

ECOLOGY OF NON-BREEDING AND BREEDING CRESTED CARACARAS
(*CARACARA CHERIWAY*) IN FLORIDA

by

James Fitzgerald Dwyer

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State
University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Fisheries and Wildlife Sciences

James D. Fraser (Co-Chair)
Joan L. Morrison (Co-Chair)
Jeffrey R. Walters
William A. Hopkins
Stephen P. Prisley

06 May 2010
Blacksburg, Virginia

Keywords: avian, bird, *Caracara cheriway*, core area, Crested Caracara, floater, Florida, habitat, home range, immature, intermittent breeding, modeling, movement, non-breeding, occupancy, population monitoring, Northern Crested Caracara, program MARK, range, raptor, roost, season, social biology, survival, threatened species.

Copyright 2010, James F. Dwyer

COPYRIGHT STATEMENT

I hereby grant to Virginia Tech and its agents the non-exclusive license to archive and make accessible under unrestricted access my dissertation in whole or in part in all forms of media now or hereafter known. I retain all other ownership rights to the copyright of the dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

-- James Fitzgerald Dwyer 06 May 2010

ECOLOGY OF NON-BREEDING AND BREEDING CRESTED CARACARAS
(*CARACARA CHERIWAY*) IN FLORIDA

James Fitzgerald Dwyer

ABSTRACT

Like many species, Florida's population of Northern Crested Caracaras (*Caracara cheriway*, hereafter "caracara") is likely declining due to loss of breeding habitat. Consequently, management-oriented restrictions on landscape modification are applied where breeding occurs, but management rarely is extended beyond breeding areas. Focusing management on breeding areas can be effective if all caracaras occupy breeding areas, all breeding areas are detected, and no intermittent breeding occurs. Management may not operate as intended if any of these criteria are unmet. To explore this possibility, I investigated the movement, habitat, survival, and social biology of non-breeding caracaras. I also investigated long-term occupancy of breeding habitat, and factors contributing to detection of breeding.

Non-breeding caracaras occupy areas much larger than individual breeding territories, particularly during breeding seasons. Pastures occupied by cattle were the most used habitat, but non-breeding caracaras also occupied habitats atypical of breeding areas. Specifically, citrus groves were occupied extensively, and row crops were used particularly during breeding seasons. Non-breeding caracaras also shared communal roosts, sometimes with hundreds of conspecifics, and roosts were occupied year-round. Survival of non-breeding caracaras was lowest during breeding seasons. Adult non-breeding caracaras persisted in groups for multiple years without establishing breeding territories. This implies that breeding habitat is limited and saturated. Given the

proportion of adults in groups, adults also were the first to find carrion more often than expected. Apparently, young caracaras benefit from grouping by following adults. I found caracaras at all sampled breeding areas where nests were originally documented during the 1990s, and found nests at 83% of territories where nests likely existed. I also found that observer experience, visit start time, and weather affected the probability that a nest would be detected. Thus, not all caracaras occupy breeding areas, and not all breeding attempts are likely to be detected. Long-term occupancy of breeding areas should render annual verification of nesting unnecessary as a trigger for maintaining management actions. Rather management should persist even without confirmation of annual breeding. Caracara management also may be optimized through supporting the non-breeding population by maintaining a matrix of cattle pasture and citrus groves, particularly around roosts.

ACKNOWLEDGEMENTS

My family and friends made this work possible. Foremost among them, I thank E. Catherine Dwyer, and Angela Mangiameli, and Angel Lollis. Dr. Jim Fraser and Dr. Joan Morrison, my major advisors, offered guidance at every turn, and I could not have completed this research without them. I am grateful to my committee members, Drs. Jeff Walters, Bill Hopkins, and Steve Prisley, for helpful comments throughout this study. The United States Fish and Wildlife Service (USFWS) provided funding (Agreement number 401815G060), as did the Virginia Tech Graduate School through a Cunningham Fellowship. Tylan Dean, Steve Schubert, Heather Tipton, and Kristi Yanchis of the USFWS, Lisa Kreiger of the South Florida Water Management District, and Chris Koepfel of the Brevard County Natural Resources Management Office were especially generous with their time and observations. I thank Captain Ray Myers of Lockwood Aviation for spending more than 1000 hours with me, rain or shine, day or night, tracking birds in a Cessna 172. For logistic support I thank Hilary Swain, Gene Lollis, and Patrick Bohlen of Archbold Biological Station's MacArthur Agro-Ecology Research Center. I thank Scott Chiavacci, Jenéle Dowling, Andrew Fleming, Matt Hanson, Lyla Hunt, Angela Mangiameli, David Moore, Micah Scholer, Amy Smith, Nancy Swick, and Nick Thompson for field assistance. Finally, I thank the members of the Fraser Lab, Dan Catlin, Jon Cohen, Joy Felio, Sarah Karpanty, and Audrey DeRose-Wilson, for helpful comments throughout this work.

ATTRIBUTIONS

Several colleagues and coworkers aided in the writing and research behind this dissertation. Their unique contributions are described briefly here.

Professor James D. Fraser- Ph.D. (Department of Fisheries and Wildlife Sciences, Virginia Tech) was the primary Advisor and Committee Chair. Dr. Fraser provided regular assistance on field research, data analysis, and presentation of results.

Professor Joan L. Morrison- Ph.D. (Department of Biological Sciences, Trinity College) is the premier researcher of Crested Caracaras in Florida. As Co-chair, Dr. Morrison provided extensive feedback through multiple versions of all chapters herein.

Professor Jeffrey R. Walters- Ph.D. (Department of Biological Sciences, Virginia Tech) served as a member of the dissertation committee, and through coursework and committee meetings and was particularly influential in discussions of the social ecology.

Professor William A. Hopkins- Ph.D. (Department of Fisheries and Wildlife Sciences, Virginia Tech) served as a member of the dissertation committee. Dr. Hopkins was particularly important in developing solutions for problems not anticipated by the author.

Professor Stephen P. Prisley- Ph.D. (Department of Forest Resources and Environmental Conservation, Virginia Tech) served as a member of the dissertation committee. Dr. Prisley was particularly influential in the spatial analyses herein.

INDEX

Introduction.....	1
Literature Cited.....	3
Chapter 1: MOVEMENTS AND HABITAT ASSOCIATIONS OF NON-BREEDING NORTHERN CRESTED CARACARAS (<i>CARACARA CHERIWAY</i>) IN FLORIDA.....	6
Abstract.....	7
Methods.....	9
Results.....	16
Discussion.....	19
Acknowledgements.....	25
Literature Cited.....	25
Chapter 2: SEASONAL SURVIVAL OF NON-BREEDING NORTHERN CRESTED CARACARAS (<i>CARACARA CHERIWAY</i>) IN FLORIDA.....	42
Abstract.....	43
Methods.....	46
Results.....	49
Discussion.....	50
Acknowledgements.....	52
Literature Cited.....	53
Chapter 3: BENEFITS AND COSTS OF GROUPING FOR NON-BREEDING NORTHERN CRESTED CARACARAS (<i>CARACARA CHERIWAY</i>)	64
Abstract.....	65
Methods.....	69

Results.....	76
Discussion.....	78
Acknowledgements.....	82
Literature Cited.....	83
Chapter 4: PERSISTENT OCCUPANCY OF NORTHERN CRESTED CARACARA	
<i>(CARACARA CHERIWAY) BREEDING SITES IN FLORIDA.....</i>	
	99
Abstract.....	100
Methods.....	102
Results.....	103
Discussion.....	104
Acknowledgements.....	106
Literature Cited.....	106
Chapter 5: TESTING SURVEY METHODS FOR NORTHERN CRESTED	
CARACARAS (<i>CARACARA CHERIWAY</i>) NESTING IN FLORIDA.....	
	110
Abstract.....	111
Methods.....	113
Results.....	115
Discussion.....	117
Acknowledgements.....	121
Literature Cited.....	121
Chapter 6: CONCLUSION.....	131

TABLE OF TABLES

Chapter 1

Table 1. Mean area estimates (km²) from range analyses for non-breeding Northern Crested Caracaras in Florida, July 2006 - March 2009.....33

Table 2. Results from compositional analysis comparing land cover types used by Northern Crested Caracaras to available land covers in Florida, July 2006 - March 2009. Ranks are shown according to randomization tests with 1000 iterations.....34

Table 3. Simplified ranking matrices for non-breeding Northern Crested Caracaras based on comparing proportional habitat associations. A triple sign (+++, or ---) indicates significant deviation from random at $P < 0.05$. Significance levels and ranks are shown according to randomization tests with 1000 iterations. Data collected July 2006 through March 2009 in Florida, USA.....36

Table 4. Partial X^2 values for each cell comparing land cover types at random locations within 6 km of a Northern Crested Caracara location to random locations beyond 6 km of a caracara location. Data collected in Florida, July 2006 - March 2009.....38

Chapter 2

Table 1. Model selection results for monthly survival of Northern Crested Caracaras (n = 58) in Florida, July 2006 through March 2009. The global model includes sex (male vs. female), stage (immature vs. floater), and seasonal (breeding vs. non-breeding) variables.....60

Table 2. Estimates and standard errors for monthly survival of Northern Crested Caracaras (n = 58) after model averaging. Data collected in Florida, July 2006 through March 2009. Non-breeding includes immatures and floaters.....61

Chapter 3

Table 1. Results of ANCOVA comparing inter-bird arrival timing (min) for Crested Caracaras and American Crows at experimental carrion. Variance is partitioned among inter-bird arrival timing, and the species of the first bird to arrive at experimental carrion.....91

Table 2. Parameter estimates from results of multiple regression analyses evaluating time spent foraging as a function of group composition by species.....92

Table 3. Outcomes of aggressive interactions based on both high and low intensity agonistic behaviors recorded in an avian scavenger guild in Florida. See text for descriptions of behaviors. Data collected from July 2006 - March 2009.....93

Table 4. Outcomes of aggressive interactions based on both high and low intensity agonistic behaviors recorded among caracaras in Florida. See text for descriptions of behaviors. Data collected from July 2006 - March 2009.....94

Chapter 4

Table 1. Annual count of territories surveyed and nests found. 1st indicates that the territory was first surveyed during the year indicated. 2nd indicates that the territory was surveyed during a previous year. Each territory was surveyed a maximum of twice. Numbers in parentheses indicate number of nests found.....109

Chapter 5

Table 1. Univariate analyses of all factors tested in detecting Caracara nests or adult Caracaras (N = 173 visits, * = significant). Data collected in Florida, U.S.A., January and February of 2007, 2008, and 2009.....124

Table 2. Model selection results for finding a Caracara nest or observing an adult Caracara in a prospective territory. Data collected in Florida, U.S.A., January and February of 2007, 2008, and 2009.....125

Table 3. Model of variables important in predicting detection of Caracara nests, and observing an adult Caracaras during visits to prospective territories (model-averaged effect estimates)^a. Data collected in Florida, U.S.A., January and February of 2007, 2008, and 2009.....126

Appendix 1. Table to be pasted into a Microsoft Excel spreadsheet for use in calculating the probability of visit and survey results based on input values.....129

TABLE OF FIGURES

Chapter 1

Figure 1. Minimum convex polygons enclosing seasonal movements by Northern Crested Caracaras aerial telemetered in Florida, U.S.A, during a breeding season (October - March), and an adjacent non-breeding season (April -September). Equal search effort was applied in each season. To avoid cluttering the map, only the sample of birds that provided ≥ 10 locations / season are represented. “CRCA_range” indicates the species range as estimated in Morrison (1996). Data collected August 2006 - March 2009. Background map layers were provided by the Florida Geographic Data Library.....39

Figure 2. Roost locations, telemetry locations, random locations, from aerial telemetry location data for non-breeding Northern Crested Caracaras tracked in Florida, U.S.A, July 2006 through March 2009. “Annual home range” indicates a 95% kernel contour generated by pooling all telemetry locations. Background map layers were provided by the Florida Geographic Data Library.....40

Figure 3. Temperature (°C) in pasture, palm, and citrus at 14:00.

Temperatures were recorded one week per month in 2008 in an area used by non-breeding Northern Crested Caracaras in Florida.

One temperature logger was deployed in each landscape type.

Breeding Season = October- March. Non-Breeding season =

April - September.....41

Chapter 2

Figure 1. Study area, species' range, and location of detected mortalities

for Northern Crested Caracaras. Data collected in Florida, July

2006 through March 2009. Background map layers were provided

by the Florida Geographic Data Library.....62

Figure 2. Month of mortality, and estimated monthly hazard function (\hat{h}_t)

for Northern Crested Caracaras radio-telemetered in Florida 2006-

2009 (n = 58 caracaras, and 18 mortalities). NBS: Non-Breeding

Season.....63

Chapter 3

Figure 1. Simulated predator used to evaluate the many eyes hypothesis

by evaluating response time as a function of group size for groups

of crested caracaras. 1a. Simulated predator in flat position under

a camouflage cover. 1b. Simulated predator in upright position

after having been remotely triggered to rise. Tests conducted in

Florida, U.S.A., 2006 - 2009.....95

Figure 2. Response time by groups of crested caracaras to a simulated predator did not support the many eyes hypothesis which postulated that response time should decrease with increasing group size. The simulated predator was a mounted coyote skin designed to appear suddenly from beneath a camouflage cover, and was hidden 30 m from carrion which caracaras fed upon (n = 37 presentations of a predator). Tests conducted in Florida, U.S.A., 2006 - 2009.....96

Figure 3. Time between arrival of the 2nd and 3rd caracaras and between subsequent caracaras was significantly less than time between sunrise and arrival of the first caracara at the carcass. The arrival of bird #1 is timed as minutes after sunrise. The arrival of bird #2 is timed as minutes after the arrival of #1. The arrival of each subsequent bird is timed as minutes after the bird immediately preceding it. Error bars indicate standard errors. Data collected in Florida, U.S.A., 2006 - 2009.....97

Figure 4. Proportion of time that a focal Northern Crested Caracara spends foraging during a 5-minute focal sample as a function of the number of group members present. Estimates were generated with the equation: Y (Time Foraging) = 108.09 + 2.88(number of caracaras) - .68(number of turkey Vultures) + 0.39 (number of Black Vultures). Only the relationship between foraging time and the number of caracaras in the group is significant ($P = 0.001$, Table 2.)98

Chapter 4

None.

Chapter 5

Figure 1. Probability that a Caracara nest is found as a function of observer hours of experience, time relative to sunrise when a visit was initiated, and whether any fog or rain obscures visibility..... 127

Figure 2. Probability that a Caracara is detected as a function of time relative to sunrise when a visit was initiated and whether any fog or rain obscures visibility.....128

TABLE OF APPENDICES

Appendix 1. In Chapter 5: Table to be pasted into a Microsoft Excel spreadsheet for use in calculating the probability of visit and survey results based on input values.....129

INTRODUCTION

The Northern Crested Caracara (*Caracara cheriway*, hereafter “caracara”) is a Falconid distributed from northern South America to the southwestern United States. A threatened (Federal Register 1987, Logan 1997) and apparently isolated population occurs in Florida (Dove and Banks 1999, Ferguson-Lees and Christie 2001) between Orlando to the north, and the Everglades to the south (USFWS 1999). This population, together with those in Texas and Arizona, define the northern boundary of the species’ range (Ferguson-Lees and Christie 2001).

Caracaras in Florida no longer occur at their type locality near St. Augustine, and the species’ range is believed to be undergoing a long-term contraction (USFWS 1999). At the same time, Florida’s human population has doubled every 20 years (FBEBR 1997). Urban land cover in Florida increased from about 1 million acres in the early 1960s to more than 5 million acres by the mid-1990s (Reynolds 2001). By the late 1990s, almost 6 million people occupied the coast of South Florida (Gannon 1996), and South Florida’s human population is expected to reach 8–15 million people by 2050 (USACE 2003).

Historical breeding habitat for caracaras included dry prairies (Abrahamson and Hartnett 1990) and other natural grasslands (Scott 1892, Nicholson 1929, Bent 1938), but as much as 80% of these habitats were lost before the mid 1990s (Shriver and Vickery 1999), and that loss continues. Presently, the caracara’s primary breeding habitat in Florida is cattle pasture (Morrison and Humphrey 2001), which likely resembles evolutionary habitats created by large prehistory herbivores. Unfortunately for the caracara, as urbanization increased, the number of cattle in Florida declined from a high

of about 2.4 million in 1974 to a low of 1.7 million in 2007 (the last year for which data are available). As cattle disappear from pastures, pastures are typically converted to more lucrative land covers like citrus and urban areas, or are modified to manage for other species (USACE 2001, 2003).

Groups of non-breeding caracaras have been observed sporadically across the species' range in Florida, (Layne 1978, Morrison 1996), and have been most associated with 3 locations near the center of the species' range (USFWS 1999). Groups also have been observed in Texas (Skoruppa and Lee 2008) where communal roosting by group members was observed (Lasley 1982). Caracaras are highly social; they routinely feed in association with other avian scavengers (Rodriguez-Estrella, R. and L.B. Rivera-Rodriguez 1997), and they engage in allopreening with conspecifics and with Black Vultures (*Coragyps atratus*; pers. obs., Lyons 1984). Despite the knowledge that a non-breeding population of caracaras exists in Florida (USFWS 1999), and that grouping is likely an important component of their ecology, little information exists to inform our understanding of how individuals or groups of non-breeding caracaras persist, or how landscape changes may impact non-breeding caracaras. To provide managers with information with which to make the best-possible decisions with respect to non-breeding caracaras, I investigated the movement and habitat (Chapter 1), survival (Chapter 2), and social biology (Chapter 3) of non-breeding caracaras.

Wildlife managers in Florida use documentation of nesting by caracaras as the primary trigger for management action. However, no information exists on the long-term occupancy of caracara territories or on the likelihood that an existing nest will be detected. In this study I also investigated long-term occupancy (Chapter 4) and factors

influential to survey success (Chapter 5) for breeding caracaras so that managers could objectively evaluate survey results. All procedures herein were approved by Virginia Polytechnic and State University's Institutional Animal Care and Use Committee (Protocol No. 10-011-FIW).

LITERATURE CITED

- ABRAHAMSON W. G. AND D. C. HARTNETT. 1990. Pine flatwoods and dry prairies. Pages 103-149 *in* Ecosystems of Florida (R. L. Myers and J. J. Eil. Eds.). University of Central Florida Press, Orlando.
- BENT, A. C. 1938. Life histories of North American Birds of Prey. Part 2. U.S. National Museum Bulletin 170.
- DOVE, C. J. AND R.C. BANKS. 1999. A taxonomic study of Crested Caracaras (Falconidae). *Wilson Bulletin* 111:330-339.
- FEDERAL REGISTER. 1987. Threatened Status for Florida Population of Audubon's Crested Caracara; 52 FR 25229-25232.
- FBEBR (FLORIDA BUREAU OF ECONOMIC AND BUSINESS RESEARCH). 1997. Florida Statistical Abstract. University Press of Florida, Gainesville, FL.
- FERGUSON-LEES, J., AND D. A. CHRISTIE. 2001. Raptors of the World. Houghton Mifflin Co. Boston. pps. 804-806.
- GANNON, M. 1996. The New History of Florida. University Press of Florida, Tallahassee, FL, USA.
- LASLEY, G. W. 1982. High numbers of Caracara found at a temporary roost. *Bulletin of the Texas Ornithological Society* 15:18-20.

- LAYNE, J. N. 1978. Threatened, Audubon's Caracara. Pages 34-36 in Rare and Endangered Biota of Florida; Vol. 2: Birds (Kale II, H. W. Ed.). University Press of Florida. Gainesville, FL.
- LOGAN, T. 1997. Florida's endangered species, threatened species, and species of special concern. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
- LYONS, J. 1984. Caracaras in captivity. Pages 69-77 in Wildlife Rehabilitation, Vol. 2. Exposition Press, Inc. Smithtown, NY.
- MORRISON, J. L. 1996. Crested Caracara (*Caracara plancus*). In The Birds of North America, No. 249 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.
- MORRISON, J. L. AND S. R. HUMPHREY. 2001. Conservation value of private lands for Crested Caracaras in Florida. Conservation Biology 15:675-684.
- NICHOLSON, D. J. 1929. The Audubon Caracara, a little known bird in Florida. Florida Naturalist 2:67-69.
- REYNOLDS, J. E. 2001. Urbanization and land use change in Florida and the South. Pages 28-49 in Current Issues Associated with Land Values and Land Use Planning (Bergstrom, J. C., Ed.). Proceedings of a Regional Workshop. Southern Rural Development Center 28-49.
- RODRIGUEZ-ESTRELLA, R. AND L.B. RIVERA-RODRIGUEZ. 1997. Crested Caracara food habits in the cape region of Baja California, Mexico. Journal of Raptor Research 31:228-233.
- SCOTT, W. E. D. 1892. Notes on the birds of the Caloosahatchie Region of Florida. Auk 9:209-218.

- SHRIVER, W. G. AND P. D. VICKERY. 1999. Aerial assessment of potential Florida Grasshopper Sparrow habitat: conservation in a fragmented landscape. Florida Field Naturalist 27:10-13.
- SKORUPPA, M. K. AND M. C. LEE. 2008. Crested Caracaras feed on pecans in South-central Texas. Journal of Raptor Research 42:299-300.
- USACE (U. S. Army Corps of Engineers). 2001. Draft integrated feasibility report for supplemental environmental impact statement: central and southern Florida project water preserve areas feasibility study. U.S. Army Corps of Engineers, Jacksonville, FL.
- USACE (U. S. Army Corps of Engineers). 2003. Municipal and industrial (M & I) water use forecast, initial Comprehensive Everglades Restoration Plan (CERP) update. July 2003. US Army Corps of Engineers, Jacksonville District, Jacksonville, FL, USA.
- USFWS (U. S. FISH AND WILDLIFE SERVICE). 1999. South Florida multi-species recovery plan. Atlanta, Georgia. 2172 pp. (pgs. 4-219 to 4-235).

CHAPTER 1

**MOVEMENTS AND HABITAT ASSOCIATIONS OF NON-BREEDING
NORTHERN CRESTED CARACARAS (*CARACARA CHERIWAY*) IN FLORIDA**

James F. Dwyer,¹ James D. Fraser,¹ and Joan L. Morrison²

¹Department of Fisheries and Wildlife Sciences, Virginia Tech, 100 Cheatham Hall,
Blacksburg, VA24061, USA

²Department of Biology, Trinity College, 300 Summit Street, Hartford, CT 06106, USA

ABSTRACT

Breeding Northern Crested Caracaras (*Caracara cheriway*) are territorial, non-migratory, and relatively well studied. Little is known however, of the movements or habitat of non-breeding caracaras. Because only breeding habitat is explicitly included in management for this threatened species, non-breeding birds may be vulnerable beyond protected areas. We used radio-telemetry, GIS, and compositional analysis to investigate movements and habitat of non-breeding caracaras in Florida. Individual non-breeders moved more widely and used more row crop habitats during breeding seasons than non-breeding seasons. Movements were centered on 13 roosts throughout the species' range, and roosts were used by more caracaras than those we tracked. Caracaras also persisted at roosts after tracked birds departed. At all orders of selection (first-regional, second-within the species' range, and third-within individual ranges), pasture occupied by cattle was ranked as the most used habitat relative to availability. In Florida, cattle have been declining for four decades, and this may present difficulties for future caracara management. Though citrus is not a major component of breeding territories, citrus was ranked second, above pastures without cattle in second order selection, and ranked third above pasture without cattle in third order selection. Citrus was used more during afternoons than mornings. For non-breeding caracaras, citrus appears to function as a refuge from high temperatures and territory defense by breeding caracaras. Management of non-breeding caracaras may be maximized through management for a matrix of cattle pastures and citrus around roosts.

KEY WORDS: *Caracara cheriway*, Northern Crested Caracara, habitat, home range, raptor, seasonal movement.

Natal dispersal describes movement between the natal area and the site of first breeding (Greenwood and Harvey 1982), and typically occurs in three stages: departure from the natal site, movement between the natal site and the first breeding site, and settlement (Clobert et al. 2001, Wiens et al. 2006). In species with delayed breeding, this process may include a series of movements and temporary settlements over one or more years, and non-breeding birds often occupy areas that are neither part of their natal territory nor their eventual breeding territory (Ferrer 1993, Ferrer and Harte 1997). This period has been called a nomadic phase, wandering phase, transient phase, or exploratory phase, in various species (e.g., Morrison and Wood 2009, Penteriani and Delgado 2009, and McIntyre et al. 2009). Movements of non-breeding birds tend to be little studied, particularly in raptors, because individuals often are wide ranging and behave secretively (Ferrer 1993, Penteriani and Delgado 2009, McIntyre et al. 2009). Studies of habitat use by non-breeders also are rare because habitat can be difficult to evaluate without movement data and because habitat used by non-breeders sometimes differs from habitat used by breeders (Brown 1969, Newton 1992, Sergio et al. 2009). Non-breeding individuals can affect population persistence through recruitment however, and may be included in management goals, so despite the challenges, movement and habitat associations of non-breeders should be determined (Rohner 1996, Penteriani et al. 2005, 2008).

The Northern Crested Caracara (*Caracara cheriway*, hereafter “caracara”) is distributed from northern South America to the southwestern United States, with an apparently isolated population in Florida (Ferguson-Lees and Christie 2001, Dove and Banks 1999). The Florida population is Federal and State listed as threatened, largely due to concerns over loss of breeding habitat (Federal Register 1987, Logan 1997), so a recovery plan deriving from and focusing on nesting habitat has been implemented (USFWS 1999). Though this plan recognizes the importance of non-breeding birds, it does not incorporate information on the movement or habitat of non-breeders because no such information exists.

Non-breeding caracaras may be juveniles, immatures, or floaters. Floaters are birds in adult plumage that are not breeding but that presumably would breed if they could secure a territory (Steenhof and Newton 2007). Juvenile and immature raptors are unlikely to breed under most circumstances. In many species, non-breeding birds trespass on territories during breeding seasons even if they have not yet achieved breeding plumage (reviewed in Reed et al. 1999). These “prospectors” appear to evaluate territory quality through observations of the number and quality of offspring produced at visited territories (e.g., Roth et al. 2009, Arlt and Part 2008, Boulinier et al. 1996). In this study we investigated movements and habitat use by non-breeding caracaras in Florida, and evaluated these patterns by season.

