occupancy Status (1) Occupied (2) Unoccupied
Tree Height ($p<0.0001$)	Tree Height ($p<0.0001$)
Horizontal Crown Diameter ($p=0.0018$)	Diameter at Breast Height ($p=0.0260$)
Vertical Crown Diameter ($p=0.0086$)	Point-Plant Distances ($p=0.0381$)
Diameter at Breast Height ($p=0.0454$)	Horizontal Crown Diameter ($p=0.0604$)
Point-Plant Distances ($p=0.1929$)	Vertical Crown Diameter ($p=0.6321$)

TABLE XXX

THE EFFECT OF NEST SITE QUALITY ON VARIABILITY OF VEGETATION PROFILE MEASURES.* OBSERVED SIGNIFICANCE LEVELS HAVE BEEN DERIVED FROM A UNIVARIATE ANALYSIS OF VARIANCE PROCEDURE APPLIED AS IN TABLE XXVIII. RESPONSE VARIABLES HAVE BEEN RANKED IN ORDER OF INCREASING PROBABILITY THAT OBSERVED VARIABILITY IS DUE TO CHANCE.

RANKED RESPONSE VARIABLES	
Reproductive Status	Occupancy Status
Middle Level Vegetation (p=0.0546)	Middle Level Vegetation (p=0.3345)
Low Level Vegetation (p=0.3037)	High Level Vegetation (p=0.5619)
High Level Vegetation (p=0.5736)	Low Level Vegetation (p=0.8246)

*Means and standard deviations (in parentheses) of vegetation profile indices for 0,25 m levels:

Status	Sites	0.25 m Levels 1	2	3	4	5	6	7
Occupied	9	.76(.32)	.40(.38)	.22(.35)	.13(.28)	.06(.16)	.04(.13)	.04(.14)
Unoccupied	8	.72(.33)	.43(.43)	.25(.38)	.14(.30)	.08(.21)	.05(.17)	.04(.16)
Nesting	7	.75(.32)	.37(.38)	.13(.33)	.11(.26)	.05(.18)	.04(.14)	.04(.15)
Non-Nesting	10	.74(.33)	.45(.42)	.27(.38)	.15(.30)	.07(.19)	.04(.16)	.04(.15)

TABLE XXXI

ESTIMATED ABUNDANCE OF BIRDS AND INSECTS AT NESTING TERRITORIES OF THE APLOMADO FALCON IN EASTERN MEXICO. DENSITY VALUES ARE ESTIMATED NUMBER OF INDIVIDUALS PER 40 HECTARES. N = TOTAL NUMBER OF INDIVIDUALS PER TAXON.

FAUNAL CATEGORY	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
INSECTS								
Coleopterans	7	11.16	1	0.17	8	11.33	-	-
Hymenopterans	9	14.35	4	5.29	9	14.35	4	5.29
Lepidopterans (moths or butterflies)	2	3.19	-	-	2	3.19	-	-
butterflies only	327	500.76	25	60.07	331	501.28	21	59.55
moths only	15	4.78	-	-	15	4.78	-	-
Orthoperans	10	14.35	14	32.28	13	14.87	11	31.76
Odonatans	120	180.21	162	397.41	168	188.54	114	389.08
Homoptera (Cicadidae)	-	-	6	11.91	-	-	6	11.91
BIRDS								
Neotropic Cormorant (*Phalacrocorax olivaceus*)	4	1.28	-	-	4	1.28	-	-
Anhinga (*Anhinga anhinga*)	37	8.43	-	-	37	8.43	-	-
Common Egret (*Casmerodius albus*)	25	5.70	2	1.32	25	5.70	2	1.32

TABLE XXXI (Continued)

FAUNAL CATEGORY	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
Snowy Egret (*Egretta thula*)	9	2.55	-	-	9	2.55	-	-
Cattle Egret (*Bubolcus ibis*)	130	43.06	24	14.29	130	43.06	24	14.29
Green Heron (*Butorides virescens*)	8	6.38	-	-	8	6.38	-	-
Bare-throated Tiger Heron (*Tigrisoma mexicanum*)	1	0.53	-	-	1	0.53	-	-
Wood Stork (*Mycteria americana*)	6	1.91	8	0.63	6	1.91	8	0.63
White-faced Ibis (*Plegadis chihi*)	1	0.32	-	-	1	0.32	-	-
Black-bellied Tree-duck (*Dendrocygna autumnalis*)	87	13.40	15	7.15	87	13.40	15	7.15
Turkey Vulture (*Cathartes aura*)	18	1.39	27	1.30	23	1.50	22	1.19
Savanna Vulture (*Cathartes burrovianus*)	-	-	3	2.38	-	-	3	2.38
Black Vulture (*Coragyps atratus*)	8	0.91	7	0.79	8	0.91	7	0.79
Osprey (*Pandion haliaetus*)	1	1.59	-	-	1	1.59	-	-
White-tailed Kite (*Elanus leucurus*)	7	3.99	-	-	7	3.99	-	-

TABLE XXXI (Continued)

