CURRENT RAPTOR STUDIES IN MÉXICO

Edited by

Ricardo Rodríguez-Estrella

Centro de Investigaciones Biológicas del Noroeste, S.C.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad

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Current Raptor Studies in México

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MÉXICO

2006

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QL696.F3 R37 2006

Current Raptor Studies in México/ Ricardo Rodríguez-Estrella, ed. México: Centro de Investigaciones Biológicas del Noroeste, S.C.: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, 2006.

2006; 323 p. :il, 25.5 cm.

ISBN 970-9000-37-3

1. Raptors—México 2. Raptors---ecology 3. Raptors—conservation
I. Rodríguez Estrella, Ricardo (Ed.)

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PREFACE

Biological diversity of México, raptors and scientific research

México is one of the most biologically diverse countries on the planet, as a result of its very complex geological history, geographic position, and environmental heterogeneity, among other factors. Its biological diversity is such, that together with 17 other countries such as India, China and Brazil, it is referred to as Megadiverse. Together, these countries sustain more than 70% of all living organisms, including plants, animals and microorganisms, México ranking first for its diversity of reptiles and amphibians, third for its mammalian diversity, fourth for its diversity of vascular plants, and eleventh for its diversity of birds. Moreover, a high percentage of the species, up to 65% in amphibians, are endemic to México; i.e. with geographic ranges restricted to the country.

The biological diversity of México has been part of the geographic and natural settings that have accompanied its inhabitants since they first settled in the country more than 12,000 years ago. The legendary diversity of the country has astonished scientists such as Baron Alexander Von Humbolt, who described México as a biological paradise. Unfortunately, this impressive natural diversity of the country is practically unknown by most Mexicans, who instead should be proud of their biological inheritance.

Nowadays, the biological diversity of México is seriously threatened. Hundreds of species and thousands of populations are endangered, mainly because of human population size and social inequity. México's population size is expected to become stable around 145 millions, but only in three decades. The loss of biological diversity has severe consequences at a biological and social level, because populations and species are the basis for the structure and functioning of biological systems, which provide us for free with environmental goods and services. These goods and services, which include the maintenance of a proper atmospheric gas composition, the ozone layer, soil fertility and quality and quantity of water, among others, generate the environmental conditions that allow life on Earth. They are the basis of our existence. Paradoxically, their continuance depends on our activities.

The only way to understand the complex relationships of living organisms with their environment, their role in providing environmental services, and better management of these living organisms to reconcile their use with their conservation, is through a solid investment in scientific research. However, many governments, including the Mexican government, surrender to the temptation of investing little in scientific and technological research, focusing on other approaches to fight social and economic problems. Those governments ignore that one of the few ways out of poverty is through the generation of scientific and technological knowledge, which is fundamental to the development of any country.

That is why I have received with great satisfaction this volume addressing the ecology and conservation of raptors – one group of species very sensitive to anthropogenic disturbances. As top predators, with low population sizes, raptors are susceptible to environmental changes that can affect them negatively, and thus increase the risk of their extinction. That is precisely why their status is an indication of environmental conditions, much like canary birds long ago used to indicate the presence of toxic gases to miners. The results presented by researchers working with raptors in México can have an immediate application in conservation.

The careful editing of the editor has produced an interesting book of high scientific quality. I am sure that time will be the best test of the benefits of this type of publications, which are essential to maintain the welfare of our society.

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México D.F.

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ACKNOWLEDGMENTS

I would like to express my gratitude to all the referees who peer reviewed the manuscripts. Their effort assures a level of standard scientific information. My special thanks to Karla Yahira Mercado Savín and Roxana C.R. Fernández for their logistic support during the editing process of this book; to Claudia Pérez for her help during the early stages of the project; to Elena Enriquez for her initial support to start the publication process; to Ira Fogel, CIBNOR editor, for his important improvements in the English text; to Diana Dorantes, CIBNOR translator, for important changes in the English text on the Preface and Chapter 10; to Laura B. Rivera-Rodríguez for the logo design; Daniela Flores Romero and Heidy Maday Arellano Lozano for the graphic design; to Dolores Vázquez Astorga for secretarial work; to CONABIO and CIBNOR for their support in the editing and printing of this book; to Mario Martínez, General Director of CIBNOR, for providing valuable assistance in all the features of this work.

Raptor studies in México: an overview

Ricardo Rodríguez-Estrella
Laura B. Rivera-Rodríguez

ABSTRACT

This paper is an overview of the studies on raptors (Falconiformes, Strigiformes, and Cathartidae) that are in course in México. A questionnaire was sent to researchers and ornithologists to collect consistent information on the studies they have done in México with raptors. We received responses from 18 researchers that have worked in 16 states of México and also added information of researchers and institutions that we were certain studied raptors, but did not submit a response. Studies occurred in 22 states. Researchers working with Mexican raptors have positions at 26 institutions. Baja California Sur, Durango, Sonora, and Jalisco reported more studies from the 1980s to 1999 than the other states. There are no studies underway in Campeche, Distrito Federal, Guerrero, Hidalgo, Puebla, Quintana Roo, Tabasco, Tlaxcala, and Yucatán. With the exception of Veracruz and Tamaulipas, there are no current studies in the states of México that contain the highest richness of raptor species nor the most rare or specialized species (Tabasco, Guerrero, Puebla, Hidalgo, Campeche, Quintana Roo, and Yucatán). Most recent research study patterns of distribution, breeding biology, trophic ecology, and general ecology. Studies have been made mainly in xerophytic scrub, oak-pine forests, grasslands, and tropical deciduous forests. Of special concern is the small number of studies or the lack of them, in tropical rainforests, thorn forests, marshes, and mangroves. Osprey (*Pandion haliaetus*), golden eagle (*Aquila chrysaetos*), peregrine falcon (*Falco peregrinus*), burrowing owl (*Athene cunicularia*), aplomado falcon (*Falco femoralis*) and bald eagle (*Haliaeetus leucocephalus*) were species receiving more attention. Although the number of raptor species in México is high, only few species have been studied. Remarkably, almost no studies with owls are currently underway, in spite of the number and diversity of owl species in México. Most studies are less than one year in duration or short-term. From species with no studies reported, 27 of the 33 Falconiformes and 20 of the 32 Strigiformes are included in the official Mexican list of threatened and endangered species (NOM-ECOL-059-2001). It is clear that studies are lacking for Strigiformes (only 4 of 36 known species are receiving attention) and it is also clear that threatened, rare, and endangered raptors (Falconiformes and Strigiformes) need the most particular awareness. Studies are lacking in the states with the highest number of owl species, i.e. Oaxaca, Jalisco, Chiapas, Durango, Michoacán, Nayarit, and Veracruz.

Key words: raptor studies, Falconiformes, Strigiformes, questionnaire, México.

RESUMEN

Este artículo hace una revisión general de los estudios que sobre aves rapaces (Falconiformes, Strigiformes y Cathartidae) se han realizado y se realizan actualmente

en México. Como parte del trabajo, se envió un cuestionario a investigadores y ornitólogos para obtener información de manera consistente sobre los estudios que realizaban en México con rapaces. Se recibió la respuesta de 18 investigadores que han trabajado en 16 estadns de México. También incluimos aquella información sobre investigadores e instituciones de los que se sabía con seguridad que estudiaban a las rapaces, pero que no contestaron el cuestionario. Los estudios con aves rapaces en México ocurrieron en 22 estados, involucrando a investigadores de 26 instituciones. Los estados que reportaron más estudios entre la década de 1980 y 1999 fueron Baja California Sur, Durango, Sonora, y Jalisco. No hay estudios realizándose en Campeche, Distrito Federal, Guerrero, Hidalgo, Puebla, Quintana Roo, Tabasco, Tlaxcala, y Yucatán. A excepción de Veracruz y Tamaulipas, no hay estudios realizándose actualmente en los estados del país que contienen la más alta riqueza de especies de rapaces, las más raras y las más especialistas (Tabasco, Guerrero, Puebla, Hidalgo, Campeche, Quintana Roo, y Yucatán). Las líneas actuales de investigación con aves rapaces se orientan a estudios sobre sus patrones de distribución, biología reproductiva, ecología trófica, y ecología general. Los estudios se han realizado principalmente en el matorral xerófilo, los bosques de encino-pino, pastizales, y selva baja caducifolia. Se denota como preocupante la carencia de estudios en la selva alta o húmeda, los bosques espinosos, pantanos y manglares. Las especies más estudiadas han sido el águila pescadora (*Pandion haliaetus*), águila real (*Aquila chrysaetos*), halcón peregrino (*Falco peregrinus*), lechucita de madrigueras (*Athene* *tunicularia*), el halcón fajado (*Falco femoralis*) y el águila calva (*Haliaeetus leucocephalus*). Aunque el número de especies de rapaces en México es alto, sólo pocas especies han sido estudiadas. Es remarcable la falta de estudios con búhos a pesar de su número y diversidad. Por otro lado, la mayoría de los estudios se realizan con tiempos menores a un año. De las especies que no tienen estudios, 27 de las 33 de Falconiformes y 20 de las 32 de Strigiformes se encuentran incluidas en la lista de especies con categoría de riesgo (NOM-ECOL-059-2001). Es claro que faltan estudios orientados a los Strigiformes (solo han recibido atención 4 de las 36 especies conocidas) y es claro también que se necesita obtener rápida información de las especies de Falconiformes y Strigiformes amenazadas, raras y en riesgo de extinción. Faltan estudios en los estados del país con el mayor número de especies de búhos como Oaxaca, Jalisco, Chiapas, Durango, Michoacán, Nayarit y Veracruz.

INTRODUCTION

In this paper we present an overview of the kind of studies on raptors (Falconiformes, Strigiformes and Cathartidre) that are in course and have been done in México. Many raptors have been considered indicators of ecosystem health and relevant species for conservation plans because they are top-order predators, sensitive to human disturbance, and have been used as umbrella species (Olendorff *et al.* 1989, Shrader-Frechette and McCoy 1993, Simberloff 1997). Also some raptors have been considered keystone species (Newton 1979, Cohen *et al.* 1990, Pimm *et al.* 1991, Marti *et al.* 1993, Simberloff 1997). We believe many raptor species can play an important role in conservation plans in México. However, it is necessary to evaluate the knowledge of their status, biology, and ecology.

For conservation purposes, we wanted a reasonable idea of the most and least studied raptors in México, mainly to determine the degree in which endemic and endangered species are receiving attention by researchers. Endemic, rare, threatened, and endangered species are crucial species for management plans (Primack 1998, Sutherland 2000). Also, we needed information on the habitats where raptors have been studied. With this information, we could assess the significance of the gaps in ornithological knowledge and suggest where studies are needed on the status, biology, ecology, and habitats of raptors. Finally, we compared the results of our analysis with the study of Ramírez-Bastida and Navarro (in this publication), who after a review of the worldwide bibliography and museum specimens, concluded that most studies on raptors in México have been oriented to obtain information on species distribution and taxonomy. We wanted to evaluate if current work with raptors fits the trends found in that study, since many studies of Mexican raptors have not been published. A list of researchers, institutions, and other individuals that provided this information is presented in the Appendix 3. We acknowledge their cooperation and information.

METHODS

In October 1999, we sent the questionnaire to ornithologists and biologists on all known lists in general (http://www.huitzil.net/Basedeornitologos.html) and to individuals that we know were working with raptors in México. In the general analysis, we also included information on researchers and institutions that we were certain had worked with raptors, but did not respond, and used this information only for the analysis of the number of researchers working with raptors, institutions, species under investigation, and the habitats where the studies were done.

The questionnaire asked for the name of the researcher(s), their institution(s), raptors investigated, kind of study performed, kind of habitat, location (state in México), and if data were published.

RESULTS AND DISCUSSION

We received 18 useful responses from people that have worked in 16 states of México and the islands in the Gulf of California (Table 1). We added information about 24 individuals that we were certain were currently investigating some aspect of raptors in México. Considering both kinds of information, raptor research was recently or currently underway in 22 states. The individuals working on any aspect of raptor studies in México were affiliated with 26 Mexican institutions (Table 2). The preponderance of investigations was in Baja California Sur (21), Durango (11), Sonora (9), and Jalisco (7) in the 1980s and 1990s (Table 1). Campeche, Distrito Federal, Guerrero, Hidalgo, Puebla, Quintana Roo, Tabasco, Tlaxcala, and Yucatán had no reports of studies underway, at least for this period. Most of the studies were carried out from 1990-2000 (Fig. 1). Mexican researchers have done more studies with raptors in México than foreigners. However, this result may be biased because there were very few responses from non-Mexican researchers. The results presented by Ramírez-Bastida and Navarro (in this publication) on museum specimens and bibliographic analysis may confirm the bias.

Table 1. Mexican states and regions where studies have been done since 1980 (n=39 researchers).

state	number of studies	number of researchers
Aguascalientes	3	3
Baja California	4	4
Baja California Sur	21	9
Coahuila	4	3
Colima	1	1
Chiapas	5	5
Chihuahua	6	6
Durango	11	3
Estado de México	1	1
Guanajuato	1	1
Jalisco	7	6
Michoacán	1	1
Morelos	1	1
Nayarit	2	2
Nuevo León	4	4
Oaxaca	3	3
San Luis Potosí	1	1
Sinaloa	1	1
Sonora	9	4
Tamaulipas	4	4
Veracruz	6	6
Zacatecas	6	6
Gulf of California Islands	2	2
General[1]	5	5

[1] Studies doing checklists

Table 2. Number of researchers by institution working with any aspect of raptors (n=36 researchers).

institution		number of researchers
Centro de Investigación Científica y Educación Superior de Ensenada (CICESE)		1
Centro de Investigaciones Biológicas del Noroeste, S. C. (CIBNOR)		3
Centro de Investigaciones en Alimentación y Desarrollo Unidad Guaymas (CIAD)		1
El Colegio de la Fontera Sur (ECOSUR)		1
Instituto de Ecología, A.C. (INECOL)		3
Universidad Autónoma de Baja California Sur (UABCS)		2
Universidad Autónoma de Chihuahua (UACh)		1
Universidad Autónoma de Nuevo León (UANL)		2
Universidad Autónoma de Tamaulipas (UAT)		1
Universidad Autónoma del Estado de México (UAEM)		1
Universidad Autónoma del Estado de Morelos (UAEM)		1
Universidad de Guadalajara (UdeG)		2
Universidad Nacional Autónoma de México (UNAM)		6
Instituto de Biología	2	
Facultad de Ciencias	3	
Instituto de Ecología	1	
Universidad Veracruzana (UV)		1
Texas A & M University		1
University of Kansas Natural History Museum		1
World Wildlife Fund (WWF)		1
Non Governmental organizations (NGO's)		7

The states having the most resident researchers (≥ 4) with some degree of interest in and currently doing work with raptors are Baja California Sur, Veracruz, Zacatecas, Jalisco, Chihuahua, Chiapas, Sonora, Baja California, and Nuevo León (Table 3). With the exception of Veracruz and Tamaulipas, there are no researchers working in the states of México containing the highest raptor species richness nor the most rare or habitat specialist species (i.e., Tabasco, Guerrero, Puebla, Hidalgo, Campeche, Quintana Roo, and Yucatán; Appendix 1).

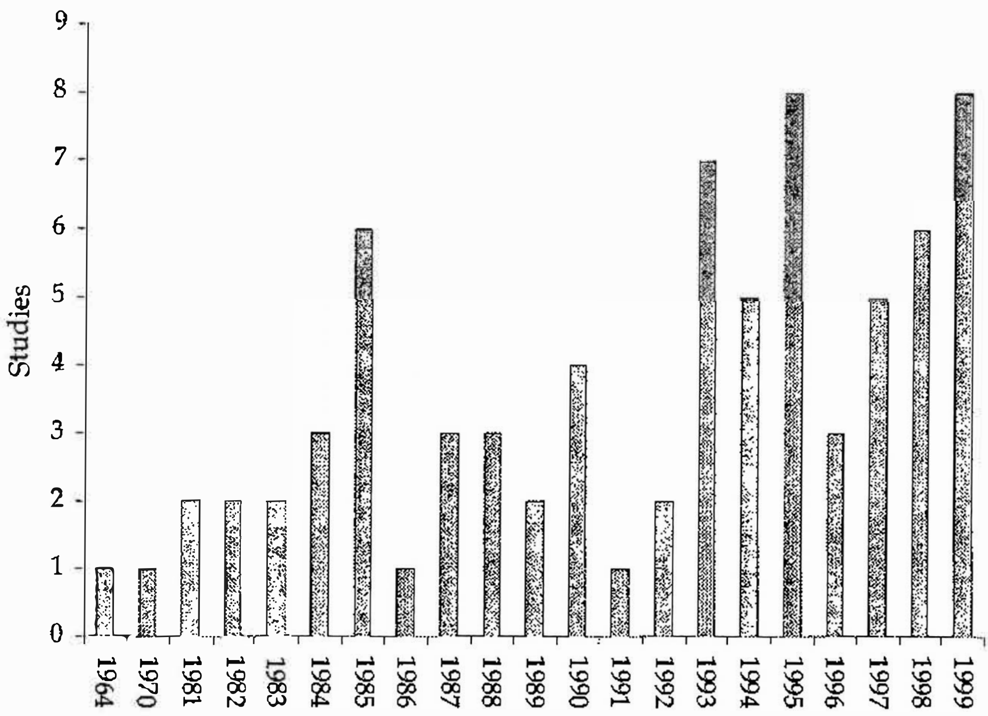

Figure 1. Year when the raptor study started or was reported (n=42 researchers).

Table 3. Number of researchers by state known to be working in México (n=39 researchers).

number of researchers	states
1	Colima, Estado de México, Guanajuato, Michoacán, Morelos, San Luis Potosí and Sinaloa
2	Nayarit
3	Aguascalientes, Coahuila, Durango and Oaxaca
4	Baja California, Nuevo León, Sonora and Tamaulipas
5	Chiapas
6	Chihuahua, Jalisco, Veracruz and Zacatecas
9	Baja California Sur
3	All México

Most recent studies have focused on distribution patterns, breeding biology, trophic ecology, and general ecology (Fig. 2). This set of topical interests is similar to the bibliographic analysis made by Ramírez-Bastida and Navarro (in this publication).

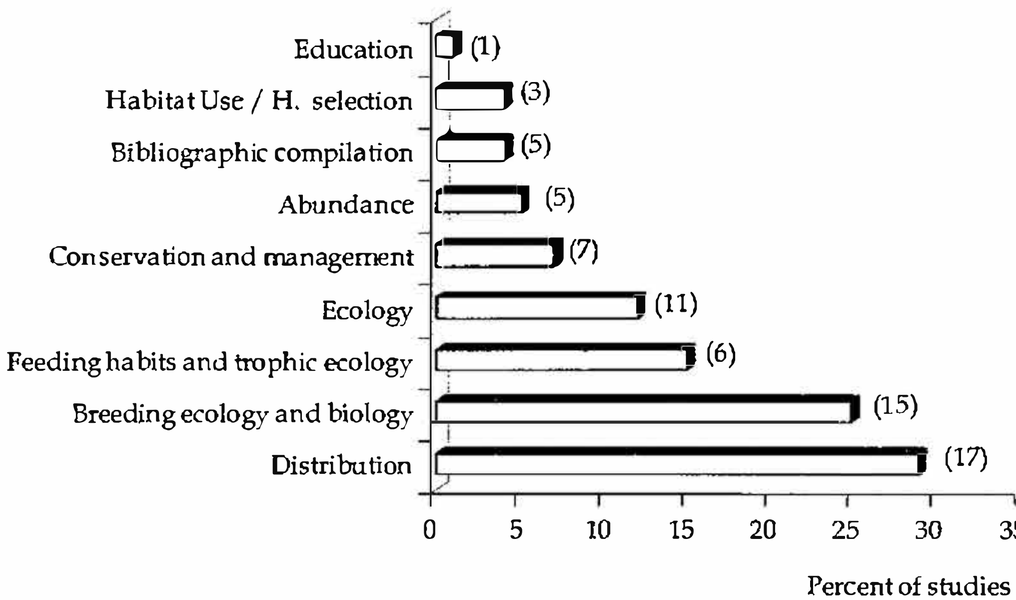

Figure 2. Study topics currently done with raptors in México. Number of researchers involved is indicated in parenthesis.

Conservation and management oriented studies seem to be few, but the questionnaire failed to determine if the biological and ecological studies were made to increase the knowledge of raptors for conservation purposes. A small number of studies on habitat selection were reported, although this kind of study is important to determine crucial habitats for raptors, and is relevant when designing management plans and the size and shape of protected areas (Church *et al.* 1996).

Studies have been done mainly in habitats containing xerophytic scrub, oak-pine forests, grasslands, and tropical deciduous forests (Fig. 3). This pattern fits well with that presented in the analysis of Ramírez-Bastida and Navarro (in this publication). However, of special concern is the restricted number of studies, or the lack of them, in tropical rainforests, thorn forests, marshes, and mangroves. More studies would be valuable contributions because these habitats have high species richness and contain some habitat specialist species.

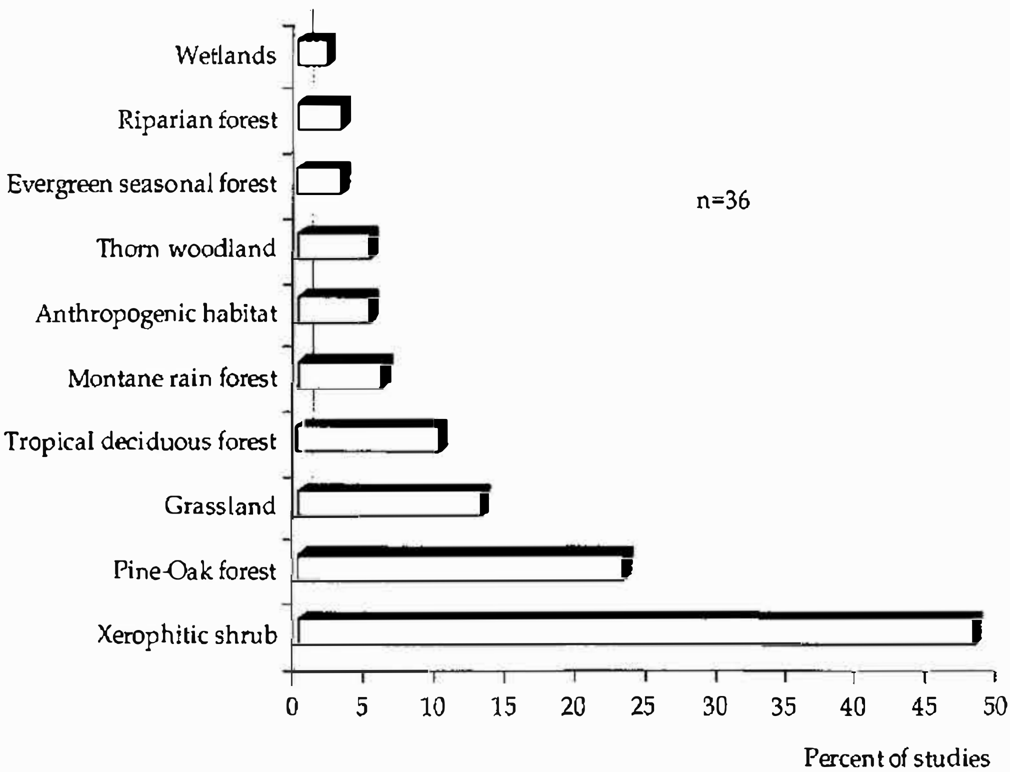

Figure 3. Proportion of raptor studies currently under investigation in México, organized by habitat. Vegetation classification follows Rzedowsky (1981).

Osprey (*Pandion haliaetus*) (13), golden eagle (*Aquila chrysuetos*) (11), peregrine falcon (*Falco peregrinus*) (8), burrowing owl (*Athene cunicularia*) (7), aplomado falcon (*Falco femorulis*) (6), and bald eagle (*Haliaeetus leucocephalus*) (6) were receiving the most attention in México (Fig. 4, Table 4). This result is surprising since species richness in México is high (Appendix 1). Remarkably, almost no studies on owls are currently being done, in spite of their number and diversity (Enriquez *et al.* 1993).

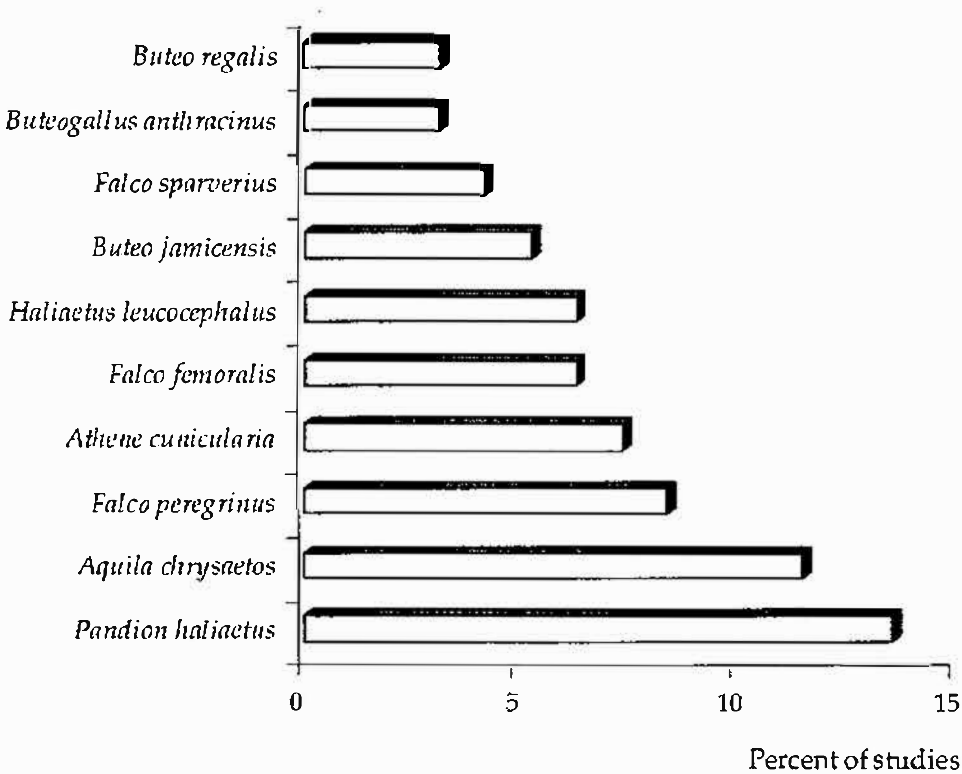

Figure 4. Most studied species of raptors in México since 1980, based on 97 studies.

The majority of raptor studies are less than one year in duration or short-term (Table 5). Medium and long-term studies have been increasing in México. Studies

Table 4. Number of studies for each raptor species done from 1980 to present (n=96).

species	number of studies	
Check list	14	
Pandion haliaetus	13	(13.5%)
Aquila chrysaetos	11	(11.5%)
Falco peregrinus	8	(8.3%)
Athene cunicularia	7	(7.3%)
Falco femoralis	6	(6.3%)
Halineetus leucocephalus	6	(6.3%)
Buteo jamaicensis	5	(5.2%)
Falco sparverius	4	(4.2%)
Buteogallus anthracinus	3	(3.1%)
Buteo regalis	3	(3.1%)
Circus cyaneus	2	(2.1%)
Accipiter cooperii	2	(2.1%)
Buteo swainsoni	2	(2.1%)
Buteo albonotatus	2	(2.1%)
Falco columbarius	2	(2.1%)
Falco mexicanus	2	(2.1%)
Bubo virginianus	2	(2.1%)
Cathartes aura	1	(1.0%)
Cathartes burrovianus	1	(1.0%)
Chondrohierax uncinatus	1	(1.0%)
Elanoides forficatus	1	(1.0%)
Ictinia mississippiensis	1	(1.0%)
Ictinia plumbea	1	(1.0%)
Accipiter striatus	1	(1.0%)
Parabuteo unicintus	1	(1.0%)
Buteo magnirostris	1	(1.0%)
Buteo lineatus	1	(1.0%)
Buteo platypterus	1	(1.0%)
Harpia harpyja	1	(1.0%)
Caracara cheriway	1	(1.0%)
Falco rufigularis	1	(1.0%)
Tyto alba	1	(1.0%)
Pulsatrix perspicillata	1	(1.0%)
Total	96	

Check list studies are those made for all raptors in a locality for presence/absence distribution purposes. Scientific nomenclature follows AOU (1998).

with burrowing owls have been underway in México for more than 10 years in collaboration with the Canadian Wildlife Service. The owl is listed as endangered in Canada and migratory populations spend the winter in México (Holroyd *et al.* 2001). Relevant studies in Veracruz have been documenting migratory raptors for more than 15 years through the Veracruz River Project in collaboration with Pronatura, Hawkwatch International, and Hawk Mountain Sanctuary (USA.). Recent interest in migratory populations of several raptors in the U.S.A. and Canada has increased the number of collaborative studies in México for species of concern in those countries. Examples of recently started collaborative studies with North America migrating populations are Swainson's hawk (*Buteo swainsoni*) in Sinaloa, Nayarit, and the Baja California Peninsula, and red-tailed hawk (*Buteo jamaincensis*) in northern México. The studies of resident populations of the aplomado falcon in Chihuahua are related to concern of declining populations in southwestern U.S.A. (Sandfort 1994, Montoya *et al.* 1997, Young *et al.* 2004). Studies of the spotted owl (*Strix occidentalis*) in Sonora (Tarango 1994, Young *et al.* 1997, Tarango *et al.* 2001) are related to management problems of this species in northwestern U.S.A. timberlands (Simberloff 1997).