METHODS

Our study area was a 43,000 km² rectangle (Fig. 1) that was larger than the known range of caracaras in Florida (35,000 km², Morrison 1996). This facilitated detection of

movements beyond the known range, and allowed us to compare habitat within the species' range with habitat within the entire study area (first order habitat selection, Johnson 1980). We used a trap baited with carrion to capture non-breeding caracaras anywhere in their range that we found them in groups. We used radio tags to track non-breeding caracaras (American Wildlife Enterprises, Monticello, FL; Holohil Sys. Limited, Carp, ON, CAN; Advanced Telemetry Systems, Inc., Isanti, MN; Wildlife Materials Inc., Murphysboro, IL). Each tag weighed approximately 30 g (< 3% of the average body mass), contained a mortality sensor, and was attached via a backpack harness of Teflon ribbon (Bally Ribbon Mills, Bally, PA, cf. Buheler et al. 1995). We identified sex chromosomally using blood samples (Avian Biotech International, Tallahassee, FL), and used handling protocols approved by the Virginia Tech Institutional Animal Care and Use Committee (permit # 10-011-FIW).

Aerial telemetry.— We sought tagged birds during weekly telemetry flights. Each week we attempted to fly to 50 randomly-generated locations within our study area. We listened for radio signals as we flew to these locations. When we detected a signal we tracked it to its source, recorded the bird's location using a WAAS enabled GPSMAP 60Cx GPS receiver (Garmin International Inc., Olathe, KS), and then resumed travel to the next random location. We found roosts by following these procedures during nocturnal telemetry. While in the air, we collected land cover data (described below) at each telemetry location and at each random location, and used these data for habitat analyses. Telemetry error should be quantified (Withey et al. 2001). We evaluated telemetry error by recording the distance and bearing between aerial telemetry locations and ground locations for dead caracaras we recovered. To test for a pattern in error

directionality, we assigned error bearings to one of four 90° quadrants (0°-90°, 9°-180°, etc.), and used a χ^2 to test whether any quadrant contained > or < 25% of recovered carcasses.

Range estimates.— We used ArcGIS 9.2 (ESRI, Redlands, CA) to analyze spatial data and to estimate used areas using kernel contours or minimum convex polygons, depending on the sample sizes available for each of three levels of analysis. Kernel analyses typically incorporate fixed kernels and least-squares cross validation (Seaman and Powell 1996, Kernohan et al. 2001,). We used fixed kernels, but nearly all of our telemetry data within and across individuals were spatially autocorrelated (Swihart and Slade 1985), rendering least-squares cross-validation inappropriate (Kenward 2001). The spatial autocorrelation in our data was similar to the “1-component ranges” investigated by Seaman et al. (1999) where reference smoothing was less biased than least-squares cross-validation, so we used reference smoothing. We report 50% and 95% kernel contours from these analyses.

We evaluated data in four ways: 1) we pooled all locations from all birds across seasons, 2) we pooled all locations from all birds within seasons, 3) we evaluated individual ranges across seasons, and 4) we compared individual movements between seasons. We pooled all locations across years and across all tagged birds in kernel analyses to estimate the total range for the non-breeding caracaras in this study. This provided the most complete dataset possible to estimate overall range. Caracaras in Florida can breed year-round (Morrison 1996), but 96% of known nesting attempts are initiated during the six month period from October through March (Morrison 1999). We refer to this period as the breeding season and the balance of the year as the non-breeding

season. We pooled all locations by season across years to estimate total seasonal ranges. We used a multi-response permutation procedure (program BLOSSOM, Cade and Richards 2005) to test whether the distribution of bird locations differed between seasons.

To evaluate how individual birds moved within the non-breeding range, we conducted separate kernel analyses for each individual. We limited these analyses to birds that yielded ≥ 30 locations, and to eliminate bias that could arise from unequal sampling, we calculated probability contours from only the first 30 locations for each bird. Few birds yielded enough locations to conduct kernel analyses within seasons. Consequently, we used minimum convex polygons to compare the relative sizes of the areas traversed by individual birds within breeding and within non-breeding seasons. Sample sizes within seasons were unequal across individuals. To prevent bias we used only the first 10 locations / bird / season in this analysis.

Roosts.— We conducted nocturnal telemetry to identify roosts. To verify that roosts supported more than just birds we radio-tracked, we visited roosts on foot at sunrise or sunset within a week of discovery and recorded birds leaving or entering roosts, respectively. To verify ongoing use of each roost, independent of tagged birds, we also visited roosts on foot monthly for the duration of the project, and recorded birds leaving or entering roosts.

Habitat analysis.— We evaluated used and available habitats using land cover categories that were important to breeding caracaras or that were common within the species' range (Morrison 1996, Morrison and Humphrey 2001, Morrison et al. 2008). We classified the land cover at all locations into one of the following 10 categories. Citrus groves (CITRU) were comprised of *Citrus spp.* in regular rows. We pooled locations in

grass and sod (GRASS). We distinguished pastures occupied by cattle at the time we collected our observation (OPAST), from those unoccupied by cattle at the time (UPAST). Any group of sabal palms (*Sabal palmetto*) that prevented us from seeing the ground between individual trees during aerial telemetry we identified as palm hammock (PALMH). Sites containing palms dispersed more widely where we could see the understory between them, such as those occurring in landscaped areas, we classified as the land cover in which the palms occurred. We pooled all agricultural crops other than citrus into a single category (ROWCP). This category included sugar cane (*Saccharum spp.*) because distinguishing sugar from other row crops caused sample sizes in both categories to be unacceptably small. We pooled all remaining vegetation into a single category of forest, shrub, and scrub (FORSS). We identified open water (OPH2O) as any standing or moving water body without emergent vegetation visible during telemetry. We identified wetlands (WETLD) as any standing or moving water body with visible emergent vegetation. We classified any location occurring within approximately 100 m of ≥ 15 structures as urban (URBAN). Farms and ranches routinely included approximately 10 structures in otherwise relatively undeveloped areas (unpub. data), and using a cutoff of 15 structures allowed us to distinguish these sites from areas with more substantial human populations.

For all habitat analyses we used diurnal telemetry locations only and included only individuals that yielded ≥ 10 locations. We used random locations to identify available habitats. We identified habitat during aerial telemetry rather than in GIS layers because GIS layers are not produced often enough to reflect short term changes, like the movement of cattle, that non-breeding caracaras may respond to.

We evaluated first, second, and third order habitat selection (Johnson 1980) by comparing used to available land cover types. To assess 1st order selection (habitat use within the region) we compared habitat at each bird's locations to the land cover at all random locations throughout the study area. Thus, the entire study area was considered available. We narrowed our definition of "available" areas for second and third order selection (habitat use within the species' range, and individual habitat use within each individual's specific range, respectively). To do so, we used ground-based nocturnal telemetry to identify birds at roosts on the night before a diurnal aerial telemetry flight. During the flight on the subsequent day we located birds and identified distances moved from roosts. We used the longest distance moved by any bird by mid-day (6 km) to define a radius around telemetry locations that would likely have been "available" to non-breeding caracaras. To assess second order selection (habitat use within the species' range) we compared habitat at each bird's locations to land cover at all random locations within 6 km of any tracked bird's location. Thus, the entire range of non-breeding caracaras was considered "available" to each individual, but areas beyond 6 km from any tracked bird were excluded. To assess third order selection (habitat use within individual ranges) we compared habitat at each bird's locations to land cover at random locations within 6 km of that bird's locations only. In this case only portions of the study area adjacent to a particular bird were considered available to that individual.

Composition analysis implements a logratio approach to comparing two sets of data. This approach accommodates the "unit-sum constraint" wherein proportions of use or availability sum to one over all resource types (Aebisher et al. 1993). We used the Microsoft ® Excel tool ComposAnalysis version 5.1 (Smith Ecology Ltd. 2004) to

conduct compositional analysis comparing land cover data between used and random locations at all levels of selection. We determined the significance of Wilk's lambda with 1000 iterations, and substituted a value of 0.01 for zero values in the matrix of land cover types (Aebischer et al. 1993, Manly 1997).

We conducted three additional habitat analyses beyond those of Johnson (1980). First, to further understand first order selection, we used X^2 analysis to compare land cover at all random points within 6 km of any bird's location to land cover at all random points greater than 6 km from any bird's location. We used partial X^2 analyses to identify the most influential components of the complete X^2 test. Second, because we were interested in possible seasonal differences in habitat use, we used X^2 analyses to compare habitat use between breeding and non-breeding seasons. Third, we divided the time we collected locations into four periods (morning 06:00-09:59, mid-day 10:00-13:59, afternoon 14:00-17:59, and evening 18:00-21:59), and compared use of citrus groves during these periods.

Habitat Temperature.— Under identical weather conditions, ambient temperature can differ between various land cover types, typically as a function of shade and humidity. We were interested in evaluating ambient temperature in the three most important habitats to non-breeding caracaras (at third order selection), but could not access citrus in a way that enabled quantification of the complexity of this habitat. Consequently, we deployed three HOBO Pro v2 temperature loggers (Onset Computer Corporation, Bourne, MA) in an area used year-round by non-breeding caracaras. We deployed one data logger in a pasture at ground level, one at ground level in an adjacent citrus grove, and one in the canopy of an adjacent palm hammock. In 2008, we recorded

air temperature at 14:00 for one week each month. We combined all temperature data within seasons for each habitat type and used ANOVA to compare average seasonal temperatures between land cover types.

RESULTS

From July 2006 through March 2009, we conducted 140 telemetry flights (\bar{x} = 7.80 hr / week) in each of 140 consecutive weeks. We radio-tracked 58 caracaras (27 male, 31 female; \bar{x} = 17.0 months / bird, SE = 1.11), and gathered 1076 diurnal and 150 nocturnal telemetry locations. We also obtained habitat information at 1040 random locations (Fig. 2).

Telemetry error.— We recovered all carcasses from within the land cover type and patch identified during aerial telemetry (n = 18 non-breeding caracaras, and 1 breeding caracara from a related study). The difference between aerial estimates and ground locations of dead birds, was \bar{x} = 163 m (SE = 27 m), which was < 0.01% of the mean range of tracked birds. We found no pattern in error directionality (X^2 = 2.639, d.f. = 3, P = 0.267).

Range Estimates.— The 95% home range for all telemetry locations encompassed 19,928 km² (Fig 2). This was 11.3% larger than the non-breeding season range, and 17.5% smaller than the size of the breeding season range for the same individuals (Table 1). Breeding season locations were more widely dispersed than locations gathered during non-breeding seasons (Multi Response Permutation Procedure, δ = -3.42, P = 0.011, n = 532 breeding season and 544 non-breeding season locations, respectively). Across seasons, individual ranges varied from 277 km² to 11285 km² (\bar{x} = 3943 km², SE = 704

km²). There was no difference by sex in these ranges (50% use area: $t = 1.247$, d.f. = 16, $P = 0.231$; 95% home range: $t = 1.299$, d.f. = 16, $P = 0.212$). Minimum convex polygons describing areas used by non-breeding caracaras were 4.9 times larger during breeding seasons than during non-breeding seasons (Fig. 1; $t = -4.072$, d.f. = 41, $P < 0.001$, $n = 17$ breeding season polygons, $n = 26$ non-breeding season polygons). Within seasons there was no difference by sex in area of minimum convex polygons ($t = -0.013$, d.f. = 41, $P = 0.9898$, $n = 23$ females, 20 males). None of the caracaras we tracked reduced within-breeding season movements to a range typical of the breeding territory of caracaras in Florida (≤ 3 km from a central location, Morrison 1996). Thus, none of the birds we tracked appear to have established breeding territories during this study.

Roosts.— During nocturnal telemetry, we found 13 roosts (Fig. 2), throughout the range of non-breeding caracaras we tracked. All roosts were used by more than just the birds we tracked and roost occupancy by caracaras persisted beyond the period of occupancy by tagged birds. One roost that was counted during a related project was occupied continuously for 33 months and included more than 300 caracaras in a single night during peak counts in the summer.

Habitat.— Habitat composition at diurnal caracara locations differed from available land cover throughout the entire study area (Tables 2 and 3; $\Lambda = 0.01$, $X^2 = 189.52$, d.f. = 9, $P < 0.001$; $n = 1076$ telemetry locations, 1040 random locations). Specifically, pastures and citrus groves were used more than expected given their availability, and forests, wetlands, urban areas, and open water were used less than expected. Habitat composition at random locations within 6 km of caracara locations also differed from random locations beyond 6 km of caracara locations ($X^2 = 139.112$,

d.f. = 9, $P < 0.001$, $n = 406$ random locations within 6 km of caracara locations, 634 random locations beyond 6 km of caracara locations). Partial X^2 values indicated that divergences from expected values in pasture with and without cattle combined accounted for 44% of the overall X^2 value indicating that caracaras tend to occupy areas composed largely of pasture (Table 4).

Habitat at caracara locations also differed from available habitat in compositional analysis of second order selection ($\Lambda = 0.03$, $X^2 = 148.08$, d.f. = 9, $P < 0.001$) and 3rd order selection: $\Lambda = 0.11$, $X^2 = 97.35$, d.f. = 9, $P < 0.001$). Pasture occupied by cattle was the top ranked land cover for non-breeding caracaras at all orders of selection, indicating that pasture with cattle was used more than expected given its availability, and the difference between use and availability was greater than that of any other land cover type. Pasture not occupied by cattle was ranked highly in 1st order selection, but was otherwise used less than expected given its availability in the landscape.

Citrus groves were ranked 2nd or 3rd overall and above pastures without cattle both within the species' range, and within individual ranges (second and third order selection, respectively). Citrus groves were not used equally throughout the day ($X^2 = 21.06$, d.f. = 3, $P < 0.001$). Citrus was used less than expected during mornings (partial $X^2 = 9.76$), and more than expected otherwise. All other land cover categories were used as expected or less than expected based on availability. Wetlands were ranked last in both second and third order selection.

Habitat use differed between seasons ($X^2 = 22.61$, d.f. = 8, $P = 0.004$, $n = 532$ breeding season locations, 544 non-breeding season locations). During breeding seasons, we found non-breeding caracaras more frequently in row crops than we did during non-

breeding seasons (4.03% vs. 2.06% of locations; partial $X^2 = 8.22$). No other partial X^2 values were > 6 , indicating that differential use of row crops was the primary driver of the overall finding of a differential use of land cover types by season, and that other used habitats were used in equivalent proportions in both breeding and non-breeding seasons.

Temperatures.— The mean daily ground temperature at 14:00 in the pasture was higher than in the adjacent citrus or palm ($F = 4.47$, d.f. = 2,129, $P = 0.013$) and during the non-breeding season ($F = 14.15$, d.f. = 2,138, $P < 0.001$).

DISCUSSION

Movements.— The ranges of non-breeding caracaras averaged 3,943 km². This is 254 times the size of the average home range of breeding caracaras in Florida (15.5 km²; Morrison 1996). Generally, territoriality evolves to ensure access to limited resources (Krohne 1998), particularly in terms of food or breeding opportunities, and animals tend to move widely when those resources are scarce. If non-breeding caracaras move widely in search of food, then food should be less available during the months when caracaras move particularly widely. Much of the caracara's vertebrate prey consists of wetland species (Morrison and Pias 2006) which become concentrated in shallow isolated wetlands during annual drawdown periods (Batzer et. al 1999, Townsend et al. 2006). Drawdown occurs during the caracara's breeding season (Morrison et al. 2009), thus making more food potentially available during this time. Caracaras also consume carrion when available, and particular carrion unique to the pasture habitat favored by caracaras is the placenta of cattle. Most calves in Florida are born December through February (Olsen et al. 1991), again increasing the availability of food during periods when non-

breeding caracaras are moving most widely. Breeding caracaras defend permanent territories year round (Morrison 1996). Consequently, if there is enough food available to support survival of non-breeding caracaras during non-breeding seasons despite territory defense by breeding birds, there is likely to be sufficient food during breeding seasons when additional food appears to be available. Lack of food seems unlikely to drive the long-distance movement of non-breeding caracaras.

Alternatively, caracaras may move more widely during breeding seasons if they are territory-prospecting. Prospecting is defined as actively visiting territories of conspecifics to evaluate quality or availability, is expected primarily when prospectors can evaluate reproductive success, and is undertaken by both immatures and adults (Boulinier et al. 1996, Reed et al. 1999, Piper et al. 2006). Non-breeding Bonelli's Eagles (*Aquila fasciata*; Balbontin and Ferrer 2009) and Spanish Imperial Eagles (*Aquila adalberti*, Ferrer and Harte 1997) prospect from temporary settlement areas centered on shared roosts. In these species, breeding habitat is limited, and roosts have been identified as important refuges where non-breeding eagles avoid aggression by territory holders. Avian survival tends to be reduced during periods of increased movement (reviewed in Kershner et al. 2004), and roosts facilitate survival between prospecting forays until permanent settlement on a territory is accomplished (Ferrer and Harte 1997, Ferrer 1993).

Thus, prospecting tends to occur during breeding seasons, to be associated with longer than usual movements, to be undertaken by non-breeders, to be based from shared roosts, and to be correlated with lowered survival. In this study we have demonstrated that many of these parameters match the ecology of non-breeding caracaras, except for

reduced survival during the prospecting period, and demonstration of habitat limitation. However, in a related study, we found that non-breeding caracaras do have lower survival during breeding seasons (Chapter 3), and we tracked individual non-breeding caracaras in adult plumage for over three years (unpub. data.). The long term persistence of individual non-breeders implies that breeding habitat is both limited and saturated (Newton 1992, Hunt 1998). Consequently, it appears that non-breeding caracaras are in fact prospecting for territories when they move more widely during breeding seasons.

Habitat use.—Habitat selection occurs at regional, local, and individual scales (first, second, and third order selection, respectively; Johnson 1980). At each scale we found that pasture containing cattle was the highest ranked habitat type for non-breeding caracaras. Pasture was also the highest ranking habitat type for breeding caracaras (Morrison and Humphrey 2001). Caracaras are strong runners that forage on foot in open habitats by scratching in soil and overturning small debris in search of invertebrates (Morrison 1996). Pastures typically support concentrations of invertebrates under piles of cattle feces, and invertebrates associated with cattle are an important part of the diet of caracaras (Morrison et al. 2008). Thus, non-breeding caracaras probably use pastures for foraging, and pastures are a primary definer of the species' range in Florida.

At all orders of selection, row crops were used less than expected given their availability, but were nevertheless used more frequently during breeding seasons than during non-breeding seasons. Caracaras are sometimes observed following tractors during the planting (Morrison 1996) or harvest of row crops (Layne 1996), but otherwise are not widely reported in these habitats. Thus, if caracaras were using row crops during periods of increased human activity in fields, then caracara movement patterns should

match the bulk of planting or harvest patterns. Sixty-six different crops are grown in South Florida (Whitty et al. 2008), and of these, 29% are typically harvested in the spring after a winter season of maximum growth, and 71% are typically harvested in the fall after a summer season of maximum growth. Most crops are not harvested during the bulk of the caracara's breeding season, except sugar cane (*saccharum sp.*). Sugar cane is harvested from late October through mid April, but occurs almost exclusively south east of Lake Okeechobee (Gilbert et al. 2009), beyond the caracara's range. Thus, increased availability of forage in row crops does not appear to be a driving factor in the seasonal movements of caracaras. Caracaras do use row crops disproportionately across the year however. Row crops are not typically included in the defended territories of breeding caracaras (Morrison and Humphrey 2001), and non-breeding caracaras may occupy these areas during breeding seasons because doing so while prospecting allows them to avoid territorial aggression by breeding birds.

Pasture and citrus were each ranked highly at all orders of selection. Pastures may resemble evolutionary environments maintained by prehistory grazers (i.e. bison), but citrus does not obviously resemble historical habitat and is not typically an important component of breeding territories (Morrison and Humphrey 2001). Thus, potential benefits of citrus are not as readily apparent. Nevertheless, we suggest three potential benefits of using citrus. 1) Territories are defended year-round (Morrison 1996), but citrus is not typically in breeding areas. Citrus may function as a social refuge where non-breeding caracaras can avoid aggression from territorial adults. 2) Non-breeding caracaras used citrus at all times of day, but used it particularly during mid-day and afternoon when ambient temperatures were greatest. Afternoon temperature in citrus

appeared substantially cooler than pasture temperatures, thus citrus groves may also function as a thermal refuge. 3) The social interactions of caracaras are complex (Chapter 3), and occur largely on the ground. Shifting habitat use into citrus may facilitate these social interactions during warmer parts of the day when caracaras would otherwise be roosting. However, our conclusions with respect to temperature should be accepted with caution until additional research can be conducted to compare temperature between habitat types in more detail.

Management implications.— Florida’s human population doubled every 20 years throughout the 1900s (FBEBR 1997), urban land use increased from about 1 million acres in the early 1960s to over 5 million acres by the mid-1990s (Reynolds 2001), and conservation efforts in the aftermath were described as “fighting over crumbs” (Myers and Ewel 1990). The expansion of the human population is ongoing, but the Comprehensive Everglades Restoration Plan (USFWS 1999) now provides a framework to organize management responses on a regional scale. This plan is focused largely on conserving and the restoring the everglades, and includes management actions that transform upland habitats upstream from the everglades into pollution control facilities. Consequently, upland species including caracaras may be sacrificed in some areas in the interest of balancing the needs of various management goals. Managers should be aware of this potential conflict when weighing alternatives.

Caracaras are listed as threatened in Florida because habitat loss was believed to be contributing to a decline in the breeding population (USFWS 1999). Our findings support previous research (Morrison and Humphrey 2001) indicating the importance of upland habitats, and expand that implication to the management of non-breeding

caracaras. Morrison and Humphrey (2001) suggested that best management practices for breeding caracaras should focus on encouraging the persistence of cattle ranching in south-central Florida, and our results suggest that such an approach also would encourage persistence of non-breeding caracaras. Cattle censuses indicate an ongoing decline in cattle numbers in Florida from a high of about 2.4 million in 1974 to a low of about 1.7 million in 2007 (the last year for which records are available (USDA 1997, 2002, 2007). Morrison and Humphrey (2001) found that caracaras rarely nest on public land, perhaps because management strategies tend to emphasize other species in these areas. We found that non-breeding caracaras occupy primarily pasture and citrus which also tends to occur on public land. Because caracaras tend not to occupy public lands, the decline of ranching on private lands will be particularly challenging for caracara management in the future. Non-breeding caracaras also occur in citrus groves, and we suggest that a matrix of pastures and citrus groves centered on roosts, and encompassing areas where we documented non-breeding caracaras would best support management for this life stage of caracaras. An ideal management goal might be to acquire ownership or easements for roosts sites. Citrus groves are regularly treated with pesticides and herbicides and the effect of exposure to these chemicals in non-breeding caracaras should be a focus of future research.

Management plans for threatened or endangered birds typically focus on breeding populations and success is evaluated in terms of productivity believed sufficient to maintain the population (Giron Pendelton et al. 1987, Steenhof and Newton 2007). That focus is flawed if it does not ensure recruitment into the breeding population of dispersing juveniles, and prospecting immatures and floaters (Ferrer and Harte 1997,

Penteriani et al. 2005). The management plan in place for caracaras follows the paradigm of nest-centered protection (USFWS 1999). Our results highlight the importance of understanding non-breeding habitat because it can differ from breeding habitat in ways that are important to the ecology of species. Because non-breeding caracaras move more widely than breeding birds and use some alternate habitats, we suggest that a breeding-centered management strategy will fail to protect the caracara population to the extent necessary to existing achieve recovery objectives (USFWS 1999).

ACKNOWLEDGEMENTS

This study was funded by the U.S. Fish and Wildlife Service grant no.145 401815G060. This is contribution No. _____ (assigned following acceptance) from the MacArthur Agro-Ecology Research Center (MAERC) of Archbold Biological Station. We thank Miguel Ferrer and Steve Schubert for helpful comments on an early draft of this manuscript. We thank Captain Ray Myers of Lockwood Aviation for piloting telemetry flights. We thank Gene Lollis and Patrick Bohlen of MAERC for logistic support and S.J. Chiavacci, J.L. Dowling, A.L. Fleming, M.R. Hanson, L.M. Hunt, A.K. Mangiameli, M.N. Scholer, N.E. Swick, and N.R. Thompson for aerial telemetry assistance.

LITERATURE CITED

- AEBISCHER, N. J., P. A. ROBERTSON, AND R. E. KENWARD. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology* 74:1313-1325.
- ARLT, D., AND T. PART. 2008. Post-breeding information gathering and breeding territory shifts in Northern Wheatears. *Journal of Animal Ecology* 77:211-219.

- BALBONTIN, J. AND M. FERRER. 2009. Movements of juvenile Bonelli's Eagles *Aquila fasciata* during dispersal. *Bird Study* 56:86-95.
- BATZER, D. P., A. S. SHURTLEFF, AND J. R. ROBINETTE. 1999. Managing fish and invertebrate resources in a Wood Stork feeding pond. *Journal of Freshwater Ecology* 14:159-165.
- BOULINIER, T., E. DANCHIN, J. Y. MONNAT, C. DOUTRELANT, AND B. CADIOU. 1996. Timing of prospecting and the value of information in a colonial breeding bird. *Journal of Avian Biology* 27:252-256.
- BROWN, J. M. 1969. Territorial behavior and population regulation in birds: a review and re-evaluation. *Wilson Bulletin* 81:293-329.
- BUEHLER, D. A., J. D. FRASER, M. R. FULLER, AND L. S. MCALLISTER, AND J. K. D. SEEGAR. 1995. Captive and field-tested radio-transmitter attachments for Bald Eagles. *Journal of Field Ornithology* 66:173-180.
- CADE, B. S. AND J. D. RICHARDS. 2005. User manual for Blossom statistical software: U.S. Geological Survey Open-File Report 2005-1353. 124 p.
- CLOBERT, J., E. DANCHIN, A. A. DHONDT, AND J. D. NICHOLS. 2001. *Dispersal*. Oxford University Press, Oxford, UK.
- DOVE, C. J. AND R. C. BANKS. 1999. A taxonomic study of Crested Caracaras (Falconidae). *Wilson Bulletin* 111:330-339.
- FBEBR (FLORIDA BUREAU OF ECONOMIC AND BUSINESS RESEARCH). 1997. *Florida Statistical Abstract*. University Press of Florida, Gainesville, FL.
- FEDERAL REGISTER. 1987. Threatened Status for Florida Population of Audubon's Crested Caracara; 52 FR 25229-25232.