FAUNAL CATEGORIES	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
Roadside Hawk (*Buteo magnirostris*)	27	4.78	16	11.97	31	4.85	12	11.91
Crested Caracara (*Polyborus plancus*)	9	4.78	-	-	9	4.78	-	-
Laughing Falcon (*Herpetotheres cachinnans*)	-	-	1	0.40	-	-	1	0.40
Aplomado Falcon (*Falco femoralis*)	6	2.76	1	0.20	6	2.76	-	-
Chachalaca (*Ortalis vetula*)	6	3.19	-	-	6	3.19	-	-
Bobwhite (*Colinus virginianus*)	29	17.54	14	2.87	41	19.62	2	0.79
Limpkin (*Aramus guarauna*)	1	0.80	-	-	1	0.80	-	-
Common Gallinule (*Gallinula chloropus*)	2	0.40	-	-	2	0.40	-	-
Jacana (*Jacana spinosa*)	2	1.59	-	-	2	1.59	-	-
Unknown Scolopacidae	1	0.23	-	-	1	0.23	-	-
Greater Yellowlegs (*Tringa melanoleuca*)	2	0.53	-	-	2	0.53	-	-
Black-necked Stilt (*Himantopus mexicanus*)	1	0.27	-	-	1	0.27	-	-

TABLE XXXI (Continued)

FAUNAL CATEGORY	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
Double-Striped Thick-Knee (*Burhinus bistriatus*)	2	1.59	–	–	2	1.59	–	–
Unknown Columbidae	6	1.41	4	11.91	6	1.41	4	11.91
Red-billed Pigeon (*Columba flavirostris*)	1	1.59	–	–	1	1.59	–	–
Mourning Dove (*Zenaida macroura*)	2	0.16	–	–	2	0.16	–	–
White-winged Dove (*Zenaida asiatica*)	2	0.16	1	0.79	2	0.16	1	0.79
Aztec Parakeet (*Aratinga astec*)	1	1.59	–	–	1	1.59	–	–
Red-crowned Parrot (*Amazona viridigenalis*)	8	3.19	2	2.65	8	3.19	2	2.65
Red-lored Parrot (*A. autumnalis*)	–	–	1	3.97	–	–	1	3.97
Yellow-headed Parrot (*A. ochrocephala*)	5	3.99	–	–	5	3.99	–	–
Yellow-billed Cuckoo (*Coccyzus americanus*)	2	0.64	–	–	2	0.64	–	–
Groove-billed Ani (*Crotophaga sulcirostris*)	48	52.63	2	0.99	48	52.63	2	0.99

TABLE XXXI (Continued)

FAUNAL CATEGORY	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
Greater Roadrunner (*Geococcyx californianus*)	1	0.80	-	-	1	0.80	-	-
White-collared Swift (*Streptoprocne zonaris*)	2	0.46	-	-	2	0.46	-	-
Unknown Trochilidae	4	3.98	2	7.94	4	3.98	2	7.94
Unknown Picidae	12	2.77	-	-	12	2.77	-	-
Common Flicker (*Colaptes auratus*)	1	0.53	-	-	1	0.53	-	-
Lineated Woodpecker (*Dryocopus lineatus*)	5	3.99	-	-	5	3.99	-	-
Acorn Woodpecker (*Melanerpes formicivorus*)	1	4.78	1	1.98	1	4.78	1	1.98
Golden-fronted Woodpecker (*Centurus aurifrons*)	1	0.32	-	-	1	0.32	-	-
Ladder-backed Woodpecker (*Dendrocopos scalaris*)	1	1.59	-	-	1	1.59	-	-
Unknown Tyrannidae	10	9.55	4	7.94	10	9.55	4	7.94
Vermilion Flycatcher (*Pyrocephalus rubinus*)	1	0.80	4	5.29	1	0.80	4	5.29
Fork-tailed Flycatcher (*Muscivora tyrannus*)	1	0.80	2	2.65	1	0.80	2	2.65

TABLE XXXI (Continued)

FAUNAL CATEGORY	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
Tropical Kingbird (*Tyrannus melancholicus*)	27	14.35	8	6.35	27	14.35	8	6.35
Social Flycatcher (*Myiozetetes similis*)	2	0.64	-	-	2	-	-	-
Great Kiskadee (*Pitangus sulphuratus*)	24	7.97	14	23.91	26	8.06	12	23.82
Dusky-capped Flycatcher (*Myiarchus tuberculifer*)	3	4.78	-	-	3	4.78	-	-
Unknown Hirundinidae	2	1.59	-	-	2	1.59	-	-
Mangrove Swallow (*Tachycineta albilinea*)	30	0.40	-	-	30	0.40	-	-
Gray-breasted Martin (*Progne chalybea*)	2	1.59	-	-	2	1.59	-	-
Barn Swallow (*Hirundo rustica*)	13	2.19	-	-	13	2.19	-	-
Mexican Crow (*Corvus imparatus*)	13	9.57	2	0.35	15	9.92	-	-
Brown Jay (*Psilorhinus morio*)	99	59.01	30	11.55	108	59.44	21	11.12
Yucutan Jay (*Cissilopha yucatanica*)	-	-	4	15.88	-	-	4	15.88

TABLE XXXI (Continued)

FAUNAL CATEGORY	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
Black-crested Titmouse (*Parus atricristatus*)	3	4.78	1	3.97	3	4.78	1	3.97
Unknown Paridae	-	-	4	7.94	-	-	4	7.94
Spotted Wren (*Campylorhynchus gularis*)	-	-	9	0.87	9	0.87	-	-
Tropical Mockingbird (*Mimus gilvus*)	-	-	1	0.79	-	-	1	0.79
Unknown Parulidae	-	-	1	0.09	1	0.09	-	-
Gray-crowned Yellowthroat (*Geothlypis poliocephala*)	1	0.53	4	8.29	3	0.88	2	7.94
Unknown Icteridae	1	1.59	-	-	1	1.59	-	-
Bronzed Cowbird (*Molothrus ater*)	1	1.59	-	-	1	1.59	-	-
Great-tailed Grackle (*Quiscalus mexicanus*)	253	105.73	19	5.45	259	106.42	13	4.76
Melodious Blackbird (*Dives dives*)	63	15.31	13	11.97	64	15.37	12	11,91
Hooded Oriole (*Icterus cucullatus*)	2	3.19	1	3.97	2	3.19	1	3.97
Black-headed Oriole (*Icterus graduacauda*)	1	0.27	-	-	1	0.27	-	-