National studies and long-term programs are increasing in México. A national program for the study and recovery of golden eagle populations in México has been underway since 2000 under the Instituto Nacional de Ecología (INE 1999), and long-term studies have been done in Zacatecas and the northern states of México (P. Tavizón, pers. comm.). Current long-term studies with osprey populations in Baja

California and Sonora are notable. These studies will provide information on population fluctuations and colonization and dispersal processes in the densest osprey colonies in North America (Cartron 2000, in this publication Cartron *et al.* and Rodríguez-Estrella *et al.*). Peregrine falcons and other raptors in desert scrub areas of Baja California are currently being surveyed. The recovery program and reintroduction of the California condor (*Gymnogyps californianus*) in Baja California is now underway since 2001 (//www.ine.gob.mx/dgoece/con_eco/condor2002.html).

Table 5. Duration of raptor studies in México (n=86).

duration	number of studies	
Less than one year	23	(26.7%)
Short term (1-3 years)	35	(40.7%)
Medium term (3-5years)	14	(16.3%)
Long term (> 5 years)	14	(16.3%)

There are 3 species of Cathartidae, 28 species and 3 subspecies of Falconiformes and 32 species of Strigiformes for which no reports of investigations were documented (Tables 6 and 7; Appendix 2). From these, 2 species of Cathartidae, 27 species of Falconiformes, and 20 species of Strigiformes are protected in México (official Mexican list of Threatened and Endangered species, NOM-ECOL-059-2001) (Tables 6 and 7; Appendix 2). Studies are lacking for Strigiformes because only 4 of 31 known species and 4 subspecies are receiving attention (Table 7). It is also clear that threatened, rare, and endangered raptors (Falconiformes and

Table 6. Number of species of Cathartidae and Falconiformes listed as endangered, threatened, and having special protection in the official list of threatened species NOM-ECOL-059-1994 (60 species) and the official list of threatened species NOM-ECOL-059-2001 (60 species and 4 subspecies).

	NOM-059-1994			NOM-059-2001		
	with studies	without studies	total	with studies	without studies	total
Extinct	0	1	1	0	3	3
Threatened	11/29	9*	20	4/20	4	8
Rare	2/2	6	8	-	-	-
Endangered	3/18	6	9	2/7	8**	10
Special protection	2/6	4**	6	13/27	12*	25
Not listed	11/30	7	18	10/31	6	16
Total	29/85	33	62	29/85	33	62

The column of species "with studies," is the number of species receiving at least one study in relation to the total number of studies done on Cathartidae and Falconiformes in each category. The 2001 official list of threatened species does not contain a rare species category. * Means 1 subespecies; ** 2 subespecies.

Table 7. Number of species of Strigiformes listed as endangered, threatened, and needing special protection in the official list of threatened species NOM-ECOL-059-1994 (32 species) and the official list of threatened species NOM-ECOL-059-2001 (32 species and 4 subspecies)

	NOM-059-1994			NOM-059-2001		
	with studies	without studies	total	with studies	without studies	total
Extinct	0	0	0	0	1*	1
Threatened	2/9	14**	16	1/1	8*	9
Rare	0	5	5	-	-	-
Endangered	1/1	2*	3	0	2*	2
Special protection	0	0	0	0	9	9
Without protection	1/1	11	12	3/10	12	15
Total	4/11	32	36	4/11	32	36

The column of species "with studies" is the number of species with at least one study in relation to the total number of studies done on Strigiformes in each category. The 2001 official list of threatened species does not have a rare species category. * Means 1 subespecies; ** 2 subespecies.

Strigiformes) need the most attention (NOM-ECOL-059-1994, -2001) (Tables 6 and 7; Appendix 2). Studies are lacking in the states with the greatest number of owl species, i.e. Oaxaca, Jalisco, Chiapas, Durango, Michoacán, Nayarit, and Veracruz (Appendix 1B). It is noteworthy that protection of raptors is proposed through the AICAS (Areas de Importancia para la Conservación de las Aves; Important Bird Areas for Conservation) program (Arizmendi and Márquez 2000). The AICAS program has been used and taken in consideration for regional conservation planning in México by CONABIO (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, http://www.conabio.gob.mx/).

We hope that this analysis of the current status of raptor research will help managers and researchers assess the opportunities and necessities in studies of the group of raptors that are currently done in México. It is urgent that ornithologists increase our general knowledge of raptors as indicators of habitat quality, as one of the most threatened categories of vertebrates in México, particularly of tropical regions. Studies should be addressed mainly to species sensitive to human activity and to "critical" habitats that maintain high raptor diversity. We propose that more studies on the responses of raptors to habitat change from human activity should be undertaken to assess the impact on habitat generalists and specialists, because some raptors may be severely impacted by human activity, while others may benefit from human activity (Bird *et al.* 1996, Rodríguez-Estrella *et al.* 1998). Such studies could provide insights on the degree of threat and endangerment for top-order predators, eliminating speculative and correlative extrapolations. Hopefully, we will be able to determine the species most sensitive to habitat change, and hence, where our conservation attention should be focused.

ACKNOWLEDGMENTS

Thanks to the Raptor Research Foundation, Inc. (RRF) for supporting the idea of the Latin American Special Meeting during the 1999 RRF conference in La Paz, B.C.S. The idea of developing this report originated when the Meeting was programmed into the annual conference. Thanks to all people and institutions that responded to the questionnaire or that gave information to complete the analysis. All of them are listed in Appendix 3. R. Ortiz-Pulido kindly permitted us to use his e-mail ornithologists' database. A. Cuarón and A. Navarro-Sigüenza provided useful comments that improved an early draft. CIBNOR and Consejo Nacional de Ciencia y Tecnología-SEMARNAT (CONACyT project 2002-C01-0318) also supported this project. LBRR received a scholarship from CONACyT.

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Appendix 1A. Distribution of Cathartidae and Falconiformes by state in México according to their resident and migratory status (from Howell and Webb 1995; Peterson and Chalif 1994; Edwards 1989). Nomenclature follows the Check List of North American Birds of the American Ornithologist Union (AOU 1998). * species not considered in the AOU checklist, but listed in the NOM-ECOL-059

Species / State	Aguascalientes	Baja California	Baja California Sur	Campeche	Coahuila	Colima	Chiapas	Chihuahua	Distrito Federal	Durango	México	Guerrero	Guanajuato	Hidalgo	Jalisco	Michoacán	Morelia	Nayarit	Nuevo León	Oaxaca	Puebla	Queretaro	Quintana Roo	Sinaloa	San Luis Potosí	Sonora	Tabasco	Tamaulipas	Tlaxcala	Veracruz	Yucatán	Zacatecas
CATHARTIDAE																																
Coragyps atratus	r			r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r/o	r	r	r	r	r	r	r	r	r
Cathartes aura	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
Cathartes burrovianus				r			r													r			r				r	r		r	r	
Gymnogyps californianus		f																														
Sarcoramphus papa				r			r					r								r			r				r			r	r	
ACCIPITRIDAE																																
Pandion haliaetus	t	r	r	i	i	i	i	t	t	t	t	i	t	i	i	i	t	i	i	i	i	t	i/r	r	i	r	i	i	t	i	i	t
Leptodon cayanensis				r			r													r			r				r			r	r	
Chondrohierax uncinatus				r		r	r					r		r	r	r		r		r	r		r	r	r		r	r		r	r	
Elanoides forficatus				t			v/t							t						t	t		t		t		t	t		t	t	
Elanus leucurus	r	r	o	r		r	r	r		r		r	r	r	r	r			r	r	r		r	r	r	r	r	r		r	r	r
Rostrhamus sociabilis				r			r													r			r				r			r	r	
Harpagus bidentatus				r			o/r					o			o					o/r			r				r			r	r	
Ictinia mississippiensis				t			t							t					t	t	t				t		t	t		t		
Ictinia plumbea				v			t/v													otv			v				v	v		v		
Haliaeetus leucocephalus															i	r	i		I/r			i					i	r		i	i	i
Busarellus nigricollis														r	r	r			r	r	r		r	r		r	r	r		r	r	

Appendix 1A. *Continued.*

Species \ State	Ags.	B.C.	B.C.S.	Camp.	Coah.	Colima	Chiapas	Chih.	D.F.	Dngo.	E. Mex.	Gro.	Gnto.	Hidalgo	Jalisco	Mich.	Morelia	Nayarit	N. L.	Oaxaca	Puebla	Qro.	Q. Roo	Sinaloa	S.L.P.	Sonora	Tabasco	Tamps.	Tlax	Ver.	Yucatán	Zac.
Circus cyaneus	i	r/i	i	t/i	i	i	i/t	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	t	i	i	i	i	i	i	i	i/t	i
Accipiter striatus	r	i	i	i	oir	i	i	i	i	r/i	r	i/r	r	i	r/i	r/i	i	i	i/r	i/r	r	r	i	i	i/r	i/r	i	i	i	i	i	i
Accipiter chionogaster *							r													r												
Accipiter cooperii	i	i/r	i	i	o/i	i	i	r/i	i	r/i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i/r	i	i	i	i	i	i
Accipiter bicolor				r			r													r			r		r		r	r		r	r	
Accipiter gentilis										r		r			r			r								r						r
Geranospiza caerulescens				r		r	r					r			r	r		r		r	r		r	r	r	r	r	r		r	r	
Leucopternis albicollis							r													r							r			r		
Buteogallus anthracinus				r		r	r	v			r	r		r	r/v	r	r	r		r			r	r	r	v/r	r	r		r	r	
Buteogallus subtilis							r																									
Buteogallus urubitinga				r		r	r			r		r		r	r	r		r		r	r		r	r	r	r	r	r		r	r	
Parabuteo unicinctus	r	r	r		r	r	r	r		r	r	r	r	r	r	r	r	r	r	r	r	r		r	r	r		r		r		r
Harpyhaliaetus solitarius					o		o/r	r		o/r	o/r				r/o	r		r		o						r/o						
Buteo nitidus				r		r	r	r			r	r		r	r	r	r	r	r	r	r		r	r	r	r	r	r		r	r	
Buteo magnirostris				r		r	r					r		r	r	r			r	r	r		r/o		r		r	r	r	r	r	
Buteo lineatus	i	r	r		i				i	i	i		i	i	i	i		i	i		i	i			i			i	i	i		i
Buteo platypterus						i	i/t					i		t	i	i		i	t	i/t	t		r/o		t		t	t		t		
Buteo brachyurus				r		r	r	r		r	r	r			r	r	r	r		r	r		r	r	r	r	r	r		r	r	
Buteo swainsoni	t				v	t	t	v	t	v	t	t	t	t	t	t	t	t	v/t	t	t	t		t	t	v		t	t	t		t
Buteo albicaudatus				r		r	r			r		r			r	r		r	r	r			r			r	r	r		r	r	r
Buteo albonotatus	t	i/t	i/t	i	v	i	i	v	t	v	i/t	i	t	t	i/t	i	i	i	v	i	t	t	i	vir	v/i	vir	i	i/o	t	i	i	v
Buteo jamaicensis	r	r	r	i	r	i/o	i	r	r	r	r	r/i	r	r	r/i	r/i	r/i	i/r	r	r/i	r	r	i	i/r	r	r/i	i	rio	r	i/r	i	r

Appendix 1A. *Continued.*

Species \ State	Ags.	B.C.	B.C.S.	Camp.	Coah.	Colima	Chiapas	Chih.	D.F.	Dngo.	E. Mex.	Gro.	Gnto.	Hidalgo	Jalisco	Mich.	Morelia	Nayarit	N. L.	Oaxaca	Puebla	Qro.	Q. Roo	Sinaloa	S.L.P.	Sonora	Tabasco	Tamps.	Tlax	Ver.	Yucatán	Zac.
Buteo regalis	i	i	i		i			i		i			i		i				i						i	i		i				i
Buteo lagopus		?						i																i								
Morphnus guianensis				?			?																									
Harpia harpyja							r/o													r										r/o		
Aquila chrysaetos	r	r/i	i/r		r			r		r			r		r			r	r			r		r	r	i/r		r				r
Spizastur melanoleucus				r			r							r				o		r	r		r		r		r	r		r	r	
Spizaetus tyrannus				r			r/o					o		r						r	r		r				r			r	r	
Spizaetus ornatus				r			r					o		r	r					r	r		r		r		r	r		r	r	
FALCONIDAE																																
Micrastur ruficollis				r			r					o		r						r			r		r		r			r		
Micrastur semitorquatus				r		r	r					r		r	r	r		r		r	r		r	r	r		r			r	r	
Ibycter americanus							f													f										f		
Caracara cheriway	r		r	r	r	r	r		r	r	r	r	r	r	r	r	r	r	r	r	r	r		r	r	r	r	r	r	r	r	r
Herpetotheres cachinnans				r		r	r					r		r	r	r		r		r	r		r	r	r	r	r	r		r	r	
Falco sparverius	r	r	r	i	r	i	i/r	i	i	i/r	r/i	i	r	r/i	i/r	i/r	i	i	r/i	i/r	i	r	i	r	r	r	i	r/i	i	i	i	r
Falco columbarius	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
Falco femoralis							r	r				o								o					r		r			r		
Falco rufigularis				r		r	r					r		r	r	r		r	r	r	r		r	r	r	r	r	r		r	r	
Falco deiroleucus																														o/r		
Falco peregrinus	r	r	r	i	r	i	i	r	r	r	i/r	i	r	r	r/i	i/r	i	r	i	i	r/i	r	i	r	r	r	i	i	r	i	i	r
Falco mexicanus	i	r	i/r	r/o	r		o/r	r		r/i			i		i				i/r	o/r		i	r		r/i	i/r	r	i				r/i
Species richness	19	19	18	40	20	28	49	24	14	25	19	35	19	31	36	30	17	31	25	47	31	17	38	28	37	29	42	38	15	47	35	22

r= Resident breeder, i= Winter visitor (no breeding), v= Summer resident (breeder), t= Transient migrant , o= Presumed resident breeding record, f= Presumed former distribution, ?= status uncertain.

Appendix 1B. Distribution of Strigiformes by sta tein México according to their resident and migratory status (from Howell and Webb 1995; Peterson and Chalif 1994; Edwards 1989). Nomenclature follows the Check List of North American Birds of the American Ornithologist Union (AOU 1989).* species not considered in the AOU checklist, but listed in the NOM-ECOL-059

species / state	Ags.	B.C.	B.C.S.	Campeche	Coahuila	Colima	Chiapas	Chihuahua	D.F.	Durango	México	Guerrero	Gnjto.	Hidalgo	Jalisco	Michoacán	Morelia	Nayarit	Nuevo León	Oaxaca	Puebla	Querétaro	Q. Roo	Sinaloa	S.L.P	Sonora	Tabasco	Tamaulipas	Tlaxcala	Veracruz	Yucatán	Zacatecas
TYTONIDAE																																
Tyto alba	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r/o	r	r	r	r	r	r	r	r	r
STRIGIDAE																																
Otus flammeolus	t				v/t			v/t	r	v/t	r	r	t	t	r	r	r	r	v	r	r	t			t	v		v	r			v/t
Megascops kennicottii	r	r	r		r			r	r	r	r		r	r	r	r	r	r	r		r	r		r	r	r			r	r		r
Megascops asio					r														r						r			r				
Megascops seductus						o					r	o/r			o/r	o/r	o/r				r											
Megascops cooperi							r													r												
Megascops trichopsis	r					r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r			r	r		r	r			r
Megascops barbarus							r/o																									
Megascops guatemalae				r		r	r	r		r		r		r	r	r		r		r	r		r/o	r	r	r	r	r		r	r	
Lophostrix cristata							r													r							r			r		
Pulsatrix perspicillata							r													r							r			r		
Bubo virginianus	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r		r	r	r	r	r
Glaucidium gnoma	r				r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r			r	r		r	r	r		r
Glaucidium minutissimum	*					?																						?				
Glaucidium hoskinsii *			r																													
Glaucidium griseiceps							r													r							r			r		
Glaucidium sanchezi														r					r									r				

Appendix 1B. Continued.

species \ state	Ags.	B.C.	B.C.S.	Camp.	Coah.	Colima	Chiapas	Chih.	D.F.	Dngo.	E. Mex.	Guerrero	Gnto.	Hidalgo	Jalisco	Mich.	Morelia	Nayarit	N. L.	Oaxaca	Puebla	Qro.	Q. Roo	Sinaloa	S.L.P.	Sonora	Tabasco	Tamps.	Tlax	Ver.	Yucatán	Zac.
Glaucidium palmarum						r		r		r	r	r			r	r	r	r		r				r		r						
Glaucidium brasilianum				r		r	r	r		r	r	r		r	r	r	r	r		r	r		r	r	r	r	r	r		r	r	
Micrathene whitneyi	t		r		v/t	i		t/v	t	t	t/i	i	t	t	i/t	i/t	i	i	v/t		r	t		vti	t	v/t		v				v
Athene cunicularia	r	r	r		r	i	i	r/i	i	r/i	i	i	r/i	i/r	i/r	i	i	i	r/i	i	i	r		i/r	r	r/i		i/r	i	i		r/i
Ciccaba virgata				r		r	r	r		r	r	r		r	r	r	r	r	r	r	r		r	r	r	r	r	r		r	r	
Ciccaba nigralineata				r			r							r									r		r		r			r	r	
Strix occidentalis		o			r			r		r			r		r	r		r	r						r	r		r				r
Strix varia						r				r		r	r		r	r		r		r	r									r		
Strix fulvescens							r																									
Asio otus	i	r/i			i	i		i	i	i	i	i	i	i	i	i	i	i	i	i	i	i		i	i	i		i	i	i		i
Asio stygius						r	o/r	o/r		o/r		r/o			r/o			o/r		r	r		o	o		r				o		r
Asio flammeus	i	i	i		i	i		i	i	i	i	i	i	i	i	i	i	i	i	i	i	i		i	i	i		i	i	i		i
Pseudoscops clamator				r			r													r							r			r		
Aegolius acadicus					r			r	r	r	r		r	r	r	r	r	r	r	r	r	r		r	r	r		r	r	r		r
Aegolius ridgwayi							r/o																									
Species richness	**10**	**7**	**7**	**7**	**12**	**16**	**18**	**17**	**11**	**18**	**15**	**16**	**13**	**16**	**19**	**18**	**15**	**18**	**15**	**20**	**17**	**11**	**7**	**13**	**17**	**17**	**9**	**17**	**10**	**18**	**6**	**13**

r=Resident breeder, i=Winter visitor (no breeding), v=Summer resident (breeder), t=Transient migrant, o=Presumed resident breeding record.

Appendix 2. Status of Cathartidae, Falconiformes, and Strigiformes in the official list of threatened species (NOM-ECOL-059-1994 and NOM-ECOL-059-2001).

species	english common name	mexican common name[1]	NOM-059		no. of
			1994	2001	studies
CICONIIFORMES					
CATHARTIDAE					
Coragyps atratus	black vulture	zopilote común			0
Cathartes aura	turkey vulture	zopilote aura			1
Cathartes burrovianus	lesser yellow-headed vulture	zopilote sabanero	A		1
Gymnogyps californianus	California condor	cóndor Californiano	P	E	0
Sarcoramphus papa	king vulture	zopilote rey	P	P	0
FALCONIFORMES					
ACCIPITRIDAE					
Pandion haliaetus	osprey	gavilán pescador			13
Leptodon cayanensis	gray-headed kite	gavilán cabeza gris	R	Pr	0
Chondrohierax uncinatus	hook-billed kite	gavilán pico gancho	R	Pr	1
Elanoides forficatus	swallow-tailed kite	milano tijereta	R	Pr	1
Elanus leucurus	white-tailed kite	milano cola blanca			0
Rostrhamus sociabilis	snail kite	gavilán caracolero	A	Pr	0
Harpagus bidentatus	double-toothed kite	gavilán con banda		Pr	0
Ictinia mississippiensis	Mississippi kite	milano de Misisipi	A	Pr	1
Ictinia plumbea	plumbeous kite	milano plomizo		A	1
Haliaeetus leucocephalus	bald eagle	águila cabeza blanca	P	P	6
Busarellus nigricollis	black-collared hawk	aguililla canela	R	Pr	0
Circus cyaneus	northern Harrier	gavilán rastrero	A		2
Accipiter striatus	sharp-shinned hawk	gavilán pecho rufo		Pr	1
Accipiter chionogaster	White breasted hawk	gavilán pecho blanco	A		0
Accipiter cooperii	Cooper's hawk	gavilán de Cooper	A	Pr	2
Accipiter bicolor	bicolored hawk	gavilán bicolor	R	A	0

Appendix 2. *Continued.*

species	english common name	mexican common name[1]	NOM-059		no. of studies
			1994	2001	
Accipiter gentilis	northern goshawk	gavilán azor	A	A	0
Geranospiza caerulescens	crane hawk	gavilán zancón	A	A	0
Leucopternis albicollis	white hawk	aguililla blanca	R	Pr	0
Buteogallus anthracinus	common black-hawk	aguililla-negra menor	A	Pr	3
Buteogallus subtilis	mongrove black hawk	aguililla negra de manglar	A	A	0
Buteogallus urubitinga	great black-hawk	aguililla-negra mayor	A	Pr	0
Parabuteo unicinctus	Harris's hawk	aguililla rojinegra	A	Pr	1
Harpyhaliaetus solitarius	solitary eagle	águila solitaria	P	P	0
Buteo nitidus	gray hawk	aguililla gris	Pr		0
Buteo mangirostris	roadside hawk	aguililla caminera	Pr		1
Buteo lineatus	red-shouldered hawk	aguililla pecho rojo		Pr	1
Buteo platypterus	broad-winged hawk	aguililla ala ancha		Pr	1
Buteo brachyurus	short-tailed hawk	aguililla cola corta			0
Buteo swainsoni	Swainson's hawk	aguililla de Swainson		Pr	2
Buteo albicaudatus	white-tailed hawk	aguililla cola blanca	Pr	Pr	0
Buteo albonotatus	zone-tailed hawk	aguililla aura		Pr	2
Buteo jamaicensis	red-tailed hawk	aguililla cola roja	Pr		5
Morphnus guianensis	crested eagle	águila crestada		P	0
Harpia harpyja	harpy eagle	águila arpía	P	P	1
Aquila chrysaetos	golden eagle	águila real	P	A	11
Spizastur melanoleucus	black-and-white hawk-eagle	águila blanquinegra	P	P	0
Spizaetus tyrannus	black hawk-eagle	águila tirana	A	P	0
Spizaetus ornatus	ornate hawk-eagle	águila elegante	P	P	0
FALCONIDAE					
Micrastur ruficollis	barred forest-falcon	halcón-selvático barrado	R	Pr	0
Micrastur semitorquatus	collared forest-falcon	halcón-selvático de collar	R	Pr	0
Ibycter americanus	red-throated caracara	caracara comecacao	P	E	0

Appendix 2. *Continued.*

species	english common name	mexican common name[1]	NOM-059		no. of studies
			1994	2001	
Caracara cheriway	crested caracara	caracara quebrantahuesos			1
†*Caracara lutosa*	Guadalupe caracara	caracara quebrantahuesos	E	E	0
Herpetotheres cachinnans	laughing falcon	halcón guaco			0
Falco sparverius	American kestrel	cernícalo Americano			4
Falco columbarius	merlin	halcón esmerejón	A		2
Falco femoralis	aplomado falcon	halcón fajado	A	A	6
F. femoralis septentrionalis	aplomado falcon	halcón fajado	A	Pr	0
Falco rufigularis	bat falcon	halcón enano o murcielaguero	A		1
Falco deiroleucus	orange-breasted falcon	halcón pecho rufo	A	P	0
Falco peregrinus	peregrine falcon	halcón peregrino	A	Pr	8
Falco mexicanus	prairie falcon	halcón Mexicano	A	A	2
STRIGIFORMES					
TYTONIDAE					
Tyto alba		lechuza de campanario			1
STRIGIDAE					
Otus flammeolus	flammulated owl	tecolotito de flama			0
Megascops kennicottii	western screech-owl	tecolote occidental			0
Megascops asio	eastern screech-owl	tecolote oriental	A	Pr	0
Megascops seductus	Balsas screech-owl	tecolote del balsas	A	Pr	0
Megascops cooperi	Pacific screech-owl	tecolote de Cooper		Pr	0
Megascops trichopsis	whiskered screech-owl	tecolote rítmico			0
Megascops barbarus	bearded screech-owl	tecolote barbudo	R	A	0
Megascops guatemalae	vermiculated screech-owl	tecolote vermiculado	R		0
Lophostrix cristata	crested owl	búho cuerno blanco	A	A	0
Pulsatrix perspicillata	spectacled owl	búho de anteojos	P	A	1

Appendix 2. *Continued.*

species	english common name	mexican common name[1]	NOM-059		no. of studies
			1994	2001	
Bubo virginianus	great horned owl	búho cornudo	A		2
B. virginianus mayensis	great horned owl	búho cornudo	A	A	0
Glaucidium gnoma	northern pygmy-owl	tecolote serrano	A		0
G. gnoma hoskinsii	northern pygmy-owl	tecolote serrano	A	Pr	0
Glaucidium minutissimum	least pygmy-owl	tecolotito menor	R		0
Glaucidium hoskinsii	Cape pigmy-owl	tecolote del cabo			0
Glaucidium griseiceps	Central American pygmy-owl	tecolote Mesoamericano		Pr	0
Glaucidium sanchezi	Tamaulipas pygmy-owl	tecolote Tamaulipeco		P	0
Glaucidium palmarum	Colima pygmy-owl	tecolote Colimense		Pr	0
Glaucidium brasilianum	ferruginous pygmy-owl	tecolote bajeño	A		0
Micrathene whitneyi	elf owl	tecolote enano	P		0
M. whitneyi graysini	elf owl	tecolote enano	P	E	0
Athene cunicularia	burrowing owl	tecolote llanero	A		7
A. cunicularia rostrata	burrowing owl	tecolote llanero	A	P	0
Ciccaba virgata	mottled owl	búho café			0
Ciccaba nigrolineata	black-and-white owl	búho blanquinegro	A	A	0
Strix occidentalis	spotted owl	búho manchado	A	A	0
Strix varia	barred owl	búho listado	A	Pr	0
Strix fulvescens	fulvous owl	búho leonado	R	A	0
Asio otus	long-eared owl	búho cara café			0
Asio stygius	Stygian owl	búho cara oscura	A	Pr	0
Asio flammeus	short-eared owl	búho cuerno corto	A	Pr	0
Pseudoscops clamator	striped owl	búho cara clara	A	A	0
Aegolius acadicus	northern saw-whet owl	tecolote afilador			0
Aegolius ridgwayi	unspotted saw-whet owl	tecolote canelo	R	A	0

1. Common names follow Escalante *et al.* 1996.

†. Extinct

Appendix 3. People and institutions a) responding the questionnaire and b) known to be working with raptors in México.

	researcher	institution
a		
	Laura B. Rivera Rodríguez	Centro de Investigaciones Biológicas del Noroeste (CIBNOR)
	Edgar S. Amador Silva	Centro de Investigaciones Biológicas del Noroeste (CIBNOR)
	Aradit Castellanos Vera	Centro de Investigaciones Biológicas del Noroeste (CIBNOR)
	Ricardo Rodríguez Estrella	Centro de Investigaciones Biológicas del Noroeste (CIBNOR)
	Juan Pablo Gallo Reynoso	Centro de Investigaciones en Alimentación y Desarrollo, Unidad Guaymas (CIAD)
	Enriqueta Velarde	Conservación del Territorio Insular Mexicano, A.C.
	Francisco Valdés Perezgasga	En defensa del ambiente A.C. (ONG)
	Jorge Nocedal	Instituto de Ecología, A.C. Centro Regional Durango
	Ernesto C. Enkerlin Hoeflich	Pronatura Noroeste- Tecnológico de Monterrey
	Ernesto Ruelas Inzunza	Pronatura Veracruz
	Patricia Manzano Fischer	Proyecto Alas
	Fernando Urbina Torres	Universidad Autónoma del Estado de Morelos, Centro de Investigaciones Biológicas
	Héctor Enrique Valdez Gómez	Universidad de Guadalajara (U de G)
	Salvador Hernández Vázquez	Universidad de Guadalajara (U de G), Centro de Ecología Costera
	Alfredo D. Cuaron	Universidad Nacional Autónoma de México (UNAM), Instituto de Ecología
	Héctor Gómez de Silva Garza	Universidad Nacional Autónoma de México (UNAM), Instituto de Ecología
	Mara Higinia Guadalupe Neri Fajardo	Universidad Nacional Autónoma de México (UNAM), Instituto de Biología, Instituto de Ecología. A.C., Unidad Durango
	Ricardo Rafael Valenzuela Ortega	Universidad Veracruzana
	A. Townsend Peterson	University of Kansas. Natural History Museum
b		
	Geoffrey L. Holroyd	Canadian Wildlife Service
	José Luis Rangel Salazar	Colegio de la Frontera Sur (ECOSUR)
	Paula Enríquez Rocha	Colegio de la Frontera Sur (ECOSUR)
	Eduardo Iñigo Elias	Cornell University
	Jesús Estudillo López	Granja la Siberia
	Horacio de la Cueva	Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)

Appendix 3. *Continued.*

researcher	institution
Rafael Villegas Patraca	Instituto de Ecología, A.C.
Adriana Flores	Instituto Nacional de Ecología, Zacatecas
Miguel A. Díaz Castorena	Instituto Nacional de Ecología, Zacatecas
Patricio Tavizón	Instituto Nacional de Ecología, Zacatecas
Eduardo Palacios Castro	Centro de Investigación Científica y de Educación Superior de Ensenada CICESE; Pronatura A.C. Península de Baja California
Gustavo Danemann	Pronatura Noroeste. Mar de Cortés
Richard D. Porter	U S Fish and Wildlife Service
Roberto Carmona Piña	Universidad Autónoma de Baja California Sur
Alberto Lafón	Universidad Autónoma de Chihuahua
Eduardo Correa	Universidad Autónoma de Chihuahua
Alan López	Universidad Autónoma de Nuevo León
Héctor Arturo Garza Torres	Universidad Autónoma de Tamaulipas
Carlos Barrera	Universidad de Guadalajara
Adolfo G. Navarro Siguenza	Universidad Nacional Autónoma de México, Museo de Zoología
Adrian Reuter Cortés	Universidad Nacional Autónoma de México
Patricia Ramírez Bastida	Universidad Nacional Autónoma de México, FES-Iztacala
Tania Macouzet Fuentes	Universidad Nacional Autónoma de México
Daniel Anderson	University of California. Daivis
Debra S. Judge	University of California. Davis
Charles Henny	University of Kansas Natural History Museum
Enrique Montoya	University of New México. Las Cruces
Jean Luc Cartron	University of New México
Felipe Chávez Ramírez	Texas A&M University; World Wildlife Fund, México

How many raptor species are there in México?