- FERGUSON-LEES, J., AND D. A. CHRISTIE. 2001. Raptors of the World. Houghton Mifflin Co. Boston.
- FERRER, M. 1993. Juvenile dispersal behavior and natal philopatry of a long-lived raptor, the Spanish Imperial Eagle *Aquila adalberti*. *Ibis* 135:132-138.
- FERRER, M. AND M. HARTE. 1997. Habitat selection by immature Spanish Imperial Eagles during the dispersal phase. *Journal of Applied Ecology* 34:1359-1364.
- GILBERT, R. A., J. M. SHINE, JR., J. D. MILLER, R. W. RICE, AND C. R. RAINBOLT. 2009. Maturity Curves And Harvest Schedule Recommendations For CP Sugarcane Varieties. Publication SS-AGR-221 of the Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville.
- GIRON PENDELTON, B. A., B. A. MILLSAP, K. W. CLINE, AND D. M. BIRD. 1987. Raptor Management Techniques Manual. National Wildlife Federation. Washington, D.C.
- GREENWOOD, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. *Journal of Animal Behavior* 28:1140-1162.
- GREENWOOD, P. J., AND P. H. HARVEY. 1982. The natal and breeding dispersal of birds. *Annual Review in Ecology and Systematics* 13:1-21.
- HUNT, W. G. 1998. Raptor floaters at Moffat's equilibrium. *Oikos* 82:191-197.
- JOHNSON, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65-71.
- KENWARD, R. E. 2001. A Manual for Wildlife Radiotagging. Academic Press. San Diego, CA.

- KERNOHAN, B.J., R. A. GITZEN, AND J. J. MILLSPAUGH. 2001. Analysis of animal space use and movements. Pages 126-166 *in* Radio Tracking and Animal Populations (J. J. Millspaugh and J. M. Marzluff , Eds.). Academic Press, San Diego, CA.
- LAYNE, J. 1996. Crested Caracara. Pages 195-210 *in* Rare and Endangered Biota of Florida (J.A. Rodgers, Jr., H.W. Kale II, and H.T. Smiths Eds.). University Press of Florida. Gainesville.
- KERSHNER, E.L., J.W. WALK, AND R.E. WARNER. 2004. Postfledging movements and survival of juvenile eastern meadowlarks (*Sturnella magna*) in Illinois. Auk 121:1146-1154.
- KROHNE, D. T. 1998. General Ecology. Wadsworth Publishing Company. Belmont, CA.
- LOGAN, T. 1997. Florida's endangered species, threatened species, and species of special concern. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
- MANLY, B. F. 1997. Randomization, Bootstrap, and Monte Carlo Methods in Biology. 2nd Ed. Texts in Statistical Science, Chapman and Hall, London.
- MCINTYRE, C. L., D. C. DOUGLAS, AND L. G. ADAMS. 2009. Movements of juvenile Gyrfalcons from western and interior Alaska following departure from their natal areas. Journal of Raptor Research 43:99-109.
- MYERS, R. L. AND J. J. EWEL. 1990. Problems, Prospects, and Strategies for Conservation. Pages 619-632 *in* Ecosystems of Florida (R. L. Myers and J. J. Ewel, Eds.). University of Central Florida Press, Orlando, FL.
- MORRISON, J. L. 1996. Crested Caracara (*caracara plancus*). In The Birds of North America, No. 249 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

- MORRISON, J. L. 1999. Breeding biology and productivity of Florida's Crested Caracaras. *Condor* 101:505-517.
- MORRISON, J. L. AND S. R. HUMPHREY. 2001. Conservation value of private lands for Crested Caracaras in Florida. *Conservation Biology* 15:675-684.
- MORRISON, J. L., AND K. E. PIAS. 2006. Assessing the vertebrate component of the diet of Florida's Crested Caracaras. *Florida Scientist* 69:36-43.
- MORRISON, J. L., K. E. PIAS, J. ABRAMS, I. G. W. GOTTLIEB, M. DEYRUP, AND M. MCMILLIAN. 2008. Invertebrate diet of breeding and nonbreeding Crested Caracaras (*Caracara cheriway*) in Florida. *Journal of Raptor Research* 42:38-47.
- MORRISON, J. L., K. E. PIAS, J. B. COHEN, AND D. H. CATLIN. 2009. Environmental correlates of breeding in the Crested Caracara (*Caracara cheriway*). *Auk* 126:755-764.
- MORRISON, J. L. AND P. B. WOOD. 2009. Broadening our approaches to studying dispersal in raptors. *Journal of Raptor Research* 43:81-89.
- NEWTON, I. 1992. Experiments on limitation of bird numbers by territorial behaviour. *Biological Reviews* 67:129-173.
- OLSEN, T. A., K. EUCLIDES FILHO, L. V. CUNDIFF, M. KOGER, W. T. BUTTS JR., AND K. E. GREGORY. 1991. Effects of breed group by location interaction on crossbred cattle in Nebraska and Florida. *Journal of Animal Science* 69:104-114.
- PENTERIANI, V., F. OTALORA, AND M. FERRER. 2005. Floater survival affects population persistence. The role of prey availability and environmental stochasticity. *Oikos* 108:523-534.

- PENTERIANI, V., F. OTALORA, AND M. FERRER. 2008. Floater mortality within settlement areas can explain the Allee effect in breeding populations. *Ecological Modeling* 213:98-104.
- PENTERIANI, V. AND M. D. DELGADO. 2009. Thoughts on natal dispersal. *Journal of Raptor Research* 43:90-98.
- PIPER, W. H., C. WALCOTT, J. N. MAGER, M. PERALA, K. B. TISCHLER, E. HARRINGTON, A. J. TURCOTTE, M. SCHWABENLANDER, AND N. BANFIELD. 2006. Prospecting in a solitary breeder: chick production elicits territorial intrusions in Common Loons. *Behavioral Ecology* 17:881-888.
- REED, J., T. BOULINIER, E. DANCHIN, AND L. ORING. 1999. Informed dispersal: prospecting by birds for breeding sites. *Current Ornithology* 15:189-259.
- REYNOLDS, J. E. 2001. Urbanization and land use change in Florida and the South. In Bergstrom, J. C. (Ed.). *Current Issues Associated with Land Values and Land Use Planning. Proceedings of a Regional Workshop. Southern Rural Development Center* 28-49.
- ROHNER, C. 1996. The numerical response of Great Horned Owls to the Snowshoe Hare cycle: consequences of non-territorial "non-breeders" on demography. *Journal of Animal Ecology* 65:359-370.
- ROTH, T., P. SPRAU, R. SCHMIDT, M. NAGUIB., V. AMRHEIN. 2009. Sex-specific timing of mate searching and territory prospecting in the Nightingale: nocturnal life of females. *Proceedings of the Royal Society of London-Series B, Biological Sciences* 276:2045-2050.

- SEAMAN, D. E., AND R. A. POWELL. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77:2075-2085.
- SEAMAN, D. E., J. J. MILLSPAUGH, B. J. KERNOHAN, G. C. BRUNDIGE, K. J. RAEDEKE, AND R. A. GITZEN. 1999. Effects of sample size on kernel home range estimates. *Journal of Wildlife Management* 63:739-747.
- SERGIO, F. B. JULIO, F. HIRALDO. 2009. Predictors of floater status in a long-lived bird: a cross-sectional and longitudinal test of hypotheses. *Journal of Animal Ecology* 78:109-118.
- STEENHOF, K. AND I. NEWTON. 2007. Assessing Nesting Success and Productivity. Pages 181-192 in *Raptor Research and Management Techniques* (Bird, D., and K. L. Bildstein Eds.). Hancock House Publishers, BC, Canada.
- SWIHART, R. K., AND N. A. SLADE. 1985. Testing for independence of observations in animal movements. *Ecology* 66:1176-84.
- TOWNSEND, S. E., E. V. PEARLSTINE, F. J. MAZZOTTI, AND C. W. DEREN. 2006. Wading birds, shorebirds, and waterfowl in rice fields within the Everglades Agricultural Area. *Florida Field Naturalist* 34:9-20.
- USDA (United States Department of Agriculture) 2007. Census of Agriculture. [Online] Available at www.agcensus.usda.gov/Publications/2007/
- USDA (United States Department of Agriculture) 2002. Census of Agriculture. [Online] Available at www.agcensus.usda.gov/Publications/2002/
- USDA (United States Department of Agriculture) 1997. Census of Agriculture. [Online] Available at www.agcensus.usda.gov/Publications/1997/

- USFWS (UNITED STATES FISH AND WILDLIFE SERVICE). 1999. South Florida multi-species recovery plan. Atlanta, Georgia. 2172 pp. (pgs. 4-219 to 4-235).
- WIENS, J. D., R. T. REYNOLDS, AND B. R. NOON. 2006. Juvenile movement and natal dispersal of northern goshawks in Arizona. *Condor* 108:253-269.
- WITHEY, J. C., T. D. BLOXTON, AND J. M. MARZLUFF. 2001. Effects of tagging and location error in wildlife radiotelemetry studies. Pages 43-75 *in* Radio Tracking and Animal Populations (J.J. Millspaugh and J.M. Marzluff, Eds.). Academic Press, London, UK.
- WHITTY, E. B., D. L. WRIGHT, AND C. G. CHAMBLISS. 2008. Agronomic Crop Species and Variety Selection. Publication SS-AGR-156 of the Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville.

Table 1. Mean area estimates (km²) from range analyses for non-breeding Northern Crested Caracaras in Florida, July 2006 - March 2009.

Data Source: Birds, Seasons	Kernel Contours (km ²)			n birds
	50% (SE)	95% (SE)	MCP ¹ (SE)	
All locations for all birds pooled, all seasons pooled	4,804 (--)	19,928 (--)	-- (--)	58
All locations for all birds pooled, non-breeding seasons ²	4,311 (--)	17,794 (--)	-- (--)	58
All locations for all birds pooled, breeding seasons ³	6,125 (--)	23,757 (--)	-- (--)	58
Average for all individuals, all seasons pooled	820 (146)	3,944 (705)	-- (--)	18
Average for all individuals, non-breeding seasons	-- (--)	-- (--)	241 (145)	26
Average for all individuals, breeding seasons	-- (--)	-- (--)	1,181 (179)	17

¹MCP: minimum convex polygon (km²).

²non-breeding seasons were April - September.

³breeding seasons were October - March.

Table 2. Results from compositional analysis comparing land cover types used by Northern Crested Caracaras to available land covers in Florida, July 2006 - March 2009. Ranks are shown according to randomization tests with 1000 iterations.

Land Cover ¹	1st Order Selection			2nd Order Selection			3rd Order Selection				
	Pu ²	(95% CI)	R ³	Pa ⁴	(95% CI)	Ra	Pa	(95% CI)	Ra	Pa	(95% CI)
OPAST	0.396	(0.337-0.454)	1	0.102	(0.084-0.120)	1	0.167	(0.131-0.204)	1	0.191	(0.167-0.216)
UPAST	0.160	(0.134-0.185)	2	0.148	(0.127-0.170)	3	0.234	(0.193-0.275)	4	0.275	(0.239-0.311)
CITRU	0.206	(0.142-0.269)	3	0.078	(0.062-0.094)	2	0.091	(0.063-0.119)	3	0.102	(0.074-0.129)
GRASS	0.076	(0.048-0.105)	4	0.042	(0.030-0.055)	4	0.052	(0.030-0.073)	5	0.061	(0.048-0.075)
PALMH	0.038	(0.023-0.053)	5	0.020	(0.012-0.029)	5	0.022	(0.008-0.037)	2	0.013	(0.006-0.019)
ROWCP	0.065	(0.042-0.087)	6	0.082	(0.065-0.098)	6	0.084	(0.057-0.111)	6	0.081	(0.049-0.113)
FORSS	0.040	(0.026-0.055)	7	0.243	(0.217-0.269)	7	0.209	(0.170-0.250)	8	0.161	(0.137-0.184)
WETLD	0.016	(0.006-0.027)	8	0.106	(0.087-0.125)	10	0.089	(0.061-0.116)	10	0.085	(0.066-0.104)
URBAN	0.002	(0.000-0.006)	9	0.095	(0.077-0.113)	8	0.027	(0.011-0.043)	9	0.023	(0.014-0.033)
OPH2O	0.000	(0.000-0.000)	10	0.084	(0.067-0.101)	9	0.025	(0.010-0.040)	7	0.011	(0.003-0.018)

* All orders of selection were significant (3rd Order Selection : $X_9^2 = 97.347$, $P < 0.001$; 2nd Order Selection : $X_9^2 = 148.076$, $P < 0.001$; 1st Order Selection : $X_9^2 = 14189.522$, $P < 0.001$).

¹ Land cover. CITRU: *Citrus spp.* in regular rows, FORSS: Forest, shrub, and scrub, GRASS: Grass and sod, OPAST: Occupied pasture (cattle present), OPH2O: Open water (no emergent vegetation), PALMH: Sabal palm (*Sabal palmetto*), ROWCP: All row crops except citrus, UPAST: Unoccupied pasture (cattle absent), URBAN: ≥ 15 structures within 100 m, WETLD: Wetland (with emergent vegetation).

² Pu. Proportion used.

³ R. Rank.

⁴ Pa. Proportion available.

Table 3. Simplified ranking matrices for non-breeding Northern Crested Caracaras based on comparing proportional habitat associations. A triple sign (+++, or ---) indicates significant deviation from random at $P < 0.05$. Significance levels and ranks are shown according to randomization tests with 1000 iterations. Data collected July 2006 through March 2009 in Florida, USA.

¹ Land cover. CITRU: *Citrus spp.* in regular rows, FORSS: Forest, shrub, and scrub, GRASS: Grass and sod, OPAST: Occupied pasture (cattle present), OPH2O: Open water (no emergent vegetation), PALMH: Sabal palm (*Sabal palmetto*), ROWCP: All row crops except citrus, UPAST: Unoccupied pasture (cattle absent), URBAN: ≥ 15 structures within 100 m, WETLD: Wetland (with emergent vegetation).

² 1st order selection (within the region).

³ 2nd order selection (within the species range).

⁴ 3rd order selection (within the individual range).

(Table 2 on next page)

	Land Cover ¹										
	OPAST	UPAST	CITRU	GRASS	PALMH	ROWCP	FORSS	WETLD	URBAN	OPH2O	Rank
1st order selection ²											
OPAST		+++	+++	+++	+++	+++	+++	+++	+++	+++	1
UPAST	---		+	+	+	+++	+++	+++	+++	+++	2
CITRU	---	-		+	+	+++	+++	+++	+++	+++	3
GRASS	---	-	-		+	+++	+++	+++	+++	+++	4
PALMH	---	-	-	-		+	+++	+++	+++	+++	5
ROWCP	---	---	---	---	-		+++	+++	+++	+++	6
FORSS	---	---	---	---	---	---		+	+++	+++	7
WETLD	---	---	---	---	---	---	-		+++	+++	8
URBAN	---	---	---	---	---	---	---	---		+	9
OPH2O	---	---	---	---	---	---	---	---	-		10
2nd order selection ³											
OPAST		+++	+	+++	+++	+++	+++	+++	+++	+++	1
UPAST	---		-	+	+	+++	+++	+++	+++	+++	3
CITRU	-	+		+	+	+++	+++	+++	+++	+++	2
GRASS	---	-	-		+	+	+++	+++	+++	+++	4
PALMH	---	-	-	-		+	+++	+++	+++	+++	5
ROWCP	---	---	---	-	-		+++	+++	+++	+++	6
FORSS	---	---	---	---	---	---		+	+	+	7
WETLD	---	---	---	---	---	---	-		-	-	10
URBAN	---	---	---	---	---	---	-	+		+	8
OPH2O	---	---	---	---	---	---	-	+	-		9
3rd order selection ⁴											
OPAST		+++	+	+++	+	+++	+++	+++	+++	+++	1
UPAST	---		-	+	-	+	+++	+++	+++	+++	4
CITRU	-	+		+	-	+	+++	+++	+++	+++	3
GRASS	---	-	-		-	+	+++	+++	+++	+++	5
PALMH	-	+	+	+		+	+++	+++	+++	+++	2
ROWCP	---	-	-	-	-		+++	+++	+++	+++	6
FORSS	---	---	---	---	---	---		+	+	-	8
WETLD	---	---	---	---	---	---	-		-	---	10
URBAN	---	---	---	---	---	---	-	+		-	9
OPH2O	---	---	---	---	---	---	+	+++	+		7

Table 4. Partial X^2 values for each cell comparing land cover types at random locations within 6 km of a Northern Crested Caracara location to random locations beyond 6 km of a caracara location. Data collected in Florida, July 2006 - March 2009.

Within 6 km of a Caracara Location	Partial X^2 Value for Each Land Cover Type									
	CITRU	FORSS	GRASS	OPAST	OPH2O	PALMH	ROWCP	UPAST	URBAN	WETLD
No	0.586	1.229	0.545	10.966	10.827	0.050	0.013	12.960	12.666	0.719
Yes	0.915	1.919	0.851	17.124	16.908	0.078	0.020	20.238	19.779	1.122

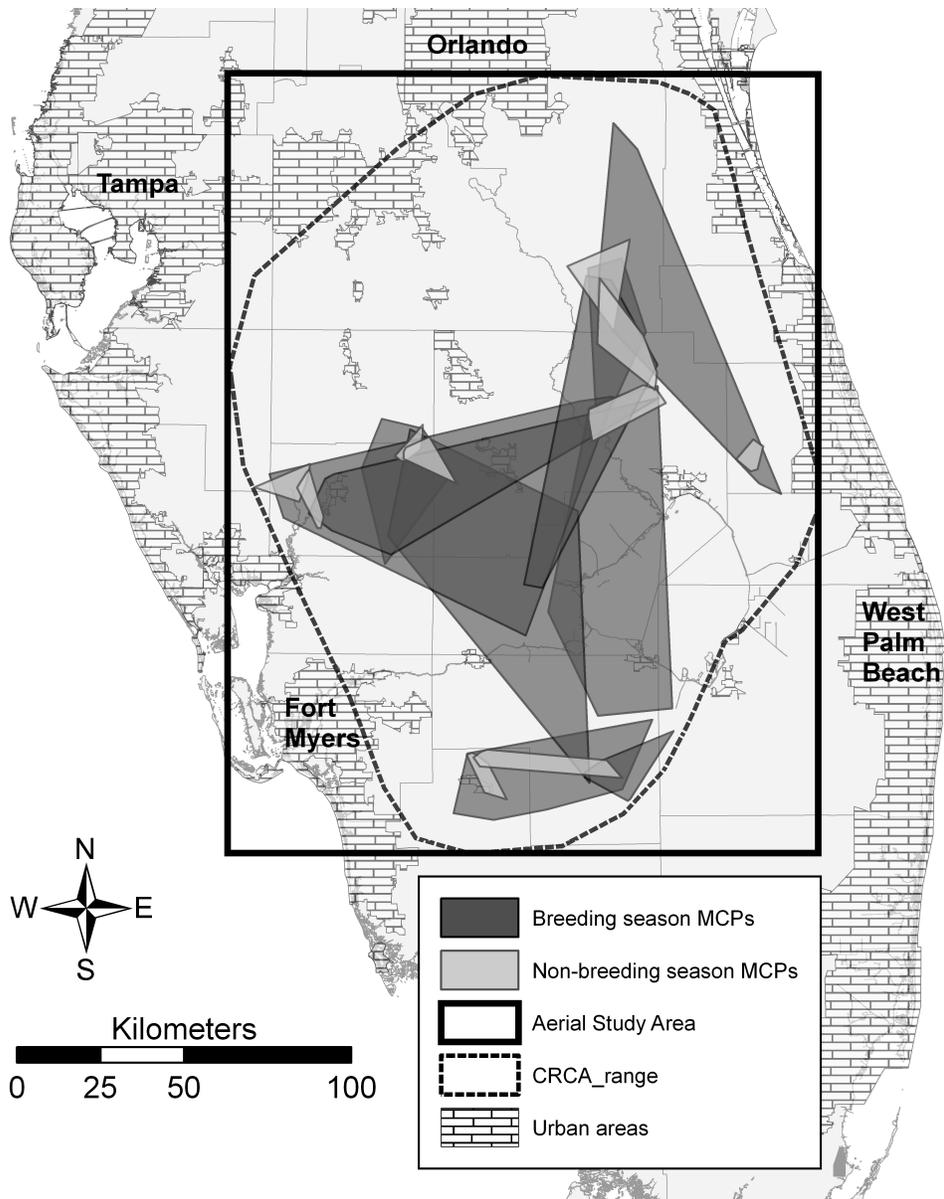


Figure 1. Minimum convex polygons enclosing seasonal movements by Northern Crested Caracaras aerial telemetered in Florida, U.S.A, during a breeding season (October - March), and an adjacent non-breeding season (April -September). Equal search effort was applied in each season. To avoid cluttering the map, only the sample of birds that provided ≥ 10 locations / season are represented. “CRCA_range” indicates the species range as estimated in Morrison (1996). Data collected August 2006 - March 2009. Background map layers were provided by the Florida Geographic Data Library.

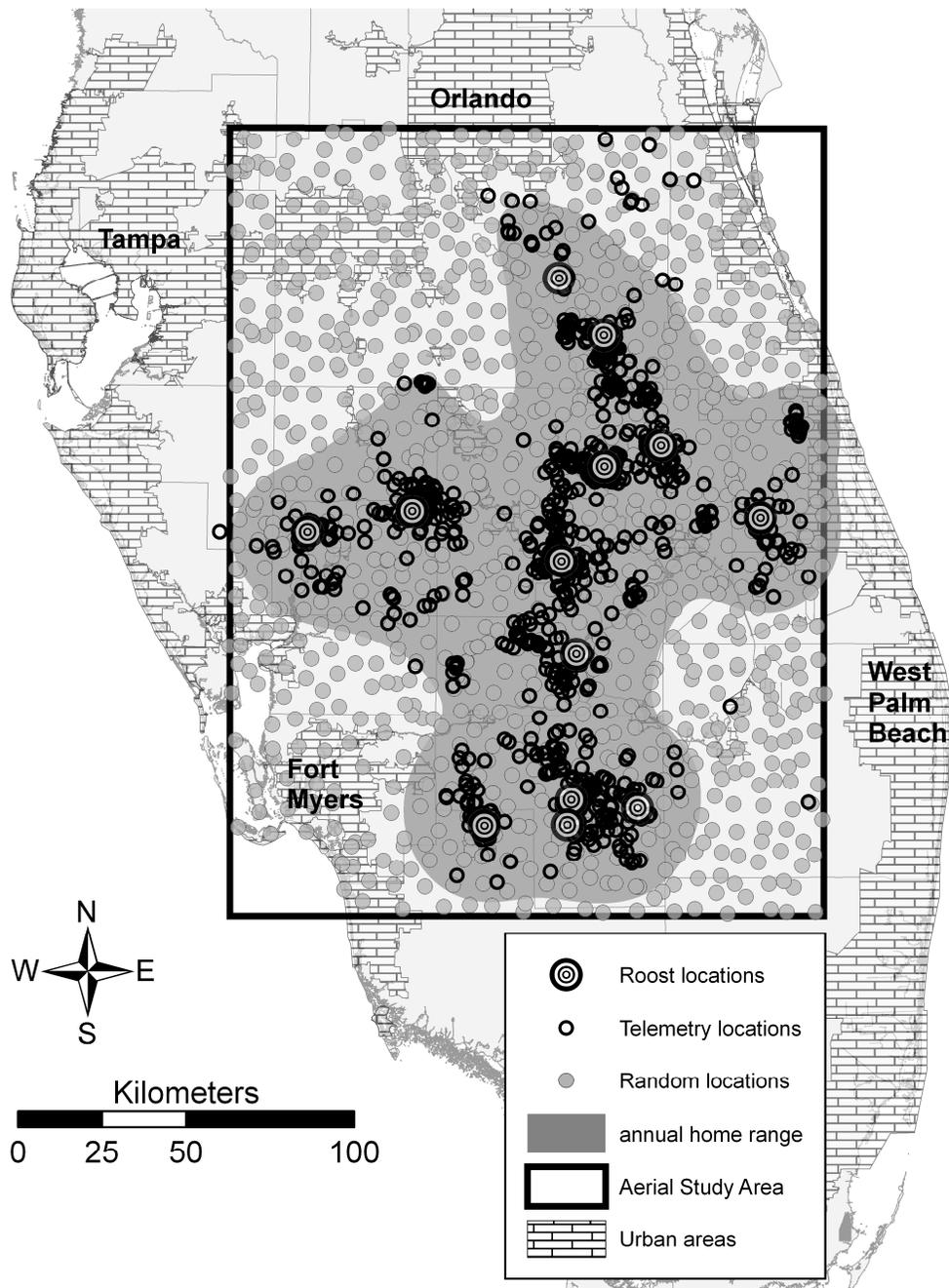


Figure 2. Roost locations, telemetry locations, random locations, from aerial telemetry location data for non-breeding Northern Crested Caracaras tracked in Florida, U.S.A., July 2006 through March 2009. “Annual home range” indicates a 95% kernel contour generated by pooling all telemetry locations. Background map layers were provided by the Florida Geographic Data Library.