TABLE XXXI (Continued)

FAUNAL CATEGORY	REPRODUCTIVE STATUS				OCCUPANCY STATUS			
	Nesting		Non-Nesting		Occupied		Unoccupied	
	N	Density	N	Density	N	Density	N	Density
Red-winged Blackbird (Agelaius phoeniceus)	3	0.53	3	7.94	3	0.53	3	7.94
Meadowlark (Sturnella sp.)	72	14.50	16	9.30	74	14.54	14	9.26
Unknown Fringillidae	18	13.29	12	23.99	22	13.46	8	23.82
Blue Bunting (Cyanocompsa parellina)	2	1.59	-	-	2	1.59	-	-
White-collared Seedeater (Sporophila torqueola)	52	43.06	38	53.35	65	44.80	25	51.61
Blue-black Grassquit (Volatina jacarina)	-	-	1	3.97	-	-	1	3.97
Rufous-crowned Sparrow (Aimophila ruficeps)	-	-	2	7.94	-	-	2	7.94
Unknown Birds	151	68.94	37	31.35	174	69.62	14	30.67

TABLE XXXII

DENSITIES OF INSECTS AND BIRDS FOR LEVELS OF NEST SITE QUALITY.

Status Variable	Level	Total Transect Length (km)	Number of Sites	INSECTS			BIRDS		
				N	Density*	SD	N	Density*	SD
Reproductive Status	Nesting	25.08	6	490	547.72	557.36	1,384	423.29	269.85
	Non-Nesting	15.84	6	212	401.32	515.17	373	307.64	109.09
Occupancy Status	Occupied	30.84	8	546	515.43	524.90	1,481	390.32	236.12
	Unoccupied	10.08	4	156	392.69	570.30	276	315.74	139.89

*Density = organisms/40 hectares

TABLE XXXIII

DENSITIES OF CATEGORIES OF BIRDS FOR LEVELS OF NEST SITE QUALITY

Levels of Nest Site Quality	CORVIDS			RAPTORS			OTHER			PREY		
	N	Density	SD	N	Density	SD	N	Density	SD	N	Density	SD
Reproductive Status:												
Nesting	112	53.6	54.8	76	22.8	26.4	372	306.4	183.2	824	99.2	120.8
Non-Nesting	36	11.6	10.0	57	11.6	10.0	51	237.2	113.6	229	27.6	41.2
Occupancy Status:												
Occupied	123	48.0	47.6	87	19.6	23.2	372	74.7	112.0	899	290.0	158.0
Unoccupied	25	12.4	12.4	46	12.4	12.4	51	41.2	45.2	154	234.8	146.4

TABLE XXXIV

DIMENSIONS OF STICK PLATFORMS USED AS NEST SITES BY APLOMADO FALCONS. MEASUREMENTS ARE IN CENTIMETERS.

Dimension	N	$\bar{X}$	Minimum	Maximum	SD
Outside Diameter	5	48.2	28.0	100.0	30.24
Outside Diameter	5	23.0	9.0	60.0	21.07
Nest Cup Diameter	4	13.5	6.0	18.0	5.26
Nest Cup Depth	4	24.5	4.0	75.0	33.97

TABLE XXXV

COMPARISON OF PERCH AND NEST TREES, WITH EACH OTHER AND WITH NEIGHBORING TREES. ALL MEASUREMENTS IN METERS.

DIMENSION	TREE TYPE					
	Perch Trees			Perch Tree Neighbors		
	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Height	26	13.37	6.90	104	9.26	5.02
DBH	15	0.07	0.02	103	0.05	0.01
Crown Height	20	5.30	3.20	101	3.48	2.34
	Nest Trees			Nest Tree Neighbors		
	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Height	18	11.30	6.22	72	9.64	5.19
DBH	16	0.05	0.01	72	0.04	0.01
Crown Height	18	4.77	4.10	71	3.67	2.68

A t-test conducted to compare the heights of perch trees and perch tree neighbors produced a significant test statistic ($T=2.5$, $0.01<p<0.001$), and provided evidence that the differences between the heights of perch and nest trees are real.

TABLE XXXVI

STEPWISE MULTIPLE REGRESSION RESULTS. THE DEPENDENT VARIABLE IN THIS CASE IS THE VARIABLE FOR SITE REPRODUCTIVE STATUS CONVERTED TO A NUMERIC DUMMY VARIABLE (NESTING = 1.0; NON-NESTING = 0). STANDARDIZED VARIABLES USED.

ANOVA R-SQUARE = 0.5309

SOURCE	DF	SS	MS	F-RATIO	PROBABILITY OF GREATER F
REGRESSION	2	1.59	0.80	5.09	0.0332
ERROR	9	1.41	0.16		
TOTAL	11	3.00			

REGRESSION COEFFICIENTS FOR INDEPENDENT VARIABLES AND PARTIAL F-TEST RESULTS

VARIABLE	B-VALUE	SE	SS	F-RATIO	PROBABILITY OF GREATER F
INTERCEPT	0.56				
SEVENTH LEVEL PROFILE	+0.38	0.15	1.00	6.39	0.0324
TREE HEIGHT	+0.33	0.12	1.20	7.68	0.0217

The regression model:

Nest Site Quality = 0.56 + 0.38(Seventh Level Profile) + 0.33(Tree Height).