Octavio R. Rojas-Soto
Adolfo G. Navarro Sigüenza

ABSTRACT

Although species richness of raptors in a given area should represent a more or less fixed number, it is affected strongly by more intensive biological surveys and the current taxonomic point of view. In this paper, we explore the effects of alternative species concepts and systematic approaches that affect species richness, patterns of diversity, endemism, and conservation of Mexican birds of prey. The need for more intensive systematic research is discussed.

Key words: taxonomy, species concepts, species richness, Accipitridae, Falconidae, Strigidae, Tytonidae.

RESUMEN

Aunque existe la idea de que el número de especies en una región es más o menos fijo, este es afectado fuertemente por muestreos intensivos en campo así como por el punto de vista taxonómico. En esta contribución exploramos el efecto de conceptos de especie alternativos y puntos de vista sistemáticos diferentes que afectan la riqueza de especies estimadas, los patrones de diversidad y endemismo, y la conservación de las rapaces de México. Se discute la necesidad de estudios sistemáticos más intensivos.

INTRODUCTION

The question about how many species of raptors there are in a region seems to be trivial because one expects to obtain a fixed number that is modified only by a limited number of sources of change, especially in relatively well-known family subgroups of the Falconiformes (eagles, hawks, falcons) and the Strigiformes (owls). One of the sources of change is the description of species new to science, which is seldom seen in raptors in the recent scientific literature. Other sources of change are the discovery of unreported species within a region, such as *Morphnus guianensis* (Javier Salgado, pers. comm.) or the extirpation or extinction of species, such as *Daptrius americanus* (Howell and Webb 1995, Iñigo-Elías 2000).

Major taxonomic revisions are taking place, including a wide variety of avian taxa (e.g. Espinosa de los Monteros 1998, Zink *et al.* 1999) including raptors (e.g. Roesing *et al.* 2003, Helbig *et al.* 2005), with the goal of having a more precise description of biodiversity, and applying this systematic knowledge to conservation.

One key approach is the application of different species concepts in biodiversity studies. Recently, there has been discussion of such applications in ornithology (Cracraft 1983, McKitrick and Zink 1988, Zink and McKitrick 1995, Peterson and Navarro 1999, Navarro and Peterson 2004), with opposing points of view expressed more or less vehemently in the literature (AOU 1998). Most of the discussion has focused on the application of the traditionally used Biological Species Concept (BSC) (Mayr 1969, AOU 1983, 1998, Sibley and Monroe 1990) against alternative species concepts, such as the Phylogenetic Species Concept (PSC) (Cracraft 1983, McKitrick and Zink 1988) and the Evolutionary Species Concept (ESC) (Wiley 1981, Peterson and Navarro 1999, Navarro and Peterson 2004).

It is argued that the BSC takes advantage of 'biological' information in its essence (reproductive compatibility), allowing researchers to recognize different species only in the same space and time reference (sympatry and synchrony, Mayr 1969). These "strengths" have been considered problematic by other researchers (Zink and McKitrick 1995) because they obscure the real dynamics of reproduction and hybridization (McKitrick and Zink 1988), and reproductive compatibility can only be tested by inference from morphological similarity. The BSC has produced a multitude of polytypic taxa that have obscured the patterns of biological diversification and distributional patterns of taxa by describing subspecies in a rather indiscriminate manner (Phillips 1986).

PSC and ESC stress aspects of ancestor-descendant relationships (lineage monophily), and the occurrence of new traits as a result of speciation and differentiation (synapomorphies). These lead us to recognize taxa that are coherent in space and time, and allow researchers to recover evolutionary patterns (Wiley 1981).

Few efforts have been made to explore applications of alternative species concepts to major taxonomic groups or whole avifaunas and implications for conservation (Hazevoet 1996). Although these general surveys (Peterson and Navarro 1999) treated birds of prey as part of complete avifaunas, no recent evaluation has been made for the group in particular.

The goal of this work is to evaluate different sources of change in species richness of Mexican raptors, and discuss the drawbacks and advantages of using alternate taxonomic views for the study and conservation of this group of bird.

HOW MANY SPECIES?

Although higher-level systematics treatments exist for some raptor groups (Griffiths 1999), few recent species-level taxonomic revisions are available for Mexican raptors (Rodríguez-Yáñez *et al.* 1994, Ramírez-Bastida and Navarro in this publication). However, increases in the total number of species have arisen from recent studies on poorly known groups, such as the pygmy owl complexes *Glaucidium gnoma* and *G. minutissimum* (Howell and Robbins 1995), that added three endemic species to México (*G. hoskinsii*, *G. palmarum* and *G. sanchezi*) and the black hawks (*Buteogallus anthracinus subtilis*) (Howell and Webb 1995, AOU 1998) that recognized a species restricted to the coastal mangroves of the Pacific coast of Central America.

A comparison of the number of taxa recognized at the species level in traditional (BSC) and alternative concepts (PSC) was made using AOU (1983, 1998), Sibley and Monroe (1990), and Navarro and Peterson (2004). The PSC approach of Navarro and Peterson led to an increased number of recognized species (11%) relative to the BSC approach used by the AOU (1998) (Table 1 and Fig. 1). Morphological studies suggest that some forms located in particular biogeographic areas of México, such as in Baja California (*Buteo [lineatus] elegans*, *Glaucidium [gnoma] californicum*), Isla de Cozumel (*B. [magnirostris] gracilis*), and Chiapas (*Accipiter [striatus] chionogaster*, *Falco [sparverius] tropicalis*, *Buteogallus [anthracinus] subtilis*), may deserve species status (Howell and Webb 1995, AOU 1998, Navarro and Peterson unpubl. data).

Table 1. Number of raptor species in México recognized by taxonomic authorities using the Biological Species Concept (AOU 1998; Sibley and Monroe 1990) and the Phylogenetic Species Concept (Navarro and Peterson 2004).

family	A.O.U. (1998)	Sibley and Monroe (1990)	Navarro and Peterson (2004.)
Accipitridae	38	39	41
Falconidae	12	12	14
Tytonidae	1	1	1
Strigidae	29	27	32

However, many other species are in need of detailed systematic revision. For example, poorly understood migration patterns may add to complex geographic and individual variability (color phases) in many species of raptors, making available evidence insufficient for correct taxonomic decisions. This is the case for the highly variable red-tailed hawk *Buteo jamaicensis* (Storer 1962), where resident populations in the mountains of mainland México co-exist during winter with northern populations. Also, there are geographically isolated and well differentiated populations in the Islas Revillagigedo (*B. j. socorroensis*), and Islas Tres Marías (Friedmann *et al.* 1950). Other examples of this poorly understood complexity are the sharp-shinned hawk *Accipiter* *striatus* (Storer 1952), hook-billed kite *Chondrohierax uncinatus* (Friedmann 1934), roadside hawk *B. magnirostris* (Peters and Griscom 1929), American kestrel *Falco sparverius* (Moore and Bond 1946), and vermiculated screech owl *Megascops guatemalae* (Marshall 1967) that present extreme geographic variations, exemplified by the number of subspecies described (Fig. 2).

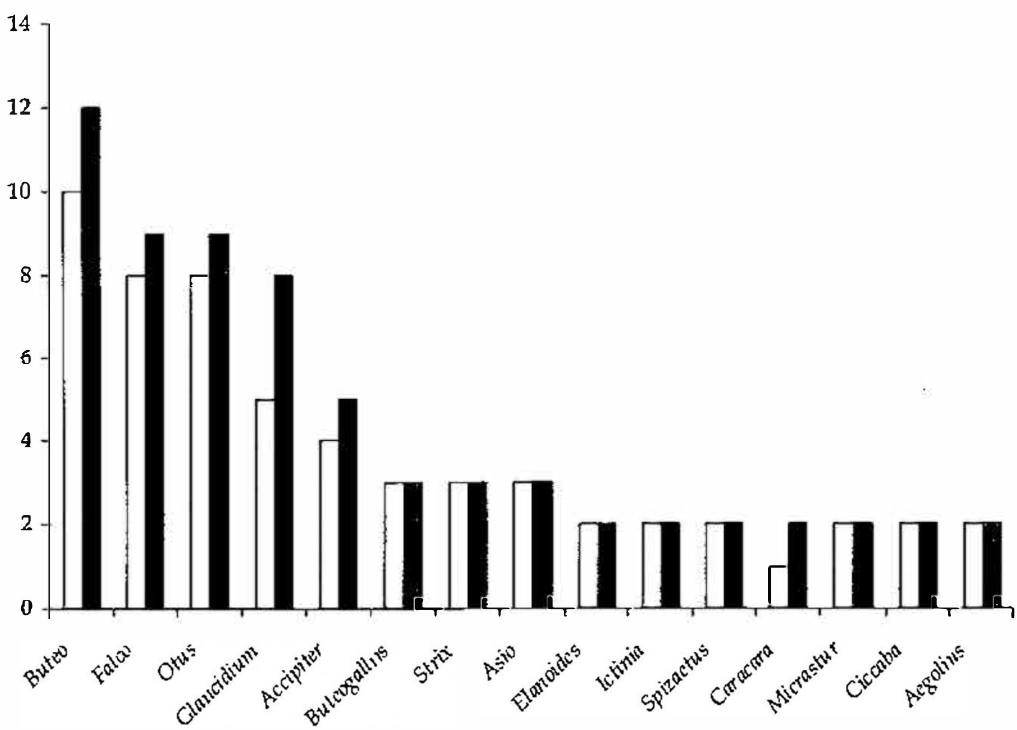

Figure 1. Number of species according to the BSC (open bars, AOU 1998) and PSC (solid bars, Navarro and Peterson 2004) of raptor genera with more than one species in México.

While many taxonomic changes refer to the splitting of species within México, the analysis of species that have wide geographic distributions, including North, Central, and South America or the Old World and the American Continent also have an impact in decisions in systematics. Some species exhibit a north-south segregating pattern that often involve one species present in North and Central America, and one in South America, such as *Caracara plancus cheriway, Asturina plagiata nitida, Glaucidium brasilianum ridgwayi* (Koenig *et al.* 1999, Navarro and Peterson 2004).

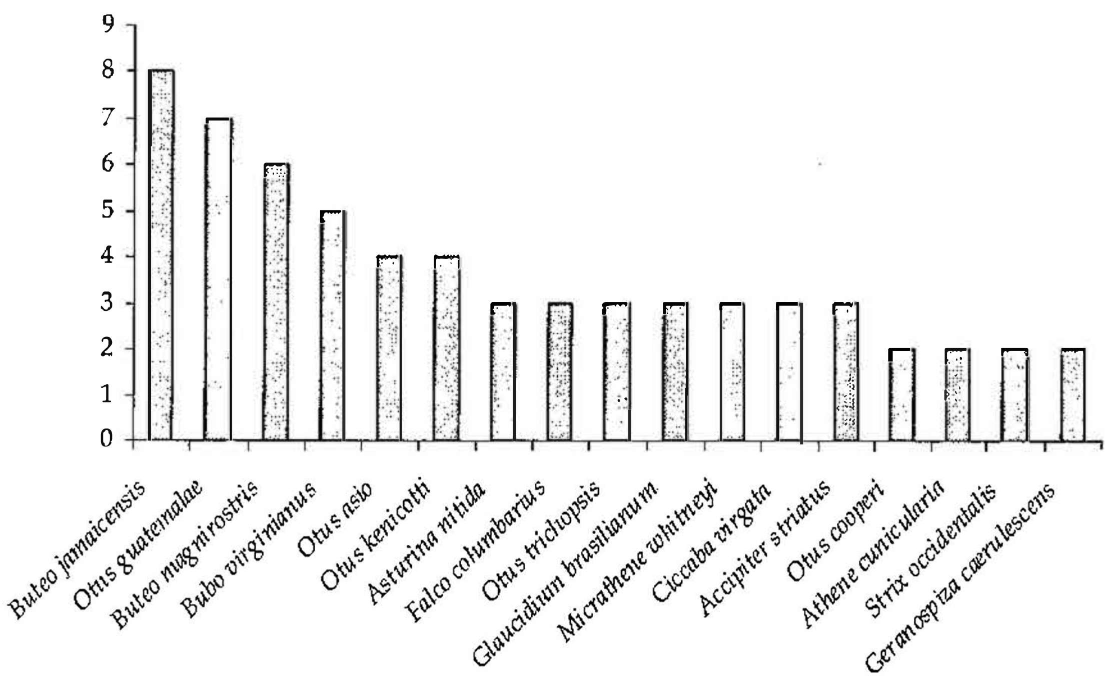

Figure 2. Number of raptor subspecies recorded in México (Friedmann *et al.* 1950, AOU 1998) with a wide geographic variation.

CONSERVATION

Conservation of keystone species has been the main engine for developing genetic studies in raptors. Various taxa exhibit deep genetic differences. Using alternative species concepts can suggest the existence of more than one species in taxa such as *Strix occidentalis* (Barrowclough and Gutiérrez 1990, Dickerman 1997).

Other factors include the use of patterns of species richness and endemism as criteria for designing priority conservation areas. An example, using all the bird species of México, is presented by Peterson and Navarro (1999). Figure 3 shows a similar attempt using only raptor species. While traditional systematic viewpoints (e.g. AOU 1998) recognize only three species of raptors endemic to México, alternative species concepts raise the number to seven (Navarro and Peterson 2004).

Taxonomic changes affect conservation decisions in a variety of ways (Hazevoet 1996, Peterson and Navarro 1999). Once a species is split or aggregated, its presence in any of the priority listings of endangered species (Collar *et al.* 1992, NOM-059-ECOL-2001) should be reassessed. Changes could transform a biological species into a set of phylogenetic species, some of which become taxa of very restricted distribution, such as the Guadalupe caracara *Caracara lutosus* or small population size, such as the Tamaulipas pigmy owl *Glaucidium sanchezi*.

CONCLUSIONS

How many species of raptors are there in México? The answer is: ***we still do not know!*** Studies of raptors are concentrated on a few species of high conservation value (Ramírez-Bastida and Navarro, in this publication), and species-level systematics for many of these groups are lacking. Detailed taxonomic knowledge is an important

A

B

Figure 3. Pattern of species richness of endemic raptors in two alternative systematic viewpoints in the biogeographic provinces of México (CONABIO 1999). (A) Endemic species as recognized by AOU (1998). Provinces hold one (light gray) or two (dark gray) endemic species. (B) Endemic species recognized by Navarro and Peterson (2004). Provinces hold one (light gray), two (medium gray), or three (dark gray) endemic species.

tool for understanding diversity and conservation of raptors. Unfortunately, there are few students or researchers in this form of research, nor do existing collections have enough specimens for detailed analyses (Peterson *et al.* 1998). However, such studies should be encouraged to increase the current biological understanding of these raptor families for many purposes, especially conservation.

ACKNOWLEDGMENTS

We appreciate the support of Ricardo Rodríguez-Estrella and the Raptor Research Foundation for enabling O. Rojas to attend the conference. Thanks also to Alejandro Gordillo, Laura López-Esquivel, Gabriela García-Deras, and Luis Antonio Sánchez for additional information. Valuable comments to this contribution were made by Andrew Burton, Armando Contreras, and Ricardo Rodríguez-Estrella. Financial support for developing various stages of the 'Atlas of the birds of México' database and analyses presented herein were obtained from the Consejo Nacional de Ciencia y Tecnología, National Science Foundation, the SEMARNAT-CONACyT Sectorial funds (C01-0265), Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), and grants DGAPA-PAPIIT IN218598 and 214200 from the Universidad Nacional Autónoma de México.

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Status of raptors in Nuevo León, México

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ABSTRACT

We report on the status of raptors in the Nuevo León State in northeastern México, including species inventory, reproductive status, residentially, protection status, general distribution, and comments on selected species. Additionally, we present a bibliographic analysis of raptor studies in Nuevo León. There are records of 41 species: 20 Accipitridae, 7 Falconidae, 1 Tytonidae, and 13 Strigidae. There are 24 breeding species, of which 19 are of uncertain breeding status, 26 permanent resident species, 8 summer resident species, 5 winter resident species, and 3 transient species. Various protection status levels are recorded: 1 is endangered, 18 threatened, 4 under special protection, 2 rare, and 15 vulnerable. As a result, 93% of the raptor species have some protection status, making it urgent to establish projects that lead us to better understanding of the biology and ecology of each raptor species, and also clarifying their distributional and reproductive status.

Key words: raptor, status, Nuevo León, México, Accipitridae, Falconidae, Tytonidae, Strigidae.

RESUMEN

El presente trabajo es un análisis de las aves rapaces del estado de Nuevo León, NE de México, donde se incluye información del inventario de especies, estatus reproductivo, residencialidad, estatus de protección, distribución general, y comentarios de algunas especies. Además se incluye un listado bibliográfico sobre este grupo de aves en el Estado. Se reportan 41 especies para Nuevo León: 20 Accipitridae, 7 Falconidae, 1 Tytonidae y 13 Strigidae. Acerca de la reproducción, 24 anidan en el Estado y para 19 no está bien conocido todavía. Hay 26 residentes permanentes, 8 residentes veraniegas, 5 residentes invernales y 3 transeúntes. Por su estatus de protección: 1 está en peligro, 18 amenazadas, 4 bajo protección especial, 2 raras y 15 vulnerables. El resultado del análisis arroja que el 93% de las aves rapaces presentan algún estatus de protección, por lo que es urgente establecer proyectos de investigación que nos permitan conocer sobre la biología y/o ecología de cada especie, y poder clarificar su distribución y estatus reproductivo.

INTRODUCTION

During the last 35 years, studies with raptors have greatly increased in numbers. During this period the Journal of Raptor Research appeared as a specialized journal presenting the results of Falconiformes and Strigiformes studies. Studies cover many subjects–ecology, biology, physiology, toxicology, immunology, and conservation. One area of pursuit during the last 30 years is the use of raptors as indicators of ecosystem health in toxicological studies (Henny *et al.* 1998, Mineau 1999). In Nuevo León, most studies of raptors are related to inventories or checklists. Few of them report on the ecology or biology.

Contreras-Balderas (1997) made a compilation of studies of birds in Nuevo León. Some of them include records of raptors in specific areas of Nuevo León (Sutton and Burleigh 1939, Sutton 1941, 1951, Sutton and Pettingil 1943, Friedmann *et al.* 1950, Blake 1953, Edwards 1955, Miller *et al.* 1957, Martín del Campo 1959, Guerrero-Torres 1972, Hubbard and Crossin 1974, Cotera-Correa and Contreras-Balderas 1985, Gracía-Manzano and Contreras-Balderas 1988, Contreras-Balderas 1993, Contreras-Balderas *et al.* 1995a, 1995b, Howell and Webb 1995, A.O.U. 1998, González-Rojas *et al.* 1998, Guzmán-Velasco 1998). Some studies are specific for raptors, as the description of a new subspecies of the bat falcon *Falco rufigularis* (Sutton 1948), the second report of hook-billed kite *Chondrohierax uncinatus*, and flammulated owl *Otus flammeolus* (Montiel de la Garza and Contreras-Balderas 1990, Contreras-Balderas 1992), the breeding biology of the black-shouldered kite *Elanus caeruleus* (Montiel de la Garza *et al.* 1991), the first record of short-eared owl *Asio flammeus* (Contreras-Balderas *et al.* 1995), and the nesting records of Swainson´s hawk *Buteo swainsoni*.

This work presents a bibliographic compilation on the status, distribution, taxonomy and ecology of raptors in Nuevo León. We also based our descriptions on the specimens deposited in the bird collection of the Laboratorio de Ornitología of the Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León (Table 1), and on the records of surveys throughout the state of Nuevo León.

STUDY AREA

Nuevo León is located in northeastern México in the dry, broadleaf, shrub form, open forest vegetation realm, having a total area of 65,000 km^2 divided into three physiographic provinces (Fig. 1). Many migratory birds pass through this region. These provinces support a great variety of plants and animals.

The coastal plain of the Gulf of México covers most of Nuevo León, mainly on the northeast, with elevations from 50 to 250 m. A transitional zone, an area of thorn scrub and mesquite, occupies the area between the coastal plain and the northern outliers of the Sierra Madre Oriental. The northern extensions of the Sierra Madre Oriental range cross Nuevo León from southeast to northwest, reaching elevations of 2000 m. The highest mountains in the state are Cerro Potosí, Ascensión, and Peña Nevada, more than 3500 m. The vegetation within the mountains consists of pine, oak, and oak-pine forests, depending on aspect and elevation. The Altiplano (Mexican Plateau) is located in the southern part of the state, west of the Range, and is an arid zone containing xerophytic scrub and grasslands. Elevations range from 1500 to 2000 m.

Human occupation since colonial times have strongly modified the landscape, leading to significant habitat loss and changes in ecosystems and vegetal associations,

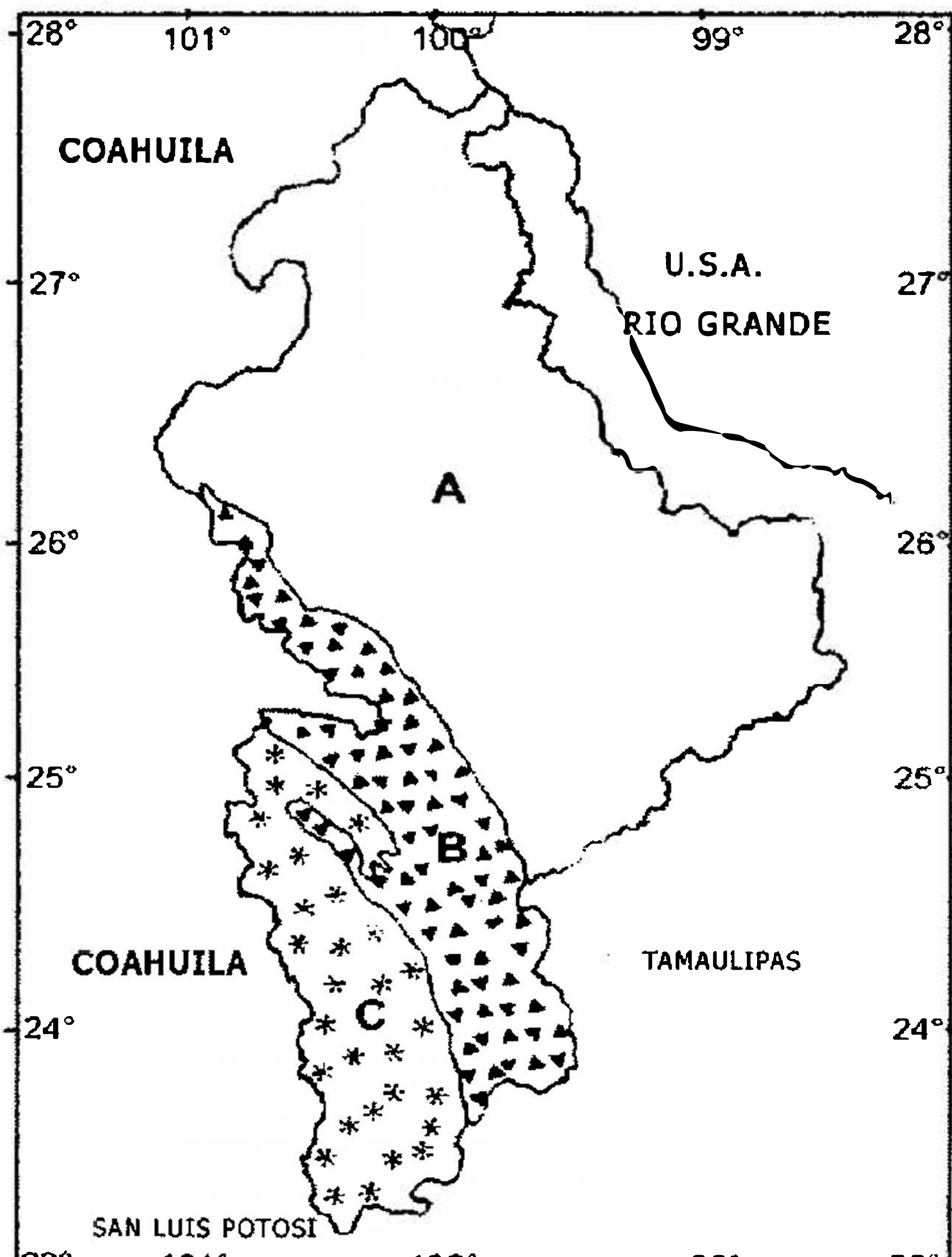

Figure 1. The three physiographic provinces of Nuevo León, México: (A) Coastal plain of the Gulf of México, (B) Sierra Madre Oriental, and (C) Mexican Plateau.

Table 1. Specimens of raptors in the bird collection at the Universidad Autónoma de Nuevo León, México.

catalog no.	sex	species	locality	date
16	M	*Buteo jamaiciencis*	Km 75 Carr. Miguel Alemán, entrada a Palmeriteas, 4 km. Apodaca. N.L.	13/02/68
17	-	*Parabuteo unicictus*	San Rafael, Guadalupe, N.L.	20/11/69
18	M	*Parabuteo unicictus*	Los Herreras, N.L.	10/12/69
19	M	*Falco sparverius*	Carret. Monterrey, Apodaca, N.L.	08/01/68
20	M	*Falco sparverius*	Colonia Larralde, Monterrey, N.L.	12/12/67
21	H	*Falco sparverius*	7 km Sur, Cadereyta, N.L.	01/01/70
22	H	*Falco sparverius*	Carret. Miguel Alemán, Apodaca. N.L.	05/01/68
23	M	*Elanus lecrurus mayusculus*	Atongo. N.L.	05/01/68
28	-	*Asio flammeus*	Mezquital. N.L.	18/12/69
368	M	*Micrathene whitneyi*	930 mts alt. Cañón de la Huasteca, Sta. Catarina, N.L.	15/04/72
377	M	*Falco sparverius*	Cerro del Diamante, 3.5 km Estesureste, Villa de García. N.L.	02/09/71
378	H	*Falco sparverius*	Rancho las Canoas, 10 km Sureste Sabinas Hidalgo. N.L.	03/10/71
379	M	*Falco sparverius*	Rancho las Piedritas, Los Ramones. N.L.	11/12/71
380	H	*Falco sparverius*	Rancho el Cerrito de Plata, Montemorelos, N.L.	19/12/71
381	M	*Falco sparverius*	Rancho el Cerrito de Plata, Montemorelos, N.L.	19/12/71
415	H	*Bubo virginianus*	Cerro del Duraznillo, Villa de García. N.L.	03/09/71
558	M	*Falco sparverius*	3 km al Noreste de Ejido Tokio, Galeana. N.L.	17/08/76
559	H	*Falco sparverius*	3 km al Noreste de Ejido Tokio, Galeana. N.L.	17/08/76
1120	M	*Megascops asio*	Rancho Ojos de Agua, 6 km al Noreste del Cañón de la Boca, Santiago. N.L.	24/04/83
1387	M	*Glaucidium gnoma*	Rancho el tejocote, Santiago, N.L.	27/07/86
1629	H	*Megascops asio*	1.5 km al Oeste de Hualahuises. N.L.	14/09/72
1630	-	*Otus trichopsis*	Río Pesquerías, Escobedo. N.L.	05/07/80
1933	M	*Otus flammeolus*	Cerro del Potosí, Galeana. N.L.	21/06/80
1934	M	*Megascopus asio*	Rancho Anáhuac, 10 km al Oeste de Hualahuises. N.L.	24/05/85
1935	-	*Bubo virginianus*	40 km Noreste de China. N.L.	26/06/80
1936	H	*Megascops asio*	Ejido Vaquerías, General Terán. N.L.	28/06/85
1937	M	*Athene cunicularia*	3 km al Norte del Ejido Tokio, Galeana. N.L.	28/11/79
1938	M	*Athene cunicularia*	Cerro Mesitas, 5 km al estenoreste del Ejido Tokio, Galeana. N.L.	18/11/79
2381	H	*Circus cyaneus*	Km 10 Carr. Mty-Colombia, Escobedo, N.L.	08/10/88
2382	-	*Buteo lineatus*	Hda. Pontezuelas, Gral. Terán. N.L.	22/01/89
2384	H	*Asturina nitida*	5 Km al este General Zuazua. N.L.	03/02/88

mainly from cutting forest, burning grasslands, fragmenting broad habitat areas, and overexploiting surface and ground water. Desertification and more frequent fires have expanded into formerly more moist areas from these activities (Contreras-Balderas and Lozano-V. 1994).