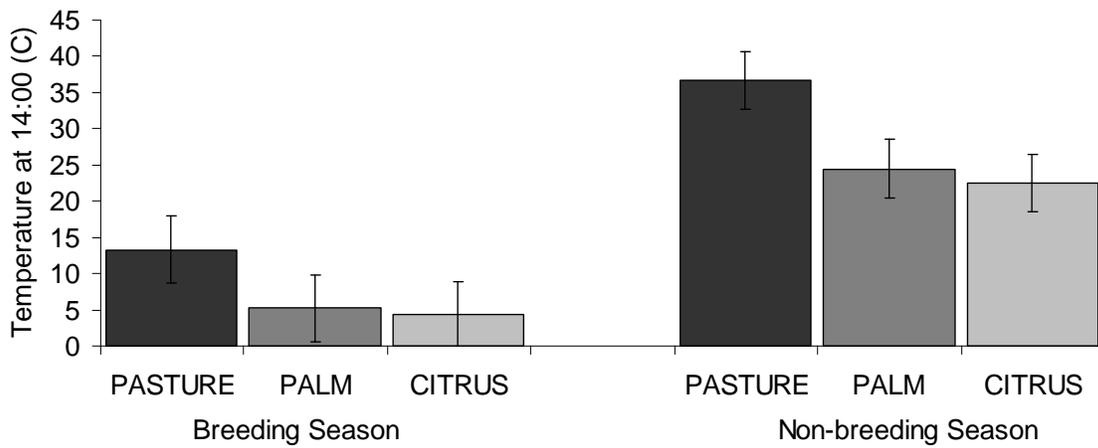


Figure 3. Temperature (°C) in pasture, palm, and citrus at 14:00. Temperatures were recorded one week per month in 2008 in an area used by non-breeding Northern Crested Caracaras in Florida. One temperature logger was deployed in each landscape type. Breeding Season = October- March. Non-Breeding season = April - September.

CHAPTER 2

SEASONAL SURVIVAL OF NON-BREEDING NORTHERN CRESTED CARACARAS (*CARACARA CHERIWAY*) IN FLORIDA

James F. Dwyer,¹ James D. Fraser,¹ and Joan L. Morrison²

¹Department of Fisheries and Wildlife Sciences, Virginia Tech, 100 Cheatham Hall,
Blacksburg, VA24061, USA

²Department of Biology, Trinity College, 300 Summit Street, Hartford, CT 06106, USA

ABSTRACT

Many birds do not breed in the year(s) immediately following independence from parental care. Instead, they spend time developing into adults or searching for a breeding opportunity. Survival during this period often is poorly understood. From July 2006 - March 2009, we used radio-tracking data collected during aerial telemetry and analyzed in program MARK to estimate monthly and annual survival for 58 non-breeding Northern Crested Caracaras (*Caracara cheriway*). We used an information theoretic approach to evaluate competing models via QAICc. Best models indicated differences in monthly survival, with lowest monthly survival during the peak of breeding (Dec-Jan; 0.953), slightly higher monthly survival during the remainder of the breeding season (Oct, Nov, Feb, Mar; 0.984), and highest monthly survival during the non-breeding season (Apr - Sep; 0.995). Within-season survival is little known for birds, and this information provides unique insight to this aspect of avian life history. We found no effect of sex or stage on monthly or annual survival, and annual survival was intermediate (0.826) to existing estimates for juveniles and breeders. The long-term persistence of individual floaters implies that breeding habitat is saturated. Management goals to increase the caracara population may be maximized if additional habitat was made available for settlement by floaters, and habitat loss may displace existing breeders into the non-breeding population. Floaters also can serve as a buffer between the mortality of breeding birds and declines in productivity, so management also should strive to retain a non-breeding population.

Key words: *Caracara cheriway*, Crested Caracara, floater, immature, non-breeding, program MARK, survival

The life histories of many bird species include one or more years after independence and before breeding when immature birds develop into adults, or adults persist as “floaters” (Newton 1998, Kenward et al. 2000). Floaters are non-territorial, non-breeding individuals in adult plumage that would presumably enter the breeding population if they could secure a territory (Newton and Rothery 2001, Penteriani et al. 2008). To avoid aggression by territorial breeders, immatures and floaters (collectively hereafter “non-breeders”) often are secretive, and may occupy habitats that differ from breeding habitat (Brown 1969, Smith 1978, Newton 1992, 1998, Sergio et al. 2009). They may also range widely while attempting to find a vacant territory (Newton 1998), or while evaluating the quality of surrounding territories, i.e., “territory prospecting” (Reed et al. 1999). Consequently, non-breeders can be difficult to study, and the rapid replacement of experimentally removed territory holders, or rapid occupancy of artificial nest sites has traditionally been the strongest support for their presence (Newton 1998).

Several authors have indicated that survival at fledgling, immediately after independence, and during dispersal, is lower than survival of adults in breeding areas, apparently because individuals are exposed to new suites of risks and challenges during those transitions (Kershner et al. 2004). Studies comparing survival of non-territorial to territorial individuals indicate that the latter have lower survival (e.g., Watson 1985, Vanderwerf 2008, Stutchbury et al. 2009), sometimes as a function of sex, density, or individual size (Stutchbury et al. 2009, te Marvelde et al. 2009, Morrison et al. 2009).

Among breeding birds, seasonal mortality has been associated with territory establishment, disease, molt, long-distance migration, severe winters, predation, and hunting (respectively: Smith 1967, Nilsson 1982, Lahti et al. 1998, Schmutz and Ely 1999, Clausen et al. 2001, Gauthier et al. 2001, Johannesen et al. 2002, Faustino et al. 2004, and Hupp et al. 2008).

Despite this knowledge, survival of non-breeders, especially seasonal survival, remains among the least understood parameters in avian demography (Medeiros and Freed 2009). Research on the survival of non-breeders may contribute substantially to management because non-breeder survival can affect population persistence (Penteriani et al. 2005a, 2008), and management strategies that neglect non-breeders may be less effective than intended (Rohner 1996).

The Northern Crested Caracara (*Caracara cheriway*, hereafter “caracara”) is distributed from northern South America to the southwestern United States, with an apparently isolated population in Florida (Ferguson-Lees and Christie 2001, Dove and Banks 1999) occurring between Orlando to the north, and the Everglades to the south (USFWS 1999). The Florida population is Federally and State listed as threatened, largely due to concerns over loss of breeding habitat (Federal Register 1987, Logan 1997), and a recovery plan for caracaras primarily deriving from and focusing on breeding birds has been implemented (USFWS 1999). Though this plan recognizes the importance of non-breeding caracaras, it does not incorporate information on their survival because no such information existed when it was written.

Breeding caracaras are non-migratory, territorial, and prevent access by non-breeders to breeding areas year-round (Morrison 1996). Annual survival of breeding

caracaras is relatively high (Morrison 2003) with survival of breeding females exceeding that of breeding males, and survival of breeders of both sexes exceeding that of juveniles. To facilitate the development of a complete survival model for caracaras, we investigated sex and stage-specific survival of immature and floater caracaras in Florida. Caracaras in Florida can breed year-round (Morrison 1996), but 96% of known nesting attempts are initiated during the six month period from October through March (Morrison 1999). We refer to this period as the breeding season, and we define December and January, the central months of the breeding season when 61% of nests are initiated, as the peak of breeding.

METHODS

Study area.— We defined our study area as a 43,000 km² rectangle (Fig. 1) that was larger than and included the entire known range of caracaras in Florida (35,000 km², Morrison 1996). This facilitated detection of movements beyond the known range, and allowed us to minimize a common problem in survival studies wherein emigration from the study area must be accounted for via censoring animals (Kenward 2001, Millspaugh and Marzluff 2001).

Aging Caracaras.— Juvenile caracaras are distinguished by their streaked breast plumage, immatures are characterized by breasts having a mix of streaking and barring, and adults, that may be floaters or breeders, have entirely barred breasts (Wheeler and Clark 1995). Caracaras transition from juvenile to immature plumage at about 12 mo of age, and have been variously reported to attain adult plumage in 2 to > 4 yr (Bent 1961, Voous 1983, Layne 1996, Clark 2001). We could not resolve this confusion, so we

assumed caracaras entered adult plumage at age 2.5 yr (30 mo), a rough average of all the published estimates we could find (USFWS 1999, Ferguson-Lees and Christie 2001, Nemeth and Morrison 2002, Wheeler 2003,). Because we could not age birds precisely, we assumed birds captured as immatures were half way to adult plumage, so we transitioned them to floaters in our models after 15 mo of tracking.

Field Methods.— We used radio tags with mortality sensors to monitor survival (American Wildlife Enterprises (AWE), Monticello, FL; Holohil Sys. Limited, Carp, ON, CAN; Advanced Telemetry Systems (ATS), Inc., Isanti, MN; Wildlife Materials Inc., Murphysboro, IL). Each tag weighed ~30 g (< 3% mean body mass; Morrison 1996), was attached via a backpack harness (cf. Buehler et al. 1995) of Teflon ribbon (Bally Ribbon Mills, Bally, PA), and was expected to transmit for 2-3 yr. We collected blood from each tagged bird, and used blood to identify sex chromosomally (Avian Biotech International, Tallahassee, FL). We used a trap baited with carrion to capture non-breeding caracaras anywhere in their range that we found them in groups. All protocols were approved by the Virginia Tech Institutional Animal Care and Use Committee (permit # 10-011-FIW).

We sought tagged birds during weekly aerial telemetry flights lasting approximately eight h each, ($\bar{x} = 7.80$ h / week for 140 consecutive weeks). We flew at 275 to 325 m above ground level and scanned the frequencies of all deployed tags during each flight. If we did not detect for > 12 mo the radio-frequency assigned to a particular bird, we dropped that individual from our scans and censored the bird in our analysis from the week when it first went undetected.

Data analysis.— We used known fate models in a staggered entry design (Pollock et al. 1989) in program MARK (White and Burnham 1999) to estimate monthly survival with respect to season, stage, and sex as described above. To evaluate seasonal effects, we tested three models. We tested a 2-season model that constrained estimated survival as constant within the breeding season, but allowed that estimate to differ from an estimate that was constant for the non-breeding season. We tested another 2-season model that constrained estimated survival as constant during the peak of breeding only, but allowed that estimate to differ from an estimate that was constant during all other months. We also tested a 3-season model that constrained estimated survival as constant in the peak of breeding, allowed that estimate to differ from an estimate for the remainder of the breeding season, and allowed both of those estimates to differ from an estimate for the non-breeding season.

To identify the best of the models tested, we used a Quasi Akaike Information Criterion (QAIC) corrected with a variance inflation factor (\hat{c}) estimated via a bootstrap goodness of fit procedure (QAICc). Our \hat{c} was 2.532, indicating overdispersion (Burnham and Anderson 2002), so we adjusted \hat{c} and the resulting QAICc in our models. Uncertainty in model selection arises when competing models score within about 4 QAICc of the top model and is handled via model averaging (Burnham and Anderson 2002). We used model averaging to generate monthly survival estimates, and we multiplied monthly estimates to generate an annual estimate. We do not report results for any candidate models with QAICc scores that differ from our best model by > 4 , except for the null and the global models.

We used program CONTRAST (Hines and Sauer 1989) to compare survival estimates between seasons, and to compare our estimates to previously reported estimates for juveniles and breeders (Morrison 2003). To quantify monthly measures of instantaneous risk of mortality, we constructed hazard functions (\hat{h}_t) (Cox 1972) by dividing the number of birds that died each month by the number that survived (Lee 1992).

RESULTS

From July 2006 through March 2009, we monitored survival of 58 caracaras (27 males, 31 females) over a mean of 17.0 months / bird (SE = 1.11). We captured 56 immature birds, and tracked 28 (50%) into the floater stage. We captured two birds as floaters, and each of these survived for the duration of the study. Fifteen of the 56 birds captured as immatures (27%) died during the study. The locations of mortalities are indicated in Fig.1. Eleven of these died as immatures, and four died as floaters. None of the birds we tracked nested during our study.

Our best models indicated seasonal effects on survival but no effect of sex or stage (Table 1). In these models, monthly survival was lowest during the peak of breeding, higher during the remainder of the breeding season, and highest during the non-breeding season (Table 2). Using output from model averaging, we multiplied monthly survival estimates to generate an annual survival estimate of 0.783 for immature and floater caracaras. The three seasonal survival estimates were different ($\chi^2 = 6.57$, $df = 2$, $P = 0.037$), and our annual estimate for non-breeding caracaras was different from those

of Morrison (2003) for juveniles and breeding adults ($\chi^2 = 15.74$, $df = 2$, $P = 0.001$). Hazard analyses also indicated lower survival during the breeding season (Fig. 2).

DISCUSSION

Each of our top models indicated strong seasonal effects on the survival of non-breeding caracaras, and two of our top three models indicated those effects were strongest during the peak of the breeding season. Other authors have associated variation in survival within or between seasons with long-distance migration, territory establishment, severe winters, hunting, disease, molt, and predation (Smith 1967, Nilsson 1982, Lahti et al. 1998, Schmutz and Ely 1999, Clausen et al. 2001, Gauthier et al. 2001, Johannesen et al. 2002, Faustino et al. 2004, and Hupp et al. 2008). These authors have not considered within-season differences in survival, however. Smith (1967) observed variation in within season survival among Black-capped Chickadees, where survival was lowest during the two week period when Chickadees establish territories. In this case, reduced survival was attributed to conflicts over breeding territories. We could find no other published literature on within-season differences in avian survival.

We found that caracaras move more widely during breeding seasons than during non-breeding seasons (Chapter 1), and that the lowest survival occurs during January December and January; the two months when the most nests are initiated (Morrison 1999). We also found that groups are composed of > 30% floaters, and that young non-breeding birds follow older non-breeding birds to foraging sites (Chapter 3). In this study, we found no difference in survival between immatures and floaters. This finding may be a consequence of our inability to age birds precisely. Alternatively, because

younger caracaras follow older birds, younger birds may have been exposed to the same movement-related risks, or conspecific aggression that floaters were. Because prospecting, i.e. evaluating territory quality (Boulinier et al. 1996, Reed et al. 1999, Roth et al. 2009) is undertaken by both floaters and immature birds in some species, younger caracaras may also have been exposed to increased risk during breeding seasons even if they moved independently of older non-breeding caracaras.

Our estimate of survival for non-breeders is intermediate between previous estimates of survival for juvenile and adult caracaras (Morrison 2003). This follows the common pattern that survival increases with increasing age until senescence begins (Low and Pärt 2009, Newton et al. 1997, Gustafsson and Pärt 1990). Young birds typically are less efficient foragers than older birds (Forslund and Pärt 1995, Lack 1954, 1966), so perhaps older non-breeders have survived the period during which their naivety may have caused their deaths. We found in a related study (Chapter 3) that immature birds follow floaters to and within foraging areas. This implies that immatures have not yet learned to maximize foraging efficiency, and suggests that our inability to precisely discriminate ages influenced our results. We also found no difference in survival by sex, perhaps because both sexes experience similar environmental conditions during this stage of their life history.

A complete annual survival model for caracaras in Florida should include the previously reported estimates of annual survival for juveniles (0.694), breeding males (0.876) and breeding females (0.906) (Morrison 2003), and our estimate for immatures and floaters (0.826).

Most management strategies for threatened or endangered raptors, including the existing management plan for caracaras in Florida (USFWS 1999), focus on breeding birds and breeding areas (Penteriani et al. 2005b). Non-breeding birds should also be included in management strategies because non-breeders stabilize breeding populations by replacing breeding individuals that die. In the absence of floaters to replace lost breeders, populations can decline. Non-breeding birds also can be important in evaluating the effectiveness and directing the future course of management actions. None of the non-breeders we tracked ever established breeding territories, and floaters make up approximately 40% of the non-breeding population (Chapter 3). This suggests that all breeding territories are occupied (Newton 1998, Hunt 1998). The creation of additional breeding habitat would likely lead to an increase in the breeding population, and losses of breeding habitat could both deprive floaters of breeding opportunities and displace breeding birds into the floater population. Future research should investigate the responses of breeding caracaras to land use changes within their territories, and investigate how floaters acquire territories.

ACKNOWLEDGEMENTS

This study was funded by the U.S. Fish and Wildlife Service grant agreement no.145 401815G060. This is contribution No. _____ (assigned following acceptance) from the MacArthur Agro-Ecology Research Center (MAERC) of Archbold Biological Station, and we thank G. Lollis and P. Bohlen of MAERC for logistic support. We thank Capt. R. Myers of Lockwood Aviation for outstanding piloting, and S. J. Chiavacci, J. L. Dowling,

A. L. Fleming, M. R. Hanson, L. M. Hunt, A. K. Mangiameli, M. N. Scholer, N. E. Swick, and N. R. Thompson for aerial telemetry assistance.

LITERATURE CITED

- BENT A. C. 1961. Life Histories of North American Birds of Prey. Dover Publications, Inc. NY, NY.
- BOULINIER, T., E. DANCHIN, J. Y. MONNAT, C. DOUTRELANT, AND B. CADIOU. 1996. Timing of prospecting and the value of information in a colonial breeding bird. *Journal of Avian Biology* 27:252-256.
- BUEHLER, D. A., J. D. FRASER, M. R. FULLER, AND L. S. MCALLISTER, AND J. K. D. SEEGAR. 1995. Captive and field-tested radio-transmitter attachments for Bald Eagles. *Journal of Field Ornithology* 66:173-180.
- BURNHAM, K. P. AND D. R. ANDERSON. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2nd edn. Springer-Verlag, NY, NY.
- BROWN, J. M. 1969. Territorial behavior and population regulation in birds: a review and re-evaluation. *Wilson Bulletin* 81:293-329.
- BROWN, D. 1975. A test of randomness of nest spacing. *Wildfowl* 26:102-103.
- CLARK, W. S. 2001. Crested Caracara in basic I plumage: Betwixt and between. *Birding* 33:524-527.
- CLAUSEN, P., M. FREDERIKSEN, S. M. PERCIVAL, G. Q. A ANDERSON, AND M. J. H. DENNY. 2001. Seasonal and annual survival of East-Atlantic Pale-Bellied Brant Geese *Branta hrota* assessed by capture-recapture analysis. *Ardea* 89:101-111.

- COX, D. R. 1972. Regression models and life tables. *Journal of the Royal Statistical Society B* 34:187-220.
- DOVE, C. J. AND R.C. BANKS. 1999. A taxonomic study of Crested Caracaras (Falconidae). *Wilson Bulletin* 111:330-339.
- FAUSTINO, C.R., C. S. JENNELLE, V. CONNOLLY, A. K. DAVIS, E. C. SWARTHOUT, A. A. DHONDT, AND E. G. COOCH. 2004. *Mycoplasma gallisepticum* infection dynamics in a house finch population: seasonal variation in survival, encounter and transmission rate. *Journal of Animal Ecology* 73:651-669.
- FEDERAL REGISTER. 1987. Threatened Status for Florida Population of Audubon's Crested Caracara; 52 FR 25229-25232.
- FERGUSON-LEES, J., AND D. A. CHRISTIE. 2001. *Raptors of the World*. Houghton Mifflin Co. Boston. pps. 804-806.
- FORSLUND, P. AND T. PÄRT. 1995. Age and reproduction in birds-Hypotheses and tests. *Trends in Ecology and Evolution* 10:374-378.
- GAUTHIER, G., R. PRADEL, S. MENU, AND J. D. LEBRETON. 2001. Seasonal survival of greater Snow Geese and effect of hunting under dependence in sighting probability. *Ecology* 82:3105-3119.
- GUSTAFSSON L, AND T. PÄRT. 1990. Acceleration of senescence in the collared flycatcher (*Ficedula albicollis*) by reproductive costs. *Nature* 347:279-281.
- HINES, J. E., AND J. R. SAUER. 1989. Program CONTRAST - A General Program for the Analysis of Several Survival or Recovery Rate Estimates. US Fish & Wildlife Service, Fish & Wildlife Technical Report 24, Washington, DC.
- HUNT, W. G. 1998. Raptor floaters at Moffat's equilibrium. *Oikos* 82:191-197.

- HUPP, J. W., J. A. SCHMUTZ, AND C. R. ELY. 2008. Seasonal survival of radiomarked Emperor Geese in western Alaska. *Journal of Wildlife Management* 72:1584-1595.
- JOHANNESSEN, E., H. STEEN, AND L. PERRIMAN. 2002. Seasonal variation in survival, weights, and population counts of Blue Penguins (*Eudyptula minor*) in Otago, New Zealand. *New Zealand Journal of Zoology* 29:213-219.
- KENWARD, R. E. 2001. *A Manual for Wildlife Radio Tagging*. Academic Press. San Diego, CA.
- KENWARD, R. E., S. S. WALLS, K. H. HODDER, M. PAHKALA, S. N. FREEMAN, AND V. R. SIMPSON. 2000. The prevalence of non-breeders in raptor populations: Evidence from rings, radio-tags, and transect surveys. *Oikos* 91:271-279.
- KERSHNER, E. L., J. W. WALK, AND R. E. WARNER. 2004. Postfledging movements and survival of juvenile Eastern Meadowlarks (*Sturnella magna*) in Illinois. *Auk* 121:1146-1154.
- LACK, D. 1954. *The Natural Regulation of Animal Numbers*. Clarendon Press. Oxford.
- LACK, D. 1966. *Population Studies of Birds*. Clarendon Press. Oxford.
- LAHTI, K., M. ORELL, S. RYTKÖNEN, AND K. KOIVULA. 1998. Time and food dependence in Willow Tit winter survival. *Ecology* 79:2904-2916.
- LAYNE, J. N. 1996. Audubon's Crested Caracara. Pages 197-210 *in* *Rare and Endangered Biota of Florida*; Vol. 5: Birds (Kale, H. W. and H. T. Smith, Eds.). University Press of Florida. Gainesville, FL.
- LEE, E. T. 1992. *Statistical Methods for Survival Data Analysis*, 2nd ed. Wiley, New York, NY.

- LOGAN, T. 1997. Florida's Endangered Species, Threatened Species, and Species of Special Concern. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
- LOW, M. AND T. PÄRT. 2009. Patterns of mortality for each life-history stage in a population of the endangered New Zealand Stitchbird. *Journal of Animal Ecology* 78:761-771.
- MEDEIROS, M. C. AND L. A. FREED. 2009. A fledgling-mass threshold greatly affects juvenile survival in the Hawaii Akepa (*Loxops Coccineus Coccineus*). *Auk* 126:319-325.
- MILLSPAUGH, J. J. AND J. M. MARZLUFF. 2001. Radio Tracking and Animal Populations. Academic Press, San Diego.
- MORRISON, J. L. 1996. Crested Caracara (*Caracara plancus*). In *The Birds of North America*, No. 249 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.
- MORRISON, J. L. 1999. Breeding biology and productivity of Florida's Crested Caracaras. *Condor* 101:505-517.
- MORRISON, J. L. 2003. Age-specific survival of Florida's Crested Caracaras. *Journal of Field Ornithology* 74:321-330.
- MORRISON, K. W., J. M. HIPFNER, C. GJERDRUM, AND D. J. GREEN. 2009. Wing length and mass at fledging predict local juvenile survival and age at first return in Tufted Puffins. *Condor* 111:433-441.
- NEMETH N. M. AND J. L. MORRISON. 2002. Natal dispersal of Crested Caracaras in Florida. *Journal of Raptor Research* 36:203-206.

- NEWTON, I. 1992. Experiments on limitation of bird numbers by territorial behavior. *Biological Reviews* 67:129-173.
- NEWTON, I. 1998. *Population Limitation in Birds*. Academic Press. New York.
- NEWTON, I., AND P. ROTHERY. 2001. Estimation and limitation of numbers of floaters in a Eurasian Sparrowhawk population. *Ibis* 143:442-449.
- NEWTON, I., P. ROTHERY, AND I. WYLLIE. 1997. Age-related survival in female Sparrowhawks *Accipiter nisus*. *Ibis* 139:25-30.
- NILSSON, S. G. 1982. Seasonal variation in the survival rate of adult Nuthatches: *Sitta europaea* in Sweden. *Ibis* 124:96-100.
- PENTERIANI, V., F. OTALORA, AND M. FERRER. 2005a. Floater survival affects population persistence. The role of prey availability and environmental stochasticity. *Oikos* 108:523-534.
- PENTERIANI, V., F. OTALORA, F. SERGIO, AND M. FERRER M. 2005b. Environmental stochasticity in dispersal areas can explain the 'mysterious' disappearance of breeding populations. *Proceedings of the Royal Society of London, Series B-Biological Sciences* 272:1265-1269.
- PENTERIANI, V., F. OTALORA, AND M. FERRER. 2008. Floater mortality within settlement areas can explain the Allee effect in breeding populations. *Ecological Modeling* 213:98-104.
- POLLOCK, K. H., S. R. WINTERSTEIN, C. M. BUNCK, AND P. D. CURTIS. 1989. Survival analysis in telemetry studies-the staggered entry design. *Journal of Wildlife Management* 53:7-15.

- REED, J., T. BOULINIER, E. DANCHIN, AND L. ORING. 1999. Informed dispersal: prospecting by birds for breeding sites. *Current Ornithology* 15:189-259.
- ROHNER, C. 1996. The numerical response of Great Horned Owls to the snowshoe hare cycle: consequences of non-territorial “floaters” on demography. *Journal of Animal Ecology* 65:359-370.
- ROTH, T., P. SPRAU, R. SCHMIDT, M. NAGUIB, AND V. AMRHEIN. 2009. Sex-specific timing of mate searching and territory prospecting in the nightingale: nocturnal life of females. *Proceedings of the Royal Society of London Series B-Biological Sciences* 276:2045-2050.
- SERGIO, F. B. JULIO, F. HIRALDO. 2009. Predictors of floater status in a long-lived bird: a cross-sectional and longitudinal test of hypotheses. *Journal of Animal Ecology* 78:109-118.
- SCHMUTZ, J. A. AND C. R. ELY. 1999. Survival of greater White-Fronted Geese: Effects of year, season, sex, and body condition. *Journal of Wildlife Management* 63:1239-1249.
- SMITH, S. M. 1967. Seasonal changes in the survival of Black-Capped Chickadee. *Condor* 69:344-359.
- SMITH, S.M., 1978. The ‘underworld’ in a territorial sparrow: adaptive strategy for floaters. *American Naturalist* 112:571–582.
- STUTCHBURY, B. J. M., J. R. HILL, P. M. KRAMER, S. A. RUSH, S. A. TAROF. 2009. Sex and age-specific annual survival in a neotropical migratory songbird, the Purple Martin (*Progne subis*). *Auk* 126:278-287.