TABLE XXXVII

STEPWISE MULTIPLE REGRESSION RESULTS. THE DEPENDENT VARIABLE IN THIS CASE IN THE REPRODUCTIVE STATUS VARIABLE. THIS MODEL, HOWEVER, IS THE BEST THREE VARIABLE MODEL. THE SAME NUMERIC DUMMY VARIABLE USED IN TABLE XXXVI HAS BEEN SUBSTITUTED FOR THE DEPENDENT VARIABLE. STANDARDIZED VARIABLES USED.

ANOVA R-SQUARE = 0.7099

SOURCE	DF	SS	MS	F-RATIO	PROBABILITY OF GREATER F
REGRESSION	3	2.13	0.71	6.53	0.0153
ERROR	8	0.87	0.11		
TOTAL	11	3.00			

REGRESSION COEFFICIENTS FOR INDEPENDENT VARIABLES AND PARTIAL F-TEST RESULTS

VARIABLE	B-VALUE	SE	SS	F-RATIO	PROBABILIT OF GREATER F
INTERCEPT	0.60				
THIRD LEVEL PROFILE	-0.30	0.14	0.54	4.98	0.0561
SIXTH LEVEL PROFILE	+0.58	0.16	1.51	13.98	0.0058
TREE HEIGHT	+0.26	0.12	0.66	6.05	0.0394

The regression model:

Nest Site Quality = 0.60 - 0.30(Third Level Profile) + 0.58(Sixth Level Profile) + 0.26(Tree Height).

TABLE XXXVIII

STEPWISE MULTIPLE REGRESSION RESULTS. THE DEPENDENT VARIABLE IS THE VARIABLE FOR SITE OCCUPANCY STATUS CONVERTED TO A NUMERIC DUMMY VARIABLE WITH LEVELS: OCCUPIED = 1; UNOCCUPIED = 0.

ANOVA R-SQUARE = 0.6897

SOURCE	DF	SS	MS	F-RATIO	PROBABILITY OF GREATER F
REGRESSION	3	1.84	0.61	5.93	0.0198
ERROR	8	0.83	0.10		
TOTAL	11	2.67			

REGRESSION COEFFICIENTS FOR INDEPENDENT VARIABLES AND PARTIAL F-TEST RESULTS

VARIABLE	B-VALUE	SE	SS	F-RATIO	PROBABILITY OF GREATER F
INTERCEPT	0.84				
FIFTH LEVEL PROFILE	+0.52	0.15	1.18	11.44	0.0096
CROWN HEIGHT	-0.51	0.16	1.11	10.76	0.0112
TREE HEIGHT	+0.46	0.13	1.32	12.77	0.0073

The regression model:

Nest Site Quality = 0.84 + 0.52(Fifth Level Profile) - 0.51(Crown Height) + 0.46(Tree Height)

TABLE XXXIX

STEPWISE MULTIPLE REGRESSION RESULTS. THE DEPENDENT VARIABLE IS THE "HYBRID" NEST SITE STATUS VARIABLE CONVERTED TO A NUMERIC DUMMY VARIABLE WITH LEVELS: NESTING = 1; OCCUPIED BUT NON-NESTING = 0; AND UNOCCUPIED = -1.

ANOVA R-SQUARE = 0.7357

SOURCE	DF	SS	MS	F-RATIO	PROBABILITY OF GREATER F
REGRESSION	3	7.11	2.37	7.42	0.0107
ERROR	8	2.55	0.32		
TOTAL	11	9.67			

REGRESSION COEFFICIENTS AND PARTIAL F-TEST RESULTS

VARIABLE	B-VALUE	SE	SS	F-RATIO	PROBABILITY OF GREATER F
INTERCEPT	0.41				
OVERALL PROFILE	+4.23	0.99	5.89	18.44	0.0026
TREE HEIGHT	+0.71	0.21	3.67	11.49	0.0095
LOW LEVEL PROFILE	-3.64	0.88	5.50	17.24	0.0032

The regression model:

Nest Site Quality = 0.41 + 4.23(Overall Profile) + 0.71(Tree Height) - 3.64(Low Level Profile).

TABLE XL

DISCRIMINANT ANALYSIS RESULTS. POSTERIOR PROBABILITIES OF MEMBERSHIP IN CATEGORIES OF NEST SITE REPRODUCTIVE STATUS FOR INDIVIDUAL NEST SITES. INDEPENDENT VARIABLES USED IN THE DISCRIMINANT FUNCTIONS WERE: INSECT ABUNDANCE; POINT-PLANT DISTANCES; TREE HEIGHT; MIDDLE LEVEL VEGETATION; AND HIGH LEVEL VEGETATION (APPENDIX G).

NEST SITE	STATUS	CLASSIFIED INTO	POSTERIOR PROBABILITIES OF MEMBERSHIP IN:	
			NON-NESTING	NESTING
1	Non-Nesting	Non-Nesting	1.0000	0.0000
2	Non-Nesting	Non-Nesting	0.9999	0.0001
3	Nesting	Nesting	0.0002	0.9998
4	Nesting	Nesting	0.0016	0.9984
5	Nesting	Nesting	0.0117	0.9883
6	Nesting	Nesting	0.0004	0.9996
7	Nesting	Nesting	0.0000	1.0000
9	Nesting	Nesting	0.0000	1.0000
10	Non-Nesting	Non-Nesting	1.0000	0.0000
11	Non-Nesting	Non-Nesting	1.0000	0.0000
12	Non-Nesting	Non-Nesting	0.9975	0.0025
14	Non-Nesting	Non-Nesting	0.9874	0.0126

TABLE XLI

DISCRIMINANT ANALYSIS RESULTS. POSTERIOR PROBABILITIES OF MEMBERSHIP IN CATEGORIES OF NEST SITE OCCUPANCY STATUS FOR INDIVIDUAL NEST SITES. INDEPENDENT VARIABLES USED IN THE DISCRIMINANT FUNCTIONS WERE: FIFTH LEVEL VEGETATION; POINT-PLANT DISTANCES; CROWN HEIGHT; CROWN DIAMETER; AND TREE HEIGHT (APPENDIX G).