METHODS

An intensive bibliographic survey of journals was undertaken to find references to raptor studies and surveys in Nuevo León. We also used information from specimens in the bird collection of the Laboratorio de Ornitología of the Facultad de Ciencias Biológicas of the Universidad Autónoma de Nuevo León and from field observations throughout the state made by authors. We followed the systematic and taxonomic nomenclature of the AOU (1998).

RESULTS

We found 41 raptor species in Nuevo León, consisting of 2 Cathartidae, 20 Accipitridae, 7 Falconidae, 1 Tytonidae, and 13 Strigidae (Table 2). Of these, 23 species are known to breed in the state, and the remaining 18 have an unknown local breeding status. In terms of residency, 25 are permanent residents, 8 summer resident, 4 wintering residents, and 3 transient (Table 2). Raptors included in the official lists for protection in México are: 1 endangered, 18 threatened, 4 under special protection, 2 rare, and 13 vulnerable (Table 2).

Table 2. Checklist of diurnal and nocturnal raptors in Nuevo León, México. The status of species listed as special concern species is presented. A=nesting, M=migratory, Pe=Endangered, Pr=Special protection, R=rare, A=Threatened, V=Vulnerable, R.p.=Permanent resident, R.v.=Summer resident, R.i.=Winter resident, T=Transient.

species	english common name	spanish common name	breeding status	protection status	resident, wintering status
Coragyps atratus	black vulture	zopilote común	A	V	R.p.
Cathartes aura	turkey vulture	zopilote aura	A	V	R.p.
Pandion haliaetus	osprey	gavilán pescador	M	V	R.v.
Chondrohierax uncinatus	hook-billed kite	milano picoganchudo	A	R	R.p.
Elanoides forficatus	American swallow-tailed kit	milano tijereta	M	R	R.v
Elanus caeruleus	black-shouldered kite	milano cola blanca	A	V	R.p.
Icitina mississippiensis	Mississippi kite	milano de Misisipi	?	A	R.v
Circus cyaneus	northern Harrier	gavilán rastrero	M	A	R.i.
Accipiter striatus	sharp-shinned hawk	gavilán pecho-rufo	M	A	R.v.
Accipiter cooperii	Cooper's hawk	gavilán de Cooper	M	A	R.v.
Buteogallus anthracinus	common black-hawk	aguililla-negra menor	M	A	R.v.
Parabuteo unicinctus	Harris's hawk	aguililla rojinegra	M	A	R.p.
Buteo nitidus	gray hawk	aguililla gris	A	Pr	R.p.
Buteo magnirostris	roadside hawk	aguililla caminera	A	Pr	R.p.
Buteo lineatus	red-shouldered hawk	aguililla pecho-rojo	M	V	R.i.
Buteo brachyurus	short-tailed hawk	aguililla braquiura	?	None	
Buteo swainsoni	Swainson's hawk	aguililla de Swainson	M	V	R.v.
Buteo albicaudatus	white-tailed hawk	aguililla cola-blanca	A	Pr	R.p.
Buteo albonotatus	zone-tailed hawk	aguililla aura	A	None	R.p.
Buteo jamaicensis	red-tailed hawk	aguililla cola-roja	A	Pr	R.p.
Buteo regalis	ferruginous hawk	aguililla real	M	V	R.i.
Aquila chrysaetos	golden eagle	águila real	A	Pe	R.p.
Caracara cheriway	crested caracara	caracara quebrantahuesos	A	V	R.p.
Falco sparverius	American kestrel	cernícalo Americano	A	V	R.p.
Micrathene whitneyi	elf owl	tecolote colicorto	A	V	R.p.
Athene cunicularia	burrowing owl	tecolote zancón	A	A	R.p.

Table 2. *Continued.*

species	english common name	spanish common name	breeding status	protection status	resident, wintering status
Ciccaba virgata	mottled owl	búho tropical	A	A	R.p.
Strix occidentalis	black-and-white owl	búho serrano ventrilistado	A	A	R.p.
Asio otus	long-eared owl	búho caricafé	M	None	R.p.
Asio flammeus	short-eared owl	búho cornicorto llanero	M	A	T
Aegolius acadicus	northern saw-whet owl	tecolote abetero norteño	A	V	R.p.

DISCUSSION AND CONCLUSION

There exists few published reports on raptors in Nuevo León and few specific studies of raptors are in progress. As a result, new additions and records of raptors in Nuevo León have been recently published (Montiel-de la Garza and Contreras-Balderas 1990, Contreras-Balderas 1992, Contreras-Balderas *et al.* 1995) and more are expected, as specific studies increase. Knowledge of raptors in Nuevo León is only partial, with local and scattered records. Thus, a general overview of the patterns of distribution of raptors is lacking. Taxonomically, few studies have been made, mainly at the intra-specific level. We found only the work of Sutton (1948) that described a subspecies of the bat falcon. Finally, almost no information exists on the biology and ecology of raptors in Nuevo León, particularly on species of special concern (endangered and threatened).

We stress the need to increase studies on the status, distribution, biology, and ecology of raptors in Nuevo León. Studies are needed to evaluate the effects of pollutants and chemicals, on these publication. We also propose more detailed studies to clarify the taxonomic status of most raptors, especially those that are permanent residents and summer breeding residents. Lastly, environmental education and planning and better management strategies for protecting raptors may be obtained.

ACKNOWLEDGMENTS

We thank Dr. Ricardo Rodríguez Estrella, for the invitation to participate in the meeting that give place to this publication.

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Recent breeding records and sightings of neotropical forest eagles in southeastern México

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ABSTRACT

From February 1998 to June 1999, field surveys in the states of Campeche, Quintana Roo, and Chiapas provided information on the status of neotropical forest eagles. Despite being unable to locate Harpy Eagles *Harpia harpyja* in the Montes Azules Biosphere Reserve in Chiapas, recent sightings at the Chajul Field Station are encouraging. Six nests of the ornate hawk-eagle *Spizaetus ornatus* were located in Campeche. Nest failure was confirmed at two nests, and suspected at three more. Humans were responsible for the confirmed failed nests.

Key words: harpy eagle, *Harpia harpyja,* Guiana crested eagle, *Morphnus guianensis,* ornate hawk-eagle; *Spizaetus ornatus*; tyrant hawk-eagle *Spizaetus tyrannus*; black and white hawk-eagle *Spizastur melanoleucus,* México, biosphere reserve, conservation.

RESUMEN

De febrero de 1998 a junio de 1999 se realizaron muestreos en los estados de Campeche, Quintana Roo y Chiapas para estudiar el estatus de las especies de águilas del bosque neotropical. A pesar de no haber podido localizar al águila harpía *Harpia*

harpyja en la Reserva de la Biosfera Montes Azules (Chiapas), las recientes observaciones en la Estación de Campo Chajul permiten ser optimistas de que aún ocurren en la zona. Se localizaron 6 nidos del águila elegante *Spizaetus ornatus* en Campeche y se confirmó el fracaso de anidación de 2 nidos y se sospecha de 3 más. Los humanos fueron responsables del fracaso de los nidos.

INTRODUCTION

It is well known that tropical forests are declining at an alarming rate. Despite the concern over the loss of tropical forests, deforestation in the tropics continues to increase (Bawa and Seidler 1998). In México, Rzedowski (1978) estimated that the country has lost 90% of its original tropical evergreen forest. Iñigo *et al.* (1987) believe that the number of neotropical forest eagles and many other neotropical raptors are declining as a consequence of forest destruction, hunting pressure, pesticide pollution, and wildlife trade, and that the endangered populations are dramatic examples of the depletion of biotic resources in tropical countries such as México.

Due to concern over the current status of neotropical forest eagles within México, a field survey was undertaken from February 1998 to June 1999, to obtain baseline data on populations of the harpy eagle *Harpia harpyja*, Guiana crested eagle *Morphnus guianensis*, ornate hawk-eagle *Spizaetus ornatus*, tyrant hawk-eagle *Spizaetus tyrannus*, and the black and white hawk-eagle *Spizastur melanoleucus* in southeastern México.

METHODS

In continuous forest, observations using 10×35 binoculars were taken from above the canopy by climbing forest emergents or climbing to lookouts over bluffs and rock faces. Neotropical hawk-eagles regularly soar over the forest, which facilitates identification (Thiollay 1989, Howell and Webb 1995). In the Calakmul Biosphere Reserve, observations were taken from atop the main pyramids at the Calakmul archeological site and from an old steel observation tower. In addition, the method of acoustic attraction developed by Whitacre *et al.* (1992) was used to attract eagles. Observations were taken from 7 to 11 a.m.

During the breeding season, an area of approximately 500 m diameter around old stick nests was searched, and an area of approximately 300 m in diameter around any conspicuously perched eagle was intensively searched. The technique of listening for calling eagles during the breeding season was also used. Interviews with local people, especially researchers and workers within the biosphere reserves, were conducted to help locate active nests. Rough topography and density of the vegetation make it probable that some nests were overlooked.

Data on nesting habitat and nest tree parameters for *Spizaetus ornatus* were obtained following Aumann (1989) and Burton *et al.* (1994). Standard equipment (tape measure, compass, and inclinometer) was used to take most measurements. Percentage canopy closure was estimated from the ground by calculating the percentage of foliage blocking sunlight. Habitat classification follows Rzedowski

(1981).

Surveys for eagles were made in the Montes Azules Biosphere Reserve in Chiapas, Calakmul Biosphere Reserve (including the tropical evergreen forests of Silvituc and Laguna Aregeña) in Campeche, and Sian Ka'an Biosphere Reserve and the Río Hondo region in Quintana Roo. From February 1998 to June 1999, 30 days were spent in Montes Azules Biosphere Reserve and 45 days in Campeche and Quintana Roo.

RESULTS

Sightings

There were no sightings of *Harpia harpyja* in the Montes Azules Biosphere Reserve despite reliable recent sightings of an adult (photographed) in 1996, juvenile in 1997, an adult in 1998 (R. Frías, pers. comm), and an adult in 1999 (R. Macías, pers. comm) at the Chajul Field Station. Similarly there were no sightings of *Spizaetus ornatus* within the Montes Azules Biosphere Reserve despite the record of an adult with a green iguana *Iguana iguana* at the Chajul Field Station in 1997 (R. Frías, pers. comm.) and another adult photographed at the Ixcán ecotourism complex in 1997 (R. Guerrero, pers. comm). One pair of vocalizing *Spizaetus tyrannus* were observed at the confluence of the Río Ixcan and the Río Lacantun, and a pair of *Spizastur melanoleucus* were observed soaring over the Chaquistero Mountain Range in February 1998. In the remaining study areas, there were no sightings of neotropical forest eagles despite employing the acoustical detection methods developed by Whitacre *et al.* (1992).

Nest sites and habitats

Six nest sites of the ornate hawk-eagle *Spizuetus ornatus* were located in Campeche (Table 1). One nest was located near Laguna Aregeña, the remaining five were located in, or near to, the Calakmul Biosphere Reserve. All nests were located in, or adjacent to, continuous forest. Four nests were located in tropical evergreen forest, one nest was located in semi-evergreen seasonal tropical forest (Schulze 1992), and one nest in tall tropical evergreen forest. Three nests were located in *Talisia olivaeformis*, two in *Bucida buceros*, and one in *Acacia angustissima*. Nest trees were not necessarily the tallest trees available. There appeared to be some preference for isolated trees in clearings within continuous forest; one nest was located in an isolated *Talisia olivaeformis* in the center of an abandoned field (50 m diameter) within an otherwise continuous tall tropical evergreen forest. Another nest was in an emergent (25 m tall) *Bucida buceros* within a large extension of semi-evergreen seasonal tropical forest subject to inundation and, another nest was in a *Talisia olivaeformis* at the edge of an abandoned quarry (30 × 90 meters) within continuous tropical evergreen forest. For the remaining three nests within continuous forest, mean canopy closure in the nest vicinity was 35% (range from 15 to 50%). Close proximity to permanent water did not appear to be a breeding prerequisite with five of the six nests located at least one km from the nearest water source (Table 1).

Of the six nests located, four were constructed in 3 or 4-branch forks in the tree crown, and two were on 2 or 3-branch forks of major horizontal branches and held by vertical leafy shoots. At four nest sites, where nest orientation was measured, two nests were facing due west, one northwest, and one due south.

Table 1. Nest tree and nest site parameters of *Spizaetus ornatus* in Campeche 1998-1999 (N=6).

parameter	mean	S.D.	min.	max
Nest tree height (m)	25.0	4.5	20.0	30.0
Nest tree girth (m) 1.5 m above ground	1.7	0.7	0.8	2.8
Nest height above ground (m)	19.7	4.1	15.0	25.0
Distance of nest from main trunk (m)	1.0	2.5	0.0	6.0
Foliage cover above nest (%)	35.0	32.1	10.0	80.0
Canopy closure (%)	20.8	20.6	0.0	50.0
Distance to nearest permanent water (m)	2758.0	3677.0	50.0	10000.0
Distance to nearest ephemeral water source (m)	194.0	395.1	12.2	1000.0

Nest success and causes of nest failure

Nest failure was confirmed at two of the six nest sites, and suspected at three of the four remaining sites. Of the two confirmed nest failures, both occurred within the Calakmul Biosphere Reserve: an eaglet was taken from a nest located in January 1999 adjacent to the road leading to the Calakmul archaeological site, despite a permanent guard post on this road. At the other nest, an adult was shot and hacked to pieces with a machete, and the nest tree was felled. Nest failure was not directly linked to habitat disturbance, but more directly to accessibility, since the nest where the eaglet disappeared was located well within the biosphere reserve near the edge of the core area of the reserve, but adjacent to the road leading to the archaeological site.

DISCUSSION

Despite covering large areas of forest, including the core area of the Montes Azules Biosphere Reserve (30-35 km along the Río Tzendales until reaching its source; the catchment area of the Río Miranda; 30 km along the Río San Pedro; the forest surrounding Laguna Lacanja; and the Chaquistero Mountain Range) no harpy eagles were sighted. The Lacandon Forest that is currently protected within the Montes Azules Biosphere Reserve suffered excessive hunting pressure in the past. Today, illegal hunting is still a problem. Five poachers' camps were observed along the Río Tzendales within the core area of the Reserve in March 1999, despite a permanent guard post at the entrance to the Río Tzendales. However, the recent sightings of harpy eagles at the Chajul Field Station are particularly encouraging and future fieldwork should be concentrated in this area.

In Quintana Roo, habitat in the Río Hondo region has been drastically altered to accommodate sugar cane production and is no longer suitable for neotropical forest eagles. Clinton-Eitniear (1986) mentions the sighting of an adult and juvenile harpy eagle at the Río Azul archaeological site by researchers from the University of Texas-San Antonio near the border between Guatemala, Belize, and México. During

January 1999, a survey of this area along a recently constructed road that reaches the border with Belize and Guatemala found new communal land had been established, along with large-scale clearing of tropical evergreen forest and subsistence hunting. This is the result of the National Development Program of México (Rangel-Salazar *et al.* 1991). In the Sian Ka'an Biosphere Reserve, forest guards reported sightings of the ornate hawk-eagle *Spizaetus ornatus*, in stands of tropical evergreen forest within the reserve. Howell and Webb (1995) recorded *S. ornatus, S. tyrannus*, and *Spizastur melanoleucus* from Sian Ka'an. The Amigos de Sian Ka'an organization (pers. comm.) has recent records for *S. ornatus* and *S. tyrannus*. This is one of the few reserves in southeastern México with abundant prey populations and intact habitats, and as such, can be expected to be important for the long-term survival of the three medium-sized neotropical eagles.

Although the Calakmul Biosphere Reserve has experienced problems with protecting wildlife within the buffer zone and along access roads, the reserve does appear to have substantial populations of prey species, including ocellated turkey *Meleagris ocellata* and plain chachalaca *Ortalis vetula* that are frequently observed along the road leading to the Calakmul archaeological site (pers. obs.). This reserve is particularly important for the continued survival of neotropical eagles in México. Of special importance is the record in Jones and Sutter (1992) for the Guiana crested eagle *Morphnus guianensis* as this is the first record of this species in México.

The perceived difference in prey populations between the Montes Azules

Biosphere Reserve and the Calakmul Biosphere Reserve probably relates to accessibility by hunters. Calakmul is characterized by large expanses of a particularly dense, entangled, low, semi-evergreen seasonal tropical forest ("bajo" forests) (Schulze 1992) that has an open canopy and dense understory and occurs in low-lying sites of deep, clay-rich soils subject to seasonal flooding and drought (Thorstrom 2000). The entangled understory, coupled with flooding during the rainy season, inhibits access by hunters. In contrast, the Montes Azules Biosphere Reserve is characterized by tall tropical primary evergreen forest with emergent species reaching to 50 m. This high and almost uniform canopy blocks sunlight from reaching the forest floor and hunters are able to move about within the forest. Hunters are also able to penetrate far into the reserve by the Tzendales, Azul, Negro, San Pedro, and Lacanja rivers, which are easily navigable in small canoes.

Human interference of eagle nests, found in the Calakmul Biosphere Reserve, appeared to be restricted to areas near to access roads and trails. Near roads and trails, most nests of eagles suffer from nest robbing, and all eagles are routinely shot on sight (Iñigo *et al.* 1987). Alvarez-Cordero (1996) found that shooting eagles and live poaching of nestlings were major threats to local populations of harpy eagles in Venezuela. Excessive trafficking of birds of prey in México was reported by Iñigo Elias (1986) and Ramos (1986). Klein *et al.* (1988) believed that ornate hawk-eagles require over a year for courtship, nesting, and raising one young to independence, so that at most, this species may produce one nestling every other year. They considered low reproduction may make the species sensitive to habitat destruction or hunting pressure. This study is in agreement with Iñigo *et al.* (1987) who state that, '*Although these eagles are protected by Mexican laws, more efforts are necessary from the government and people to conserve México's diverse wildlife resources*'.

ACKNOWLEDGEMENTS

I wish to dedicate this work to the memory of the late Alfonso Franco Ponce who was deeply concerned with the conservation of Mexican wildlife and who provided considerable financial and logistical support to enable the successful completion of this study. I thank Gaspar Jiménez de la Cruz for assistance with fieldwork, and R. Ursúa for guidance during tree climbing. L. Valenzuela, Zoh Laguna (Calakmul) located 4 of the 6 *S. ornatus* nest sites. Special thanks to R. Frías and R. Macías for providing harpy eagle and ornate hawk eagle records from the Chajul Field Station and R. Guerrero for the ornate hawk-eagle record at Ixcán. This study was funded by A. Franco Alvarez, E. Franco Alvarez (INFRA S.A. de C.V.), and the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad , México (Proyecto L321). Climbing equipment was donated by IDEA WILD and E. Bertello.

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Food habits of breeding peregrine falcons (*Falco peregrinus*) in the Ojo de Liebre Lagoon, Baja California Sur, México

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ABSTRACT

Feeding habits of the peregrine falcon (*Falco peregrinus anatum*) were studied by analyzing prey remains at 3 eyries in the Laguna Ojo de Liebre, Baja California Sur, México, during the 1993 and 1994 breeding seasons. The falcons consumed water and terrestrial birds and one species of mammal, the pygmy pocket gopher (*Thomomys umbrinus*). We collected 86 feeding items. The diet included 17 species of waterbirds, of which 6 comprised 69% of the diet. Marbled godwit (*Limosa fedoa*) was the most common. The variety of prey items found in the study area was greater than that reported for peregrine falcons on Gulf of California islands. This may be attributable to greater diversity and availability of prey in the lagoon.

Key words: peregrine falcon, diet, Ojo de Liebre Lagoon, B.C.S., México.

RESUMEN

Estudiamos los hábitos alimenticios del halcón peregrino (*Falco peregrinus anatum*) mediante el análisis de restos de presas en 3 nidos, en la Laguna Ojo de Liebre, Baja California Sur, México, durante el período reproductor de 1993 y 1994. Los halcones consumieron aves acuáticas y terrestres y tuzas (*Thomomys umbrinus*). Colectamos un total de 86 restos de especímenes. La dieta incluyó 17 especies de aves acuáticas, sin embargo, 6 especies comprendieron el 69% de las presas. Una de las especies, *Limosa fedoa*, constituyó el grueso de la dieta. La variedad de la dieta encontrada en el área de estudio fue más amplia que la reportada para halcones peregrinos residentes en islas del Golfo de California. Esto puede deberse a la mayor diversidad y disponibilidad de presas en los humedales de la Laguna Ojo de Liebre.

INTRODUCTION

The peregrine falcon (*Falco peregrinus*) is widely distributed in the world (Ratcliffe 1993). In México, it is a resident of the northern and central part of the country. A major concentration of this bird is known from the Baja California Peninsula and the Gulf of California islands (Hunt *et al.* 1988, Porte *et al.* 1988). Though a well-studied bird in most parts of its range, very little is known about its biology, ecology, and conservation status on the west coast of the Baja California Peninsula, where they were historically abundant until the early 1970s (Banks 1969, Porter *et al.* 1988).

Recent reports suggest that the peregrine falcon is now recovering in the region (Castellanos *et al.* 1994, 1997). The species was recently removed from the status of endangered birds in México (NOM-059-ECOL-2001). Research on its feeding ecology may provide basic information for managers to develop appropriate management strategies in México. In this paper, we document food habits of the peregrine falcon in the large Pacific coastal lagoon called Laguna Ojo de Liebre of the Baja California Peninsula, México. This lagoon, part of El Vizcaino Biosphere Reserve and listed as a natural site in the World Heritage List (UNESCO 1994), is a recently documented nesting area of the peregrine falcon (Castellanos *et al.* 1994).

STUDY AREA AND METHODS

Laguna Ojo de Liebre (~27.8°N,114°W), on the west coast of the state of Baja California Sur, (Fig. 1), is about 48 km long and 22 km wide, with shallow waters, deep channels, and strong tidal currents. The lagoon is a large complex of wetlands supporting more than 94 species of birds (Massey and Palacios 1994), of which 16 breed on small islands in the lagoon complex (Castellanos *et al.* 2001). The climate is arid and semi-arid. The mean annual precipitation is less than 36 mm, most of which occurs in winter (Salinas *et al.* 1991). *Ruppia maritima, Zoostera marina*, and *Phyllospadix scoulen* cover portions of the lagoon's bottom and shoreline (Lot *et al.* 1986). Five small relatively flat islands and several light towers along a navigation channel are within the lagoon. Surrounding the lagoon are coastal dune scrub (*Ambrosia, Dalea,* and *Plantago* spp.), the Vizcaino desert flat, which is covered with 30 to 60 cm high halophyte scrubs (*Ambrosia, Bursera, Frankenia, Bouteloa,* and *Muhlenbergia* spp.) (León de la Luz *et al.* 1991), salt production ponds, and a few coastal outposts and the nearby town of Guerrero Negro.

Figure 1. Map of the vegetation zones and location of the study site.

Prey remains were collected during the breeding season from three peregrine falcon nests, one on the ground on Piedras Island and the other two on channel towers near the sand dune coast. The bulk of the prey remnants were collected from the nest on Piedras Island. The first collection, in May 1993, involved all recognizable material accumulated for an unknown period of time. The nest site area was cleaned and a second collection was made in June 1993. Regular collections (25 to 30 days apart) were made from March to June 1994. To determine diet, remains collected in both years were combined and identified by comparison with reference collection specimens at the Museo de Historia Natural of the Universidad Autónoma de Baja California Sur (UABCS). Frequency of prey in the diet is expressed in percent.

RESULTS AND DISCUSSION

During the sampling, 86 individual prey items were identified, including 18 species of birds and one mammal, the pygmy pocket gopher (*Thomomys umbrinus*). Six species of birds constituted 68.6% of the prey items found in the peregrine falcon nests. The marbled godwit was the most frequent bird in our sample, representing 38% of the items, followed by the black-crowned night heron, long-billed curlew, short-billed dowitcher, royal tern, and willet (Table 1). Three of the bird species (black-crowned night heron, royal tern, and snowy egret) breed in colonies on two small islands in the lagoon.

Table 1. Prey remains identified in peregrine falcon eyries during the breeding season of 1993-1994.

scientific name	common name	items	frequency (%)
Limosa fedoa	marbled godwit	33	38.37
Nycticorax nycticorax	black-crowned night heron	6	6.98
Numenius americanus	willet	5	5.81
Catoptrophorus semipalmatus	long-billed curlew	5	5.81
Limnodromus griseus	short-billed dowitcher	5	5.81
Sterna maxima	royal tern	5	5.81
Calidris alpine	dunlin	2	2.33
Larus spp.	gulls	2	2.33
Calidris alba	sanderling	1	1.16
Actitis macularia	spotted sandpiper	1	1.16
Arenaria interpres	ruddy turnstone	1	1.16
Heteroscelus incanus	wandering tattler	1	1.16
Phalaropus fulicaria	red phalarope	1	1.16
Egretta thula	snowy egret	1	1.16
Larus philadelphia	Bonaparte gull	1	1.16
Sterna hirundo	common tern	1	1.16
Pluvialis squatorola	black-bellied plover	1	1.16
Mimus sp.	mockingbird	1	1.16
	unidentified birds	11	12.79
Thomomys umbrinus	pocket gopher	2	2.33

Peregrine falcons capture a wide variety of prey including birds (Ratclife 1993), small mammals (Porter and White 1973, Bradley and Oliphant 1990), and bats (Stager 1941, Porter and Jenkins 1988). However, this species is considered a bird predator specialist (Ratcliffe 1993). Studies throughout the world (Cade 1960, White and Cade 1971, Porter and White 1973, Czechura 1984, Vasina and Straneck 1984, ●ro and Tella 1995) documented a diet based on a wide variety of bird species. In some places, peregrine falcons prey on fewer species of birds (Beebe 1960, Ratcliffe

1993, Velarde 1993).

Our findings indicate that the peregrine falcon diet includes many bird species. This dietary breadth is greater than that documented for peregrine falcons on the Gulf of California islands. Velarde (1993) found that peregrine falcons on Isla Rasa rely on three species of marine birds (Larids). She mentioned the finding of Anderson that peregrine falcons on Isla Partida preyed heavily on two resident marine bird species (Alcids) (*Oceanodroma microsoma* and *O. melania*). We have no systematic data on abundance and availability of peregrine falcon prey in the Laguna Ojo de Liebre. However, our data suggest that peregrine falcons rely mainly on waterbirds there, as do their counterparts in the Gulf of California islands (Porter and Jenkins 1988, Velarde 1993). This can be explained because they regularly inhabit small islands and coastal locations (Ratcliffe 1993), and by the particular environmental conditions of the lagoon.

Peregrine falcons take birds in proportion to their abundance, but they also may exhibit preferences for some species because of factors such as size, behavior, availability, and hunting ability (Hunter *et al.* 1988, Porter and White 1973, Ratcliffe 1993). Surveys of wintering shorebirds made by Morrison *et al.* (1992), and Page *et al.* (1997) in the Laguna Ojo de Liebre indicate that the marbled godwit is the most abundant large-size shorebird there, followed by willets and dowitchers. The predominance of marbled godwit in the peregrine falcon diet reflects their relative abundance in the area.

Of the waterbirds breeding in the area, only three were taken by peregrine falcons: royal tern, snowy egret, and black-crowned night heron. The last two breed on Piedras Island. The falcon nest is located a few meters from them. The royal terns nest in a dense colony of about 2,800 pairs (Castellanos *et al.* 2001) in an open area on Conchas Island. Remains of this prey were found in the falcon nests on the channel towers, about 22 km from Conchas Island. These three species of resident birds are less abundant than the marbled godwit, willet, and dowitcher, but we suspect that their colonial nesting near peregrine eyries make them more accessible to peregrine falcons.

Very few land birds were found amongst the prey remains we collected. The limited occurrence of terrestrial birds can be explained in part by the halophyte scrub of the Vizcaino Flats, which support a few small passerines, such as sparrows (Emberizidae), which typically are not important prey species of the peregrine falcon (Ratcliffe 1993). However, the low frequency of small terrestrial birds may be a limitation of the sampling method (Marti 1978). For example, we observed peregrine falcons consuming American pipits (*Anthus rufescens*) on several occasions and found no remains of this species. Peregrine falcons resist capturing ground prey, such as rodents (Porter and White 1973). However, the open landscape surrounding the lagoon may leave the pygmy pocket gopher, a small rodent, common in some parts of El Vizcaino Desert, exposed when it emerges from its burrows, and vulnerable to predation by the falcons.