- TE MARVELDE, L., P. L. MEININGER, R. FLAMANT, N. J. DINGMANSE. 2009. Age-specific density-dependent survival in Mediterranean Gulls *Larus melanocephalus*. *Ardea* 97:305-312.
- USFWS (U. S. FISH AND WILDLIFE SERVICE). 1999. South Florida multi-species recovery plan. Atlanta, Georgia. 2172 pp. (pgs. 4-219 to 4-235).
- VANDERWERF, E. A. 2008. Sources of variation in survival, recruitment, and natal dispersal of the Hawai'i 'Elepaio. *Condor* 110:241-250.
- VOOUS, K. H. 1983. Birds of the Netherlands and Antilles. Walburg Press, Netherlands.
- WATSON, A. 1985. Social class, socially induced loss, recruitment and breeding of Red Grouse. *Oecologia* 67:493-498.
- WHEELER, B. K. 2003. Raptors of Eastern North America. Princeton University Press, Princeton, NJ, U.S.A.
- WHEELER, B. K., AND W. S. CLARK. 1995. A Photographic Guide to North American Raptors. Academic Press, San Diego, CA.
- WHITE, G. C. AND K. P. BURNHAM. 1999. Program MARK: Survival estimation from populations of marked animals. *Bird Study* 46 Supplement, 120-138.

Table 1. Model selection results for monthly survival of Northern Crested Caracaras (n = 58) in Florida, July 2006 through March 2009. The global model includes sex (male vs. female), stage (immature vs. floater), and seasonal (breeding vs. non-breeding) variables.

Model	QAIC _c	ΔAIC _c	w _i	Likelihood	k	Deviance
3-Season ¹	92.86	0.00	0.40	1.00	3	86.84
2-Season #1 ²	92.98	0.12	0.37	0.94	3	88.98
2-Season #2 ³	94.15	1.29	0.21	0.52	2	90.14
Null Model	98.56	5.70	0.02	0.06	1	96.56
Global Model	210.17	117.31	0.00	0.00	66	71.78

¹3-Season: the peak of breeding is constant (Dec-Jan), off-peak breeding is constant (Oct-Nov, and Jan-Mar), and the non-breeding season is constant (Apr-Sep), but each of these is allowed to differ from one another.

²2-Season #1: model the entire breeding season (Oct-Mar) is constant but allowed to differ from the non-breeding season (Apr-Sep), which is also constant.

³2-Season #2: the peak of breeding (Dec-Jan) is constant but allowed to differ from all other months (Feb-Nov), which also are constant.

Table 2. Estimates and standard errors for monthly survival of Northern Crested Caracaras (n = 58) after model averaging. Data collected in Florida, July 2006 through March 2009. Non-breeding includes immatures and floaters.

Stage	Months	Estimate	SE	Lower	Upper
				C.I.	C.I.
Juvenile ¹	Each month	0.970	0.005	0.958	0.979
	Annual	0.694	--	--	--
Non-breeding	Apr, May, Jun, Jul, Aug, Sep	0.995	0.004	0.985	1.000
	Oct, Nov, Feb, Mar	0.984	0.007	0.944	0.996
	Dec, Jan	0.953	0.019	0.884	0.982
	Annual	0.826	--	--	--
Breeding ¹	Male (annual)	0.876	0.003	0.855	0.898
	Female (annual)	0.906	0.002	0.894	0.919

¹ From Morrison (2003)

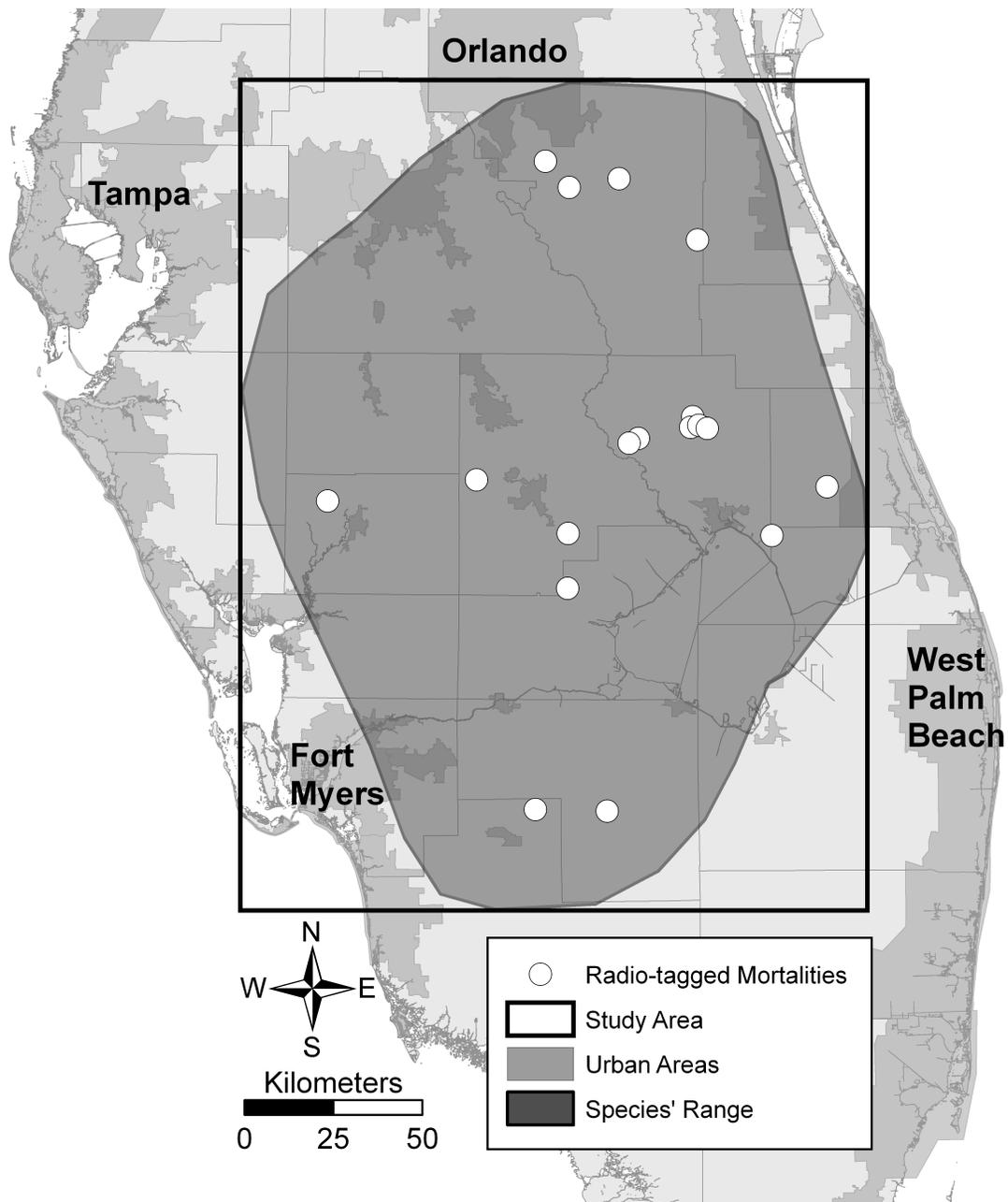


Figure 1. Study area, species' range, and location of detected mortalities for Northern Crested Caracaras. Data collected in Florida, July 2006 through March 2009.

Background map layers were provided by the Florida Geographic Data Library.

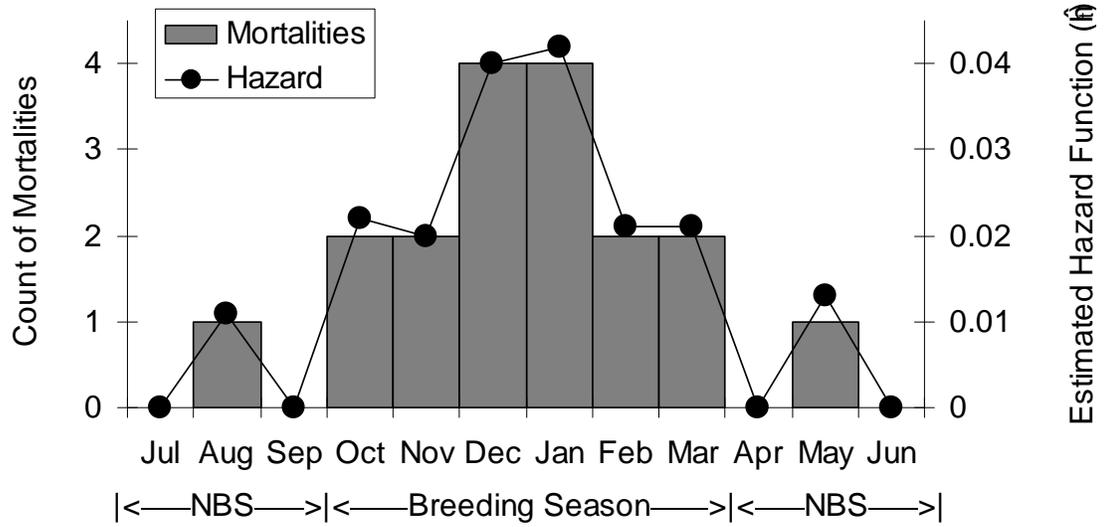


Figure 2. Month of mortality, and estimated monthly hazard function (\hat{h}) for Northern Crested Caracaras radio-telemetered in Florida 2006-2009 (n = 58 caracaras, and 18 mortalities). NBS: Non-Breeding Season.

CHAPTER 3

BENEFITS AND COSTS OF GROUPING FOR NON-BREEDING NORTHERN CRESTED CARACARAS (*CARACARA CHERIWAY*)

James F. Dwyer,¹ James D. Fraser,¹ and Joan L. Morrison²

¹Department of Fisheries and Wildlife Sciences, Virginia Tech, 100 Cheatham Hall,
Blacksburg, VA24061, USA

²Department of Biology, Trinity College, 300 Summit Street, Hartford, CT 06106, USA

ABSTRACT

Grouping is widespread among animals, and may confer benefits and costs to group members. Northern Crested Caracaras (*Caracara cheriway*) participate in single species and mixed-species groups, but little information exists to evaluate potential consequences of grouping. In this study, we evaluated a potential anti-predation benefit by exposing various sized groups of caracaras to a simulated predator. We evaluated potential benefits of local enhancement and social learning by creating patches of prey within foraging areas and documenting arrival timing and leader-follower relationships among group members. We conducted 5-minute focal samples and 30-minute group samples to collect data on social interactions and used the results to identify intraspecific and interspecific dominance hierarchies. Caracaras do not appear to gain predator detection benefits from grouping. Caracaras arrived non-randomly at prey, and adult caracaras were the first to arrive more often than expected given the proportion of adults in groups. I.e., adult caracaras tended to lead groups, and young birds benefited through social learning. Caracaras spent more time foraging and engaging in intra-specific aggression as group size increased. Thus caracaras appear to pay competition costs for grouping, but because adult caracaras were dominant, younger birds paid higher competition costs. Adults apparently benefited from grouping by allowing juvenile and immature birds to be the first to approach prey that might be dangerous or defended by a competitor. Caracaras occur primarily in open habitats, and the habitat choices of non-breeding caracaras appear to support both foraging and behavioral ecological needs.

Key words: *Caracara cheriway*, competition, Crested caracara, group, local enhancement, many eyes hypothesis, Social learning.

Grouping is widespread among animals, and typically benefits individuals through reduced exposure to predators, competitors, or cold, or through increased access to potential mates or limited resources (Clark 1986). Grouping often operates via conspecific attraction (Krause and Ruxton 2002). For instance, Common Starlings (*Sturnus vulgaris*) draw together in the presence of a potential predator (Zoratto et al. 2009), young Common Ravens (*Corvus corax*) recruit peers to carrion defended by territorial adults (Heinrich 1988), and Gray Partridges (*Perdix perdix*) huddle together in cold weather to reduce heat loss (Putala et al. 1995). Grouping also may operate via synchronous response to environmental cues, particularly when resources are patchy and abundant within patches. In these cases animal aggregations may be distinguished from true groups. For instance, Oilbirds (*Steatornis caripensis*) aggregate at fruiting trees (Cleere 1998), but each bird may be drawn independently via olfactory cues (Beauchamp 2007), and various gull species aggregate where they can kleptoparasitize seabirds returning to nests after foraging (St. Clair et al. 2001, Finney et al. 2003). Grouping also may have costs if groups attract predators or if competition occurs between group members (Krause and Ruxton 2002). In species where the benefits and costs of grouping are unknown, consequences of grouping behavior should be considered in a multiple competing hypotheses framework (e.g. Caro 1986, Pasinelli and Walters 2002, Sergio et al. 2009).

Groups of Northern Crested Caracaras (*Caracara cheriway*, Dove and Banks 1999, hereafter “caracara”) have been reported from Florida, Texas, Baja California, and Guatemala (Morrison 1996, Lasley 1982, Rodriguez-Estrella 1996, Johnson and Gilardi 1996, respectively). These reports provide count and location data but little additional information. An apparently non-migratory, isolated population of caracaras exists in Florida (Ferguson-Lees and Christie 2001). The Florida population is Federally and State listed as threatened (Federal Register 1987, Logan 1997) and a recovery plan primarily deriving from and focusing on breeding caracaras has been implemented (USFWS 1999). This plan does not incorporate information on caracaras in groups because very little information exists.

Herein we evaluate three hypotheses predicting how caracaras may benefit from grouping (predation avoidance, local enhancement, social learning) and we evaluate one potential cost (increased competition). Larger groups often react more quickly to predators than do smaller groups (Pulliam 1973). The many eyes hypothesis suggests that individuals join groups because as group size increases, individuals can invest progressively less effort in anti-predator vigilance without increasing their risk of predation (Pulliam 1973). Time can then be allocated to other activities. We predicted caracaras would follow this pattern, and we tested that prediction by exposing groups of various sizes to a simulated predator.

Grouping may facilitate the discovery of patchy or cryptic resources, particularly food (Giraldeau and Caraco 2000, Pulliam and Millikan 1982). Local enhancement occurs when group members use one another as cues to the location of productive foraging areas (Thorpe 1963, Poysa 1992, Fleming et al. 1992). In social learning, less

informed individuals learn from more informed individuals (May and Reboresda 2005, Gajdon et al. 2006, Schwab et al. 2008). Social foragers often use one another as indicators of food resources (Thorpe 1963), and younger birds tend to be less efficient foragers than older birds (Burger 1988; Marchetti and Price 1989; Wunderle 1991). We predicted that caracaras would follow these patterns, and we tested these predictions by recording age-based arrival timing and leader-follower roles at carrion. Increased competition may occur when individuals consume a finite resource (Ricklefs 2000).

Competition for resources is one of the most common costs of grouping, and can be separated into two broad categories. Exploitative competition occurs when individuals compete indirectly by consuming a resource that then becomes unavailable to others, and interference competition occurs when individuals compete directly through agonistic behaviors (Ricklefs 2000). Both occur in new world avian scavenger guilds (Wallace and Temple 1987, Buckley 1996, Travaini et al. 1998). When foraging rate increases with group size in the absence of predation risk, scramble competition may be inferred (Krause and Ruxton 2002). To consider competition as a potential cost of grouping, we evaluated activity patterns in foraging areas as a function of group size, and we predicted that in the absence of support for predation benefits foraging rate would increase with increasing group size. The costs of competition often are not borne equally by all group members (Newton 1997). In mixed-species groups, larger species are typically dominant over smaller species, and within species older individuals are usually dominant over younger individuals. We predicted that caracaras would follow these patterns, and we tested interference competition by recording the outcomes of intra- and interspecific aggressive interactions where at least one participant was a caracara.

METHODS

Study area.— This study occurred throughout the range of non-breeding caracaras in Florida between Orlando to the north, and the Everglades to the south, from July 2006 through March 2009. When we began this study, three locations where groups had been observed during the 1990s had been reported near the center of the species' breeding range (USFWS 1999), and one location had been reported near the eastern periphery of the range (Morrison 1996). The persistence and membership of groups in these areas, and the occurrence of groups in other areas had not been investigated. To identify where groups occurred we used data from a related study wherein we radio-tagged a sample of non-breeding caracaras and used weekly aerial telemetry flights to track their movements ($\bar{x} = 7.80$ flight hr / week for 140 consecutive weeks; Chapter 1). We conducted this study everywhere these data indicated that groups were present, as well as anywhere we observed groups while traveling to locations suggested by these data. Much of the caracara's range in Florida is privately owned (Morrison and Humphrey 2001), inaccessible to wildlife surveyors (USFWS 1999), and characterized by cattle pastures (Chapter 1). Caracaras forage primarily in pastures (Morrison and Pias 2006, Morrison et al. 2008), so we conducted this study in or adjacent to cattle pastures throughout the species' range.

Groups.— No single definition of groups applies well across all species or contexts (Krause and Ruxton 2002). Groups in which all members are unlikely to be perceived by a single observer are particularly difficult. Prior and Weatherhead (1991) defined foraging groups of Turkey Vultures as all individuals arriving at a carcass within 5 minutes. Birds that arrived later “joined” the existing group. Marzluff et al. (1996)

identified groups of Common Ravens as all birds that roosted together the night before a daytime observation, regardless of the separation that developed between individuals during the following day. We use the word “group” to describe all the avian scavengers > 1 that we could see at any given time. Mixed species groups (Morse 1970) are widely recognized, and inter-specific interactions can be important in group benefits (reviewed in Farley et al. 2008, Gibson et al. 2002, Krause and Ruxton 2002). Caracaras are routinely observed in association with Black Vultures and Turkey Vultures, particularly at carrion (Lasley 1982, NG and Jaspersen 1984, Rodríguez-Estrella and Rivera-Rodríguez 1992, Layne 1996, Buckley 1996), so we included other avian scavengers in our evaluation of caracara groups.

Use of carrion.— Caracaras readily consume carrion (Rodríguez-Estrella and Rivera Rodríguez 1997, Morrison and Pias 2006). Providing carrion may be perceived as having the potential to cause grouping, but Prior and Weatherhead (1991) based their definition of groups on a response by scavenging birds to carrion, and Marzluff et al. (1996) released birds at carrion to test leader and follower roles. To create experimental situations in the field, we placed mammalian carrion (hereafter “experimental carrion”; Buckley 1996) 50 minutes before sunrise in areas within 5 km of where telemetry data or our ground-based observations had indicated that a group occurred within the previous week. We used the carcasses of medium sized mammals that we found dead along the edges of highways in our study area; Northern Raccoon (*Procyon lotor*), Virginia Opossum (*Didelphis virginiana*), Nine-banded Armadillo (*Xenartha dasypodidae*). We used only carcasses that weighed approximately 4-6 kg, and were dead less than approximately 24 hours before being used or frozen for later use. The placement of

experimental mammalian carrion before dawn precluded prior knowledge of the carrion by caracaras. We used a knife to slice open carcasses from chin to pelvis so that caracaras could access the body cavity (Wallace and Temple 1987). We conducted all observations using 10x binoculars (Zeiss, Jena, Germany), and a 20-60x spotting scope (Nikon, Tokyo, Japan) from inside a vehicle parked 70 m from carcasses.

The many eyes hypothesis.— To test this hypothesis, we exposed caracara groups of different sizes to a simulated predator, and we predicted that the time for all members of the group to adopt vigilant posture would decrease with increasing group size (“latency sampling,” Martin and Bateson 2007). We used head position as an indicator of vigilance (sensu Coolen et al. 2001). To do so we estimated a line originating at the bird’s eyes and projecting through its nares. When this line was parallel to or above the horizon, we identified “vigilant” posture. Because we could not be sure that all avian scavengers would react identically to our simulated predator, in this test we included only groups composed exclusively of caracaras.

We did not evaluate a prediction based on measuring a response by the first animal to become alert because at least one member of the groups we studied was usually alert. Some authors have argued that using the alertness of all group members as a response variable is problematic because larger groups should exhibit longer response times. This has not been found in empirical testing however (reviewed in Krause and Ruxton 2002).

We constructed a simulated predator from a Coyote (*Canis latrans*) mount attached to a frame that allowed us to raise the simulated predator remotely (Fig. 1a and 1b). We covered the simulated predator in camouflage fabric that fell away as we raised

the mount. We placed experimental carrion 30 m from the head of the mount and used a video camera to record the response of caracaras feeding on carrion to the appearance of the simulated predator. We raised the simulated predator when all group members had fed for ≥ 5 min, and we recorded responses for 5 min thereafter. We reviewed video recordings to estimate response time to the nearest sec. If being in groups yields benefits from increased vigilance, then the single greatest incremental benefit is likely to occur when an animal transitions from being solitary to being in a group of two (Krause and Ruxton 2002). Thus our test also included the response of a sample of single caracaras that were not in groups. We used linear regression to model response time as a function of group size, and we used a t-test to compare the sizes of groups that responded to those that did not.

Local enhancement and social learning.— If group members use one another as indicators of a food resource, then when an individual discovers a food source, other individuals should accumulate quickly thereafter. To test local enhancement, we evaluated inter-individual arrival time at experimental carrion (sensu Fleming et al. 1992). We predicted that the time between sunrise and arrival by the first caracara at experimental carrion would be greater than the time between arrival of the first caracara and arrival of the second caracara. We predicted that the time differential for each additional arrival, up to 10 birds, would be less than the differential between sunrise and arrival of the first caracara. We used ANCOVA to model inter-individual arrival times (min) as a function of arrival order and the species that first discovered experimental carrion.

A difficulty in testing this hypothesis was in establishing an objective baseline to compare arrival times. Caracaras typically depart roosts 20 min before sunrise (Dwyer; unpub. data), flying at about 30 kph (Layne 1996). Thus by sunrise, they could be up to 10 km from roosts. We conducted local enhancement tests within 5 km of roosts, and because we timed arrival relative to sunrise, thus effectively discarding the first 20 minutes of search time from our test, we attempted to make our test conservative against a significant result.

We predicted that if social learning occurs in caracaras, young caracaras should learn from adults, and therefore adults should lead groups to and within foraging areas. To test this, we recorded the age of the first caracara to arrive at experimental carrion, and the age of each additional caracara to arrive within the subsequent 2 hr. We aged caracaras as juvenile, immature, and adult as in Wheeler and Clark (1999). We estimated the 95% confidence interval of the proportion of times adult caracaras were the first to find carrion, and the 95% confidence interval for the proportion of adult caracaras in groups. Theoretical and simulation tests indicate that when 95% confidence intervals overlap by < 85%, then statistical significance at $\alpha = 0.05$ is implied (Payton et al. 2000) and that when confidence intervals do not overlap at all, this test is particularly conservative (Payton et al. 2003). Thus, if confidence intervals for adults discovering carrion and adults in groups did not overlap, we considered the difference significant.

Competition costs.— Exploitative competition between species is typically evaluated via arrival order of species at carrion, and can be difficult to demonstrate otherwise. Interference competition can be observed with relative ease if it occurs (Krause and Ruston 2002).

We predicted that if exploitative competition were occurring, then species would tend to arrive at carrion in a particular order. Furthermore, the time an individual spent foraging within a short observation period would increase with increasing group size until the carrion was entirely consumed. The same pattern might also occur however if anti-predator benefits allowed individuals to reallocate time away from vigilance behavior. Thus, if foraging time increased but vigilance time did not decrease with increasing group size, vigilance benefits may be excluded (Krause and Ruxton 2002). We may also observe foraging time increasing with increasing group size if local enhancement benefits facilitate the discovery of additional prey. However, if consumption of the carrion leads to the depletion of the resource, then local enhancement benefits may also be excluded.

To test for competition effects we used focal sampling (Martin and Bateson 2007) to compare behavior patterns among groups of different sizes and composition. We conducted these tests primarily around carrion, thus eliminating local enhancement benefits *a priori*, and facilitating the inclusion of the entire avian scavenger guild in our analysis. At the initiation of each focal sample we recorded the number of animals of each species in the group, and then collected a 5-min focal sample from a randomly selected caracara. We recorded the time in seconds this caracara spent engaged in foraging behavior and in vigilant posture. We used multiple regression to model the time caracaras spent engaged in each behavior category as a function of group size and composition. We defined vigilant posture as described above, and we defined foraging as occurring when birds pecked at the ground or fed on carrion.

Interference competition often increases with group size, and is not limited to within-species effects. Caracaras occur in mixed species groups that may also include

Bald Eagles, Turkey Vultures, Black Vultures, and American Crows. Thus, we predicted that if interference competition were occurring then we should observe agonistic behaviors within groups. Specifically, we predicted that social hierarchies would be apparent within groups including caracaras, and that those hierarchies would follow trends common to most avian scavenger guilds, i.e., that between species larger birds would be dominant over smaller birds, and that within caracaras, older birds would be dominant over younger birds.

To evaluate the potential for interference competition we conducted 30-minute group samples, wherein we recorded the aggressor and receiver of all agonistic interactions by all group members. We defined aggressive behaviors as low intensity and high intensity. Low intensity interactions did not involve physical contact, and included head-throwback displays, rattle and cackle vocalizations (Morrison 1996), mantling over prey, flapping wings to prevent the approach of another bird, or supplanting a peer at a food item or at a perch. High intensity interaction did involve physical contact and included the aggressor striking the receiver with beak, foot, or wing, or did not involve physical contact but did involve a foot or aerial chase. We are not aware of other authors distinguishing interactions as low and high in this way, but we did so because it was sometimes difficult to be certain of the intended recipient of a low intensity interaction. For example when a caracara made a vocalization or mantled over prey while at the center of a group, we could not always be certain whether the behavior was targeted at a specific individual, or the whole group.

We compared all aggressions, which included both low and high intensity aggressions, and we compared only high intensity interactions. Wallace and Temple

(1987) and Travaini et al. (1998) used proportions of interactions won by various species and ages to identify intra- and inter-species hierarchies. If the 95% confidence interval for the proportion of interactions won by a certain species or age class was entirely below 50%, then we considered the species or age class subordinate. If the 95% confidence interval for the proportion of interactions won was entirely above 50%, then we considered the species or age class dominant. If the confidence interval overlapped 50%, then we considered the two groups equal.

The winner was the bird that initiated the aggressive interaction, unless the receiver rebuffed the aggression. Thus, if a bird attempted to land on an occupied perch, and displaced a previously perched bird, the new bird was identified as the “winner.” If the perched bird refused to vacate the position, thus forcing the intruding bird to redirect, the perched bird was identified as the “winner.” Through identification of which species and which age tended to win encounters with which others, we constructed dominance hierarchies.

RESULTS

The many eyes hypothesis.— We conducted 44 simulated predator trials. These trials included caracaras only. Mean number of birds during trials was 9.5 (SE = 1.31, range = 1 - 36). In 84% of trials, all birds in groups entered vigilant posture ≤ 60 sec after presentation of the simulated predator. There was no relationship between group size and response time ($F = 68.43$, $df = 1$ and 35 , $P = 0.414$; Fig. 2). Groups that did not respond to the simulated predator were larger (14.3, SE = 3.23) than groups that did respond (8.6, SE = 1.4; $n = 44$, $t = 1.83$, $P = 0.048$).