NEST SITE	STATUS	CLASSIFIED INTO	POSTERIOR PROBABILITIES OF MEMBERSHIP IN:	
			NON-NESTING	NESTING
1	Occupied	Occupied	0.0000	1.0000
2	Occupied	Occupied	0.0000	1.0000
3	Occupied	Occupied	0.0000	1.0000
4	Occupied	Occupied	0.0001	0.9999
5	Occupied	Occupied	0.0855	0.9145
6	Occupied	Occupied	0.0000	1.0000
7	Occupied	Occupied	0.0000	1.0000
9	Occupied	Occupied	0.0000	1.0000
10	Unoccupied	Unoccupied	1.0000	0.0000
11	Unoccupied	Unoccupied	1.0000	0.0000
12	Unoccupied	Unoccupied	0.9999	0.0001
14	Unoccupied	Unoccupied	0.9641	0.0359

TABLE XLII

POTENTIAL APLOMADO FALCON MANAGEMENT AREAS IN THE UNITED STATES (NOTE: THE WORD "POTENTIAL" CONNOTES ONLY THAT THESE AREAS ARE WITHIN THE FORMER UNITED STATES RANGE OF THE APLOMADO FALCON AND MIGHT CONTAIN SUITABLE HABITAT FOR THE SPECIES).

AREA	VISITED BY AUTHOR	APLOMADOS HAVE NESTED THERE	APLOMADOS OBSERVED THERE SINCE 1950	AREA CONTAINS POTENTIALLY SUITABLE HABITAT
NEW MEXICO				
Guadalupe Mountains National Park	–	?	–	?
Carlsbad Caverns National Park	+	?	–	+
Lincoln National Forest (areas surrounding the Sacramento and Guadalupe Mountains)	–	?	–	?
White Sands National Monument	+	?	–	–
San Andres National Wildlife Refuge	–	?	–	?
Jornada Experimental Range	–	+	–	?
Fort Bliss Military Reservation	+	?	+	+
Fort Bliss Target Range	–	?	–	?
White Sands Missile Range	–	?	–	?
Gila National Forest (Burro Mountains)	–	?	–	?
Coronado National Forest (Peloncillo Mountains)	–	?	–	?
Hatchet Mountains Wildlife Area	–	nearby	–	?
ARIZONA				
Coronado National Forest (Chiricahua, Dragoon, Whetstone, and Huachuca Mountains)	+	nearby	–	+
Fort Huachuca Military Reservation	+	+	–	+
Willcox Playa Bombing Range	–	?	–	?
Santa Rita Range Reserve	–	?	–	?
The Research Ranch	+	nearby	–	+

TABLE XLII (Continued)

AREA	VISITED BY AUTHOR	APLOMADOS HAVE NESTED THERE	APLOMADOS OBSERVED THERE SINCE 1950	AREA CONTAINS POTENTIALLY SUITABLE HABITAT
TEXAS				
Big Bend National Park	+	?	+	+
Laguna Atascosa Wildlife Refuge	+	nearby	+	+
Aransas Wildlife Refuge	−	?	+	?
Welder Wildlife Refuge	+	?	+	+
Falcon State Park	+	?	nearby	+
Black Gap Wildlife Management Area	+	?	nearby	?
The King Ranch (south Texas ranch)	+	+	−	+

TABLE XLIII

LISTING OF AREAS DESIGNATED AS UNIQUE WILDLIFE ECOSYSTEMS WITHIN THE FORMER UNITED STATES RANGE OF THE APLOMADO FALCON.

AREA	VISITED BY AUTHOR	APLOMADO HAVE NESTED THERE	APLOMADOS OBSERVED THERE SINCE 1950	AREA CONTAINS POTENTIALLY SUITABLE HABITAT
NEW MEXICO				
Animas Mountains, Hidalgo Co.	-	nearby	-	?
Guadalupe Canyon, Hidalgo Co.	-	?	-	?
ARIZONA				
San Pedro River, Cochise Co.	+	nearby	+	+
Guadalupe Canyon, Cochise Co.	-	?	-	?
The Research Ranch, Santa Cruz Co.	+	nearby	-	+
Sonoita Plains/San Rafael Valley, Santa Cruz Co.	+	nearby	nearby	+
TEXAS				
Chinati Mountains, Presidio Co.	-	?	-	?
Devils River/Pinto Canyon, Val Verde Co.	-	?	-	?
Hidden Trail Canyon, Val Verde Co.	-	?	-	?
Lamar Peninsula - St. Charles Bay, Aransas Co.	-	?	nearby	?
Lower Canyons of the Rio Grande - Bullis Gap, San Francisco Canyon, Brewster Co.	+	?	nearby	?
Sierra Vieja - Capote Falls, Presidio Co.	+	?	+	?
Southmost Ranch, Cameron Co.	-	nearby	-	?
Mt. Livermore - Davis Mountains, Jeff Davis Co.	+	nearby	-	+
Big Bend Ranch, Presidio and Brewster Cos.	-	?	-	?
La Sal Vieja, Hidalgo Co.	-	nearby	nearby	?
Falcon Woodland, Starr Co.	+	-	nearby	probably not

APPENDIX D

SIZE CLASSES OF UNIDENTIFIED AVIAN PREY

(TABLE XLIV)

TABLE XLIV

SIZE CLASSES FOR AVIAN PREY OF THE APLOMADO FALCON. PREY CAPTUED AND/OR EATEN WERE PLACED INTO APPROPRIATE SIZE CATEGORIES WHEN MORE SPECIFIC IDENTIFICATION WAS NOT POSSIBLE.