Given the variety, abundance, and availability of prey, we believe that additional pairs of peregrine falcons could be sustained in the Laguna Ojo de Liebre. The development of a conservation program offering artificial nesting sites could be an appropriate strategy to increase their numbers in the lagoon, an area where cliffs and other elevated suitable nesting sites are scarce.

ACKNOWLEDGMENTS

We thank the technical staff of SEMARNAP in Guerrero Negro, B. C. S., J.C. Peralta and the Compañía Exportadora de Sal, S. A. for their support with field work; and L. Herrera for allowing us to use the reference collection at the Museo de Historia Natural-UABCS. The editor at CIBNOR improved the English text. We wish to thank Dr. E. Glazier for his assistance with the English edition of an early draft. R. Carmona and E. Ojeda provided reference assistance. Financial support was provided by CIBNOR and CONACyT. We thank 3 anonymous reviewers for their comments on a previous draft.

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Comparative study of diurnal raptors at two locations along the coast of Jalisco: El Playón de Mismaloya and the Península El Tamarindo

Salvador Hernández Vázquez

ABSTRACT

I studied the abundance and habitat associations of diurnal raptors at two locations along the coast of Jalisco, El Playón de Mismaloya Reserve and the Peninsula El Tamarindo. Monthly surveys of raptors were conducted from November 1997 to October 1998 at El Playón de Mismaloya, and from May 1999 to February 2000 at the Peninsula El Tamarindo. At the 2 locations combined, I recorded 18 species. The highest number and density of raptor species was observed during the winter (December to March). Differences in species assemblages and abundance between the two locations appeared related mainly to the relative distribution of habitat types. At El Playón de Mismaloya, which has several wetlands and extensive open areas (e.g., cultivated fields and sand dunes), the most common raptors were the crested caracara (*Caracara cheriway*), osprey (*Pandion haliaetus*) and American kestrel (*Falco sparverius*), 3 species preferring open habitats with short vegetation. At El Tamarindo, dominated by forests, the most common raptor was the gray hawk (*Asturina nitida*), frequently observed on high perches near the local golf

course. These results suggest raptor densities were highest in areas altered by humans (e.g., crop fields at El Playón de Mismaloya), such results were driven largely by the dominance of the crested caracara and the American kestrel, 2 species benefiting from human activities that clear habitat.

Key words: diurnal raptors, temporal variation, occurrence, Jalisco, México.

RESUMEN

En este estudio evalué la ocurrencia de las aves rapaces diurnas, y su variación temporal y espacial, en 2 sitios de la costa de Jalisco, México: El Playón de Mismaloya y la Península El Tamarindo. En el primer sitio las aves rapaces fueron contadas mensualmente de noviembre de 1997 a octubre de 1998, mientras que en el segundo los conteos fueron de mayo de 1999 a febrero de 2000. En ambos sitios se registraron 18 especies de aves rapaces diurnas. La mayor abundancia relativa tanto de especies como de individuos, fue registrada durante el invierno (diciembre a marzo). La variación en la distrubición de los hábitats entre los sitios influyó en la ocurrencia y abundancia de las especies. En El Playón de Mismaloya hubo varios humedales costeros y grandes áreas despejadas (ejemplo; áreas de cultivo y dunas), mientras que en El Tamarindo predominaron las áreas boscosas. Las especies más abundantes en El Playón de Mismaloya fueron el caracara común (*Caracara cheriway*), gavilán pescador (*Pandion haliaetus*) y el cernícalo Americano (*Falco sparverius*), las cuales fueron más comunes en hábitats despejados o con poca vegetación. En El

Tamarindo la especie más abundante fue el aguililla gris (*Asturina nitida*), frecuentemente observada en árboles con perchas altas ubicadas en la orilla del campo de golf. Los resultados obtenidos sugieren que la densidad de aves rapaces fue mayor en áreas alteradas por la actividad humana (campos de cultivo en El Playón de Mismaloya), debido principalmente a la dominancia de caracara común y cernícalo amricano, 2 especies que se benefician de los hábitats abiertos originados por la actividad humana.

INTRODUCTION

Of the 292 diurnal raptors species known from around the world, 76% are located in tropical regions, and they are threatened by loss of habitat, pollution, and hunting (Bildstein *et al.* 1998). To date, however, most studies of raptors in the tropics have focused on only those species found in urban areas, while the use of other more natural habitats remains poorly known (Stinson 1980, Bildstein *et al.* 1998). This is unfortunate as effective conservation measures depend on knowledge of population size (number of breeding adults), spatial distribution (Krebs 1987, Meffe and Carroll 1997), and reproductive biology (Bierregaard 1998).

In México in particular, characterized by high avian species diversity (Howell and Webb 1995), there have been relatively few raptor studies. This is true for example for the coast of Jalisco, which has been the focus of only one study of diurnal raptors (Hernández-Vázquez *et al.* 2000). The current study is intended to contribute toward greater knowledge of the biology and ecology of diurnal raptors along the Pacific slope of tropical México. The main specific objective of the study was to document the diversity, abundance, seasonality, and habitat use of diurnal raptors at two locations along the coast of Jalisco, El Playón de Mismaloya Reserve and the Península El Tamarindo.

STUDY AREA

The study focused on two locations along the coast of Jalisco, El Playón de Mismaloya and the Península of El Tamarindo (Fig. 1). At both locations, the weather is tropical, warm-humid, with a mean annual temperature of 26-28°C. The warmest months of the year are June, July and August, with an average temperature of 27°C. A rainy season extends from July through October, and drier weather dominates from November to June. Mean annual precipitation ranges between 700 and 800 mm.

The Reserve of El Playón de Mismaloya is located along the central coast of Jalisco. It was decreed as a site of protection of sea turtles in 1986. Since then it has been recategorized as a sanctuary integrated within the Mexican federal system of natural protected areas, still for the protection of sea turtles. Observations of diurnal raptors were recorded within the protected area and its immediate surroundings, altogether covering an area of 55 km^2, or a 55 km stretch of coast extending 1 km inland. This site is characterized by vast expanses of open habitats, such as sand dunes extending 200 m from the high tide line and far beyond, crop fields (e.g., watermelon, papaya, sorghum, mango, banana, chili), grazing pastures, rows of trees and wetlands (estuaries and lagoons) (Hernández-Vázquez *et al.* 2000). The marine zone adjacent to El Playón de Mismaloya is located within the Marine Priority Region known as Mismaloya-Punta Soledad (Area 25) (Arriaga-Cabrera *et al.* 1998).

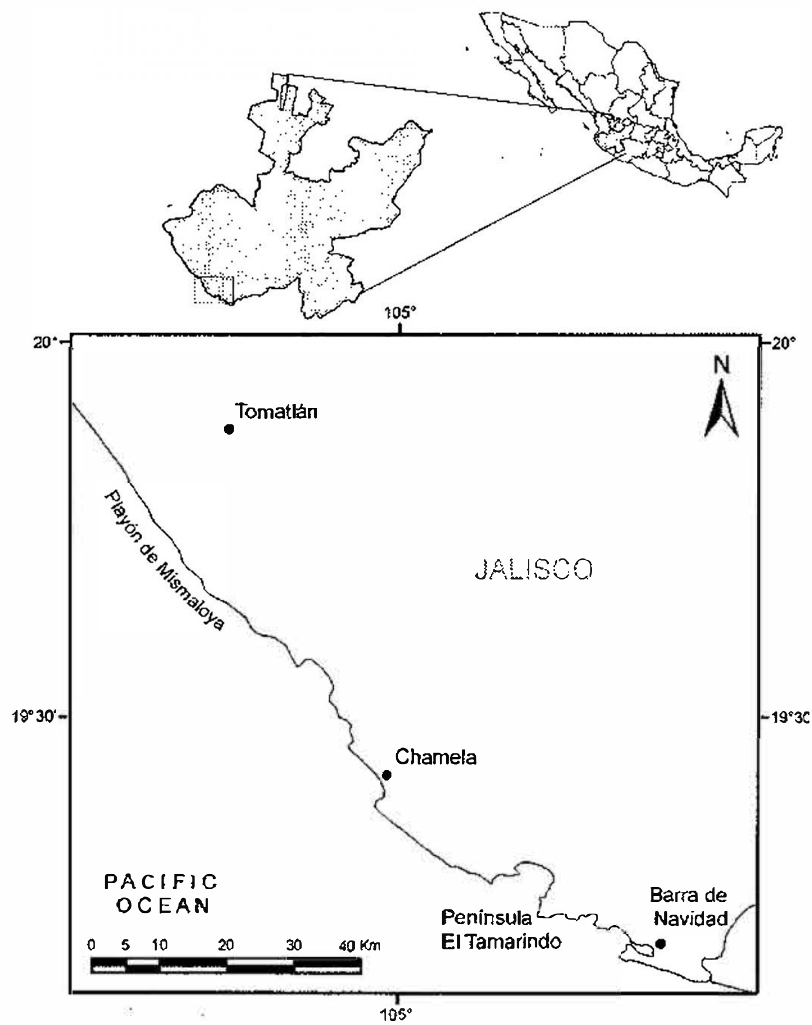

Figure. 1. Geographic location of El Playón de Mismaloya and Península El Tamarindo, Jalisco, México.

The Península El Tamarindo consists of private land. Ecotourism activities are the primary land use, but the area also has been set aside for the protection of its flora and fauna. The monitored area was about 30 km^2 and located within the county of La Huerta, along the southern coast of Jalisco. Geographically the study area is bound to the south by El Palmito beach, to the north by La Manzanilla estuary, to the east by the road to Barra de Navidad - Puerto Vallarta and to the west by the Pacific Ocean. El Tamarindo is characterized by tropical semideciduous forest, palm groves, and a golf course. The terrain is irregular, with some hills reaching an elevation up to 175 m above mean sea level. Westward, there are approximately 14 km of coastline consisting of tall cliffs and three small (<1 km long) beaches. El Tamarindo is adjacent to the Marine Priority Region known as Chaméla-El Palmito (Area 26) (Arriaga-Cabrera *et al.* 1998).

METHODS

I conducted monthly surveys (six days of surveys) from November 1998 through December 1999 at El Playón de Mismaloya, and from May 1999 through February 2000 at El Tamarindo. Every survey was conducted in the morning and lasted between four and five hours (from 07:00 am to 12:00 pm). During each survey I recorded all raptors observed, along with information on their activities (e.g., resting, feeding, hunting) and habitat associations. Habitats were grouped according to biological and geographic attributes. Habitat types at El Playón de Mismaloya consisted of tropical deciduous forest, mangrove, xerophytic scrub, sand dunes, cultivated areas (crop fields, and pastures), sandy plains, beach, and wetlands. At El Tamarindo palm groves, tropical deciduous forest and tropical semideciduous forest, secondary vegetation, golf course and the beach. Birds were identified visually through 10x50 binoculars and a 15-60x telescope. All scientific and common names are reported according to the American Ornithologist's Union (A.O.U. 1998).

After each survey I tabulated the number of individuals observed per species and the total numbers of birds. Species observation frequency was calculated dividing the number of surveys during which a bird of this species was observed by the total numbers of surveys, and is here expressed as a percentage. A measure of raptor density in both study areas was derived from dividing the total number of birds or species by the total area covered by those areas (birds or species by 1 km^2).

RESULTS

Species composition and total numbers of birds

The black vulture (*Coragyps atratus*) and the turkey vulture (*Cathartes aura*) were abundant in the area (420 observations of these 2 vulture species combined were recorded at El Playón de Mismaloya, and 130 at El Tamarindo). These 2 scavenger species, now placed within the Ciconiiformes (herons, storks, spoonbills, ibis) (A.O.U. 1998), were not considered in the analysis.

A total of 391 raptor observations were recorded at El Playón de Mismaloya against 90 at El Tamarindo. Of the 18 raptor species detected in the two study areas combined, 11 (8 winter visitors and 3 residents) occurred at El Playón de Mismaloya, and 14 (five winter visitors and nine residents) at El Tamarindo. The two locations shared a total of seven species: osprey (*Pandion haliaetus*), northern Harrier (*Circus cyaneus*), common black-hawk (*Buteogallus anthracinus*), roadside hawk (*Buteo magnirostris*), crested caracara (*Caracara cheriway*), American kestrel (*Falco sparverius*), and peregrine falcon (*Falco peregrinus*). Four species were detected only at El Playón de Mismaloya: sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*Accipiter cooperii*), red-tailed hawk (*Buteo jamaicensis*), and merlin (*Falco columbarius*) and seven only at El Tamarindo: hook-billed kite (*Chondrohierax unicinatus*), crane hawk (*Geranospiza caerulescens*), gray hawk (*Asturina nitida*), short-tailed hawk (*Buteo brachyurus*), zone-tailed hawk (*Buteo albonotatus*), collared forest-falcon (*Micrastur semitorquatus*), and laughing falcon (*Herpetotheres cachinnans*) (Table 1). Of the 18 species recorded, nine are listed as species at risk by the Mexican federal government (CIPAMEX 1989, Ceballos and Márquez 2000, NOM-059-ECOL-2001) (Table 1).

At El Playón de Mismaloya, the most abundant species appeared to be the crested caracara, with a total of 150 (38%) observations. Next were the osprey and the American kestrel, with 126 (32.2%) and 79 (20.2%) observations, respectively. The rest of the species detected at El Playón de Mismaloya represented less than 10% of the total numbers of observations (Table 1).

At El Tamarindo the number of observations per species was overall low.

Table 1. Total numbers, frecuency and density (birds/km^2) of birds observed at El Playón de Mismaloya and Península El Tamarindo. FO=observation frequency (%), SP=special protection, T=threatened, WV=winter visitor, R=resident.

scientific name	common name	Mismaloya			El Tamarindo			conservation status (NOM-059- 2001)	migratory status
		no. (%)	FO	density	no. (%)	FO	density		
Pandion haliaetus	osprey	126 (32.2)	100	2.29	7 (7.8)	50	0.23		WV
Chondrohierax uncinatus	hook- billed kite				3 (3.3)	30	0.10	SP	R
Circus cyaneus	northern Harrier	13 (3.3)	42	0.24	6 (6.7)	50	0.20		WV
Accipiter striatus	sharp-shinned hawk	2 (0.5)	17	0.04				SP	WV
Accipiter cooperii	Cooper's hawk	2 (0.5)	17	0.04				SP	WV
Geranospiza caerulescens	crane hawk				1 (1.1)	10	0.03	T	R
Asturina nitida	gray hawk				24 (26.7)	70	0.80		R
Buteogallus anthracinus	common black-hawk	7 (1.8)	42	0.13	4 (4.4)	30	0.13	SP	R
Buteo magnirostris	roadside hawk	2 (0.5)	17	0.04	3 (3.3)	30	0.10		R
Buteo brachyurus	short-tailed hawk				1 (1.1)	10	0.03		R
Buteo albonotatus	zone-tailed hawk				9 (10.0)	20	0.30	SP	WV
Buteo jamaicensis	red-tailed hawk	2 (0.5)	8	0.04				SP	WV
Micrastur semitorquatus	collared forest-falcon				6 (6.7)	30	0.20	SP	R
Caracara cheriway	crested caracara	150 (38.4)	100	2.73	9 (10.0)	10	0.30		R
Herpetotheres cachinnans	laughing falcon				7 (7.8)	50	0.23		R
Falco sparverius	American kestrel	79 (20.2)	33	1.44	4 (4.4)	30	0.13		WV
Falco columbarius	merlin	2 (0.5)	17	0.04					WV
Falco peregrinus	peregrine falcon	6 (1.5)	16	0.11	6 (6.7)	20	0.20	SP	WV
	Total	391 (100)		7.10	90 (100)				

The gray hawk had the highest observed abundance, with a total of 24 (26.7%) observations, followed by the zone-tailed hawk and the crested caracara, each detected a total of nine times. The osprey, hook-billed kite, northern Harrier, crane hawk, common black-hawk, roadside hawk, short-tailed hawk, collared forest-falcon, laughing falcon, American kestrel, and peregrine falcon seemingly occurred at low densities, as they were detected 1-7 times only (Table 1).

Seasonal patterns

At El Playón de Mismaloya the highest observed density of raptors was in the winter (i.e., from December to March), in particular during December (1.58 birds/km^2). Similary, the number of species observed during surveys was highest during the winter (Fig. 2a). Species that contributed the most to findings of highest raptor abundance during the winter were crested caracara, osprey, and American kestrel. The crested caracara was recorded year-round (observation frequency = 100%), but numbers of observation of this species increased during the winter, reaching a peak in December (0.49 birds/km^2) and again in March (0.52 birds/km^2) (Fig. 2b).

The osprey was also recorded in all months (observation frequency =100%), but, like the crested caracara the highest density of birds was observed from November to March, and in particular in December (0.63 birds/km^2) (Fig. 2c). The American kestrel was recorded just from December to March (frequency =33%), with a maximum observed density in February (0.54 birds/km^2) and March (0.47

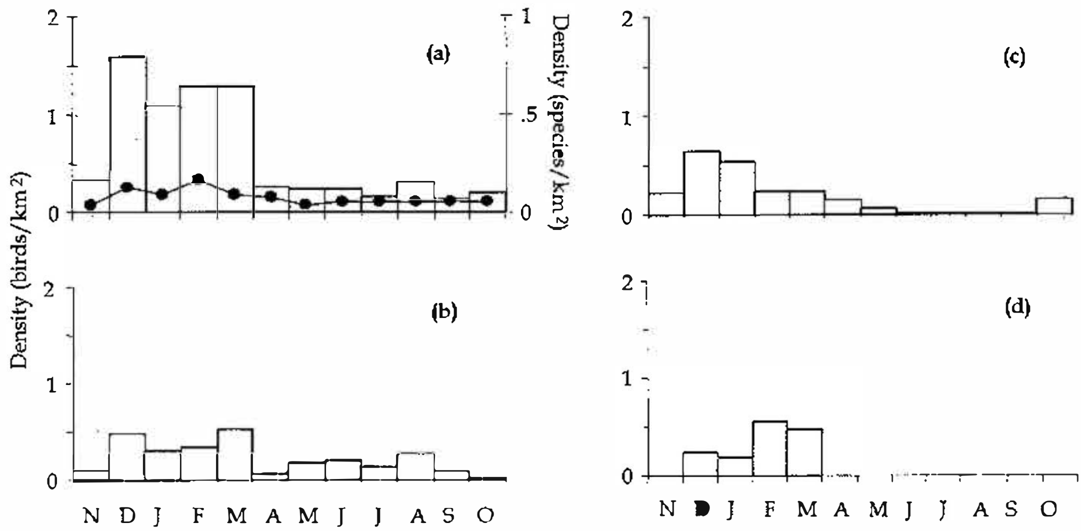

Figure 2. Density of birds (column) and species (line) observed at El Playón de Mismaloya. (a)=total, (b)=crested caracara, (c)=osprey, and (d)=American kestrel.

birds/km^2) (Fig. 2d).

At El Tamarindo the highest density of birds and species was observed during the autumn and winter, from November to February. Maximum raptor density observed was in December (0. 6 birds/km^2) and January (0.53 birds/km^2) (Fig. 3a). The species with the greatest population density observed was the gray hawk, detected in May and from September through February (frequency =70%), with a maximum observed density of 0.23 birds/ km^2 in December (Fig. 3b).

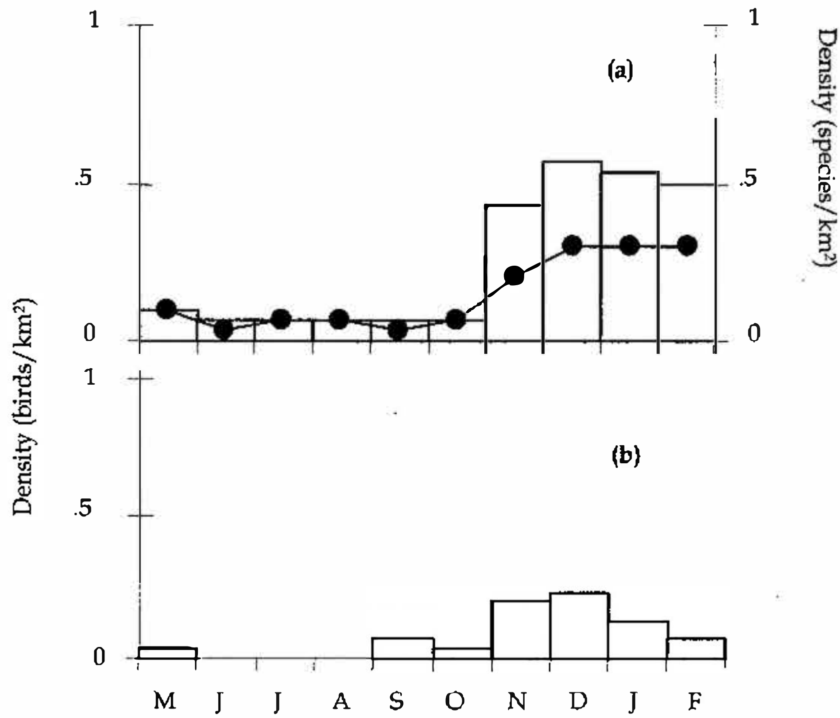

Figure 3. Density of birds (column) and species (line) observed at La Península El Tamarindo. (a)=total, (b)=gray hawk.

Spatial variation

At El Playón de Mismaloya the most observed raptors were registered in open areas, such as xerophytic scrub (81 observations), beach (78 observations), sand dunes (58 observations), and cultivated areas (50 observations). Crested caracaras were recorded resting on the ground most frequently in xerophytic scrub (37 observations), sand dunes (23 observations), sandy plains (20 observations), and on the beach (15 observations). They were observed feeding most frequently on the beach (45 observations) and sand dunes (10 observations). Resting ospreys were detected principally perched on xerophytic scrub (27 observations), tropical deciduous forest (13 observations) and mangrove (12 observations). Feeding ospreys were typically in wetlands (58 observations), and at the beach (16 observations). The American kestrel was observed only on perches in cultivate areas (crop fields and pastures) (42 observations), sand dunes (25 observations), and xerophytic scrub (12 observations). All other species (northern Harrier, sharp-shinned hawk, Cooper's hawk, common black-hawk, roadside hawk, red-tailed hawk, merlin and peregrine falcon) were observed too rarely to detect clear patterns of habitat occurrence (Table 2).

Table 2. Numbers of diurnal raptors observed in habitat types and activity at *Playón de* Mismaloya. TD=tropical deciduous forest, MA=mangrove, XS=xerophytic scrub, SD=sand dunes, CA=cultivated areas, SP=sandy plains, BE=beach, WE=wetlands.

common name	repose								feeding							
	TD	MA	XS	SD	CA	SP	BE	WE	TD	MA	XS	SD	CA	SP	BE	WE
osprey	13	12	27	-	0	0	0	0	0	0	0	0	0	0	16	58
northern Harrier	7	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0
sharp-shinned hawk	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooper's hawk	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
common black-hawk	1	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0
roadside hawk	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
red-tailed hawk	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
crested caracara	0	0	37	23	0	20	15	0	0	0	0	10	0	0	45	0
American kestrel	0	0	12	25	42	0	0	0	0	0	0	0	0	0	0	0
merlin	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
peregrine falcon	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
Total	25	17	81	48	50	20	17	0	1	0	0	10	0	0	61	61

At El Tamarindo the most observed raptors were registered in the tropical semideciduous forest (58 observations), the beach (19 observations), and the palm groves (11 observations). In this place the most abundant species was the gray hawk. All birds of this species were observed resting on perches in the forest canopy (18 observations), and in palm groves (6). All other species were observed mainly resting in trees of the forest, palm groves, secondary vegetation, and in the beach. All 7 osprey observations were of individuals perched at the beach (Table 3).

Table 3. Numbers of diurnal raptors observed in habitat types and activity at *El Tamarindo*. PG=palm groves, TS=tropical semideciduous forest, SV=secondary vegetation, GC=golf course, BE=beach.

common name	repose					feeding				
	PG	TS	SV	GC	BE	PG	TS	SV	GC	BE
osprey	0	0	0	0	7	0	0	0	0	0
hook-billed kite	0	3	0	0	0	0	0	0	0	0
northern Harrier	0	6	0	0	0	0	0	0	0	0
crane hawk	0	1	0	0	0	0	0	0	0	0
gray hawk	6	18	0	0	0	0	0	0	0	0
common black-hawk	0	4	0	0	0	0	0	0	0	0
roadside hawk	0	3	0	0	0	0	0	0	0	0
short-tailed hawk	1	0	0	0	0	0	0	0	0	0
zone-tailed hawk	0	9	0	0	0	0	0	0	0	0
collared forest-falcon	4	2	0	0	0	0	0	0	0	0
crested caracara	0	0	0	2	3	0	0	0	0	4
laughing falcon	0	7	0	0	0	0	0	0	0	0
American kestrel	0	0	1	0	3	0	0	0	0	0
peregrine falcon	0	4	1	0	0	0	1	0	0	0
Total	11	57	2	2	13	0	1	0	0	4

DISCUSSION

Species composition and total numbers of birds

The 18 species identified in the two study areas combined represent about 35% of all diurnal birds of prey for México and 72% of diurnal birds of prey known from the coast of Jalisco (Howell and Webb 1995). Of the total 18 species, 9 (50%) are listed as species of concern, 5 at El Playón de Mismaloya and 6 at El Tamarindo (CIPAMEX 1989, Ceballos and Márquez 2000, NOM-059-ECOL-2001). Although it is difficult to determine exactly all the reasons why these species are threatened today (some impacts act in synergy), a significant contributing factor is habitat alteration or habitat loss (Bildstein *et al.* 1998, Lederle *et al.* 2000, Ceballos and Márquez 2000).

Higher density at El Playón de Mismaloya could be related to the habitat distribution and also the feeding habits of the most common observed species (see Johnsgard 1990). El Playón de Mismaloya and its surrounding area are characterized by open vegetation (e.g., cultivated areas, dunes, wetlands and beaches). In contrast, El Tamarindo is characterized by dense natural vegetation.

At El Playón de Mismaloya, open areas were preferred by some species, such as the crested caracara, American kestrel, and osprey, the latter associated with wetlands in particular. Open areas were often the result of human activity, and similar patterns have been reported in other studies (e.g., Beauvais and Enderson 1992, Donázar *et al.* 1993, Hernández-Vázquez *et al.* 2000). According to those studies, the highest raptor densities were associated with a few vegetation types or areas affected by human activities, for example cultivated areas or trails. These same studies argue that the high concentration of posts are located in the boundary of these sites, it's an important factor which was influenced by the high concentration of birds in this area. It is also possible that the low numbers of raptors observed at El Tamarindo were due to the greater difficulty of detecting birds in forests compared to open areas (Meyburg and Van Balen 1994, Thiollay 1994). At that location, raptor abundance was likely underestimated.

Seasonal patterns

The high density of birds and species was in part due to an influx of migratory species and individuals during the winter (December to March). Migratory species that contributed substantially to higher raptor densities were the osprey and the American kestrel at El Playón de Mismaloya, and the gray hawk at El Tamarindo. Although the crested caracara and the gray hawk are considered resident species along the coast of Jalisco (Howell and Webb 1995), their populations increased during the winter, suggesting an influx of migratory individuals. For these two species, migrations are suspected with concentration of more inland populations along the coast during the winter (Hernández-Vázquez *et al.* 2000). However, more specific studies are required to confirm migratory movements.

Spatial variation

Differences in densities of birds between El Playón de Mismaloya and El Tamarindo could be related to habitat differences, as it was demonstrated that more complex, heterogeneous habitats support larger bird populations (Tomoff 1974, Blondel 1985). El Tamarindo is privately-owned and characterized by forest, the only open area consisting of a golf course. The lack of open areas plus the scarcity of wetlands could explain the observed low density of some raptor species by comparison with El Playón de Mismaloya, where both wetlands and open areas are common.

Crested caracara, osprey, and American kestrel were the most abundant species at El Playón de Mismaloya (150, 126 and 79 observations, respectively). The crested caracara was frequently observed resting on xerophytic scrub and sand dunes, and feeding on the beach. Johnsgard (1990) mentions that this species, which does eat carrion but prefers to hunt, is associated with open fields, where it relies on a large variety of prey. During this study it was observed attacking a snowy egret (*Egretta thula*) on the beach.

Osprey rely almost exclusively on fish for their diet (Johnsgard 1990, Howell and Webb 1995), and in this study they were observed fishing in lagoons and estuaries. When ospreys were not feeding or hunting they were observed perched on high tree branches, with a clear view of their fishing grounds (see Schnell 1968). The absence of wetlands at El Tamarindo may explain in part why ospreys were not any more abundant at that location. All seven observations of ospreys at El Tamarindo were at the small beaches of this area.

The American kestrel is a small raptor and, as is typical for this species (Johnsgard 1990, Howell and Webb 1995, Eakle *et al.* 1997), was found more frequently in open areas such as crop fields, and sand dunes. For the species, detection of prey taking refuge among the vegetation is easier in open habitats (Johnsgard 1990, Howell and Webb 1995, Eakle *et al.* 1997). A study conducted by Sarano and Gubanich (1995) indicated that the American kestrel chooses its preys based on activity rather than size. With its open vegetation, El Playón de Mismaloya provides suitable foraging grounds for the American kestrel, which was observed typically on low perches (<4 m height) such as trees, electrical wires, and vegetation, and less frequently hovering in midair. Schnell (1968) mentions that the American kestrel can hover due to its small body weight; hovering allows the American kestrel to watch more closely its potential prey, and perches are used only for resting.