Local enhancement and social learning.— We conducted 48 arrival order trials. Caracaras were the first to arrive at 43 of these and American Crows were the first to arrive at 5. The first bird (American Crow or caracara) to arrive at carrion took longer to arrive relative to sunrise than the second bird (always a caracara) took to arrive after the first (Fig. 3). Each additional caracara also arrived more quickly after its immediate predecessor than the first bird arrived after sunrise. Thus, the first species to discover experimental carrion was not an important predictor of arrival timing, but arrival order was (Overall test: $F = 6.40$, model $df = 10$, error $df = 359$, $P < 0.001$) The mean time between sunrise and the first bird to arrive at carrion was 31.1 min (SE = 8.3 min, range = 26 min before sunrise to 270 min after sunrise, $n = 48$), and mean inter-arrival time for birds arriving subsequently after a preceding bird was 3.8 min (SE = 0.5 min, range = 0 to 87 min, $n = 322$). When a caracara arrived first, adult caracaras were the first to arrive in 59% of trials (95% C.I. 46-72), but made up only 37% (95% C.I. 32-42) of the individuals in the groups that formed at that carrion. These confidence intervals do not overlap, indicating that adults discover carrion first more often than expected given the proportion of adults in groups.

Competition costs.— We conducted 339 five-minute focal observations. Time that focal caracaras spent foraging increased with increasing numbers of caracaras, but not with increasing numbers of Turkey Vultures or Black Vultures ($F = 3.86$, $df = 3$ and 319, $P = 0.010$; Table 2). Group size did not influence time spent vigilant ($F = 1.91$, $df = 3$ and 319, $P = 0.126$). We recorded 2,779 aggressive interactions including at least one caracara and 1,116 interactions with caracaras as both the aggressor and the receiver of aggression. Caracaras were subordinate to Bald Eagles, but dominant over Turkey

Vultures, Black Vultures, and American Crows regardless of whether we considered all aggressions (Table 3), or contact aggressions only. Adult caracaras were dominant over immature and juvenile caracaras regardless of whether we considered all aggressions (Table 4), or contact aggressions only. There was no difference in dominance ranking between immature caracaras and juveniles.

DISCUSSION

Potential explanations for ultimate causation for grouping typically include predation avoidance (Krause and Ruxton 2002), overcoming competitors (Roell 1978), accommodation of physiological tolerances where groups form to survive cold weather (Ancel et al. 1997), access to mates (i.e., leks), and access to limited resources (Marzluff et al. 1996, Sonerud et al. 2001). Limited resources are most often identified as food or habitat (Greene 1987, Flemming et al. 1992, Baglione et al. 2002).

All group members do not necessarily gain identical benefits or pay identical costs when participating in groups (Lemon 1991, Newton 1998). In many species, young birds are less efficient foragers than older birds (Burger 1988; Marchetti and Price 1989; Wunderle 1991). We found that juvenile and immature caracaras apparently gain disproportionate social learning benefits from joining groups. These benefits are probably minimal for adult caracaras because adults were disproportionately likely to be the discoverers of experimental carrion. However, adults do follow other birds to food when possible, and it is possible that some adults could consistently be followers either by choice or necessity. Thus all ages of caracaras gain local enhancement benefits. Nevertheless, grouping appears less beneficial to adults than to juveniles and immatures

unless adults gain some compensatory benefit. Caracaras conform to the typical age-based hierarchy in this study and in Baja California (Rodríguez-Estrella, R. and L. B. Rivera-Rodríguez. 1992). As in other studies, adult caracaras were dominant to juveniles and immatures and may have recovered the costs of parasitism by younger birds by appropriating items subsequently discovered by younger birds. Thus, local enhancement appears to benefit all ages of non-breeding caracaras, though through different mechanisms. We also observed, but did not quantify a behavior wherein adults sometimes approached a piece of experimental carrion to within about 5 m, but then did not approach closer until a younger bird contacted the carrion. The adult then supplanted the younger caracara and fed. Adult caracaras are known to be particularly wary (Morrison and McGehee 1996), and may tolerate younger conspecifics because they can be used to verify that a potential carrion item is truly dead, or that it is not being defended by a stronger competitor or potential predator.

Caracaras also feed with and share nocturnal roosts with Turkey Vultures and Black Vultures (Lasley 1982, Johnson and Gilardi 1996) and may gain similar social learning and local enhancement benefits from these species. Caracaras were dominant to Turkey Vultures and Black Vultures though both vulture species outweigh caracaras. This runs counter to most avian scavenger guilds where sized-based hierarchies are closely adhered to (Newton 1998), but follows other studies which include Northern Crested Caracaras (Buckley 1996, Rodriguez-Estrella and Rivera-Rodriguez 1992), and in the closely related Southern Crested Caracaras (*Caracara plancus*) that have found similar results (Wallace and Temple 1987, Travaini et al. 1998). Because vultures routinely engage in intra-specific aggressive interactions (Kirk and Houston 1995), and

groups of vultures were previously reported to be consistently intimidated by groups of Black Vultures (Morrison 1996), this pattern requires explanation. We recorded the outcome of aggressive interactions in terms of winners and losers. We did not record the subsequent behavior of participants, but we can report anecdotally that receivers of aggression usually retreated less than a meter from the aggressor and then resumed pre-aggression activity without receiving additional aggression. Thus a subordinate bird supplanted from a perch often simply moved to the next adjacent perch, and a subordinate driven from carrion would often simply feed at the opposite side of the carrion from where the aggression occurred. By contrast, when an aggressive individual was rebutted with aggression, the aggression typically escalated until the losing bird was driven from view during an aerial chase. Thus, there appeared to be a relatively low cost to accepting aggression and a potentially high cost to retaliating.

We found no evidence that caracaras in groups gain anti-predation benefits through increased vigilance. Rather, when exposed to a simulated predator, group members were less likely to interrupt foraging when groups were larger. This could occur if the cost of interrupting foraging increased with group size, or if being in a larger group facilitated other anti-predation benefits. In Florida, vultures sometimes outnumber caracaras by as much as 4:1 at roosts, but despite the presence of as many as 400 vultures at a shared roost (unpub. data), caracaras arrived at experimental carrion before vultures did in 100% of our trials. Thus, though caracaras are usually dominant over vultures, caracaras also appear to minimize competition by beginning to forage before vultures begin flying (Morrison 1996), perhaps because defense of a resource may be impossible against the overwhelming number of subordinate vultures that may accumulate (Wallace

and Temple 1987, Heinrich 1988, Marzluff et al. 1996). We found evidence of both exploitative and interference competition among caracaras in groups, but during our observations of caracaras we never observed a predation attempt on a caracara. Nor could we find any published report of predation of caracaras after the nestling stage. Thus our findings do not support inference for alternative anti-predation benefits for caracaras in Florida, and it appears that with increasing group size the potential costs of missing a feeding opportunity drive the behavior pattern we found.

However, this may be true only of our study population. Caracaras are widely distributed throughout South and Central America where potential predators not present in Florida may exist, and caracaras in Florida may have lost anti-predator behaviors in Florida that are adaptive and retained in other portions of their range.

Grouping is widespread among both facultative and obligate avian scavengers likely because individuals accumulate at patchy but ephemeral food sources. We found that caracaras of all ages spend more time foraging as group size increases. In the absence of predation risk, scramble competition may be inferred if foraging rate increases with group size (Krause and Ruxton 2002). Competition costs appear high in caracara groups; we found that 32% of the 142 non-breeding birds we captured had cuts or scars on the exposed skin of their faces or legs (unpub. data). Based on the long-term persistence of individual non-breeding birds outside of territories (Chapter 2), the high survival of non-breeding (Chapter 2) and breeding birds (Morrison 2003), and the long-term persistence of breeding territories (Chapter 4), we argue that the breeding population of caracaras in Florida is likely limited by habitat. Consequently, competition costs may

be particularly high in groups because very little outlet exists for these birds to transition to breeding sites.

We found that caracaras benefit from group formation through local enhancement and social learning. Each of these benefits may be interpreted as a response to food as a limiting resource. However, caracaras are broadly generalist foragers that consume carrion (Rodriguez-Estrella and Rivera-Rodriguez 1997, insects (Morrison et al. 2008), live fish, avian, and mammalian prey (Morrison and Pias 2006), and even vegetable matter (Skoruppa and Lee 2008). Thus, food resources are unlikely to limit caracaras directly. However, when animals must learn about a wide variety of food types, learning may be protracted. In this scenario knowledge of the location, capture techniques, and handling methods of food may be limiting, and we hypothesize that the ultimate limiting resource for juvenile and immature caracaras is the knowledge upon which foraging skills are based. Non-breeding caracaras primarily occupy pastures and citrus groves. Each of these land covers facilitates observation of the actions of peers across long distances (by looking along rows or beneath trees in citrus). Thus, the habitat choices made by caracaras appear important to both their behavioral and their foraging ecology.

ACKNOWLEDGEMENTS

This study was funded by the U.S. Fish and Wildlife Service grant agreement no.145 401815G060. This is contribution No. _____ (assigned following acceptance) from the MacArthur Agro-Ecology Research Center (MAERC) of Archbold Biological Station. We thank Gene Lollis and Patrick Bohlen of MAERC for logistic support and S.J.

Chiavacci, J.L. Dowling, A.L. Fleming, M.R. Hanson, L.M. Hunt, A.K. Mangiameli, M.N. Scholer, A.M. Smith, N.E. Swick, and N.R. Thompson for field assistance.

LITERATURE CITED

ANCEL, A., H. VISSER, Y. HANDRICH, D. MASMAN, AND Y. LEMAHO. 1997. Energy saving in huddling penguins. *Nature* 385:304-305.

BAGLIONE, V., D. CANESTRARI, J.M. MARCOS, M. GRIESSER, AND J. EKMAN. 2002. History, environment and social behaviour: Experimentally induced cooperative breeding in the carrion crow. *Proceedings of the Royal Society of London Series B-Biological Sciences* 269:1247-1251.

BEAUCHAMP, G. 2007. Exploring the role of vision in social foraging: What happens to group size, vigilance, spacing, aggression and habitat use in birds and mammals that forage at night? *Biological Reviews* 82:511-525.

BUCKLEY, N. J. 1996. Food finding and the influence of information, local enhancement, and communal roosting on foraging success in North American Vultures. *Auk* 113:473-488.

BURGER, J. 1988. Effects of age on foraging in birds. Pages 1127-1140 *in* *Proceedings of the Nineteenth International Ornithological Conference* (H. Quillet, Ed.). University of Ottawa Press, Canada.

CARO, T. M. 1986. The functions of stotting: a review of the hypotheses. *Journal of Animal Behavior* 34:649-662.

CLARK, C. W. AND M. MANGEL. 1986. The evolutionary advantages of grouping. *Theoretical Population Biology* 30:45-75.

- CLEERE, N. 1998. Nightjars. Pica Press, Sussex.
- COOLEN, I., L. A. GIRALDEAU, AND M. LAVOIE. 2001. Head position as an indicator of producer and scrounger tactics in a ground-feeding bird. *Animal Behavior* 61:895-903.
- DOVE, C. J. AND R. C. BANKS. 1999. A taxonomic study of Crested Caracaras (Falconidae). *Wilson Bulletin* 111:330-339.
- FARLEY, E. A., K. E. SIEVING, AND T. A. CONTRERAS. 2008. Characterizing complex mixed-species bird flocks using an objective method for determining species participation. *Journal of Ornithology* 149:451-468.
- FEDERAL REGISTER. 1987. Threatened Status for Florida Population of Audubon's Crested caracara; 52 FR 25229-25232.
- FERGUSON-LEES, J., AND D. A. CHRISTIE. 2001. *Raptors of the World*. Houghton Mifflin Co. Boston. pps. 804-806.
- FINNEY, S. K., M. P. HARRIS, L. F. KELLER, D. A. ELSTON, P. MONAGHAN, AND S. WANLESS. 2003. Reducing the density of breeding gulls influences the pattern of recruitment of immature Atlantic Puffins *Fratercula arctica* to a breeding colony. *Journal of Applied Ecology* 40:545-552.
- FLEMING, S. P., P. C. SMITH, N. R. SEYMOUR, AND R. P. BANCROFT. 1992. Ospreys use local enhancement and flock foraging to locate prey. *Auk* 109:649-654.
- GAJDON, G. K., N. FIJN N, AND L. HUBER. 2006. Limited spread of innovation in a wild parrot, the Kea (*Nestor notabilis*). *Animal Cognition* 9:173-181.

- GIBSON, R. M., A. S. ASPBURY, AND L. L. MCDANIEL. 2002. Active formation of mixed-species grouse leks: a role for predation in lek evolution? Proceedings of the Royal Society of London Series B-Biological Sciences 269:2503-2507.
- GIRALDEAU, L. A, AND T. CARACO. 2000. Social Foraging Theory. Princeton University Press. Princeton, NJ.
- GREENE, E. 1987. Individuals in an Osprey colony discriminate between high and low quality information. Nature 329:239-241.
- HEINRICH, B. 1988. Winter foraging at carcasses by 3 sympatric corvids, with emphasis on recruitment by the Raven (*Corvus corax*). Behavioral Ecology and Sociobiology 23:141-156.
- JOHNSON, M. D., AND J. D. GILARDI. 1996. Communal roosting of the Crested Caracara in southern Guatemala. Journal of Field Ornithology 67:44-47.
- KIRK, D. A. AND D. C. HOUSTON. 1995. Social dominance in migrant turkey vultures at carcasses: evidence for despotic distribution? Behavioral Ecology and Sociobiology 36:323-332.
- KRAUSE, J. AND G. D. RUXTON. 2002. Living in Groups. Oxford University Press. New York.
- LASLEY, G. W. 1982. High numbers of caracara found at temporary roost. Bulletin of the Texas Ornithological Society 15:18-20.
- LAYNE, J. 1996. Pages 197-210 in Rare and Endangered Biota of Florida (J. A. Rodgers, Jr., H. W. Kale II, and H.T. Smith, Eds.). University Press of Florida. Gainesville, FL. pgs 197-210.

- LEMON, W. C. 1991. Foraging behavior of a guild of neotropical vultures. *Wilson Bulletin* 103:698-702.
- LOGAN, T. 1997. Florida's Endangered Species, Threatened Species, and Species of Special Concern. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
- MARCHETTI, K. AND T. PRICE. 1989. Differences in the foraging of juvenile and adult birds-the importance of developmental constraints. *Biological Reviews* 64:51-70.
- MARTIN, P. AND P. BATESON. 2007. *Measuring Behavior: An Introductory Guide*. Third Edition. Cambridge University Press. Cambridge, U.K.
- MARZLUFF, J. M., B. HEINRICH, AND C. S. MARZLUFF. 1996. Raven roosts are mobile information centers. *Animal Behavior* 51:89-103.
- MAY, D. AND J. C. REBOREDA. 2005. Conspecific and heterospecific social learning in shiny cowbirds. *Animal Behaviour* 70:1087-1092.
- MORRISON, J. L. 1996. Crested Caracara (*Caracara plancus*). *In* *The Birds of North America*, No. 249 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, D.C.
- MORRISON, J. L. 2003. Age-specific survival of Florida's Crested Caracaras. *Journal of Field Ornithology* 74:321-330.
- MORRISON, J. L. AND MCGEHEE, S. M. 1996. Capture methods for Crested Caracaras. *Journal of Field Ornithology* 67:630-636.
- MORRISON, J. L. AND S. R. HUMPHREY. 2001. Conservation value of private lands for Crested caracara in Florida. *Conservation Biology* 15:675-684.

- MORRISON, J. L. AND K. E. PIAS. 2006. Assessing the vertebrate component of the diet of Florida's Crested Caracara (*caracara cheriway*). Florida Scientist 69:36-43.
- MORRISON, J. L., K. E. PIAS, J. ABRAMS, I. G. W. GOTTLIEB, M. DREYUP, AND M. MCMILLAN. 2008. Invertebrate diet of breeding and non-breeding Crested caracaras (*caracara cheriway*) in Florida. Journal of Raptor Research 42:38-47.
- MORSE, D. H. 1970. Ecological aspects of some mixed-species foraging flocks of birds. Ecological Monographs 40:119-168.
- NEWTON, I. 1997. Population Ecology of Raptors. Academic Press. New York.
- NEWTON, I. 1998. Population Limitation in Birds. Academic Press. New York.
- NG, D. AND B. D. JASPERSON. 1984. Interspecific allopreening between Crested Caracara and Black Vulture. Condor 86:214-215.
- PASINELLI, G., AND J. R. WALTERS. 2002. Social and environmental factors affect natal dispersal and philopatry of male Red-cockaded Woodpeckers. Ecology 83:2229-2239.
- PAYTON, M. E., A. E. MILLER, AND W. R. RAUN. 2000. Testing statistical hypotheses using standard error bars and confidence intervals. Communications in Soil Science and Plant Analysis 31:547-551.
- PAYTON, M. E., M. H. GREENSTONE, AND N. SCHENKER. 2003. Overlapping confidence intervals or standard error intervals: What do they mean in terms of statistical significance? Journal of Insect Science 3.33:1-6.
- POYSA, H. 1992. Group foraging in patchy environments - The importance of coarse level local enhancement. Ornis Scandinavica 23:159-166.

- PRIOR, K. A., AND P. J. WEATHERHEAD. 1991. Turkey Vultures foraging at experimental patches – a test of information-transfer at communal roosts. *Behavioral Ecology and Sociobiology* 28:385-390.
- PULLIAM, H. R. 1973. On the advantages of flocking. *Journal of Theoretical Biology* 38:419-422.
- PULLIAM, H. R., AND G. C. MILLIKAN. 1982. Social organization in the non-reproductive season. Pages 169-197 *in* *Avian Biology*, vol. 6. (D.S. Farner, J. R. King, and K.C. Parkes, Eds.). Academic Press, New York.
- PUTAALA, A., E. HOHTOLA, AND R. HISSA. 1995. The effect of group-size on metabolism in huddling Grey Partridge (*Perdix perdix*).
- RICKLEFS, R. E. 2000. *The Economy of Nature*, 5th Edition. W. H. Freeman and Company. New York, New York.
- RODRIGUEZ-ESTRELLA, R. 1996. Response of Common Black Hawks and Crested caracara to human activities in Mexico. *In* *Raptors in Human Landscapes* (D.M. Bird, D. Varland, and J.J. Negro, Eds.). Academic Press, London, UK. Pages 356-363.
- RODRÍGUEZ-ESTRELLA, R. AND L. B. RIVERA-RODRÍGUEZ. 1992. Kleptoparasitism and other interactions of Crested Caracara in the Cape Region, Baja California, Mexico. *Journal of Field Ornithology* 63:177-180.
- RODRÍGUEZ-ESTRELLA, R. AND L. B. RIVERA-RODRÍGUEZ. 1997. Crested Caracara food habits in the cape region of Baja California, Mexico. *Journal of Raptor Research* 31:228-233.

- ROELL, A. 1978. Social behaviour of the Jackdaw, *Corvus monedula*, in relation to its niche. Behaviour 64: 1-122.
- SCHWAB, C., T. BUGNYAR, AND K. KOTRSCHAL. 2008. Preferential learning from non-affiliated individuals in Jackdaws (*Corvus monedula*). Behavioural Processes 79:148-155.
- SERGIO, F., J. BLAS, R. BAOS, M. G. FORERO, J. A. DONAZAR, AND F. HIRALDO. 2009. Short- and long-term consequences of individual and territory quality in a long-lived bird. Oecologia 160:507-514.
- SKORUPPA, M. K. AND M. C. LEE. 2008. Crested caracaras feed on pecans in South-central Texas. Journal of Raptor Research 42:299-300.
- SONERUD, G. A., C. A. SMEDSHAUG, AND O. BRATHEN. 2001. Ignorant crows follow knowledgeable roost-mates to food: support for the information center hypothesis. Proceedings of the Royal Society of London Series B-Biological Sciences.
- ST. CLAIR, C. C., R. C. ST. CLAIR, AND T. D. WILLIAMS. 2001. Does kleptoparasitism by Glaucous-winged Gulls limit the reproductive success of Tufted Puffins? Auk 118:934-943.
- THORPE, W. 1963. Learning and Instinct in Animals, 2nd Ed. Methuen and Co., Ltd., London, UK.
- TRAVAINI, A., J. A. DONAZAR, A. RODRIGUEZ, O. CEBALLOS, M. FUNES, M. DELIBES, AND F. HIRALDO. 1998. Use of European Hare (*lepus europaeus*) carcasses by an avian scavenging assemblage in Patagonia. Journal of Zoology 246:175-181.
- USFWS (U. S. FISH AND WILDLIFE SERVICE). 1999. South Florida multi-species recovery plan. Atlanta, Georgia. 2172 pp. (pgs. 4-219 to 4-235).

- WALLACE, M. P., AND S. A. TEMPLE. 1987. Competitive interactions within and between species in a guild of avian scavengers. *Auk* 104:290-295.
- WHEELER, B. K. AND W. S. CLARK. 1999. *A Photographic Guide to North American Raptors*. Academic Press. San Diego.
- WUNDERLE, J. M. 1991. Age-specific foraging proficiency in birds. *Current Ornithology* 8:273-324.
- ZORATTO, F., D. SANTUCCI, AND E. ALLEVA. 2009. Theories commonly adopted to explain the antipredatory benefits of the group life: the case of Starling (*Sturnus vulgaris*). *Rendiconti Lincei-Scienze Fisiche E Naturali* 20:163-176.

Table 1. Results of ANCOVA comparing inter-bird arrival timing (min) for Crested Caracaras and American Crows at experimental carrion. Variance is partitioned among inter-bird arrival timing, and the species of the first bird to arrive at experimental carrion.

<u>Source</u>	<u>df</u>	<u><i>F</i></u>	<u><i>P</i></u>
Arrival number	9	7.1080	< 0.001
Discovering species	1	0.0012	0.972

Table 2. Parameter estimates from results of multiple regression analyses evaluating time spent foraging as a function of group composition by species.

<u>Term</u>	<u>Estimate</u>	<u>Std. Error</u>	<u><i>t</i></u>	<u><i>P</i></u>
Intercept	108.09	7.71	14.01	<0.001*
Crested Caracara	2.88	0.89	3.22	0.001*
Turkey Vulture	-0.68	1.06	-0.64	0.522
Black Vulture	0.39	0.51	0.78	0.436

Table 3. Outcomes of aggressive interactions based on both high and low intensity agonistic behaviors recorded in an avian scavenger guild in Florida. See text for descriptions of behaviors. Data collected from July 2006 - March 2009.

Caracara's Opponent	<u>All Aggressions</u>			<u>Contact Aggressions</u>		
	% Wins	95% C.I.	n	% Wins	95% C.I.	n
Bald Eagle	10	4-16	104	0	N/A	2
Turkey Vulture	77	74-80	709	72	67-77	263
Black Vulture	88	87-90	1925	92	90-94	538
American Crow	81	68-93	41	74	67-109	9

Table 4. Outcomes of aggressive interactions based on both high and low intensity agonistic behaviors recorded among caracaras in Florida. See text for descriptions of behaviors. Data collected from July 2006 - March 2009.

<u>Contestant</u>	<u>All Aggressions</u>			<u>Contact Aggressions</u>		
	<u>% Wins</u>	<u>95% C.I.</u>	<u>n</u>	<u>% Wins</u>	<u>95% C.I.</u>	<u>n</u>
Adult's Opponent						
Immature	71	65-77	217	80	68-92	40
Juvenile	63	59-67	553	66	59-74	134
Immature's Opponent						
Juvenile	42	37-47	346	49	38-60	84



Figure 1. Simulated predator used to evaluate the many eyes hypothesis by evaluating response time as a function of group size for groups of crested caracaras. 1a. Simulated predator in flat position under a camouflage cover. 1b. Simulated predator in upright position after having been remotely triggered to rise. Tests conducted in Florida, U.S.A., 2006 - 2009.

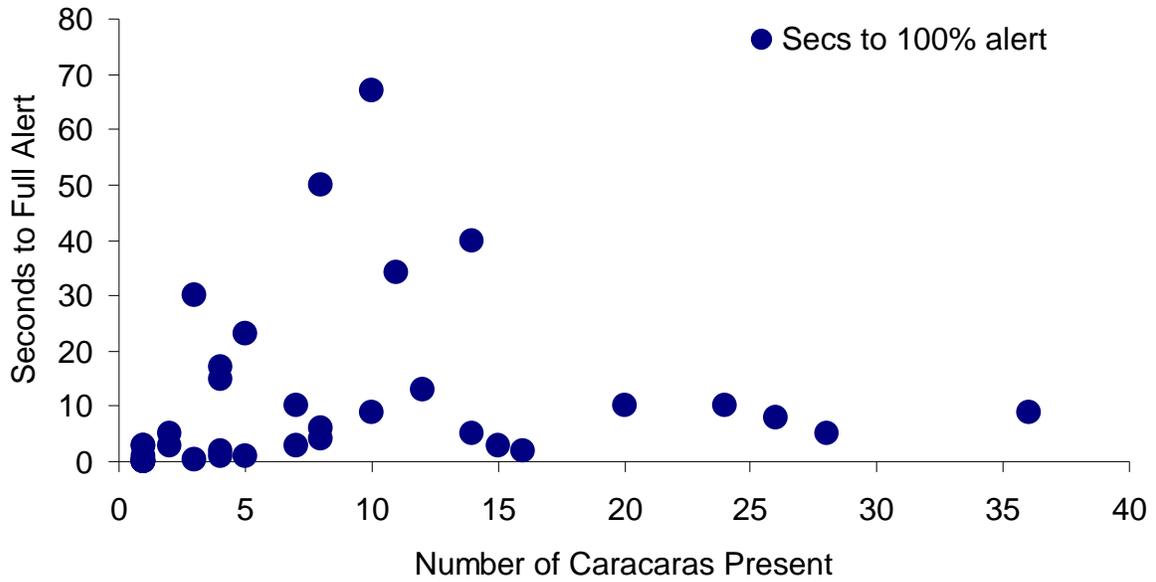


Figure 2. Response time by groups of crested caracaras to a simulated predator did not support the many eyes hypothesis which postulated that response time should decrease with increasing group size. The simulated predator was a mounted coyote skin designed to appear suddenly from beneath a camouflage cover, and was hidden 30 m from carrion which caracaras fed upon (n = 37 presentations of a predator). Tests conducted in Florida, U.S.A., 2006 - 2009.