SIZE CLASSES (SPECIES SIMILAR IN SIZE TO UNKNOWN PREY BIRDS)	ASSIGNED WEIGHT (GRAMS)
1. Hummingbird-sized	5
2. Bunting-sized	14
3. Bronzed Cowbird-sized	60
4. Kiskadee-sized	74
5. Groove-billed Ani-sized	83
6. Female Great-tailed Grackle-sized	150
7. Male Great-tailed Grackle-sized	250

APPENDIX E

EXPLANATION OF SPECIMEN NUMBERS GIVEN IN APPENDIX C, TABLES VII, VIII, AND IX (TABLE XLV)

TABLE XLV

MUSEUM COLLECTIONS CONTAINING SPECIMENS MENTIONED IN TABLES IX, X, AND XI, APPENDIX C.

ABBREVIATION		COLLECTION
NMNH	-	National Museum of Natural History
MCZ	-	Museum of Comparative Zoology
AMNH	-	American Museum of Natural History
WCH	-	San Bernardino County Museum
VPSU	-	Virginia Polytechnic State University
WFVZ	-	Western Foundation of Vertebrate Zoology
UMMZ	-	University of Michigan Museum of Zoology
CMNH	-	Cincinnati Museum of Natural History
SDNH	-	San Diego Natural History Museum
USNM	-	United States National Museum
YPM	-	Yale Peabody Museum
MVZ	-	University of California, Museum of Vertebrate Zoology

APPENDIX F

NEST SITE BACKGROUND INFORMATION

(TABLE XLVI)

TABLE XLVI

NEST SITE BACKGROUND INFORMATION

SITE	LOCATION	YEAR BIRDS LAST PRESENT	STATUS IN 1979		DOMINANT WOODY VEGETATION
			REPRODUCTIVE	OCCUPANCY	
1	N. Chiapas	1979	Non-Nesting	Occupied	*Ceiba*, *Sterculia*, *Guazuma*
2	Cen. Veracruz	1979	Non-Nesting	Occupied	*Sabal*, *Acrocomia*, *Acacia*, *Tabebuia*
3	N. Chiapas	1979	Nesting	Occupied	*Ceiba*, *Sterculia*, *Coccoloba*, *Quercus*
4	C. Veracruz	1979	Nesting	Occupied	*Quercus*, *Coccoloba*
5	C. Veracruz	1979	Nesting	Occupied	*Tabebuia*, *Coccoloba*
6	C. Veracruz	1979	Nesting	Occupied	*Tabebuia*, *Coccoloba*
7	C. Veracruz	1979	Nesting	Occupied	*Scheelia*, *Tabebuia*, *Ficus*, *Ceiba*, *Enterolobium*
8	N. Veracruz	1979	Nesting	Occupied	*Acacia*, *Tabebuia*, *Guazuma*
9	N. Veracruz	1979	Nesting	Occupied	*Acacia*, *Enterolobium*, *Parmentiera*
10	N. Chiapas	1977	Non-Nesting	Unoccupied	*Quercus*, *Ceiba*, *Cecropia*, *Guazuma*
11	N. Chiapas	1978	Non-Nesting	Unoccupied	*Ceiba*, *Sterculia*, *Guazuma*
12	N. Chiapas	1978	Non-Nesting	Unoccupied	*Sabal*, *Tabebuia*
13	C. Veracruz	1977	Non-Nesting	Unoccupied	*Quercus*, *Coccoloba*
14	C. Veracruz	1977	Non-Nesting	Unoccupied	*Tabebuia*, *Enterolobium*, *Coccoloba*
15	C. Veracruz	1977	Non-Nesting	Unoccupied	*Scheelia*, *Acrocomia*, *Tabebuia*
16	N. Veracruz	1977	Non-Nesting	Occupied	*Acacia*, *Tabebuia*, *Guazuma*
17	N. Veracruz	1977	Non-Nesting	Occupied	*Acacia*
18	N. Veracruz	1977	Non-Nesting	Occupied	*Acacia*, *Parmentiera*, *Enterolobium*

APPENDIX G

PROCEDURES FOR QUANTITATIVELY EVALUATING

POTENTIAL APLOMADO FALCON HABITAT.

(TABLES XLVII - XLIX)

PROCEDURES FOR QUANTITATIVELY EVALUATING POTENTIAL APLOMADO FALCON HABITAT

Habitat Measurements. Within the areas that have been selected for habitat analysis work, randomly select 1-5 points as origins for the faunal and floral transects. The number of points will depend on the amount of time and assistance available. At nest sites in eastern Mexico, vegetation analyses required 30-60 minutes for three people to complete. Faunal transects each required 1-2 hours per day, and should be continued over 2-3 days to sufficiently sample an area.