At El Tamarindo the gray hawk was the most frequently observed raptor. In contrast to the species mentioned above, it was associated more with wooded areas. Johnsgard (1990) mentions that the gray hawk does indeed prefer wooded areas, where it perches in the foliage to watch and listen for prey (consisting of small vertebrates, such as mammals, snakes, birds) in nearby trees or on the ground. In the majority of cases the gray hawk, and also the zone-tailed hawk, northern Harrier, and peregrine falcon were observed at the top of trees adjacent to the golf course. Once again, use of such situated perches presumably allowed these raptors to scan their surroundings easily, as they searched for prey such as mice or snakes. Hunting on the wing also would be easy on the golf course, due to the lack of dense vegetation.

CONCLUSION

Studies comparing the raptor communities of two or more sites help us understand distribution patterns and habitat associations and use. In this study, the impact of human activities was not evaluated. As mentioned earlier, habitat loss and degradation are negatively affecting many raptor species, and although our results suggest raptor densities were highest in areas altered by humans (e.g., crop fields at El Playón de Mismaloya), such results were driven largely by the dominance of the crested caracara and the American kestrel, two species benefiting from human activities opening up habitat. Further research is needed to investigate anthropogenic impacts on raptors (especially those listed as conservation sensitive) in the two study areas, and more generally along the coast of Jalisco.

ACKNOWLEDGEMENTS

This work was funded by the Centro Universitario de la Costa Sur, Universidad de Guadalajara, El Tamarindo Foundation, and CONABIO. My thanks to R. Rodríguez-Estrella for his valuable comments to improve this document. To Francisco Ramírez, R. Esparza Salas, C. Valadez González, F. Alvarado Rámos and B. Durand Martínez for their support in the field work. I am grateful to Edgar

Minervini and Nathalie Dolgushkin for their translation from Spanish to English. J-L. Cartron and editorial staff of CIBNOR greatly improved the English. J.-L. Cartron and two anonymous reviewers improved this chapter.

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Spatial analysis of landscape diversity for the aplomado falcon (*Falco femoralis septentrionalis*) in northern México

Elsa Margarita Zamarrón Rodríguez
Alberto Lafón Terrazas

ABSTRACT

The aplomado falcon in northern Chihuahua is listed as an endangered species in México and the United States, yet is rarely studied. It has a limited distribution, but according to the literature, its presence is associated more closely with the spatial arrangement of different vegetation types and soils than with the attributes of the vegetation. Our objective was to determine distributions of soil and vegetation types within its local habitat through satellite imagery. The 41 sites were classified according to observed activities during field work, of which 23 were perching sites and 18 were nesting sites in the municipalities (counties) of Buenaventura, Coyame, and Villa Ahumada in Chihuahua. According to analysis of the satellite imagery, the aplomado falcon landscape in the nest and perch territories is mostly heterogeneous and diverse as a consequence of the number of uses and varied patch patterns. The small and large patches of pasture and original habitat caused by fragmentation, creates contact conditions of different land uses at boundary edges and a great habitat diversity. We concluded that the presence of the aplomado falcon

is related to the spatial arrangement of the multitude of types of vegetation.

The combination of proportions of each land use show how the development in land use has been. Continued research is needed to develop a useful method to quantify changes in landscape patterns and to give an ecological meaning to the index value in relation to the process of changing patterns.

Key words: aplomado falcon, spatial analysis, nesting and perch sites, Chihuahua, México.

RESUMEN

El halcón fajado (*Falco femoralis*) presente en el norte de Chihuahua, se encuentra considerado como en peligro de extinción en México y EEUU aunque ha sido raramente estudiado. Tiene una distribución limitada pero se sabe que su presencia se asocia con el arreglo espacial de los tipos de vegetación y suelos. El objetivo de este trabajo fue determinar las distribuciones de los tipos de suelo y vegetación dentro del hábitat halcón fajado el área de estudio a través de imágenes de satélite. Fueron clasificados 41 sitios de acuerdo a las actividades observadas de los halcones individualmente, de los cuales 23 fueron clasificados como sitios de percheo, y 18 como sitios de anidación en los municipios de Buenaventura, Coyame, y Villa Ahumada en Chihuahua. De acuerdo a los análisis con las imágenes de satélite, el paisaje en los sitios de nidos y territorios de percheo del halcón fajado es heterogéneo y diverso, lo cual es consecuencia del número de usos y la variedad de patrones de

distribución que tienen los parches de hábitat. Los parches pequeños y grandes de pastizal original resultantes del proceso de fragmentación, crean condiciones de contacto entre diferentes áreas y tipos de hábitat con usos de la tierra diversos, lo que genera en los bordes una gran diversidad de tipos de hábitats que son utilizados por el halcón. Se concluye que la presencia del halcón fajado en el área de estudio se relaciona con el arreglo espacial de la gran diversidad de tipos de vegetación. Los índices empleados fueron considerados en diferentes combinaciones. La combinación de la proporción de cada uso de tierra muestra la forma en que han cambiado los usos de la tierra. Se requiere investigación para desarrollar un método que cuantifique los cambios en los patrones del paisaje.

INTRODUCTION

Grasslands are the main natural resource for cattle ranching in Chihuahua, México. Overgrazing by cattle over many years and droughts have degraded extensive areas in this vegetation type. Additionally, agricultural expansion with subsequent drought has led to abandonment of fields and the loss of wildlife habitat, leaving these fragmented areas reduced to small patches or native vegetation islands surrounded by diverse forms of land use. Understanding how species respond to habitat fragmentation can determine the way a species population can be managed, either as separated evolutionary units or as a single meta-population. Patches of habitat components can be of diverse sizes and types, such as reduced in size, isolated, connected by narrow corridors, marginal in composition, or different in quality.

The subspecies of the aplomado falcon *Falco femoralis septentrionalis* existing in the state of Chihuahua was, in 1986, placed on the endangered list in the United States; the main cause for its population decline is the agro-chemicals used in northern México. Since May 16, 1994, this bird has been listed as an endangered species by the Mexican government.

The reports of sightings in Chihuahua brought the attention of the Land Management Bureau of the United States and New Mexico State University, providing funds to the Universidad Autónoma de Chihuahua for studies of population distribution in northern Chihuahua and its habitat.

Initially, we found a lack of information about the habitats that are used by aplomado falcons in Chihuahua. We found necessary to quantify changes in patterns of vegetation to understand the ecological dynamics occurring in the predominantly grassland ecosystem. Quantification can be accomplished from several different approaches: 1-describe qualitative changes and assign numerical values, 2- map and graph patterns and assign numerical values, and 3- apply indices to create categories. This last method has been recently developed and provides an opportunity to statistically compare patterns at different scales (Zarate 1995).

The indices used in this study test the hypothesis that the occurrence of aplomado falcons in certain areas is in function of the spatial arrangement of types of vegetation. Our objectives were 1. to analyze landscape diversity inside the falcon's current home range through satellite imagery; and 2. to determine the presence of the species as a function of the distribution of patches in terms of several indices related to components of the habitats.

STUDY AREA

This area is located in the central zone in the state of Chihuahua in the municipalities of Coyame, Villahumada, and Buenaventura (Fig. 1.). This region is a landscape of widely spaced small mountain ranges and intervening plains, with local relief less than 150 m. The arid plains (bolsons) are gently sloping internal basins between the ranges that have central area of saline and clay soils, marshes, and small, ephemeral ponds. The numerous mountains are long and narrow, oriented northwest to southeast; some more than 100 km long and a width rarely exceeding 15 km (Cárdenas 1994).

This region is dry and temperate. Summers have 120 to 150 mm precipitation and winters have less than 12 cm. Annual precipitation varies between 200 and 300 mm and occurs primarily in a period of 40 to 60 days during the summer. Average annual temperature in the valleys and desert fluctuate between 16°C and 22°C, respectively, with extreme seasonal variations. All climates are arid and semi-arid (BSk and BWh) in low altitude and moderate altitude variations(García 1973).

METHODS

Geographic Information Systems

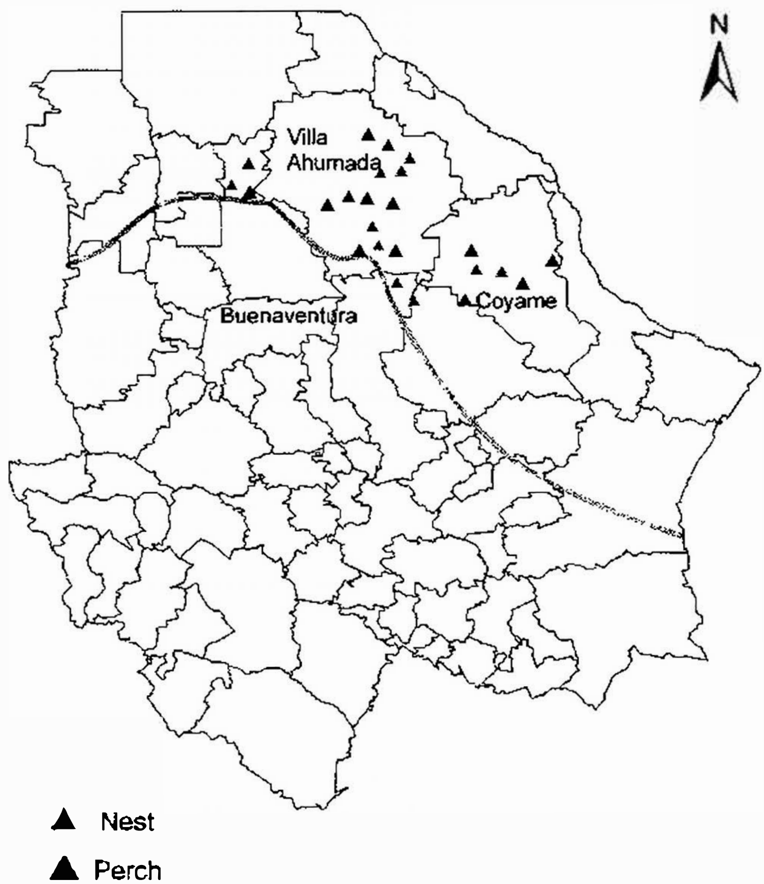

Figure 1. Location of nest and perch sites of aplomado falcon in the state of Chihuahua, México.

METHODS

Geographic Information Systems

To evaluate habitat diversity in the areas of perching and nesting aplomado falcons, we used satellite images TM10 from 1999, scenes 3233 and 3333; bands 3, 4, and 5 with a resolution of 25 m. We also used 20 topographic maps (scale 1:50,000) prepared by INEGI.

The study started with classification of the imagery with the program IDRISI, v. 2; the steps in this procedure were: documentation, compositing in false color, and re-sampling adjustments in a linear format. The images were modified with a 5×5 mode filter, from which the classification was made.

Sightings of aplomado falcons were located by UTM coordinates. The UTM positions were modified for the projection; the program ArcInfo™ (ESRI, Redlands, CA) converted the positions to decimal degrees. With each site located, the program ArcView™ v. 3.2 (ESRI, Redlands, CA) defined a buffer zone of 4 km to represent the home range of individuals. Each buffer represented a 160×160-pixel matrix. These buffers were imported to IDRISI. v. 2 to locate the buffer zones within each satellite image, obtaining 41 vector-formatted maps. Finally, each vector-formatted map was converted to a raster-formatted map with IDRISI. These processes created maps and data for spatial analysis (Zarate 1995).

Spatial Analysis

The raster-formatted images of each site were analyzed with programs (SCANNER, ANES, and DIPA) for spatial analysis developed by Zarate (1995). The program was performed in Fortran 77 and processed the raster images. The results are the indices we estimated.

These programs analyze a matrix where each cell corresponds to the image pixels. The results are transferred to the landscape level by a diversity index considering boundary equitability, heterogeneity, dominance, and contagion indices. Structural elements of landscape were: number of patches, number of uses, and number of boundaries (O'Neill *et. al.* 1988, Reese and Ratti, 1988, Ritters *et al.* 1996, Rescia *et al.* 1997).

The indices of spatial diversity (boundary equitability, heterogeneity, dominance, and contagion) and the structure elements of the nest and perch areas were analyzed by descriptive statistics (mean, standard deviation, maxima, and minima).

Boundary equitably (BE) expresses the relative proportions in which types of boundaries are distributed along the landscape. This index can be used as a measure of the degree of landscape diversity. It takes values between 0 and 1, with values close to 1indicating greater spatial diversity. It is used to compares landscapes with different numbers of patches and land uses.

Heterogeneity (He) is used to measure the spatial complexity of landscapes.

Dominance (D) measures the extent to which one or a few types of land dominate the landscape (O'Neill *et al.* 1988).

The maximum diversity occurs when all land uses are present in equal proportions. If a value D approaches 1.0, it indicates that the landscape is dominated by one or a few uses. When a value D approaches 0.0, it indicates that many land uses occur in approximately the same proportions.

Contagion index (CI) measures the extent to which land uses are aggregated or clustered. At high CI values, contiguous patches are found in the study area. At low values, the landscape contains many small patches (O'Neill *et al.* 1988).

RESULTS AND DISCUSSION

Index of spatial diversity and structure characteristics of nests and perches

The study area included perch and nest sites (Fig. 1). It was observed that the changes in land use practices are the main cause of the habitat's structure impact, reflecting these effects in the size and form of the patches that compose it.

Montoya and Zwank (1995) maintain that grazing lands where aplomado falcons are located are historic areas. With this background, the habitat of the aplomado falcon has little spatial diversity, since the grazing lands contain little variation in the kind and distribution of land use.

Table 1 for nests and Table 2 for perches show that the averages of indices for the two types of sites are practically the same. The land use that has contributed the most to landscape diversity are the grazing lands because the area in the home range and the other types of vegetation and uses show probabilities of having boundaries (NB) with a higher number of uses in their temporal home range. These boundaries are important transition zones and produce relatively "adequate" habitats for wildlife. Hanen *et al.* (1988) pointed out that species diversity in an ecotone can be higher than in the adjacent patches.

The land uses that contribute less to spatial diversity are those that occupy the least area, as is the case for crop land, permanent and intermittent ponds, and water ditches. The dominance index (D) alone gives no information on which particular land use is dominant (Fig. 2).

Table 1. Indices of landscape diversity and structure of nest sites of the aplomado falcon in Chihuahua, México.

	diversity				structure		
	BE	He	D	CI	NP	NU	NB
$\bar{X}$	0.60	0.61	0.40	0.52	119.06	4.50	329.67
S.D.	0.05	0.05	0.13	0.11	43.33	1.15	146.10
Total	10.71	11.05	7.12	9.4	2143	81	5934
Min	0.46	0.52	0.2	0.32	53	3	108
Max	0.67	0.68	0.61	0.75	196	6	618

BE=Boundary equitably, He=Heterogeneity, D=Dominance, CI=Contagion Index, NP=Number of patches, NU=Number of uses, and NB=Number of boundaries.

Table 2. Indices of landscape diversity and structure of perch sites of the aplomado falcon in Chihuahua, México.

	diversity				structure		
	BE	He	D	CI	NP	NU	NB
$\bar{X}$	0.60	0.62	0.38	0.52	131.61	4.57	383.13
S.D.	0.06	0.06	0.12	0.10	49.53	0.95	174.62
Total	13.79	14.25	8.78	11.97	3027	105	8812
Min.	0.45	0.47	0.07	0.33	45	3	114
Max.	0.67	0.7	0.57	0.69	207	6	712

BE=Boundary equitably, He=Heterogeneity, D=Dominance, CI=Contagion index, NP=Number of patches, NU=Number of uses, and NB=Number of boundaries.

Presence of the aplomado falcon at selected sites

Aplomado falcons were found in areas with a mix of vegetation types, of varying match sizes, small and large. Forman and Gordon (1986) point out that this set of conditions favor a stable balance between interior and boundary species, which increases the possibility of a population's survival. The large areas have more vertebrate species, probably due to an increase of habitat heterogeneity. It seems that any increase in species number or trophic richness results from increased habitat structural complexity than by the size of the patch. Thus, this condition favors the presence of birds on grazing lands, prey of the aplomado falcon.

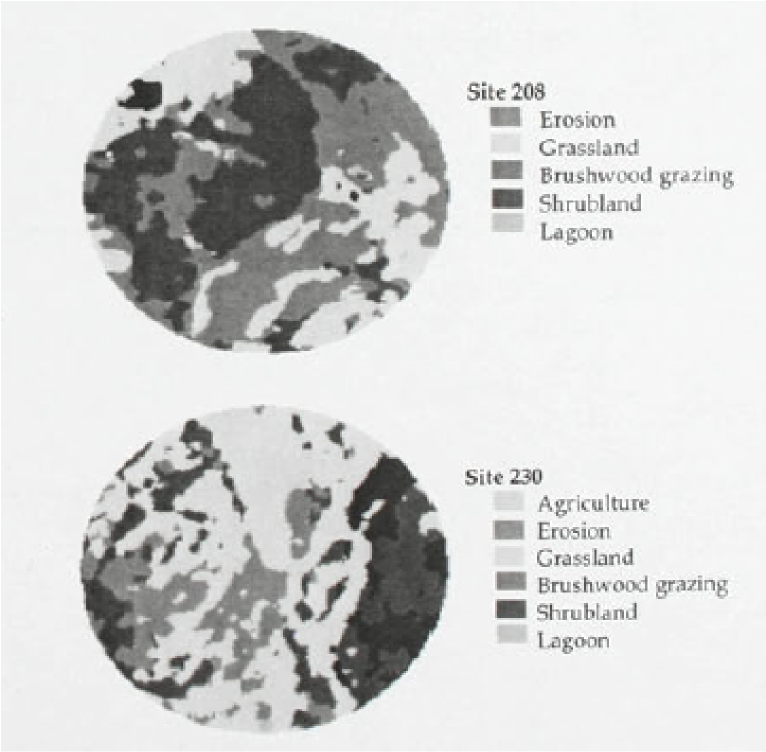

Figure 2. Examples of vegetation patches and configuration of observed sites.

Most sightings of aplomado falcons were on private lands where grazing conditions were ranked as regular and good (COTECOCA 1978). This habitat, with time, usually increases the number of uses (NU), in this case, erosion and reduction of vegetation class (grazing lands). As a consequence, this increases the other landscape indices.

Spatial diversity surrounding nest and perch sites are practically the same (Tables 1 and 2). Of the indices measuring spatial diversity, some indices are more sensitive to subtle differences than others. A better understanding of landscape changes require the analysis of sites in the past to the present with the He index as an measure of landscape heterogeneity, CI as an measure of fragmentation, and NU as a measure of the changes of natural grazing lands to new land uses and types of vegetation through natural succession. The present study is considered as the baseline year to understand landscape dynamics in the future as it concerns the maintenance of aplomado falcon populations.

CONCLUSIONS

Fragmentation of patches of similar and different habitats and a concomitant increase in the number of ecotones between land uses in ongoing. For a good understanding of the ecological consequences of changes in this landscape, it is necessary to describe the current pattern using suitable indices.

Additionally, the indices do not give enough information on changes in the geographical location of the patches, and several indices have to be considered in combination with others to provide meaningful information. For example, the conditions at nest and perch sites are generally heterogeneous because the number of land uses and quantity of perches favor contacts with diverse numbers of boundaries types (ecotones). Also, perches close to different land uses favor a greater variety of microhabitats, microclimates, and the possibility of protective features for predators.

The results of this study indicate that area around nest and perch sites of aplomado falcons are heterogeneous. It could be that aplomado falcons exploit frequently the ecotones where a great array of prey can be found. We propose a study to clarify the use of ecotones by aplomado falcons, as the great diversity of species located in the ecotones than in the central habitat areas or patches indicates that it can be happening.

The index method permits the analysis of changes in the habitats of aplomado falcon from previous years through the uses of satellite images and can show changes that can suggest strategies for aplomado falcon conservation and management.

ACKNOWLEDGMENTS

ALT would like to express his gratitud to BLM in New Mexico for the support. We also thank: New Mexico State University, Environmental and Natural Resources Secretary (SEMARNAT), University of Chihuahua, Ranch Owner. Thanks to Alejandro Zarate, Alicia Melgoza, Jorge Jiménez, and Felipe Rodríguez.

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Ecology and population status of ospreys (*Pandion haliaetus*) in coastal Sonora

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Tad A. Pfister

ABSTRACT

Osprey (*Pandion haliaetus*) population status, productivity, and diet have been documented recently in coastal Sonora. Here, we expand on this previous work and provide new information on the local ecology, distribution, and nesting success of the species. During foraging bouts, ospreys experience low (14%-31%) dive success along the mainland, with successful dives initiated from significantly lower heights than unsuccessful dives. Along Bahía Sargento nesting pairs resort partially to perch-hunting, a technique rarely documented for the species. Both low dive success and perch-hunting may be the result of a diet rich in needlefish (*Strongylura* and/or *Tylosurus* spp.). As piscivorous fish, needlefish are probably elusive prey for ospreys hunting on the wing. At the same time, they frequently swim to the edge of the water, where they may be more vulnerable to ospreys sallying out from a vantage point on the beach. A population survey conducted in 1998 along a >100-km stretch of the mainland coast and on four offshore islands found high densities of nesting pairs in particular on Isla Turner and Roca Foca (20 nests on cliffs); the Bahía

Kino and Estero La Cruz area (23 nests on cardons and utility poles); Bahía Sargento (18 nests on cardons); an approximately 4-km stretch of shoreline between El Desemboque and the mouth of the Río San Ignacio (11 nests on cardons, 1 nest on a tower); and the Valle de las Aguilillas along the eastern shore of Isla Tiburón (12 occupied nests on cardons along a 2 km-transect). In 1998, only 17 (29%) of 58 nesting pairs on the mainland succeeded in producing fledglings. Mean productivity of nesting pairs was 0.48. It tended to conform to the low productivity levels observed during the previous two years. However, reproductive success during the 1990s is difficult to interpret, as it was characterized by very high inter-annual and spatial variation. Potential threats to the osprey in coastal Sonora include overfishing in the Gulf of California, human disturbance near nest sites, and electrocutions on power poles.

Key words: dive success, Gulf of California, México, osprey, *Pandion haliaetus*, perch-hunting, population status, productivity, Sonora.

RESUMEN

La situación poblacional, la productividad y la dieta del águila pescadora (*Pandion haliaetus*) ha sido documentada recientemente en la costa de Sonora. Aquí, se da mayor información sobre estos tópicos así como sobre la ecología y estatus poblacional de la especie en la localidad. Durante el forrajeo, las águilas pescadoras tienen un éxito de pesca bajo (14-31%) a lo largo de la costa, siendo exitosos aquellas

picadas iniciados a alturas significativamente más bajas que aquellos picados no exitosos. A lo largo de Bahía Sargento las parejas reproductivas utilizan la técnica de percheo para caza, una técnica poco documentada para la especie. Tanto el bajo éxito de picada como el percheo para caza pueden ser el resultado de una dieta rica en pez aguja (*Strongylura* y/o *Tylosurus* spp.). Dada su condición de predador de otros peces, los peces aguja son probablemente presas elusivas para el águila pescadora. Al mismo tiempo, estos peces frecuentemente nadan sobre la orilla del agua donde son más vulnerables a las águilas que cazan desde perchas cercanas a la playa. En un muestreo poblacional en 1998 a lo largo de una franja >100 km de la costa continental y en 4 islas se encontraron altas densidades de parejas anidantes en particular en Isla Turner y Roca Foca (20 nidos en los acantilados); el área de Bahía Kino y Estero La Cruz (con 23 nidos en cardones y postes eléctricos); Bahía Sargento (18 nidos en cardones), y en una franja de aproximadamente 4-km de la línea costera entre El Desemboque y la boca del Río San Ignacio (11 nidos en cardones, 1 nido en una torre); el Valle de la Aguilillas a lo largo de la costa este de Isla Tiburón (12 nidos ocupados en cardones a lo largo de un transecto de 2 km). En 1998, solo 17 (29%) de los 58 nidos seguidos en el continente fueron exitosos en la liberación de volantones. La productividad promedio de las parejas anidantes fue de 0.48. La tendencia en la baja productividad detectada durante los 2 años previos se mantuvo. Sin embargo, el éxito reproductivo durante los 1990s es difícil de interpretar debido a que se caracterizó por una muy alta variabilidad espacial e interanual. Las amenazas potenciales al águila pescadora en la costa de Sonora incluyen la sobrepesca en el Golfo de California, el disturbio por humanos en las cercanías de los nidos y la electrocución en tendidos eléctricos, en los postes.

INTRODUCTION

The osprey (*Pandion haliaetus*) occurs throughout much of the world (Poole 1989). On the North American continent it breeds from Alaska and Canada south to Belize (Poole 1989, Howell and Webb 1995), with a large year-round resident population found along the Pacific coast of Baja California and along the coastline of the Gulf of California in northwestern México (Henny and Anderson 1979, 2004).

Most of the published literature on Mexican ospreys has focused on the Baja California peninsula and its coastal islands (e.g., Gaylord 1897, Grinnell 1928, Kenyon 1947, Jehl 1977, Reitherman and Storrer 1981, 1982, Judge 1983, Danemann and Guzmán Poo 1992, Castellanos and Ortega-Rubio 1995). By comparison, the amount of information available on this species has been more limited for coastal Sonora. The naturalist and explorer Charles Sheldon spent several months there in the early 1920s, but he mentions ospreys only briefly in his diary (see Carmony and Brown 1993). Van Rossem (1932) reported ospreys nesting on Isla Tiburón, but gave no quantitative estimate of the number of pairs. Like Van Rossem before him, Wauer (1999) surveyed the avifauna of Isla Tiburón, in 1978. The note he published based on his survey (Wauer 1980) is an interesting yet anecdotal observation on the nesting ecology of the osprey. Among other observations of breeding waterbirds, Mellink and Palacios (1993) reported osprey nests on utility poles in northwestern Sonora. Russell and Monson (1998) provided a short species account for the osprey in *The Birds of Sonora*, but with little new information. Cartron (2000) reported numbers of osprey nesting pairs and productivity from 1992 through 1997, from Punta Santa Rosa north to the mouth of the Río San Ignacio on the mainland (Fig. 1). In addition, Cartron and Molles (2002) documented the diet of ospreys in that same area during the 1995 and 1996 nesting seasons.

To date, the most important body of information on the population status, distribution, and nesting ecology of ospreys in Sonora has originated from two surveys by Henny and Anderson (1979, 2004), conducted in 1977 and 1992-1993 (coastal Sonora was surveyed in 1993) at the scale of the entire Gulf of California and Baja California region. Henny and Anderson (2004) compared the distribution of nesting pairs and population levels between 1977 and 1992-1993. They also addressed the issue of deriving accurate estimates of nesting population numbers from a one-time survey of a non-synchronized breeding population (an attempt was made to account for those pairs that failed before the 1992-1993 survey or started after the survey -the same adjustment was also made to the earlier 1977 data; see further on).

Regrettably, additional information that was gathered on the osprey of Sonora has remained unavailable or difficult to find. Frederick and Frances Hamerstrom monitored osprey nests near El Desemboque through much of the 1960s and 1970s (H. McGavran Corneli, pers. comm.). Although they presented an aspect of their work at a Raptor Research Foundation symposium in 1985, they never formally published the results of their work. As part of his Ph.D., Charles P. Schaadt (1989) studied ospreys near El Desemboque and at Punta Baja in 1985 and 1987. His dissertation reports several findings about the breeding biology and growth and development of Sonoran ospreys. Schaadt also mentions local numbers of occupied nests found during his two field seasons, but his work remains generally unknown of biologists working on ospreys in México. Sommer studied osprey foraging at Punta La Ona in 1986, but his work has remained unpublished until now. The results of two detailed ground surveys conducted by Charles J. Henny and Daniel W. Anderson in the Bahía Kino area have remained unpublished (D. W. Anderson, pers. comm.).

The main general objective of this chapter is to add to the amount of published information on ospreys in costal Sonora, for use in future studies. Based on research by us, we present here a compilation of data on osprey foraging, distribution, and productivity in the region. Results are discussed within the context of information already available from previous studies.

METHODS

Study area

The study area was located along the eastern side of the Gulf of California, in Sonora, México (Fig. 1). It encompassed a >100-km stretch of coast on the mainland from Estero La Cruz north to the vicinity of Cerro El Puerto, 5 km north of the mouth of the Río San Ignacio. Population surveys (see further on) were also conducted along the coasts of four offshore islands, Isla Tiburón, Isla San Esteban, Isla Turner (Dátil), and Roca Foca (Isla Cholludo).

Overall, the mainland coast is characterized by extensive sandy beaches along shallow bays. Beyond the beaches, the landscape supports a lush desert vegetation dominated by arborescent shrubs and cacti. Punta Tepopa is a rocky headland continued to the north by a steeply sloping pebble beach. Along Bahía Sargento and just south of El Desemboque, the beach abuts sand cliffs. There are also several negative estuaries (estuaries fed only by tidal waters, also called esteros) lined by mangroves, the largest one being Estero La Cruz at the resort town of Bahía Kino. Finally, two Seri Indian villages are located in the study area. One is Punta Chueca, the other El Desemboque, just south of the intermittent Río San Ignacio.