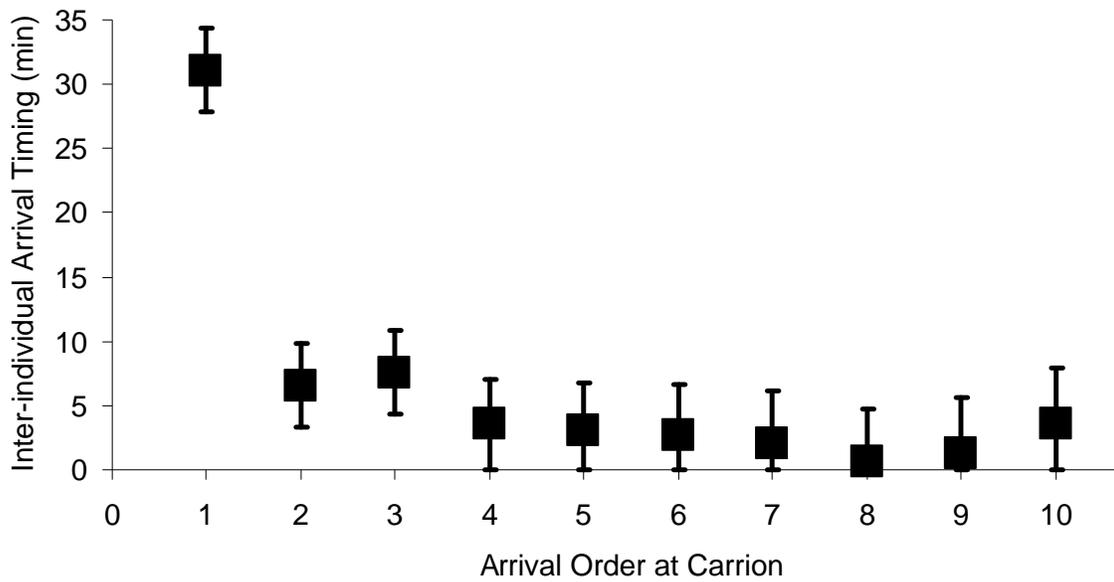


Figure 3. Time between arrival of the 2nd and 3rd caracaras and between subsequent caracaras was significantly less than time between sunrise and arrival of the first caracara at the carcass. The arrival of bird #1 is timed as minutes after sunrise. The arrival of bird #2 is timed as minutes after the arrival of #1. The arrival of each subsequent bird is timed as minutes after the bird immediately preceding it. Error bars indicate standard errors. Data collected in Florida, U.S.A., 2006 - 2009.

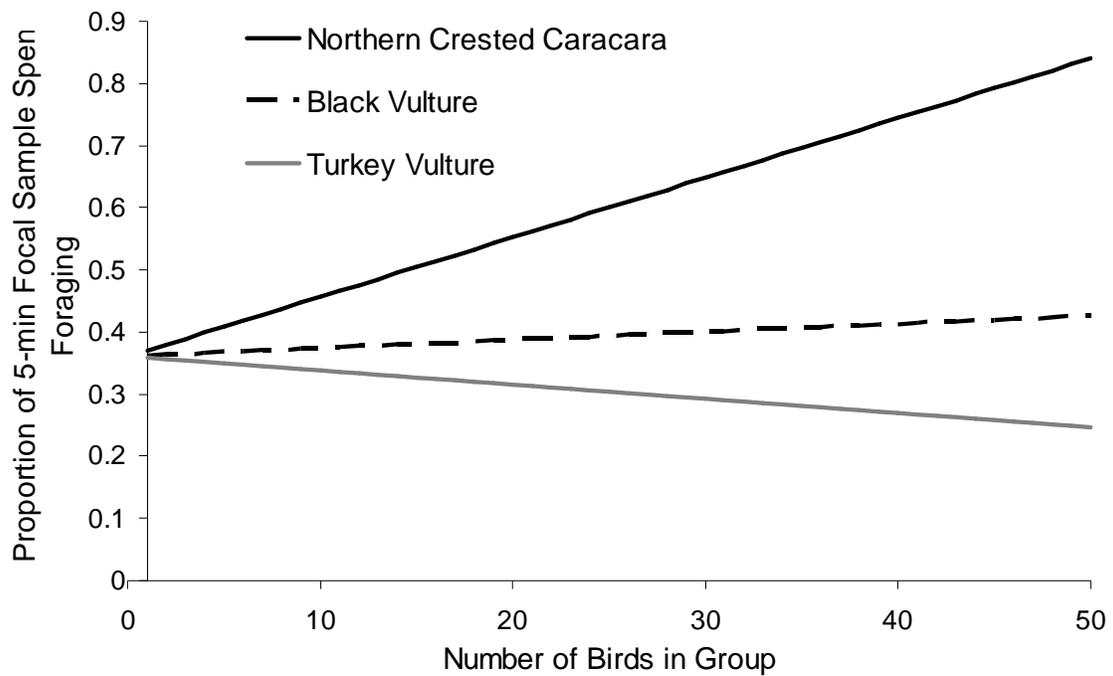


Figure 4. Proportion of time that a focal Northern Crested Caracara spends foraging during a 5-minute focal sample as a function of the number of group members present. Estimates were generated with the equation: Y (Time Foraging) = $108.09 + 2.88(\text{number of caracaras}) - .68(\text{number of turkey Vultures}) + 0.39 (\text{number of Black Vultures})$. Only the relationship between foraging time and the number of caracaras in the group is significant ($P = 0.001$, Table 2.)

CHAPTER 4

PERSISTENT OCCUPANCY OF NORTHERN CRESTED CARACARA (*CARACARA CHERIWAY*) BREEDING SITES IN FLORIDA

James F. Dwyer,¹ Joan L. Morrison,² and James D. Fraser¹

¹Department of Fisheries and Wildlife Sciences, Virginia Tech, 100 Cheatham Hall,
Blacksburg, VA24061, USA

²Department of Biology, Trinity College, 300 Summit Street, Hartford, CT 06106, USA

ABSTRACT

The population of Northern Crested Caracaras (*Caracara cheriway*; hereafter “caracara”) in Florida is believed to be in decline due to widespread conversion of nesting habitat to alternate land uses. The existing management strategy for caracaras relies on an assumption of annual breeding and subsequent detection and protection of nest sites. If long-term occupancy of breeding sites occurs in the absence of annual breeding, then management strategies may need to be modified so management persists through years when breeding does not occur or is not detected. To assess long-term occupancy of caracara breeding sites in Florida, in 2007-2009 we surveyed 49 sites where breeding had occurred in the 1990s. We found nests at 81.6% (40 of 49) of sites we surveyed, and observed adult caracaras at each of the remaining sites. Thus, breeding sites appear to be occupied over periods of at least a decade even if nesting may not occur annually. If caracara management strategies are not modified to accommodate these findings, then management may inadvertently facilitate attrition of the breeding population.

KEY WORDS: *Caracara cheriway*, Northern Crested Caracara, intermittent breeding, occupancy, population monitoring, raptor.

Long-term data sets are useful in evaluating population trends (Flather and Sauer 1996, Sauer et al. 2003) and judging the effectiveness of management actions (Bildstein 1998). Depending on the species of interest, trends may be monitored on wintering areas, breeding grounds, or along migration routes (Pehlak et al. 2006, Costanzo and Hindman 2007, Bildstein 2008). Ideally, annual systematic surveys are used to compile long-term datasets, but annual effort is not always feasible. In the absence of annual data, intermittent observations may be useful for directing management, inferring population trends, or identifying the need for more intensive monitoring.

In Florida, the Northern Crested Caracara (*Caracara cheriway*; hereafter “caracara”) was Federal and State listed as threatened in 1987 due to concerns that the population was declining because nesting habitat was being converted to alternate land uses (Federal Register 1987, Logan 1997). Subsequent management of caracaras has focused primarily on minimizing habitat loss near nest sites as long as breeding sites remain active (USFWS 1989, 1999). However, if a nest is not found in a particular site in a given year, the site may be identified as inactive and management efforts may be suspended in that area. This strategy does not explicitly incorporate contingencies for intermittent breeding, breeding failure, or failure to detect breeding. If breeding caracaras occupy sites for long periods, and yet display actual or apparent intermittent breeding, then occupied sites may be vulnerable to landscape modification under this management strategy. We evaluated the current occupancy and breeding status of a sample of caracara breeding sites studied during the 1990s. Because caracaras can be particularly sensitive to disturbance within 300 m of nest sites (Morrison 2001), we

focused particularly on evaluating territories where land use within 300 m of the previous nest site had been modified since the 1990s.

METHODS

Our study was centered at the MacArthur Agro-Ecology Research Center (27°09'11"N, 81°11'50"W) near Lake Placid, FL, and was in the caracara's core breeding range. Within this range, Morrison and Humphrey (2001) studied caracaras on 73 breeding sites from 1996-1999. We resurveyed a sample of these sites during the breeding seasons of 2007-2009. We recorded observations of caracara nests and adult caracaras during surveys consisting of up to three 2-hr visits at each site. Each visit ended before 11:00 or began after 16:00 local time (Morrison 2001), and surveys ended when we found a nest or completed three visits, whichever came first. We surveyed in January and February, by which time approximately 91% of nests were likely to have been initiated for the year (Morrison 1999). We conducted surveys from within a parked vehicle to minimize disturbance to nesting birds. We assigned observers randomly to visits and surveys, used different personnel each year, and did not provide personnel conducting surveys in 2008 or 2009 with information gathered during the previous year.

We considered sites to contain breeding birds if we observed an adult in a nest in incubation posture or feeding nestlings or fledglings. We used plumage characteristics to distinguish adult caracaras from dependent young (Wheeler and Clark 1999).

Morrison and Humphrey (2001) found evidence of intermittent breeding by caracaras, and we found evidence that not all nests are likely to be detected (Chapter 5). In this study, we did not attempt to distinguish intermittent breeding from failure to detect

breeding, but we did assess the current potential of these two factors collectively. To do so, in 2009 we surveyed a random sample of sites where we had found a nest in 2007 or 2008. Because Morrison and Humphrey (2001) found that sites are consistently occupied over periods of 2-4 years, we suggest that sites where we observed adult caracaras in 2009 but did not find a nest imply either intermittent breeding or failure to detect nesting.

Caracaras can be particularly sensitive to activity within 300 m of nests (Morrison 2001), but the long-term response of breeding caracaras to changes in land use near their breeding sites or throughout the range has not been evaluated. Consequently, prior to beginning our surveys, we evaluated the land cover within 300 m of all territories in Morrison and Humphrey (2001) and identified those where $\geq 50\%$ of the habitat had been modified from the habitat of the 1990s. We surveyed all modified territories, and a random sample of territories where land use had not changed. We used χ^2 analyses to test for differences in the proportion of modified and unmodified territories where we found nests or observed adult Caracaras.

RESULTS

We conducted 77 surveys at 49 sites, including 15 surveys at 10 modified sites. No additional modified sites were available. We found nests at 40 sites (81.6%; 95% C.I. = 70.8% - 92.5%), including 9 nests at modified sites (Table 1). There was no difference in the proportions of modified and unmodified sites where we found nests ($\chi^2 = 0.59$, $df = 1$, $P = 0.44$). We found at least one adult caracara at every site. Thus, there was no difference in the proportions of modified and unmodified sites where we observed adult caracaras. At one site we observed 3 pairs of adults, each using non-overlapping portions

of the 1990s site and adjacent pasture, and each with a nest. We conducted two surveys (1 survey in each of 2 years) at 24 sites and found nests in both years at 13 of these sites (54.2%; 95% C.I. = 34.2% - 74.1%).

DISCUSSION

The management plan for caracaras allows human modification of breeding sites if nesting is not documented in a given year, even if nesting was documented previously (Dwyer, pers. obs.). This occurs despite findings by Morrison and Humphrey (2001) that some pairs skip breeding in some years. More than 10 years after Morrison and Humphrey (2001) studied the breeding sites we sampled, we found caracaras in every sampled site, and most sites (> 80%) supported confirmed nests. Because we conducted our surveys before a few breeding attempts for the year were not yet initiated (Morrison 1999), and because 100% detection is unlikely (Chapter 5), some nests also were likely to have occurred at sites where we did not detect nests. Thus, long-term occupancy of breeding sites appears to be typical of the ecology of caracaras in Florida.

Site persistence occurred regardless of whether the habitat immediately surrounding the 1990s nest tree had been modified. Caracaras exhibit high site fidelity even though habitat modification may negatively affect fitness. Across territorial species, site fidelity can be particularly high when most or all breeding habitat is occupied. Caracaras are capable of breeding at age three (Nemeth and Morrison 2002), but some individuals persist as non-breeders until ages 5-6 or older (Chapter 5). The presence of adult non-breeders in a population suggests that breeding habitat is limited and occupied (Hunt 1998), reinforcing the concern that the caracara's breeding population may be

habitat limited (USFWS 1987). Caracaras whose breeding sites are modified may remain in place because no alternative territories of sufficient quality are likely to exist.

Consequently, the persistence of breeding pairs on modified territories may not be sufficient evidence to assert that territory modification is not deleterious. Productivity should be used to evaluate this possibility. We did not evaluate productivity, and future research should focus on comparing productivity on modified and unmodified territories, particularly on territories where a before-after-control-impact design may be used to isolate the effects of specific modifications. It is possible that some of the adult birds we observed at sites where we did not find nests were non-breeding caracaras, however, non-breeders typically occur in groups (Chapter 3) and we never saw groups on these sites. Thus, it is more likely that these sites continue to be occupied by breeding pairs.

The current management strategy focused on finding active nests of caracaras is likely to facilitate attrition of breeding sites, and may directly result in further reductions of this threatened population. Therefore we suggest that reliance on detection of nests during the particular breeding season when habitat modification is proposed may be a poor trigger for implementing management activities. Adult caracaras are more easily detected than nests, particularly by less experienced surveyors (Chapter 5), and breeding sites tend to persist over periods of at least a decade. Consequently, If management goals remain focused on preventing the loss of breeding habitat, then triggers for caracara management should be expanded to include simple observations of adult caracaras so that as many breeding sites as possible are managed as intended. Searching for breeding sites in areas where they are not yet known also should be incorporated in future management so that managers can identify potential areas of interest before those areas attract

developers. If this is not done, then the breeding population is likely to continue to be depleted as a consequence of attrition at sites where breeding is not recognized.

ACKNOWLEDGEMENTS

This study was funded by the U.S. Fish and Wildlife Service grant agreement no.145 401815G060. This is contribution No. _____ (assigned following acceptance) from the MacArthur Agro-Ecology Research Center of Archbold Biological Station. We thank G. Lollis and P. Bohlen of MAERC for logistic support, and A. Fleming, L. Hunt, M. Scholer, and N. Swick for field assistance. A. Mangiameli of Audubon North Carolina provided comments on an early draft.

LITERATURE CITED

- BILDSTEIN, K. L. 1998. Long-term counts of migrating raptors: A role for volunteers in wildlife research. *Journal of Wildlife Management* 62:435-445.
- BILDSTEIN, K. L. 2008. A brief history of raptor conservation in America. In *State of North America's Birds of Prey*, K.L. Bildstein, J.P. Smith, E.R. Inzunza, and R.R. Veit, Eds. Nuttall Ornithology Club and American Ornithologists Union, Cambridge, MA, and Washington D.C.
- BRUINZEEL, L. W. 2007. Intermittent breeding as a cost of site fidelity. *Behavioral Ecology and Sociobiology* 61:551-556.
- CATRY, P., R. A. PHILLIPS, K. C. HAMER, N. RATCLIFFE, AND R. W. FURNESS. 1998. The incidence of nonbreeding by adult Great Skuas and Parasitic Jaegers from Foula, Shetland. *Condor* 100:448-455.

- COSTANZO, G. R., L. J. HINDMAN. 2007. Chesapeake Bay breeding waterfowl populations. *Waterbirds* 30:17-24.
- FEDERAL REGISTER. 1987. Threatened Status for Florida Population of Audubon's Crested Caracara; 52 FR 25229-25232.
- FLATHER, C. H., AND J. R. SAUER. 1996. Using landscape ecology to test hypotheses about large-scale abundance patterns in migratory birds. *Ecology* 77:28–35.
- LOGAN, T. 1997. Florida's endangered species, threatened species, and species of special concern. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
- MORRISON, J.L. 1996. Crested Caracara (*caracara plancus*). In *The Birds of North America*, No. 249 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.
- MORRISON, J.L. 1998. Effects of double brooding on productivity of Crested Caracaras. *Auk* 115:979-987.
- MORRISON, J.L. 1999. Breeding biology and productivity of Florida's Crested Caracaras. *Condor* 101:505-517.
- MORRISON, J.L. 2001. Recommended management practices and survey protocols for Audubon's Crested Caracara (*Caracara cheriway audubonii*) in Florida. Technical Report No. 18. Florida Fish and Wildlife Conservation Commission Project NG96-021. Contract Number 96115. Tallahassee, FL, USA.
- MORRISON, J. L. AND S. R. HUMPHREY. 2001. Conservation value of private lands for Crested Caracara in Florida. *Conservation Biology* 15:675-684.

- PEHLAK, H., A. LOHMUS, A. KURESOO, AND L. LUIGUJOE. 2006. Land-based census of wintering waterfowl: Reliability and conservation implications. *Waterbirds* 29:76-80.
- SAUER, J. R., J. E. FALLON, AND R. JOHNSON. 2003. Use of North American breeding bird survey data to estimate population change for bird conservation regions. *Journal of Wildlife Management* 67:372–389.
- USFWS (UNITED STATES FISH AND WILDLIFE SERVICE). 1989. Recovery plan for the Florida population of Audubon's Crested Caracara. Atlanta, Georgia. 29 pp.
- USFWS (UNITED STATES FISH AND WILDLIFE SERVICE). 1999. South Florida multi-species recovery plan. Atlanta, Georgia. 2172 pp. (pgs. 4-219 to 4-235).
- WHEELER, B. K. AND W. S. CLARK. 1999. *A Photographic Guide to North American Raptors*. Academic Press. San Diego.

Table 1. Annual count of territories surveyed and nests found. 1st indicates that the territory was first surveyed during the year indicated. 2nd indicates that the territory was surveyed during a previous year. Each territory was surveyed a maximum of twice. Numbers in parentheses indicate number of nests found.

	<u>2007</u>		<u>2008</u>		<u>2009</u>		<u>Total</u>	
	1 st	2 nd						
Modified	2 (1)	0 (0)	8 (8)	1 (0)	0 (0)	4 (2)	10 (9)	5 (2)
Unmodified	13 (9)	0 (0)	15 (11)	4 (2)	11 (6)	19 (16)	39 (26)	23 (18)
<u>Total</u>	<u>15 (10)</u>	<u>0 (0)</u>	<u>23 (19)</u>	<u>5 (2)</u>	<u>11 (6)</u>	<u>23 (18)</u>	<u>49 (35)</u>	<u>28 (20)</u>

CHAPTER 5

TESTING SURVEY METHODS FOR NORTHERN CRESTED CARACARAS (*CARACARA CHERIWAY*) NESTING IN FLORIDA

James F. Dwyer,¹ Joan L. Morrison,² and James D. Fraser¹

¹Department of Fisheries and Wildlife Sciences, Virginia Tech, 100 Cheatham Hall,
Blacksburg, VA24061, USA

²Department of Biology, Trinity College, 300 Summit Street, Hartford, CT 06106, USA

ABSTRACT

Wildlife surveys are important for setting, tracking, and evaluating management goals. In Florida, the management of the threatened Northern Crested Caracara (*Caracara cheriway*, hereafter “caracara”), focuses largely on protecting nests identified during surveys of potential breeding territories. If no nest is found, management measures may not be applied. Thus, surveys containing type II error (false negative) may negatively affect the caracara population. To assess factors important in detecting caracara nests and adult caracaras during surveys, we sampled 49 prospective caracara territories during the breeding seasons of 2007 - 2009 and used an information-theoretic approach to compare nested logistic regression models of detection of nests and adults. Surveys comprised three visits. The probability that a nest would be detected on any given visit increased by about 0.5% for every hour of experience an observer had up to about 70 hr (our maximum). The probability of detection of caracara nests and sightings of adult caracaras decreased by 2-3.5% for every hour after sunrise. If visibility during any portion of a visit was obscured by fog or rain, the probability of detecting a nest decreased by as much as 60%, and the probability of observing an adult caracara decreased about 50%. We recommend that managers disregard negative results from surveys conducted under conditions which are unlikely to yield positive results, and repeat those surveys under better conditions.

Key words: breeding territory, *Caracara cheriway*, Crested Caracara, survey methods

Decision-making in wildlife management often hinges on inferences about population size and distribution drawn from surveys. For instance, harvest limits for game species and recovery goals for endangered species routinely are informed by survey results (USFWS 1986, Lancia et al. 2005). Survey results can be misleading however if detection probabilities are not considered and accounted for (Thompson 2002, Pollock et al. 2004). Surveys of secretive animals can be particularly difficult and often require rigorous methods to quantify type II error, i.e., failure to detect an individual that actually is present (Nadeau et al. 2008, Crowe and Longshore 2010).

The Northern Crested Caracara (*Caracara cheriway*, hereafter “caracara,” Dove and Banks 1999) in Florida is a Federal and State listed threatened species primarily because surveys conducted during the 1980s suggested a decline in the nesting population (Federal Register 1987, Logan 1997). Subsequent recovery plans (USFWS 1989, 1999) focused on protecting nest sites of caracaras and identified a recovery goal of 300 nesting pairs persisting for at least 10 yr. Surveys in prospective territories are used to evaluate progress toward that goal, to identify areas where management actions will be applied, and to make decisions about changes in land use. Thus, surveys are an important part of the management of caracaras, but no evaluation of detection probability during surveys has been undertaken for this species. Because caracaras can be secretive around nest sites (Morrison 2001) we suspected that detectability was likely below 100%, so we set out to quantify the likelihood that a survey would lead to the detection of a nest in areas where a nest was likely.

Over the past decade, caracara surveys have generally followed recommendations in Morrison (2001), which suggests that nests be sought January through March before

11:00 or after 16:00 local time over 2-4 hr visits. These survey protocols have not been critically evaluated. Thus, our objectives were to test these protocols and to offer refinements to increase the likelihood of detection, if appropriate. We also evaluated the influence of two variables not addressed in the previous protocol: observer experience, and visibility as a function of precipitation. We evaluated each of these factors with respect to detecting caracara nests and observing adult caracaras, and we use our analyses to predict the probability of detection based on these three factors (visit start time, observer experience, and visibility as a function of weather).

METHODS

Our study was centered at the MacArthur Agro-Ecology Research Center (27°09'11"N, 81°11'50"W) near Lake Placid, Florida, and included 1990s breeding territories in the following five counties: De Soto, Glades, Highlands, Indian River, and Okeechobee. We randomly selected 49 of the 73 caracara breeding territories identified in Morrison and Humphrey (2001) and surveyed them during the breeding seasons of 2007 through 2009. We chose to work at previously documented breeding territories so we could test survey methods where caracara nests were reasonably likely to be present. However, because these territories had not been surveyed since 1999, and no information existed regarding the long term occupancy of breeding territories, we did not know whether caracaras were still present at these territories when we began our study. Thus, though we used the exact locations of previous nests to orient our surveys, we surveyed areas where nest sites were unknown and refer to these areas as "prospective" territories. We conducted surveys from within a vehicle parked where a large area of potential

breeding habitat was visible. We conducted up to three 2-hr long visits per territory per year, but if we found a nest on a first or second visit, we considered the survey complete and did not conduct additional visits in that year.

We evaluated seasonal variation in detection by assigning each visit to a 2-week period (1-15 January, 16-31 January, 1-14 February, and 15-28 February). We randomly assigned visit order within 2-week periods, and randomly assigned observers and start times relative to sunrise. When our surveyors visited territories more than once, they did not exchange details of negative visit results between observers, nor did they conduct visits from the same observation points. Avian surveyors often assume reduced detection during inclement weather and do not conduct surveys during these periods (e.g. Crowe and Longshore 2010). We wanted to demonstrate the size of a weather effect on detection, so if rain or fog obscured visibility during any portion of a visit, we conducted the visit as scheduled, but recorded the visit as “obscured”. Observer variability in perception can influence survey results (Nichols et al 2000), and quantifying such nuisance variables can be critical to effective modeling. Thus, to test for an observer effect, we recorded observer experience as the number of minutes of experience an observer had surveying for caracara nests before beginning the current visit, though for ease of interpretation we discuss hours of experience hereafter. Our observers were employed as full time caracara field researchers who spent the remainder of their work week studying non-breeding caracaras in related studies (Chapters 1-3).

To reduce our candidate models from all possible subsets, we used univariate logistic regression and χ^2 analyses to select candidate variables for further evaluation (Hosmer and Lemshow 1989). To minimize the risk of excluding factors that might be

influential, we used $P \leq 0.45$ from univariate analyses as our cutoff for including candidate factors in multivariate modeling. We then tested all possible combinations of those potentially influential factors. We used proc GENMOD with a logit link in program SAS (Cary Institute, Cary, NC) to model the probability that a visit would result in finding a caracara nest, and separately, to model the probability that a visit would result in observing an adult caracara. This procedure allowed us to include territory as a random effect, and thus account for having conducted unequal numbers of visits (1-3) at various territories. We used an inverse logit link to transform outputs from regression models into predictions of probabilities of detection. We tested the fit of our global models with a Hosmer and Lemeshow goodness of fit test (Hosmer and Lemeshow 1989, Shaffer 2004). We used AIC values in an information theoretic approach to compare candidate models, and accounted for uncertainty in model selection by computing Akaike weights (w_i) and model averaged effect estimates (Burnham and Anderson 2002).