Next, duplicate my methods for locating vegetation transects (Chapter V). This should produce three, 200 m transect routes radiating outward from each sampling origin. Faunal transect routes should then be located by randomly selecting one compass coordinate per origin, then extending a straight route 2-3 km to either side of the origin following the compass coordinate. Finally, the methods described in Chapter V should be employed to collect faunal density estimates and floral measurements.

Data Transformation and Summarization. Faunal densities were not transformed in my analyses. All quarter method measures, however, were converted to common logarithms ($\log_{10}(x+1)$), while vegetation profile indices were transformed using the arcsin transformation ($\arcsin(x^{\frac{1}{2}})$). Sokal and Rohlf (1969) present reasons for transforming data, and illustrate methods for conducting various transformations. The ultimate objective of this procedure is to convert the data to measurement scales in which the variance of samples is independent of the magnitude of the sample mean, and a measurement scale in which the data do not deviate significantly from a normal distribution.

Standardization of the Data. Next, the data must be standardized (Draper and Smith 1966, Sokal and Rohlf 1969, and others present descriptions of this technique). This procedure reduces the effect of large differences in the magnitudes of measurements for variables of different types, on round-off errors incurred during the regression calculations. To standardize data collected from potential management areas, the means derived from the transformed variates of the unknown sites are added to the set of data collected in Mexico. The mean and standard deviation of each, now enlarged group of observations per variable, is calculated. These parameter estimates are used to convert each new observation to its "standardized normal deviate" (deviations from the sample mean measured in units of sample standard deviations) by entering each observation into the formula:

$$\frac{x_i - \bar{x}_i}{s_i}$$

in which x_i = the value associated with each site for the i-th. variable; $\bar{x}_i$ = the mean of the set of site means for the i-th. variable; and s_i = the standard deviation for the sample of x_i's within the i-th. variable.

Habitat Quality Evaluation. Now the standardized normal deviates for the unknown site are entered into the following formulae to obtain the scores of habitat quality:

Reproductive Status = 0.6350 + 0.2629(Insect Density) - 0.2066 (Point-Plant Distance) + 0.3409(Tree Height) - 0.4383(Middle Layer Vegetation Density) + 0.7420(Upper Layer Vegetation Density).

Occupancy Status = 0.8801 + 0.5452(Fifth Level Vegetation Density) - 0.1834(Point-Plant Distance) - 0.6433(Vertical Crown Diameter) + + 0.2874(Horizontal Crown Diameter) + 0.4170(Tree Height).

Values for potential nesting and occupied sites should be close to one, while values for potential non-nesting and unoccupied sites should be close to zero. Because of overlap in the independent variables included in each model, only eight habitat variables are actually required to produce a set of habitat quality scores (Tables XLVII, XLVIII, and XLIX). Tables XLVII, and XLVIII contain the data on which the habitat quality models are based. In addition, these tables have been used to create a final table (Table XLIX) containing habitat quality scores for the nest sites examined in eastern Mexico. These three tables should enable an individual to conduct a practice run of the standardization and habitat scoring procedures before actually dealing with data collected at a true site of interest in the United States.

TABLE XLVII

TRANSFORMED MEASUREMENTS FOR EASTERN MEXICAN NEST SITES.

Site	Insect Density[a]	Point-Plant Distances[b]	Vertical Crown Height[b]	Horizontal Crown Diameter[b]	Tree Height[b]	Fifth Level Vegetation Density[c]	Middle Level Vegetation Density[d]	Upper Level Vegetation Density[e]
1	20.93	1.5325	1.1317	1.8515	1.8370	0.0773	0.5521	0.0672
2	0.00	1.5345	1.2363	1.6638	1.8205	0.2029	0.3606	0.1342
3	3.38	1.6550	1.5195	2.0096	2.0329	0.0826	0.1770	0.0654
4	0.80	1.3331	1.4187	1.7317	2.0157	0.0268	0.1636	0.0134
5	18.25	1.1452	1.3692	1.8131	1.8218	0.0738	0.1847	0.0503
6	0.00	1.2814	1.4298	1.8133	1.8665	0.2232	0.4454	0.2056
7	29.12	1.3626	1.3610	1.7270	1.8003	0.2655	0.6652	0.2774
8	-	1.6228	1.4540	1.9734	1.9915	0.0000	0.0595	0.0000
9	29.03	1.6693	1.4758	2.0766	2.0190	0.0000	0.0000	0.0000
10	2.33	1.2382	1.4277	1.6622	1.8682	0.0268	0.3520	0.0327
11	30.87	1.8835	1.3120	1.8263	1.8308	0.0000	0.1594	0.0000
12	6.07	1.2191	1.6415	1.7767	1.9069	0.1695	0.6310	0.1041
13	-	1.2857	1.5893	1.8952	1.9705	0.0738	0.1357	0.0562
14	0.00	1.2480	1.3609	1.7852	1.8596	0.0000	0.0553	0.0000
15	-	1.3220	1.3096	1.8113	1.8334	0.5030	0.7168	0.4520
16	-	1.4284	1.0112	1.5025	1.8306	0.1309	0.3492	0.1116
17	-	1.4141	1.1894	1.8497	1.8326	0.2232	0.4571	0.1619
18	-	1.3764	1.3665	1.9500	1.9078	0.0000	0.0000	0.0000

[a]Insects/ha; [b]$\text{Log}_{10}(x+1)$; [c]$\text{Arcsine}(x^{\frac{1}{2}})$; [d](Arcsine(Third Level$^{\frac{1}{2}}$) + Arcsine(Fourth Level$^{\frac{1}{2}}$))/2; [e](Arcsine(Fifth Level$^{\frac{1}{2}}$) + Arcsine(Sixth Level$^{\frac{1}{2}}$))/2. Note: A dash ('-') indicates that the measurement was not taken at a particular site. On the other hand, '0.00' indicates that nothing was detected at a site during a particular measurement technique. Sites containing missing values were not used in the regression and discriminant analyses.