With an area of 1,208 km2, Isla Tiburón is the largest island in the Gulf of California. It is separated from the mainland by a narrow channel, the Canal del Infiernillo. The western coast and part of the southern coast are characterized by rocky cliffs. In contrast, the eastern and northern shorelines consist mainly of sandy beaches like the mainland. East of the Sierra Kun Kaak in the northeastern part of Isla Tiburón is a coastal plain known as the Valle de las Aguilillas, characterized by tall desert vegetation. The other three islands included in the study area are located off

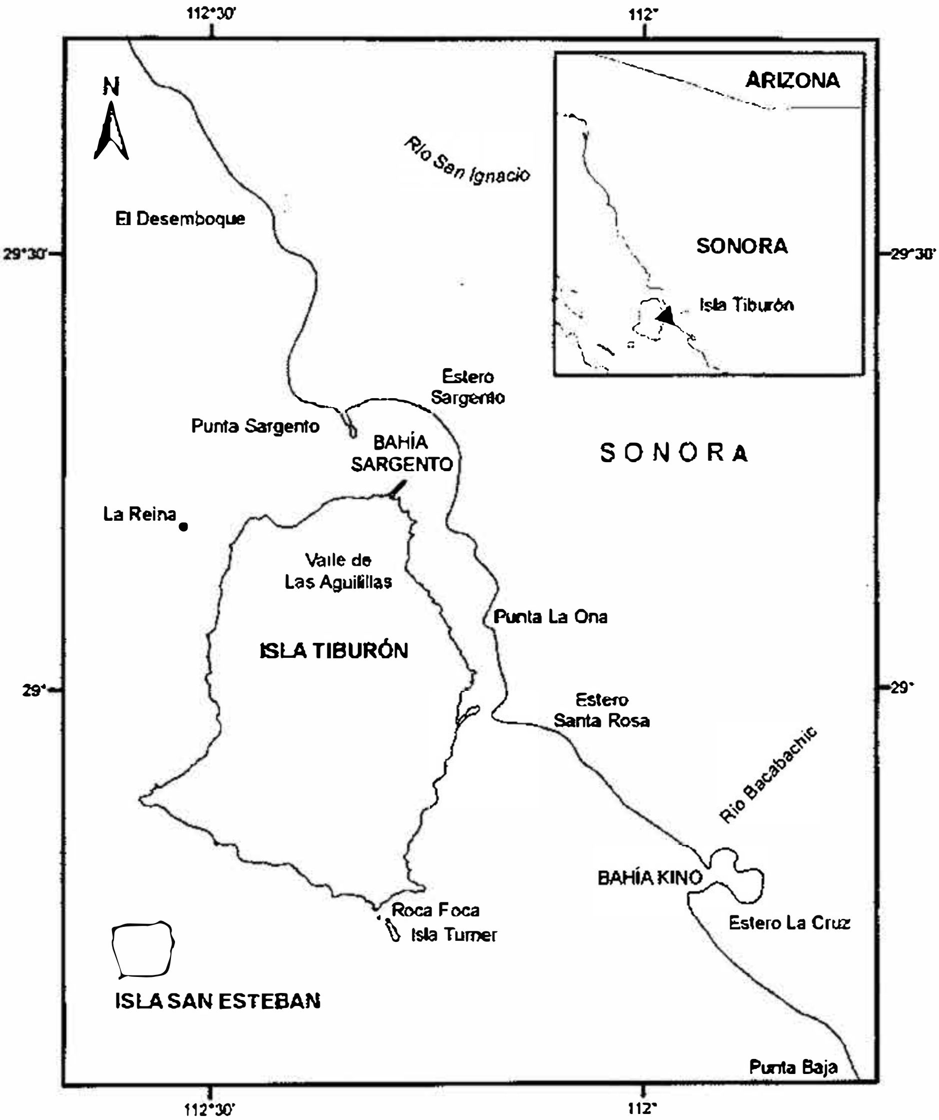

Figure 1. Study area (mainland and offshore islands). Research on the mainland included studies of osprey foraging at Punta La Ona and Bahía Sargento in 1986 and 1992-1995, respectively; nest monitoring in 1998; and osprey population surveys on the mainland and offshore islands in 1998. Osprey surveys were conducted on the mainland from Estero La Cruz north beyond the Río San Ignacio to the vicinity of Cerro El Puerto. Surveys were also conducted along the shoreline of four islands, including Isla San Esteban, Isla Turner, and Roca Foca. Only a portion of Isla Tiburón's shoreline was surveyed: the south side of the island and the western shore north to a point opposite the offshore rock La Reina. On the east side of the island, and towards its northern end, a location known as the Valle de las Aguilillas was visited.

the southern side of Isla Tiburón. Isla San Esteban is a 43 km^2 island with much of its shoreline consisting of sea cliffs. The other two islands are smaller. Their shorelines are dominated by the presence of sea cliffs.

Data on foraging

Data on foraging at Punta La Ona and along Bahía Sargento are from Sommer and Cartron, respectively. At Punta La Ona, osprey activity was observed daily from 07:00 to 18:00, March 14 to March 23, 1986. Ospreys were watched from an observation point that permitted a complete view of the small bays and shoreline to the north and south of Punta La Ona. Osprey activity was monitored by two to four observers with 7 x 35 binoculars. Individual (foraging and non-foraging) birds were watched from the moment they were first detected until they flew out of range. Species of captured prey were identified by their silhouettes. The numbers of successful, unsuccessful, and aborted dives were recorded, as were several parameters associated with foraging bouts, including time of day, search pattern (i.e., circular *vs.* non-circular), height of flight, wind speed, wind direction, and distance to shore, determined with an anemometer and a range finder. The influence of these parameters on dive success was tested with one-way ANOVA and stepwise Discriminant Analysis.

At Bahía Sargento, Cartron observed foraging ospreys with 10 x 50 binoculars for a total of 27 hours from April 24 through April 29, 1992; 26 hours from May 18 through May 24, 1992; 18 hours from March 13 through March 24, 1994; and 9.5 hours from March 11 through March 17, 1995. Except for two full days of continuous observations in March 1992, foraging data were recorded primarily (but not exclusively) during the early morning. Here again, individual birds were watched from the moment they were first detected until they flew out of range. The numbers of successful, unsuccessful, and aborted dives were recorded.

Osprey population survey

In March and April 1998, Cartron, Kilpatrick, and Pfister conducted osprey population surveys on the mainland from Estero La Cruz to the vicinity of Cerro El Puerto (29°34.69 N; 112°27.08 W) north of the Río San Ignacio. These surveys were conducted on foot. Surveys were also conducted along the shorelines of Isla Tiburón, Isla Turner, Roca Foca, and Isla San Esteban. The survey of Isla Tiburón was only along the southern coastline, and along the western shore north to a point opposite the offshore rock La Reina (29°03.83 N 112°30.24). On March 19, 1998, we visited the Valle de las Aguilillas along the eastern side of Isla Tiburón. Although we did not conduct an extensive survey at that location, we recorded all occupied nests along an approximately 2 km north-south transect. Except for our visit to the Valle de las Aguilillas, all island surveys were conducted from a boat. A nest was recorded as occupied when we observed at least one adult standing or laying in it.

Nest monitoring

Nest monitoring during the 1998 nesting season was conducted on the mainland by Cartron and Kilpatrick. Monitoring began in January of that year and continued through late May. Using a pole-mounted mirror, clutch size was determined for only a subset of all the nests observed on the mainland. All methodology used for nest monitoring is described by Cartron (2000). Breeding pairs were said to be late if they produced a clutch after March 15, the approximate midpoint of the breeding season for most pairs.

RESULTS

Foraging

Ospreys observed in this study typically foraged on the wing. At Punta La Ona in 1986, 51 (68%) of 75 observed foraging bouts resulted in the capture of a fish. Of 187 observed completed dives, 53 (28%) were successful, with needlefish comprising 56% of the fish captured. Observations of ospreys foraging on the wing along Bahía Sargento indicated a similar or somewhat lower rate of success: 10 (20%) of 49 completed dives were successful in April 1992, with another 39 aborted dives observed. In May 1992, 8 (14%) of 56 completed dives were successful, with another 65 dives aborted. In March 1995, 8 (31%) of 26 observed completed dives were successful.

Time of day influenced patterns of osprey activity (Fig. 2). The proportion of observations of foraging ospreys *vs.* non-foraging ospreys varied significantly between morning, midday, and afternoon hours (χ^2=8.4, d.f.=2, *P*=0.015), with the proportion of non-foraging osprey observations highest during midday hours (i.e., 11:00 to 13:00, Fig. 2). Collectively, four variables were useful in distinguishing foraging bouts with dives from foraging bouts without dives (canonical r^2=0.192). Ospreys were more likely to dive if flying 1) early or late during the day (rather than around midday), 2) near shore, 3) at low average heights, and 4) while following a non-repetitive search pattern. Height of flight in particular was significantly lower during foraging bouts with dives (F=4.9, d.f.=1, *P*=0.03). Successful dives at Punta La Ona occurred from a mean height of 10.8 m, or significantly lower than the mean height (i.e., 33.4 m) recorded for unsuccessful dives (F=69.9, d.f.=1, *P*=0.0001).

At Bahía Sargento, the west-facing small cliffs lining up the beach served as vantage points for ospreys. From these cliffs, ospreys sallied straight out to the edge of the water in shallow dives. In April 1992, a total of 38 dives attempted from cliffs resulted in the capture of 8 fish (6 needlefish). There were 20 aborted dives and 10 completed dives that were unsuccessful, for an overall observed 44% success rate of completed dives. Perch-hunting was observed in all months from February through May (J.-L. Cartron, pers. obs.).

Estimate of population numbers during the 1998 nesting season

We found a total of 130 occupied nests in the study area in March and April 1998

(Table 1). On the mainland, the largest concentrations of occupied nests were observed in the Bahía Kino and Estero La Cruz area, along Bahía Sargento, and along a 4 km stretch of coast from El Desemboque north to the mouth of the Río San Ignacio. Ospreys nested on each of the four islands we surveyed. Although Isla Tiburón had the largest number of observed nests, it was on the two smallest islands (Isla Turner and Roca Foca) that the density of nests seemed generally highest. On Isla Tiburón, one location, the Valle de Las Aguilillas, seemingly harbored a high density of nesting pairs.

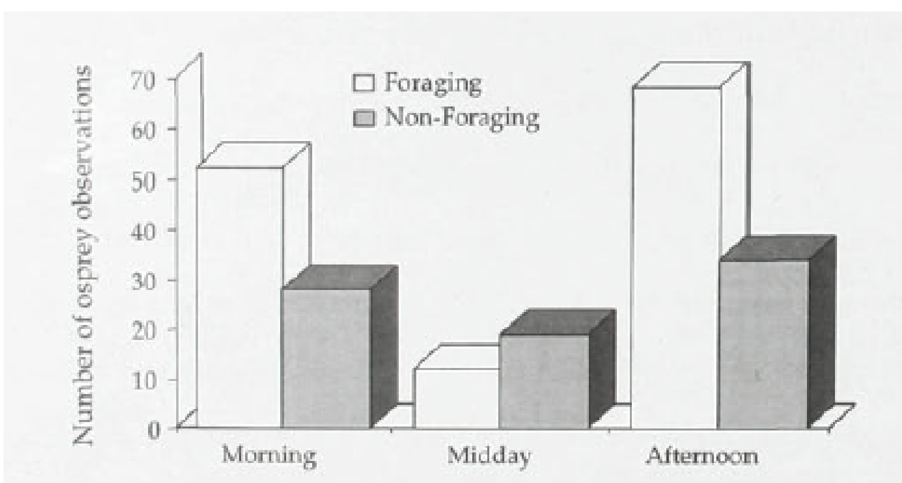

Figure 2. Total number of observations of foraging and non-foraging ospreys at Punta La Ona, March 14-23, 1986. Numbers of observations are reported for the morning hours (i.e., before 11:00), during midday (11:00 to 13:00), and in the afternoon (after 13:00). There was a significant difference in the number of observations of foraging ospreys vs. non-foraging ospreys across the different time periods (χ^2=8.38, d.f.=2, P=0.015). The midday hours were the only period during which most observations were of ospreys not foraging (i.e., ospreys were perched or flying over land).

Table 1. Observed numbers of occupied osprey nests during 1998 surveys. Occupied nests were those with at least one adult bird present.

location of survey	type of nest substrate		
	cliff	cardon	pole/tower
Mainland			
Bahía Kino and Estero La Cruz	--	15	8
Punta La Ona	--	1	--
Bahía Sargento	--	18	--
Punta Tepopa to El Desemboque	--	10	--
El Desemboque to the Río San Ignacio	--	11	1
Coast north of the Río San Ignacio	--	7	--
Roca Foca	5	--	--
Isla Turner	15	--	--
Isla Tiburón			
Southern coast	10	--	--
Western coast north to la Reina	7		
Valle de las Aguilillas [1]	--	12	--
Isla San Esteban	10	--	--
Total	47	74	9

[1] The survey of osprey nests at this location was limited to a south-north transect approximately 2 km long

Nests on the mainland were typically built on cardons (*Pachycereus pringlei*), while all insular nests –except along the eastern side of Isla Tiburón- were along rocky cliffs on emergent boulders, spires, or ledges. In the Valle de las Aguilillas, all 12 occupied nesrs were on cardons (all of these nests were active [i.e., with eggs or young] at the time of the survey).

Productivity during the 1998 nesting season

On the mainland we observed clutches as early as January, with only two late breeding pairs between Punta Santa Rosa and the Río San Ignacio. Two additional late pairs were observed, one north of the Río San Ignacio, the other in Bahía Kino. Between Punta Santa Rosa and the Río San Ignacio, the mean clutch size of 23 active nests was 2.96 (range=2-4). Not included in our calculation of mean clutch size was a nest built on a tower north of El Desemboque. This nest, which subsequently failed, held a total of 7 eggs on March 16 (possibly the result of two females having laid their eggs in that same nest).

Productivity on the mainland in 1998 is summarized in Table 2. Successful nests appeared spatially clumped along the mainland coast. From Mancha Blanca to the Río San Ignacio, 2 (10%) of 20 pairs succeeded in producing a total of 3 fledglings. This low proportion of successful nests contrasted with observed patterns north of the Río San Ignacio. Along Bahía Sargento, 6 (31%) of 19 nesting pairs were successful. Successful nests at this last location occurred in two clumps, each one composed of three nests spaced consecutively along the coast. Including nests with known reproductive outcome north of the mouth of the Río San Ignacio (n=6) and in Bahía Kino (n=13), 17 (29%) of 58 nesting pairs were successful on the mainland. Mean productivity was 0.48 fledglings/nesting pair during the 1998 nesting season, and the mean productivity of successful pairs (n=17) was 1.64.

DISCUSSION

Although much remains unknown about Sonoran ospreys, research by us and others has revealed important information on the local ecology and population status of the species. In mainland Sonora, ospreys nest on cardons, saguaros, cliffs, utility poles, and towers (Henny and Anderson 1979, 2004, Russell and Monson 1998, Cartron 2000). On the islands, they typically nest on cliffs, except on the eastern side of Isla Tiburón, where they nest on cardons (Henny and Anderson 1979, 2004, this study).

Table 2. Summary of observed osprey productivity during the 1998 nesting season along the coast of mainland Sonora, from Bahía Kino north to the vicinity of Cerro El Puerto. Nests are divided into three groups based on location, for the purpose of allowing comparisons with previous years (Cartron 2000, Fig. 3). There were no nests discovered between Bahía Kino and Punta Santa Rosa. Reproductive success for four pairs (one in Bahía Kino, two between Punta Santa Rosa and the Río San Ignacio, and one between the Río San Ignacio and Cerro El Puerto) that reproduced late in the season could not be determined. A total of nine nests in the Bahía Kino area could not be monitored due to lack of access (e.g., nests on islands in Estero La Cruz).

	location		
	Bahía Kino	Punta Santa Rosa north to the mouth of the Río San Ignacio	Río San Ignacio north to Cerro El Puerto
No. nesting pairs	13	39	6
No. (%) breeding pairs	9 (69)	27 (69)	5 (83)
No. (%) successful pairs	5 (38)	8 (21)	4 (67)
No. fledglings	7	16	5
Productivity (mean no. fledglings) of nesting pairs	0.54	0.41	1
Productivity (mean no. fledglings) of breeding pairs	0.78	0.59	1.2
No. (%) successful pairs with 3 fledglings	--	2 (25)	--
No. (%) successful pairs with 2 fledglings	2 (40)	4 (50)	2 (50)
No. (%) successful pairs with 1 fledgling	3 (60)	2 (25)	2 (50)
Mean brood size at fledging	1.4	2	1.5

Breeding in Sonora is characterized by a high degree of asynchrony among pairs (Cartron 2000). Egg-laying may begin as early as late December (Sheldon 1922, in Carmony and Brown 1993), but some pairs are with eggs as late as May (Cartron unpubl. data). Hatching typically occurs in March (Cartron unpubl. data). Mean hatching intervals are 3.85 days for three-egg clutches and 1.66 days for two-egg clutches (Schaadt 1989). Clutch size is typically 2 or 3, rarely 4 (Cartron 2000). The incubation period, as determined by Judge (1983) for the Bahía de los Angeles islands, is probably also 38 days in coastal Sonora (see Schaadt 1989). Schaadt (1989) documented a reduced growth rate, longer nestling period (i.e., males: 57.8 days in Sonora vs. 54.4 days in Nova Scotia; females: 59.1 days in Sonora vs. 56 days in Nova Scotia), and later emergence of flight feathers in young ospreys in Sonora, compared to migratory populations of this species.

Breeding ospreys exhibit a high tolerance for other species nesting near them. Wauer (1980) recorded the presence of a great-blue heron (*Ardea herodias*) nest and an osprey nest in the same cardon on Isla Tiburón. Both nests were occupied and looked active. On the mainland of Sonora, we have recorded instances of ospreys nesting within 300 m of great-blue heron or Harris's hawk (*Parabuteo unicinctus*) nests. On the islet Roca Foca in 1997, ospreys nested near an occupied peregrine falcon (*Falco peregrinus*) eyrie.

Worldwide, the osprey is an opportunistic predator, its diet reflecting largely the local availability of prey species (Poole 1989). From Bahía Sargento north to the mouth of the Río San Ignacio, the preybase of nesting ospreys consists of at least 19 fish species from 18 families (Cartron and Molles 2002). Most prey are striped mullets (*Mugil cephalus*) or needlefish (*Strongylura* and/or *Tylosurus* spp.). The Pacific porgy (*Calamus brachysomus*) and the fine-scaled triggerfish (*Balistes polylepis*) are also frequently consumed at some locations (Cartron and Molles 2002), but the prevalence of needlefish and mullets in the diet of ospreys is apparently general to much of the Sonoran coastline (Cartron, unpubl. data, D.A. Thomson, pers. comm.). The striped mullet in particular is described as abundant throughout the Gulf of California (Thomson and McKibben 1976). It is a dominant species at Estero Sargento along Bahía Sargento (Castro *et al.* 1990).

Although not formally documented, the range of prey sizes is high. Toward the higher end of this range, a needlefish captured at Punta La Ona weighed 450 g, or approximately 25% of an adult osprey's body mass. The bird that had caught it was harassed by another osprey when it dropped it (Sommer, unpubl. data). A striped mullet, dropped by an osprey under similar circumstances, measured 38 cm in length (J. Torre, pers. comm.). Ospreys that catch large fish may be chased also by other species such as the yellow-footed gull (*Larus livens*) and again, as a result, may let go of their prey (T. Pfister, pers. obs.).

If compared with some other parts of the species' range (French 1972, MacCarter 1972, Ueoka 1974, Lind 1976, Prevost 1977, Swenson 1978), osprey dive success is low in coastal Sonora. At least at one location, breeding ospreys rely partially on perch-hunting. Both low dive success and the occurrence of perch-hunting are likely influenced by a diet rich in needlefish. In a study of ospreys Swenson (1979) found that dive success is largely determined by the feeding ecology of prey species. Whereas a diet composed chiefly of benthic-feeding fish (taken only in shallow water) may be associated with dive success greater than 60%, other fish are seemingly more difficult to capture, and dive success reaches a low of only 20-40% when prey consist mainly of limnetic (or pelagic) fish that are piscivorous (Swenson 1979). Needlefish are piscivorous, their swiftness as predators likely making them also elusive prey. Low dive success may mean that ospreys foraging on the wing must engage in more dives in order to be successful, with an associated higher energetic cost and perhaps even increased risk of injury over time.

Perch-hunting has been described in Senegal (Prevost 1982). Among its advantages is the energy cost, undoubtedly lower as it involves no flight time for detecting prey. Dives at shallow angles probably also allow ospreys to abort more easily, with again a lower energy cost. In Senegal, however, perch-hunting is not an effective foraging method and may be practiced by ospreys only because as winter residents, they do not have to provide for nestlings (Prevost 1982). In contrast, along Bahía Sargento perch-hunting may be an important foraging technique due to overall low dive success. Nesting pairs may capitalize on frequent pulses of schools of fish, including needlefish, swimming to the edge of the water. Perch-hunting has been observed also along the southern coast of Isla Tiburón, but only in the fall (T. Pfister, pers. obs.).

Based on our study, ospreys tend to avoid the midday hours for foraging (Fig. 2). At that time the sun is near its zenith and the shadows of ospreys fall directly below them. This may increase the chances that a diving osprey could be detected by fish swimming near the surface, giving them additional time to react. Interestingly, perch-hunting along Bahía Sargento was observed in the early morning and in the afternoon. It was not observed in the morning after the sun had risen above the mountains to the east (J.-L. Cartron, pers. obs.). The shadow of an osprey diving from a cliff at that time would fall toward open water and again could be detected by a fish.

Osprey population changes between 1977 and 1993 along coastal Sonora have been documented by Henny and Anderson (2004). The authors estimate that in 1993, 254 pairs nested along the mainland of coastal Sonora, or an increase of 81% since 1977. In particular, there was a range expansion north in Sonora by 1993 as a result of birds nesting on power poles in an area with flat terrain and no suitable cacti (see also Mellink and Palacios 1993). On Isla Tiburón, an estimated 164 pairs nested on Isla Tiburón in 1993, or an increase of 128% since 1977. The number of nesting pairs on Isla San Esteban, Isla Turner, and Roca Foca collectively doubled between 1977 and 1993, to 46. Another significant change since the 1970s is the fact that Isla Alcatraz (an island not surveyed by us but directly off Bahía Kino) harbored osprey nesting pairs in the 1970s (D. W. Anderson pers. comm.). In recent years, however, no osprey has nested on this island (T. Pfister, pers. obs.).

Comparing our 1998 survey results with those of Henny and Anderson (1979, 2004) is difficult for several reasons. Whereas our survey was conducted from the ground and by boat, Henny and Anderson's surveys were from the air. They used limited data collected from the ground at the time of their surveys to estimate the number of nests missed by them (see discussion on correcting for visibility rate in Henny and Anderson 2004). However, during our one-time surveys of ospreys on islands, we may not have found all occupied nests, yet we do not have any means to evaluate just how many nests were missed. Also, in Henny and Anderson (1979, 2004), our study area on the mainland was divided between two larger regions that extended farther to the north and the south. Based on observed rather than estimated numbers of nesting pairs, it appears that our results are comparable to those of Henny and Anderson's (2004) 1992-1993 survey, at least for Isla San Esteban, Isla Turner, and Roca Foca combined (27 nests observed by Henny and Anderson in 1993, 30 by us in 1998).

Our survey has greater significance at a local rather than regional scale, documenting high densities of nesting pairs on Isla Turner and Roca Foca; the Bahía Kino and Estero La Cruz area; Bahía Sargento; an approximately 4 km stretch of shoreline between El Desemboque and the mouth of the Río San Ignacio; and the Valle de las Aguilillas along the eastern shore of Isla Tiburón. Anecdotally, Punta Baja just south of our study area may represent another area where high numbers of ospreys nest. At that location Schaadt (1989) had found 20 nests apparently occupied (10 active, the others 'with birds associated with them') in 1987.

Osprey productivity in 1998 tended to conform to the low productivity levels observed during the previous two years. However, reproductive success during the 1990s is difficult to interpret, as it was characterized by very high inter-annual and spatial variation (Cartron 2000, Fig. 3). The high degree of spatial clumping of successful and unsuccessful nests during the 1990s (Cartron 2000) suggests that productivity is controlled primarily by site-specific factors. In 1997, the least productive year for ospreys, only two (5%) of 40 pairs produced fledglings, and the productivity of nesting pairs was only one tenth that observed in 1995 (Fig. 3). In 1997, nesting failure was a widespread phenomenon on the mainland, but not on offshore islands (Cartron 2000).

Conservation threats to the osprey in coastal Sonora remain unclear. Although rare, shooting has been documented (Cartron 2000). Nest disturbance by tourists occurs in particular near El Desemboque. However, nest disturbance seems limited at other locations where osprey reproductive success was consistently low during the 1990s. While overfishing is widespread in the Gulf of California (Greenberg and Vélez-Ibáñez 1993, Musick *et al.* 2000, Brusca *et al.* 2005, Greenberg, in press), there is no information on potential recent changes in the population status of needlefish and mullets along coastal Sonora. In the Canal del Infiernillo, fisheries rely heavily on mullets as bait for crab trapping and to sell for human consumption

(Torre-Cosio 2002). During the 1990s, fishing nets and traps were often set near shore along Bahía Sargento, with an unknown effect on the foraging success of ospreys. Cartron (2000) had observed a lower mean clutch size and a higher number of late breeding pairs during years of low productivity, suggesting lack of food as the limiting factor. In 1998, low productivity was apparently associated with delayed reproduction for four pairs, but not with reduced mean clutch size (<2.8).

The fact that ospreys nest on utility poles in Bahía Kino is significant. A very high incidence of raptor and raven electrocutions has been documented from northwestern Chihuahua and northeastern Sonora (Cartron *et al.* 2000, 2005, this volume). The vast majority of electrocutions occur on concrete poles fitted with steel cross-arms, the osprey being one of the species found among electrocuted raptors. In the Bahía Kino area, osprey mortality by electrocution occurs on both wooden and concrete poles (O. Briseño, engineer, Comisión Federal de Electricidád, pers. comm.). In the 1990s, concrete poles were installed for a power line supplying Punta Chueca with electricity (J.-L. Cartron, pers. obs.), and more generally ospreys appear to now often nest on concrete poles in northwestern Sonora (see Henny and Anderson 2004). On the one hand, the installation of new power lines in areas with flat terrain and no available cacti poles may represent a significant positive development for nesting ospreys. However, additional research is needed to evaluate the incidence of osprey electrocutions and characterize the overall impact of utility poles. Also needed is additional research on the impact of disturbance and overfishing, two likely

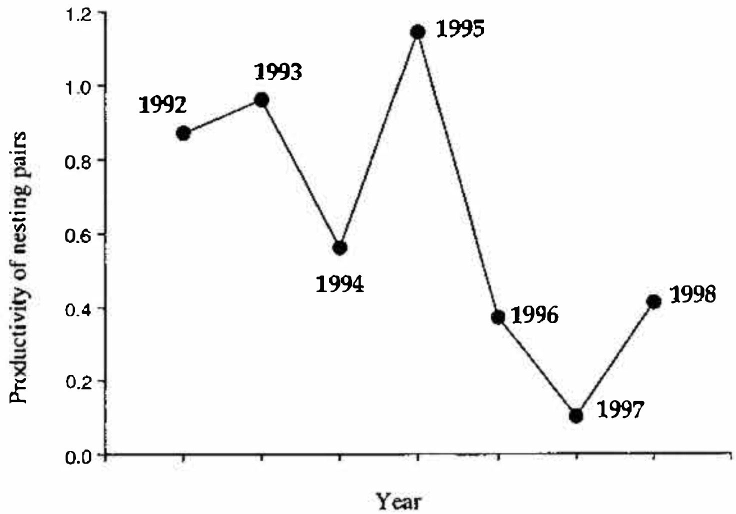

Figure 3. Productivity of ospreys on the mainland north of Bahía Kino, 1992-1998. Note that productivity was determined only for nests between Punta Santa Rosa and El Desemboque in 1992-1994. Beginning in 1995, the study area was expanded northward to the mouth of the Río San Ignacio. Despite pronounced spatial variation in osprey reproductive success on the mainland, overall there was no difference in productivity south *vs.* north of El Desemboque in 1995, 1996, and 1997 (Cartron 2000). For this reason, reproductive data from the two areas were pooled in 1995 and thereafter. Productivity reported for 1998 is for the same area as the previous three years.

growing problems, on ospreys in coastal Sonora.

ACKNOWLEDGMENTS

We are grateful to Ricardo Rodríguez-Estrella for his invitation to contribute this chapter to this book. Many individuals helped gather data in the field or provided logistic support: R. Anderson, L. Bourillón, J. Brown, C. Cartron, F. Casali, A. García, M. Hohmann, A. Kodric-Brown, C. Marlett, R. Mody, M. Molles, R. Nugent, R. Pfister, B. Roger, A. Thomas, J. Torre, and H. Waldman. Information on mortality by electrocution was provided by O. Briseño, Comisión Federal de Electricidad. Other useful information was provided by D. Anderson, C. Hcooy, and J. Torre. We thank the Seris, who granted us permission to land on Isla Tiburón. Ricardo Rodríguez-Estrella, Dan Anderson, and Chuck Henny provided helpful comments on earlier drafts of the chapter.