RESULTS

From 2007 through 2009 we conducted visits at 49 prospective caracara territories. We found nests at 39 territories, and adult caracaras at 48 territories. Univariate analyses indicated that visit start time, visibility, and hours of experience might be important predictors of the probability of detecting a nest and that there was no year effect (Table 1). In multivariate analyses, all three were included in the top model (Table 2), while only visibility and start time were included in the only other model with substantial support ($\geq 0.125 w_i$; Burnham and Anderson 2002). Univariate analyses also indicated that visit start time and visibility might be important predictors of the

probability of detecting an adult caracara. In multivariate analyses, both were included in the top model, and visibility only was included in the only other highly ranked competing model.

We used regression coefficients from model averaging (Table 3), to model the probability that a nest would be detected or an adult caracara would be observed on a given visit (Figs. 1a, 1b, and c). In the event that a complete survey (three visits) results in a lack of detecting either a nest or an adult caracara, visit detection probabilities may be combined to estimate the survey detection probability given that a nest existed (Eqn. 1).

$$P_s = (A) + ((1-A)*(B)) + ((1-A)*(1-B)*(C)) \quad (1)$$

Where P_s is the probability of detection for the survey, A is the estimated probability of success of the first visit, B is the estimated probability of success of the second visit, and C is the estimated probability of success of the third visit.

After accounting for other factors, the probability that a nest would be detected on any given visit increased by about 0.5% for every hour of experience an observer had up to about 70 hr (our maximum), but experience did not affect whether adult caracaras were seen. Detection of caracara nests decreased by 2-3.5% for every hour after sunrise a visit began, depending on the hour, and observations of adult caracaras consistently decreased by about 2.5%.

DISCUSSION

The probability that a visit or series of visits will lead to the discovery of a caracara nest or the observation of an adult caracara, given that a nest or caracara is present, can be predicted with three easily collected input variables: observer hours of experience, visit start time relative to sunrise, and the occurrence of precipitation during a visit.

Observer experience influenced nest detection but not observation of adult caracaras. This suggests that experience is particularly important for tracking birds to nests. Because our observers were working with caracaras full time, our detection skills may be above average. Thus, observer experience effects may be even more pronounced than indicated here, and may also influence the probability of observing an adult caracara despite our lack of support for that possibility.

Detection of both nests and adults decreased with increasing start times after sunrise. Sunrise times fluctuate from about 6:30 in the summer to about 7:15 in the winter (using daylight savings times) at the center of the species' range in Florida. Visits should be planned to be initiated at sunrise, rather than conforming to "the normal work day." That is, to maximize detection, observers should arrive at prospective territories before dawn and be surveying as ambient light becomes available. Figs. 1 and 2 indicate that when visibility was obscured by fog or rain during any portion of a visit, probability of detection of a caracara nest during that visit was reduced by about 60%, and detection of adult caracaras was reduced by about 50%. Fog and rain were most likely to occur at dawn, and thus reduced visibility specifically during the period when detection would otherwise have been greatest. Beginning a visit after fog or other precipitation has

dispersed substantially reduces the likelihood that a nest will be detected. Our visits lasted two hours. Longer visits could be conducted, or visits could be initiated after rain or fog ended, but this would simply extend visits into periods when detection probabilities are low. Consequently, we suggest that observers following the protocol in Morrison (2001) suggesting 2-4 hr visits may be more effective if visits were reduced to 2 hr only, and remaining time were reallocated to subsequent early morning visits if needed. Observers required a minimum of about 40 hours of experience surveying for caracaras before the probability of detecting a nest reached 50%, and then regardless of experience detection probability declined quickly with increasing start time after sunrise, or when visibility is obscured by weather.

By using parameter estimates (Table 3) to construct regression equations, managers attempting to locate caracara nests or adults may identify the probability that a caracara nest or adult caracara would have been seen if one were present. As an example, we construct the equation for detecting a nest here (Equation 2).

$$Y = -3.229 + (0.020*\text{hrs experience}) - (0.170*\text{start time hrs after sunrise}) + (2.403*\text{weather}) \quad (2)$$

where weather is a categorical value of “1” if the entire visit is conducted in the absence of any fog or rain, and “0” if any portion of the visit (however brief) occurs concurrent to precipitation at the survey site. Because this equation derives from a logistic regression, users of equation (2) must perform an inverse logit link transformation on the output value (Y) to adjust Y to a 0 to 1 probability scale (Equation 3).

$$\text{Probability (nest found)} = (1 / (1 + e^{(Y \text{ value from model})})) \quad (3)$$

The procedure for constructing the equation for observing an adult caracara is identical to the above, but the other set of parameter estimates from Table 3 are used. The inverse logit link transformation is identical. For convenience we have included each of these equations as part of a table intended to be pasted into and used within an excel spreadsheet (Appendix 1).

We suggest that land managers identify a threshold of the probability of success below which they do not accept the results of surveys that do not yield detection of nests when surveys occur in areas where a nest is likely. Managers may require survey personnel to report visibility, start time, and experience, and managers may then use those parameters to identify whether a visit with negative results meets that threshold (Appendix 1). This tool should be used immediately after a visit is conducted so that if the probability of success is low, the visit, and the survey if necessary, can be repeated under conditions meeting minimum requirements. If surveyors were required to provide in their reports their raw data and an estimate of the likelihood of their success based this tool, then surveyors may be more inclined to repeat surveys without having to be asked to do so. This should increase the likelihood that surveys which do not yield evidence of nesting or occupancy are valid, and provide resource managers with more reliable data upon which to base decisions.

The detection probabilities of individual visits may be combined to estimate the detection probability of a complete survey (Equation 1, Appendix 1). For example, under

ideal conditions of 70 hours of experience, a sunrise start time, and a clear day, the probability that a visit will be successful is about 0.65. Substituting 0.65 in equation (1) reveals that three visits, each conducted under ideal conditions together yield a survey detection probability of 0.96. By contrast, an observer which had only 33, 35, and 37 hours of experience, respectively over three visits (experience hours gained during each visit are incorporated into subsequent visits), that began visits one hour after sunrise, and that conducted one visit amid a brief bout of early morning fog would yield a survey detection probability of 0.69.

Caracaras initiate 96% of nesting attempts during the six month period from October through March (Morrison 1999). Morrison (2001) recommended that nesting surveys take place from January through March. Surveys during this period are likely to occur after some breeding pairs have nested, but before the young produced in those nests have dispersed from natal territories. Thus, if the presence of fledglings were sufficient to trigger management action, then this survey period would be sufficient. However, management activities usually are centered on nest locations, and do not include explicit provisions for finding fledglings but not nests. Consequently, we recommend that management be explicitly expanded to include fledglings, or that nest survey periods be extended to include at least the period from October through March, and ideally through the entire breeding season of September through April (Morrison et al. 2009) when any nesting or dependent young may occur.

ACKNOWLEDGEMENTS

This study was funded by the U.S. Fish and Wildlife Service grant agreement no.145 401815G060. This is contribution No. _____ (assigned following acceptance) from the MacArthur Agro-Ecology Research Center (MAERC) of Archbold Biological Station. We thank G. Lollis and P. Bohlen of MAERC for logistic support and A. Fleming, L. Hunt, M. Scholer, and N. Swick for field assistance.

LITERATURE CITED

- BURNHAM, K.P., AND D.R. ANDERSON. 2002. Model Selection and Multimodel Inference: A Practical Information-theoretic Approach, 2nd ed. Springer-Verlag, New York.
- CROWE, D. E. AND K. M. LONGSHORE. 2010. Estimates of density, detection probability, and factors influencing detection of burrowing owls in the Mojave desert. *Journal of Raptor Research* 44:1-11.
- DOVE, C. J. AND R.C. BANKS. 1999. A taxonomic study of Crested Caracaras (Falconidae). *Wilson Bulletin* 111:330-339.
- FEDERAL REGISTER. 1987. Threatened Status for Florida Population of Audubon's Crested Caracara; 52 FR 25229-25232.
- HOSMER, D. W. AND S. LEMSHOW. 1989. Applied Logistic Regression. John Wiley & Sons, Inc. NJ.
- LANCIA, R.A., W.L. KENDALL, K.H. POLLOCK, AND J.D. NICHOLS. 2005. Estimating the Number of Animals in Wildlife Populations. Pages 106-153 *in* Techniques for Wildlife Investigations and Management (Braun, C. E., Ed.). Port City Press, Baltimore.

- LOGAN, T. 1997. Florida's endangered species, threatened species, and species of special concern. Florida Game and Fresh Water Fish Commission, Tallahassee, FL.
- MORRISON, J.L. 1999. Breeding biology and productivity of Florida's Crested Caracaras. *Condor* 101:505-517.
- MORRISON, J.L. 2001. Recommended management practices and survey protocols for Audubon's Crested Caracara (*Caracara cheriway audubonii*) in Florida. Technical Report No. 18. Florida Fish and Wildlife Conservation Commission
- MORRISON, J.L., AND S.M. MCGEHEE. 1996. Capture methods for crested Caracaras. *Journal of Field Ornithology* 67:630-636.
- MORRISON, J.L. AND S.R. HUMPHREY. 2001. Conservation value of private lands for Crested Caracaras in Florida. *Conservation Biology* 15:675-684.
- MORRISON, J. L., K. E. PIAS, J. B. COHEN, AND D. H. CATLIN. 2009. Environmental correlates of breeding in the Crested Caracara (*Caracara cheriway*). *Auk* 126:755-764.
- NADEAU, C. P., C. J. CONWAY, B. S. SMITH, AND T. E. LEWIS. 2008. Maximizing detection probability of wetland-dependent birds during point-count surveys in Florida. *Wilson Journal of Ornithology* 120:513-518.
- NICHOLS, J. D., J. E. HINES, J. R. SAUER, F. W. FALLON, J. E. FALLON, AND P. J. HEGLUND. 2000. A double-observer approach for estimating detection probability and abundance from point counts. *Auk* 117:393-408.
- POLLOCK, K. H., H. MARSH, L. L. BAILEY, G. L. FARNSWORTH, T. R. SIMONS, AND M. W. ALLDREDGE. 2004. Separating components of detection probability in abundance estimation: an overview with diverse examples. Pages 43-58 in *Sampling Rare or*

- Elusive Species: Concepts, Designs, and Techniques for estimating population parameters (W. L. Thompson, Ed.). Island Press, Washington, D.C.
- SHAFFER, T. L. 2004. A unified approach to analyzing nest success. *Auk* 121:526-540.
- THOMPSON, W. L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. *Auk* 119:18-25.
- UNITED STATES FISH AND WILDLIFE SERVICE. 1986. California Condor Recovery Plan, Third Revision. Portland, Oregon. 62 pp.
- UNITED STATES FISH AND WILDLIFE SERVICE. 1989. Recovery plan for the Florida population of Audubon's Crested Caracara. Atlanta, Georgia. 29 pp.
- UNITED STATES FISH AND WILDLIFE SERVICE. 1999. South Florida multi-species recovery plan. Atlanta, Georgia. 17 pp.

Table 1. Univariate analyses of all factors tested in detecting Caracara nests or adult Caracaras (N = 173 visits, * = significant). Data collected in Florida, U.S.A., January and February of 2007, 2008, and 2009.

<u>Parameter</u>	<u>Caracara Nest Found</u>		<u>Adult Caracara Seen</u>	
	χ^2	<i>P</i>	χ^2	<i>P</i>
Visit Start Time	7.733	0.0050*	1.709	0.1910
Weather	7.668	0.0056*	13.623	0.0002*
Hours Experience	5.118	0.0237*	0.001	0.9781
Visit Period	2.108	0.5502	1.337	0.7203
Year	0.138	0.9335	3.727	0.1551

Table 2. Model selection results for finding a Caracara nest or observing an adult Caracara in a prospective territory. Data collected in Florida, U.S.A., January and February of 2007, 2008, and 2009.

<u>Model</u>	<u>k</u>	<u>-ln(L)</u>	<u>ΔAIC</u>	<u>w_i</u>
Finding a Caracara Nest				
Experience + Time + Weather	4	95.05	0.00	0.822
Weather + Time	3	97.81	3.52	0.141
Time + Experience	3	99.82	7.54	0.019
Weather + Experience	3	100.36	8.60	0.011
Time	2	102.73	11.36	0.002
Weather	2	102.75	11.40	0.002
Null	1	105.60	15.09	0.001
Experience	2	108.04	13.98	0.001
Observing an Adult Caracara				
Time + Weather	3	84.89	0.00	0.698
Weather	2	86.74	1.70	0.299
Null	1	92.55	11.32	0.002
<u>Time</u>	<u>2</u>	<u>92.69</u>	<u>13.61</u>	<u>0.001</u>

Table 3. Model of variables important in predicting detection of Caracara nests, and observing an adult Caracaras during visits to prospective territories (model-averaged effect estimates)^a. Data collected in Florida, U.S.A., January and February of 2007, 2008, and 2009.

	<u>Nest Detection^b</u>		<u>Adult Observation^c</u>	
	$\hat{\beta}$	SE	$\hat{\beta}$	SE
Intercept	-3.229	1.063	-0.368	1.063
Experience	0.020	0.009	----	----
Start Time	-0.170	0.058	-0.100	0.578
<u>Weather</u>	<u>2.403</u>	<u>1.056</u>	<u>2.060</u>	<u>1.056</u>

^a Users of this equation must perform an inverse logit link transformation on the Y (output) value to transform values to a 0 to 1 scale.

$$\text{Probability} = (1 / (1 + e^{(Y \text{ value from model})}))$$

^b Hosmer and Lemeshow goodness-of-fit test for global model of nest detection: $X^2 = 9.72$, $df = 8$, $P = 0.2853$.

^c Hosmer and Lemeshow goodness-of-fit test for global model of observing an adult: $X^2 = 5.12$, $df = 8$, $P = 0.7459$.

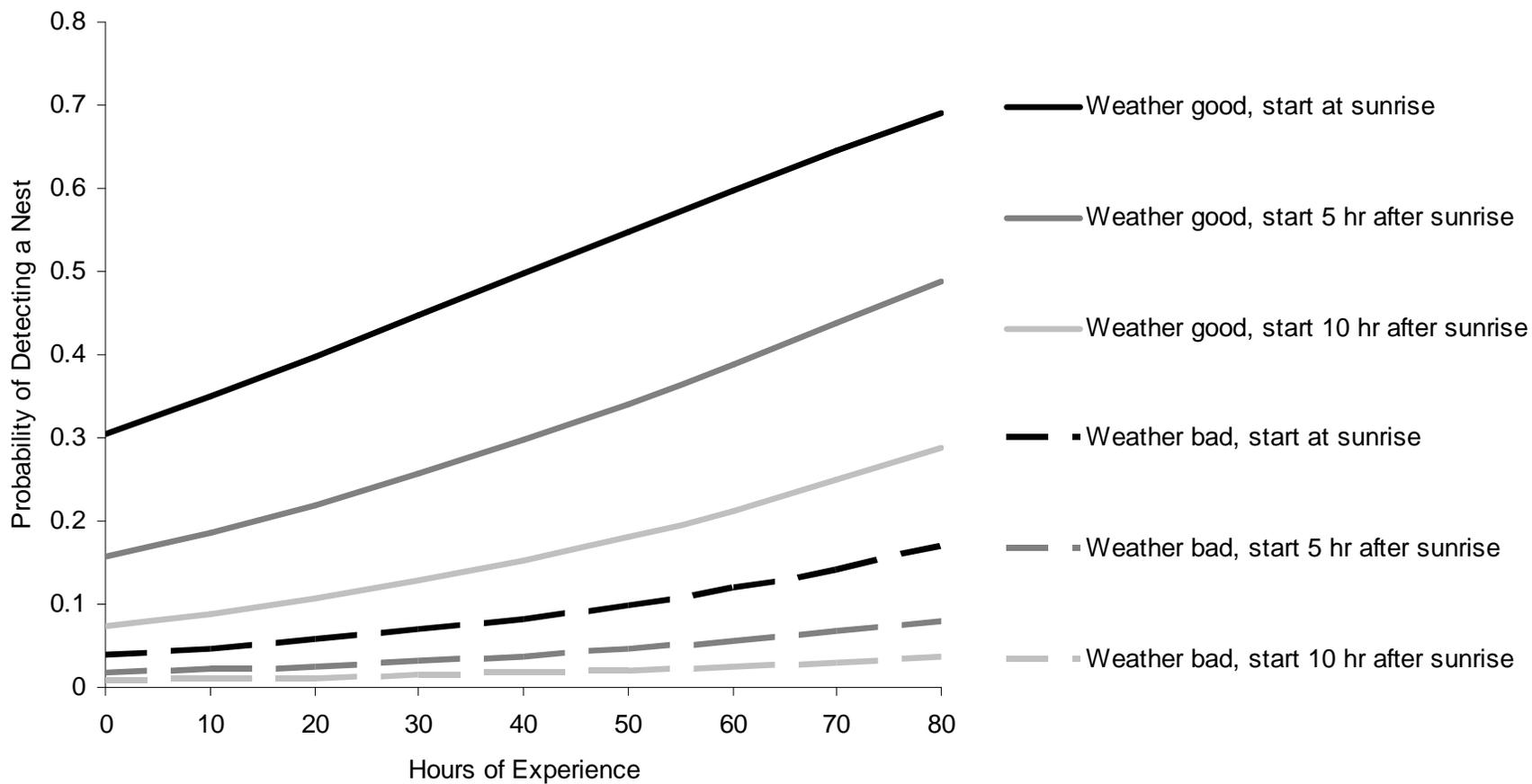


Figure 1. Probability that a Caracara nest is found as a function of observer hours of experience, time relative to sunrise when a visit was initiated, and whether any fog or rain obscures visibility.

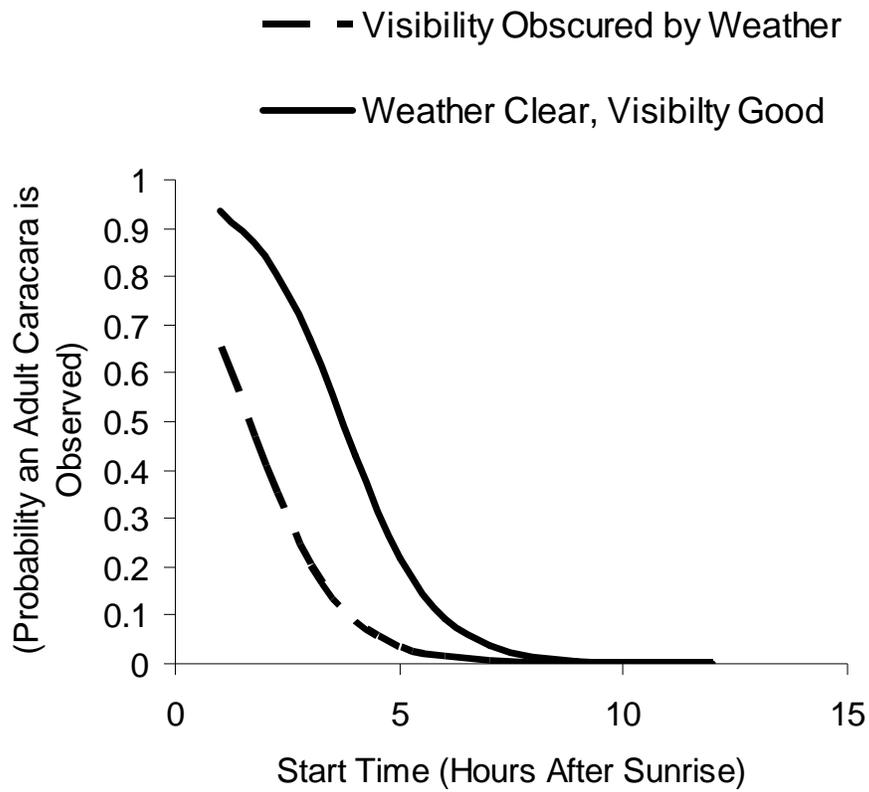


Figure 2. Probability that a Caracara is detected as a function of time relative to sunrise when a visit was initiated and whether any fog or rain obscures visibility.

Appendix 1. Prediction Calculator for Detecting Caracara Nests and Adults

Appendix 1. Table to be pasted into a Microsoft Excel spreadsheet for use in calculating the probability of visit and survey results based on input values. An electronic version of this file is available by emailing biojimmi@yahoo.com or jfdwyer@gmail.com.

DIRECTIONS (Paste this cell into A1)			
1) Copy this ENTIRE table into a Microsoft Excel worksheet (A1:E36)			
2) Enter visit results in cells with double borders			example
3) Read predictions from shaded cells with single borders			example
INPUT VALUES (Descriptors of Visit(s))			
	Hours Experience	Start Time after Sunrise	Weather
Visit 1			
Visit 2			
Visit 3			
OUTPUT VALUES (Probability of Success)			
	Nest Found	Adult Observed	
Visit 1	=B29	=B33	
Visit 2	=B30	=B34	
Visit 3	=B31	=B35	
Survey	=B32	=B36	
CALCULATIONS (Do not alter these cells)			
Parameter name	Parameter estimate		
Nest Intercept	-3.229309		
Nest Hours			
Experience	0.0203713		
Nest Start Time	-0.1703831		
Nest Weather	2.4032401		
Adult Intercept	-0.3682772		
Adult Start Time	-0.9904907		
Adult Weather	2.0624893		
P (Visit 1 Nest)	=(1/(1+(EXP(-(B22+(B23*B9)+(B24*C9)+(B25*D9))))))		
P (Visit 2 Nest)	=(1/(1+(EXP(-(B22+(B23*B10)+(B24*C10)+(B25*D10))))))		
P (Visit 3 Nest)	=(1/(1+(EXP(-(B22+(B23*B11)+(B24*C11)+(B25*D11))))))		
P (Survey Nest)	=(B29)+((1-B29)*B30)+((1-B29)*(1-B30)*B31)		
P (Visit 1 Adult)	=(1/(1+(EXP(-(B26+(B27*C9)+(B28*D9))))))		
P (Visit 2 Adult)	=(1/(1+(EXP(-(B26+(B27*C10)+(B28*D10))))))		
P (Visit 3 Adult)	=(1/(1+(EXP(-(B26+(B27*C11)+(B28*D11))))))		
P (Survey Adult)	=(B33)+((1-B33)*B34)+((1-B33)*(1-B34)*B35)		

CHAPTER 6
CONCLUSION

Most avian management strategies in the United States are directed at breeding territories. Management of caracaras in Florida has followed this paradigm, and management-based restrictions on landscape modification are applied if, and only if, a nest is detected. Areas where caracaras are observed but nests are not found typically are not included in management decision making. This is the best strategy for managing caracaras only if all caracaras occupy nesting territories, all caracara nests are detected, and nesting occurs annually. Herein, I demonstrate that none of these criteria are met for Florida's population of caracaras. Specifically, non-breeding caracaras occupy much larger areas than the territories of individual breeding pairs, occupy habitat types atypical of breeding territories, and occupy communal roosts which regularly contain hundreds of individuals, but do not support nests. I also demonstrated that observers are occasionally likely to conclude that a nest did not exist when in truth a nest did exist but was not detected, because the observer was inexperienced, observations were conducted too late in the day, or poor weather obscured visibility during some portion of a survey.

To maximize the effectiveness of caracara management, the strategies currently in use for triggering management action should be revised to incorporate non-breeding caracaras. With respect to non-breeding caracaras, five of our most important findings are that 1) communal roosts used by non-breeding caracaras are distributed regularly throughout the species' range, 2) roosts are used year-round over multiple years by young birds from throughout the species' range in Florida, 3) pastures are the primary defining feature of the range, particularly pastures with cattle, 4) local enhancement and social learning require that non-breeding caracaras be able to detect one another over large distances, thus linking the importance of the open structure of pastures to the behavioral

ecology of non-breeding caracaras, and 5) within their range non-breeding caracaras use habitats atypical of breeding territories, particularly citrus groves. Specifically, I found that 58% of the locations I collected for non-breeding caracaras occurred on pastures, 20% occurred in citrus groves, and 6% in row crops.

These findings indicate that management of non-breeding caracaras should be expanded to include communal roosts and surrounding habitat. A matrix of pasture, citrus, and palm habitats should be encouraged in areas where caracara management is prioritized, and an ideal management goal might be to acquire ownership or easements for roost sites. However, we do not know the potential impact to non-breeding caracaras of the pesticides, herbicides and other chemicals applied to citrus, and future research should evaluate possible consequences to caracaras occupying these areas. Previous research indicates the importance of wetland species in the diet of caracaras, and the small wetlands typical of pasture habitats also should be perpetuated. Caracaras at communal roosts can be particularly difficult to detect in the absence of a nocturnal tracking system, so roosts should be conserved even when use of roosts is not detected.

I also found long-term persistence of adult non-breeding caracaras in the floater stage, and this, together with the fact that deceased territory holders are immediately replaced (Morrison unpubl. data) leads me to believe that all breeding habitat is occupied. I.e., the breeding population of caracaras in Florida is habitat limited. Thus, any loss of breeding habitat will necessarily reduce the breeding population. Additionally, I found that territories tend to persist for at least a decade. Because breeding pairs have strong site fidelity, because breeding can not always be confirmed, and because the population is threatened, I suggest that all pasture habitat where caracaras are observed should be

managed as if it were part of a caracara's breeding territory. Future management should focus on identifying caracara nest sites throughout the range, particularly around the periphery of the range and in areas where urbanization is expanding, so that management strategies can be applied before those sites are targeted by developers. If this does not occur, the breeding population of caracaras in Florida is likely to continue to decline. Future research also should focus on areas where landscape modification is likely to occur so that the responses of breeding caracaras to the loss of their habitat can be quantified and used to inform future management decisions and strategies.

Intermittent breeding occurs in this caracaras. In most species with intermittent breeding, breeding is skipped during periods of high stress. Reducing or abandoning management when breeding does not occur effectively targets caracaras for negative action precisely when the birds are most vulnerable. If breeding is suspected, management activities should be applied regardless of whether nests are identified.

Finally, the tool provided in Chapter 5 Appendix 1 of this document should be used to evaluate the quality of surveys. Surveys which are unlikely to yield accurate data on occupancy of potential territories should be discarded and repeated immediately before unreliable conclusions have the opportunity to undermine management action. If managers record the likelihood of each survey's effectiveness together with the individual and organization which conducted the survey, use of this tool will also allow managers to quantify the effectiveness of survey personnel. Only effective surveyors should be used to train additional surveys, and surveyors which routinely produce questionable data should be precluded from conducting additional surveys.