TABLE XLVIII

STANDARDIZED MEASUREMENTS FOR EASTERN MEXICAN NEST SITES.

Site	Insect Density	Point-Plant Distances	Vertical Crown Height	Horizontal Crown Diameter	Tree Height	Fifth Level Vegetation Density	Middle Level Vegetation Density	Upper Level Vegetation Density
1	0.7156	0.5834	-1.2353	0.2462	-0.6887	-0.2903	1.0648	-0.2445
2	-0.9127	0.5940	-0.8764	-1.1228	-0.8982	0.6635	0.2443	0.3195
3	-0.6497	1.2160	0.9845	1.3999	1.7911	-0.2499	-0.5423	-0.2590
4	-0.8504	-0.4464	0.3225	-0.6271	1.5734	-0.6733	-0.5997	-0.6969
5	0.5071	-1.4170	-0.0033	-0.0338	-0.8817	-0.3164	-0.5096	-0.3862
6	-0.9127	-0.7135	0.3953	-0.0321	-0.3156	0.8170	0.6075	0.9199
7	1.3527	-0.2944	-0.0573	-0.6619	-1.1544	1.1383	1.5493	1.5245
8	-	1.0497	0.5543	1.1358	1.2671	-0.8768	-1.0457	-0.8096
9	1.1818	1.2897	0.6974	1.8880	1.6154	-0.8768	-1.3008	-0.8096
10	-0.7314	-0.9366	0.3814	-1.1344	-0.2938	-0.6733	0.2075	-0.5343
11	1.4889	2.3962	-0.3793	0.0627	-0.7680	-0.8768	-0.6177	-0.8096
12	-0.4404	-1.0353	1.7866	-0.2996	0.1964	0.4100	1.4027	0.0661
13	-	-0.6914	1.4436	0.5651	1.0016	-0.3164	-0.7192	-0.3365
14	-0.9127	-0.8860	-0.0575	-0.2372	-0.4025	-0.8761	-1.0637	-0.8096
15	-	-0.5036	-0.3948	-0.0470	-0.7349	2.9410	1.7705	2.9938
16	-	0.0459	-2.3560	-2.2995	-0.7704	0.1167	0.1955	0.1292
17	-	-0.0281	-1.1848	0.2331	-0.7443	0.8170	0.6575	0.5526
18	-	-0.2227	-0.0209	0.9648	0.2073	-0.8768	-1.3008	-0.8096

TABLE XLIX

HABITAT QUALITY SCORES FOR THE CALIBRATION DATA.

Nest Site	Reproductive Status		Occupancy Status	
	True Status	Score	True Status	Score
1	Non-Nesting	-0.1803	Occupied	1.1931
2	Non-Nesting	0.0961	Occupied	0.9994
3	Nesting	0.8691	Occupied	1.0367
4	Nesting	0.7858	Occupied	0.8633
5	Nesting	0.6973	Occupied	0.5922
6	Nesting	0.8512	Occupied	1.0612
7	Nesting	1.1100	Occupied	0.8119
9	Nesting	1.1992	Occupied	0.9331
10	Non-Nesting	0.0487	Unoccupied	-0.0091
11	Non-Nesting	-0.5667	Unoccupied	-0.0956
12	Non-Nesting	0.2343	Unoccupied	0.1400
14	Non-Nesting	-0.7627	Unoccupied	0.3659

VITA

Dean Purdy Hector

Candidate for the Degree of

Master of Science

Thesis: THE HABITAT, DIET, AND FORAGING BEHAVIOR OF THE APLOMADO FALCON, FALCO FEMORALIS (TEMMINCK)

Major Field: Wildife Ecology

Biographical:

Personal Data: Born in McAllen, Texas (Hidalgo County), on 15 May 1952, the son of Herbert Neil and Pat Purdy Hector.

Education: Graduated from McCallum High School, Austin, Texas, in May 1970; enrolled in the University of Texas at Austin, 1970-1971; enrolled in the University of Texas at El Paso, Spring 1972; received Bachelor of Arts Degree in Zoology from the University of Texas at Austin, 1975; enrolled in master's program at the University of Texas at Austin, 1975; enrolled in master's program at Brigham Young University, Provo, Utah, 1976; completed requirements for the Master of Science Degree at Oklahoma State University, May, 1981.

Professional Experience: Graduate Teaching Assistant, Department of Zoology, The University of Texas at Austin (Parasitology), 1975; Graduate Teaching Assistant, Department of Zoology, Brigham Young University (Comparative Anatomy and Introductory Zoology), 1976; Graduate Teaching Assistant, School of Biological Sciences, Oklahoma State University (Wildlife Field Techniques, Comparative Anatomy, and Vertebrate Natural History), 1978-1980; Curatorial Assistant, Texas Natural History Collections, Texas Memorial Museum, 1976; Expedition Member, National Geographic Society Research Project dealing with the ecology of the Cave Swallow, 1976; Research Associate, Small Animal Toxicology, International Research and Development Corporation, 1977-1978; Field Technician, USDA-Forest Service/ Chihuahuan Desert Research Institute, 1978.

Professional Societies: American Ornithologists' Union, 1980; Cooper Ornithological Society, 1979; Wilson Ornithological Society, 1980; Raptor Research Foundation, Inc., 1975.