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Breeding biology and success of the osprey (*Pandion haliaetus*) in Laguna San Ignacio, B.C.S., México, in 1998, 2000, and 2001

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ABSTRACT

Few studies have been done with year-round resident osprey (*Pandion haliaetus*) populations. Studies with resident populations are needed to understand the behavioral ecology and the dynamics of population movements and also for conservation purposes. We present our results on the breeding biology and success of a year-round resident population in Laguna San Ignacio, Baja California Sur, México during three breeding seasons, 1998, 2000, and 2001. The aim of this study is to contribute to the long-term studies of the osprey populations of the middle portion of Baja California peninsula, probably among the densest populations in the world. The breeding chronology extended from December to June in 1998, December to July in 2000, and January to July in 2001. A strong asymmetry existed in laying, hatching and fledging dates in all years. A total of 110 fledglings were recorded from the 116 active nests surveyed in 1998, 77 fledglings from the 93 active nests in 2000 and 41 fledglings from 78 active nests in 2001. Productivity for

successful nests was 1.7, 1.5 and 1.3 fledglings/nest, while total productivity (for both successful and unsuccessful nests) was 0.9, 0.8 and 0.7 fledglings/nest. High mortality rates existed in 1998 and 2000 during the incubation period before hatching (25% and 22%, respectively) even higher in 2001 (32%), but it increased during rearing (38%, 51% and 62%, respectively). Significant differences were detected in fledging success only between 1998 (the year with highest success) and 2001 (the year with lowest success), both from laying ($z_{1998-2000}=1.08$, $P>0.05$; $z_{1998-2001}=2.61$, $P<0.01$; $z_{2000-2001}=1.19$, $P>0.05$) and hatching ($z_{1998-2000}=1.67$, $P>0.05$; $z_{1998-2001}=3.61$, $P<0.01$; $z_{2000-2001}=1.77$, $P>0.05$) periods. Asynchronous reproduction seems to be a general pattern for resident breeding populations as Laguna San Ignacio, Laguna Ojo de Liebre and Guerrero Negro, coastal Sonora and Bahía de Los Angeles resident breeding colonies in Baja California, and those of Florida showed a similar trend in asynchronous reproduction. The productivity of the osprey populations of Laguna San Ignacio is within that reported for resident populations, but seems to be lower than the productivity of migrant populations. The 68-75% of hatching success recorded for the Laguna San Ignacio osprey population is within the normal range reported for the species. Our results show the osprey population of Laguna San Ignacio can be considered a stable population, although with trends to decrease.

Key words: osprey, breeding biology, *Pandion haliaetus*, Laguna San Ignacio, Baja California Sur, México.

RESUMEN

Pocos estudios se han realizado con poblaciones de águilas pescadoras (*Pandion haliaetus*) residentes todo el año. Los estudios con poblaciones residentes se requieren para entender la ecología del comportamiento y la dinámica de los movimientos de las poblaciones, así como con fines de conservación. Se presentan los resultados sobre la biología y éxito reproductivo de una población residente todo el año en Laguna San Ignacio, Baja California Sur, México durante 3 estaciones reproductivas, 1998, 2000 y 2001. El propósito de este estudio es contribuir a los estudios planeados a largo plazo de las poblaciones de águila pescadora en la porción media de la península de Baja California, que probablemente contiene las poblaciones más densas en el mundo. La reproducción ocurrió entre diciembre y junio de 1998, diciembre y julio de 2000, y enero a julio de 2001. Se presentó una fuerte asimetría en las fechas de puesta, eclosión y liberación de volantones en ambos años. Un total de 110 volantones fueron registrados en 116 nidos activos en 1998, 77 volantones en 93 nidos activos en 2000, y 41 volantones en 78 nidos activos en 2001. La productividad de los nidos exitosos fue de 1.7, 1.5 y 1.3 volantones/nido, mientras que la productividad total (considerando tanto nidos exitosos como no exitosos) fue de 0.9, 0.8 y 0.7 volantones/nido. Se registraron altas tasas de mortalidad en 1998 y 2000 durante el periodo de incubación antes de la eclosión (25% y 22%, respectivamente) siendo aún mayor en 2001 (32%), pero se incrementó durante la crianza (38%, 51% y 62%, respectivamente). Se detectaron diferencias significativas en el éxito de volantones

sólo entre 1998 (el año con el éxito más alto) y 2001 (el año con el éxito más bajo), tanto desde el periodo de la puesta ($z_{1998\text{-}2000}=1.08$, $P>0.05$; $z_{1998\text{-}2001}=2.61$, $P<0.01$; $z_{2000\text{-}2001}=1.19$, $P>0.05$) como desde la eclosión ($z_{1998\text{-}2000}=1.67$, $P>0.05$; $z_{1998\text{-}2001}=3.61$, $P<0.01$; $z_{2000\text{-}2001}=1.77$, $P>0.05$). La reproducción asincrónica parece ser un patrón general para poblaciones residentes reproductivas puesto que las poblaciones reproductivas de Laguna San Ignacio, Laguna Ojo de Liebre y Guerrero Negro, la costa de Sonora y Bahía de Los Ángeles en Baja California, y aquellas de Florida muestran una tendencia similar a la reproducción asincrónica. La productividad de la población del águila pescadora en Laguna San Ignacio se encuentra entre los rangos reportados para poblaciones residentes, y es menor que la de las poblaciones migratorias. El 68-75% de éxito en la eclosión registrado para la población de Laguna San Ignacio se encuentra en el rango normal reportado para la especie. Los resultados de este trabajo muestran que la población de águila pescadora de Laguna San Ignacio puede ser considerada como estable pero con una tendencia a decrecer.

INTRODUCTION

The osprey (*Pandion haliaetus*) is one of the most studied raptor species around the world. The concern for the crash of several populations in the USA. due to pesticides, and the extirpation from several European countries due to human activity, promoted intensive studies on the biology and ecology of ospreys in many regions of its distribution (Newton 1989, Poole 1989). However, most studies have been done with populations that migrate once they breed (Poole 1989). Few studies have been made with year-round resident populations, and most of them have been made in Florida and México (Ogden 1977, Henny and Anderson 1979, Judge 1983, Salinas *et al.* 1989, Castellanos and Ortega 1995, Cartron 2000, Cartron *et al.* in this publication). Studies with resident populations are needed to understand the behavioral ecology and the dynamics of population movements related to food availability (Poole 1989). Our results focus on the breeding biology and success of a year-round resident population in Baja California Sur, México. The osprey population of Laguna San Ignacio has been reported since the beginning of 1900s by Bancroft (1927) who cited only few nesting pairs. Now, the population has increased to over 80 pairs, even growing to almost 120 breeding pairs (Reitherman and Storrer 1981, 1982, Danemann 1994).

The aim of this study is to present information on the osprey population of Laguna San Ignacio in three breeding periods, in order to contribute to the long-term studies started for the osprey populations of the middle portion of Baja California peninsula, probably among the densest in the world.

STUDY AREA

The study was conducted in Laguna San Ignacio located in the middle portion of the Baja California peninsula (Fig. 1). The lagoon is shallow with an average depth of 2 to 4 m, and some channels with 26 m of profundity. Climate is warm and dry with annual average temperatures oscillating between 18 and 22°C. Precipitation occurs in the summer and is less than 150 mm annually (Reitherman and Storrer 1981, Danemann 1994). The breeding population we studied constructed their nests in two small islands, Isla Garzas and Isla Pelícanos (both are also known as Whale Island). During low tide, both islands connect and can be reached by foot. The total area of

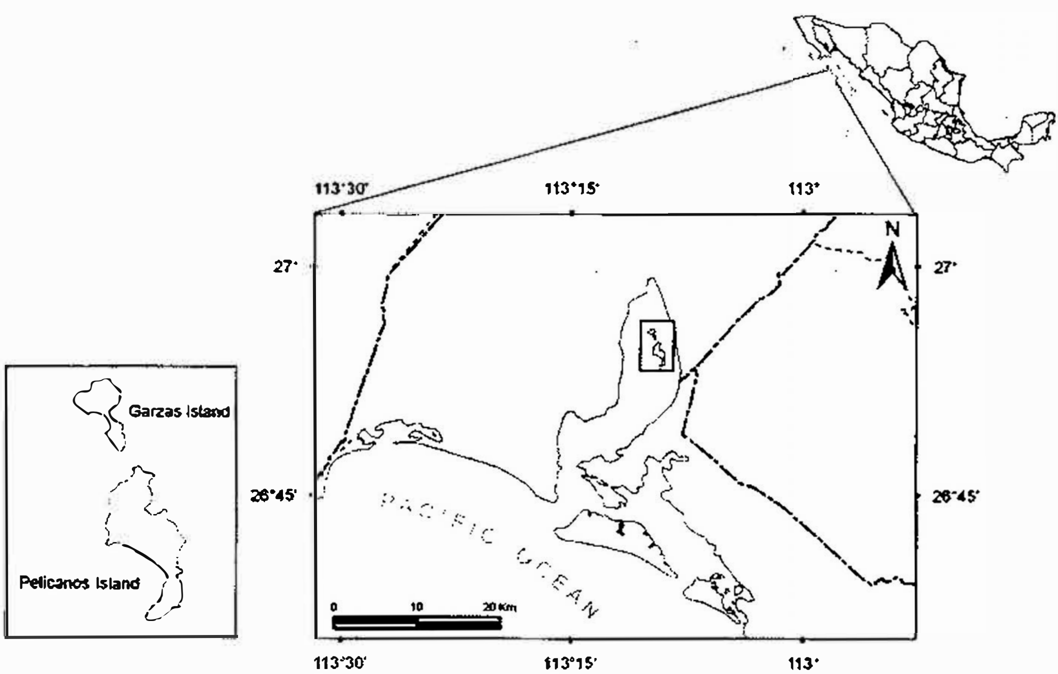

Figure 1. Isla Garzas and Isla Pelícanos study area in Laguna San Ignacio, B.C.S.

Vegetation is scarce and is dominated by characteristic plants of the adjacent desert on the mainland, mainly cholla (*Opuntia* spp), garambullo (*Lophocereus schotti*), and pitaya agria (*Machaerocereus gummosus*). Other breeding colonies of marine birds in the orders of hundreds occur in the islands, such as cormorant (*Phalacrocorax auritus*), brown pelicans (*Pelecanus occidentalis*), rededish egret (*Egretta rufescens*), great blue heron (*Ardea herodias*), Caspian tern (*Sterna caspia*), and western gull (*Larus occidentalis*).

Although some fishermen visit the island, they only stay at the coast to prepare the fish they netted. No other human activity was recorded during our visits to the islands. The islands are under official protection as they are included in the Vizcaino Biosphere Reserve. Thus, visits to the islands are completely limited to research purposes.

METHODS

From January to July 1998, 2000 and 2001, we visited the colonies of Isla Garzas and Isla Pelícanos located at Laguna San Ignacio in a monthly basis to determine the breeding chronnlogy and biology of reproductive pairs. Nests were visited throughout the breeding period, which lasted approximately 92 days from the incubation to chicks fledging (Danemann 1994). In every visit, we marked all new active nests, and recorded the content of the new nests. To determine whether a nest was active or not we observed the presence or absence of eggs or chicks. Nests were checked only once during the incubation period (39 days; from Danemann 1994). Age of chicks was determined by comparing the measurements of bill, tarsus and wing of every chick with those of the growth curves estimated by Danemann (1994) for the same population. We used calipers with accuracy of 0.1 mm to take measurements. At the age of 20 days we tagged the chicks with plastic bands (white and blue colors, containing a black alphanumeric code). The frequency of visits to the colonies depended upon the estimated age of fledging of chicks to record the exact number of fledglings, but an average of 7-9 visits were made during the nestling period. A nest was considered to be successful if fledglings were observed around the nests. Productivity was calculated as the number of fledglings *per* nest. The number of chicks dying during the different periods was recorded, and then we estimated the total productivity of breeding pairs.

RESULTS

We surveyed 116, 93 and 78 active nests in 1998, 2000 and 2001 breeding seasons, respectively. The breeding chronology extended from December to June in 1998, December to July in 2000, and January to July in 2001 (Fig. 2). A strong asymmetry existed in laying, hatching and fledging dates in all years, but differences between years in the average dates for each reproductive stage were not significant (Fig. 1; t-student tests $P > 0.05$, Sokal and Rohlf 1995).

A total of 110 fledglings were recorded from the 116 active nests surveyed in 1998, 77 fledglings from the 93 active nests in 2000, and 41 fledglings from 78 active nests in 2001. Breeding success varied between years, 62% in 1998, 49% in 2000 and 39% in 2001 (Table 1). Productivity for successful nests was 1.7, 1.5 and 1.3 fledglings/nest, while total productivity (for both successful and unsuccessful nests) was 0.9, 0.8 and 0.7 fledglings/nest (Table 1). High mortality rates existed in 1998 and 2000 during the incubation period before hatching (25% and 22%, respectively) even higher in 2001 (32%), but it increased during rearing (38%, 51% and 62%, respectively) (Table 1). Significant differences were detected in fledging success only between 1998 (the year with highest success) and 2001 (the year with lowest success), both from laying ($z_{1998\text{-}2000}$=1.08, P>0.05; $z_{1998\text{-}2001}$=2.61, P<0.01; $z_{2000\text{-}2001}$=1.19, P>0.05) and hatching ($z_{1998\text{-}2000}$=1.67, P>0.05; $z_{1998\text{-}2001}$=3.61, P<0.01; $z_{2000\text{-}2001}$=1.77, P>0.05) periods (test of hypothesis between means, Daniel 1996).

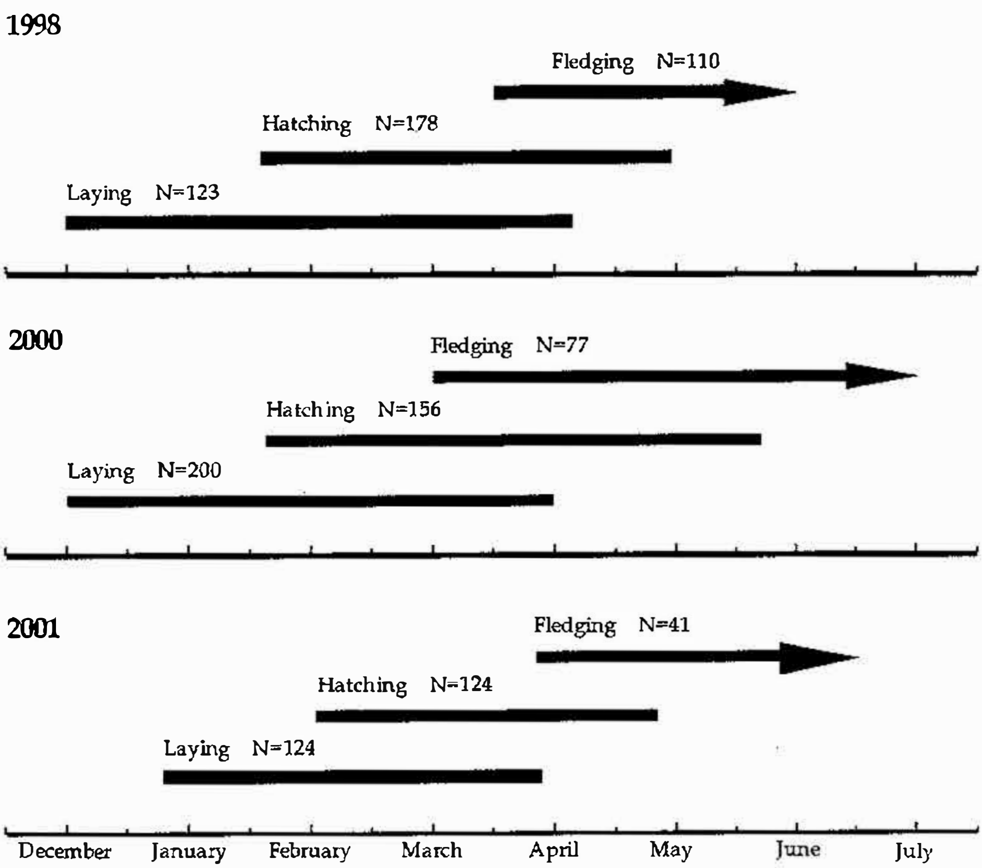

Figure 2. Breeding chronology of the osprey in Laguna San Ignacio, B.C.S., México; 1998, 2000, and 2001.

Table 1. Summary of the osprey productivity in Laguna San Ignacio, B.C.S., México during the 1998 and 2000 breeding seasons.

	1998	2000	2001
No. active nests	116	93	78
No. successful nests (%)	65 (56)	51 (55)	32 (41)
No. of eggs	237	200	180
No. eggs hatching (%)	178 (75)	156 (78)	122 (77.7)
No. unsuccessful eggs	59	44	38
No. fledgings (% nestling survival)	110 (62)	77 (49)	47 (38)
Fledging success (%)	62 (35)	49 (31)	41 (34)
Productivity fledglings/successful nest	1.67±0.46	1.50±0.6	1.28±0.52
Productivity fledglings/attempt	0.95±0.65	0.83±0.9	0.68±0.74

DISCUSSION

The resident osprey population of Laguna San Ignacio continues to be one of the densest populations in the world, with an estimated density of 89.2 pairs/km^2 in 1998, 71.5 pairs/km^2 in 2000 and 60 pairs/km^2 in 2001. Since the first report for this population in 1927 (Bancroft 1927) when reproduction was reported 'in small numbers', the population size has showed continued growth. The trend of increasing numbers of active osprey pairs is similar to that reported for Laguna Ojo de Liebre (Salinas *et al.* 1991, Castellanos and Ortega 1995), which is located about 100 km North of Laguna San Ignacio. Laguna Ojo de Liebre contains an estimated population of 150 active pairs but density is lower here. In spite of this growth rate, the last estimated trends for the osprey population in Laguna San Ignacio indicate this population is declining. El Niño events, low prey availability and parasitism (see

Blanco *et al.* in this publication) may be playing an important synergistically role in the declining of the population.

Asynchronous reproduction seems to be a general pattern for resident breeding populations. Ojo de Liebre and Guerrero Negro lagoons, coastal Sonora and Bahía de Los Angeles resident breeding populations in Baja California, and those of Florida showed a similar trend in asynchronous reproduction as in our study area (Judge 1983, Poole 1989, Castellanos and Ortega 1995, Cartron 2000). However, the longest periods of breeding activity are reported for the middle portion of Baja California populations, about eight months (December to July; Castellanos and Ortega 1995, this study), while those of Bahía de Los Angeles (at the north of the Gulf of California) and Florida lasted about 3 months (January to March; Judge 1983, Poole 1989). In contrast, the breeding period for migrant populations of northern latitudes is very short and synchronous (Poole 1989). For instance, the laying period in northern latitudes lasts three weeks (Poole 1989) while it lasted about 16, 16 and 12 weeks in the Laguna San Ignacio population in 1998, 2000 and 2001, respectively. Weather and food availability seem to be the main factors influencing the migratory process. Resident populations stay in areas with more stable conditions, with more predictable food sources (Poole 1989). Mild weather conditions and predictable food sources permit long breeding periods of birds. The osprey population of Laguna San Ignacio seems to be in this last kind of condition.

The overall productivity of the osprey population of Laguna San Ignacio is comparable to that reported for other resident populations (Poole 1989, Castellanos and Ortega 1995, Cartron 2000, Cartron *et al.* in this publication), but is lower than the productivity of migrant populations (Poole 1989). The 68-75% of hatching success recorded for the Laguna San Ignacio osprey population is within the normal range reported for the species (Henny and Anderson 1979).

Preliminary data of osprey population studies in Laguna San Ignacio and Laguna Ojo de Liebre led us to propose that the middle portion of Baja California Peninsula, particularly the islands of the Pacific coast, is playing an important role in the dynamics and stability of osprey populations along the Pacific coast of Baja California. More in-depth studies should be done to be certain about our proposal, but the conservation of Laguna San Ignacio will assure the preservation of one of the densest breeding populations in the world.

ACKNOWLEDGMENTS

We thank A. Cota, N. Sánchez, A. Pelaez, I. Román, K. Grajales, R. Valenzuela, Beatriz Marquez, and R. Bolaños for field assistance. Jean-Luc Cartron and A. Castellanos made valuable comments to an early draft. Consejo Nacional de Ciencia y Tecnología (SEMARNAT-CONACyT C01-0318) and CIBNOR gave financial support. LBRR received a CONACyT scholarship grant for completing her M.Sc. Thesis. EM received a CONACyT scholarship grant for completing her Bachelor's Thesis.

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High infestation by blood parasites (Haematozoa) in nestlings of colonial ospreys (*Pandion haliaetus*) from Baja California, México

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ABSTRACT

Despite the cosmopolitan distribution of the osprey (*Pandion haliaetus*) and interest in its study and conservation, there is limited information on pathogens, parasites and diseases negatively affecting health and survival rates in their populations. In this work, we describe parasitism by blood parasites in nestlings of colonial ospreys from Baja California, México. A very high prevalence of infection with blood parasites (53%) in nestling ospreys was found, especially for *Leucocytozoon toddi* (39.2%) and for *Plasmodium polare* (13.7%). The intensity of haematozoan infections was very high (mean: 128 parasites/2,000 erythrocytes), which ranged from 40 to 320 parasites per 2,000 erythrocytes. A preliminary assessment of the effects on nestling health of blood parasites and their possible vectors was conducted to establish their potential role in the declining of this population. This is the first intensive survey of blood parasites in nestling ospreys from breeding colonies and the first record of both parasite species in ospreys.

Key words: osprey, blood parasites, coloniality, Laguna San Ignacio, B.C.S.

RESUMEN

A pesar de la distribución cosmopolita del águila pescadora (*Pandion haliaetus*) y del gran interés en su estudio y conservación, existe muy poca información sobre los parásitos, patógenos y enfermedades que pueden estar afectando negativamente a la salud y las tasas de supervivencia en sus poblaciones. Describimos el parasitismo por hematozoos en pollos de águilas pescadoras coloniales en Baja California, México. Se encontró una alta prevalencia de infección por hemoparásitos (53%), especialmente para *Leucocytozoon toddi* (39.2%) pero también para *Plasmodium polare* (13.7%). La intensidad de infección fue muy elevada (media: 128 parásitos/2,000 eritrocitos), variando desde 40 hasta 320 parásitos por 2,000 eritrocitos. Se ofrece una valoración preliminar de los efectos de los parásitos sanguíneos y sus vectores potenciales sobre la salud de los pollos para establecer su posible papel en la regresión de la población. Este es el primer estudio sobre parásitos sanguíneos en pollos de águila pescadora nidificando de forma colonial, y los primeros registros sobre infección por ambos hemoparásitos en esta especie.

INTRODUCTION

Parasites may have important negative effects on behavior and fitness of their avian hosts (Møller *et al.* 1990, Loye and Zuk 1991). Among the most common endoparasites of birds, blood parasites (Haematozoa) have become of great interest because of their potential effects on host fitness (Atkinson and van Riper 1991) and their implications on parasite-mediated sexual selection (Clayton 1991). Haematozoa may reduce the fitness of their hosts due to their negative effects on health, especially listlessness and loss of condition (Atkinson and van Riper 1991, Bennett *et al.* 1993, Valkiūnas 1993) that indirectly may decrease survival rates and breeding output (Møller *et al.* 1990). Prevalence and intensity of infection with haematozoa have shown to vary between species, populations, seasons and years presumably because of ecological factors that affect both host condition and vector abundance (Tella *et al.* 1999). Host condition is a main component of individual quality determining fitness (Clutton-Brock 1988), and it may influence the response of the immune system to the wide array of parasites generally infecting birds (Gershwin *et al.* 1985). The development and expression of immunity against parasitic infections may be modulated by additional factors such as stress, age, sociality or a combination of these and other factors (Lloyd 1995). The study of prevalence and intensity of infection by haematozoa may be of interest to understand the role of parasites in ecology and conservation of their hosts. In fact, parasites, especially blood parasites, have been involved in the decline and extinction of several bird populations (Warner 1968, van Riper *et al.* 1986, van Riper 1991, Savidge *et al.* 1992, Work *et al.* 2000). Here, we describe parasitism by blood parasites in nestlings of colonial ospreys (*Pandion haliaetus*) from Baja California, México. A preliminary assessment of the effects on nestling health of blood parasites and their possible vectors was conducted to establish their potential role in the declining of this population (Rodríguez-Estrella *et al.*, in this publication).

Despite the cosmopolitan distribution of ospreys and interest in their study and conservation, there is limited information on pathogens, parasites and diseases that negatively affect health and survival rates of their populations (Schmidt and Huber 1985, Kinsella *et al.* 1996, Miller *et al.* 1997, Dennis *et al.* 2000). Baja California peninsula together with its adjacent islands is one of the main strongholds of ospreys in the world. In this region, ospreys reach the densest concentration of breeding pairs worldwide (Henny and Andersson 1979, Reitherman and Storer 1981, Danemann 1994). In contrast with other populations, ospreys in Baja California nest in colonies at high densities, although the species is not strictly colonial in the area, some pairs nesting isolated or in loose groups (Danemann 1994, Castellanos and Ortega 1995, Cartron 2000). High breeding density may impose costs for individual birds such as higher transmission of parasites although the particular life histories of parasites and their strategies of transmission may shape this relationship (Tella 2002). Studies on the effects of parasites with different life strategies are needed to assess whether coloniality is associated with a greater risk of parasitism in this species. This knowledge may be helpful to assess the potential costs that derive from the evolutionary transition from solitary to colonial nesting (Rolland *et al.* 1998, Tella 2002), which may have implications for management and conservation. In addition, differences in risk of blood parasitization between solitary and colonial nesting (Tella 2002) might have implications on the evolution of certain hosts traits (Clayton 1991), such as the reduced sexual dimorphism in plumage showiness found in the study population of ospreys (Blanco and Rodríguez-Estrella 1999).

Almost nothing is known about prevalence and intensity of parasites on birds inhabiting the peninsula of Baja California (Tella *et al.* 2000), especially blood parasites (Blanco *et al.* 2001). In this paper, we present the results of a survey of blood parasites on osprey nestlings from colonies located in Baja California. This is, to our knowledge, the first sampling for avian haematozoa in nestlings of a raptor species in Baja California and the first intensive survey of blood parasites in nestling from breeding colonies of this species.

STUDY AREA

The study was conducted in Laguna San Ignacio located in the middle portion of the Baja California peninsula. The lagoon is shallow with an average depth of 2 to 4 m; with some channels 26 m deep. The climate is warm and dry with annual average temperatures that oscillate between 18 and 22°C. Precipitation occurs in the summer and is less than 150 mm per year (Reitherman and Storrer 1981, Danemann 1994). The breeding population we studied constructed their nests in two small islands, Isla Garzas and Isla Pelicanos (both are also known as Whale Island). During low tide, both islands connect and can be reached by foot. The total area of both islands is 1.3

km^2. In this area, ospreys nest at high densities although abundance of breeding pairs greatly varied every other year in the last decades. The study area and osprey colonies were described in detail in another work (Rodríguez-Estrella *et al.* in this publication).

MATERIAL AND METHODS

During the breeding season of 2001, osprey colonies were monitored as described in Rodríguez-Estrella *et al.* (in this publication). Nests were accessed during nestling banding operations in May and June 2001 at breeding colonies established in Isla Pelicanos and Isla Garzas. Nestlings were sampled on average at 45 days old (range: 32-59 days), that is, when they were feathered but before fledging. The age of nestling ospreys at sampling fairly exceeds the minimum prepatent period reported for some blood parasites in nestlings of other raptor species (13 and 14 days for sparrowhawks *Accipiter nisus* and Goshawks *Accipiter gentilis,* respectively (Peirce and Marquiss 1983, Toyne and Ashford 1997). Nestlings were bled from the brachial vein and a thin smear was made using a drop of blood. Blood smears were air dried, fixed with ethanol in the field, and stained in the laboratory with Giemsa. We searched for extracellular parasites (trypanosomes, microfilariae) by scanning whole smears under low magnification (X40). Intraerythrocytic parasites were quantified under oil at 1,000X by counting the number of parasites per 2,000 erythrocytes, i.e. 40 microscope fields (Godfery *et al.* 1987). The smears were examined at least four different times by the same observer. Prevalence was defined as the proportion of hosts with slide-positive infections. The intensity of infection was presented and analyzed excluding samples in which no blood parasites were detected. Parasites were identified by comparing their color, morphology and size with descriptions of known species. Overall, we sampled 51 nestlings from 37 nests. Ectoparasites were systematically searched on the nestling body and counted. Several specimens were collected and stored in ethanol to be identified in the laboratory later on. A drop of blood was used for sexing the nestlings through molecular procedures after DNA extraction (Fridolfsson and Ellegren 1999).

RESULTS

Two haematozoan species were identified: *Leucocytozoon toddi* and *Plasmodium polare*. The identification of the *Plasmodium* species is preliminary and needs to be confirmed by further examinations. No extracellular parasite was found although the inspection of blood smears is not the best method to detect them. Haematozoan prevalence varied depending on parasite species (Table 1). Overall, 53% of nestlings (n=51) were infected with haematozoan parasites. No nestling presented concurrent infections, i.e. with the two parasite species. Prevalence of haematozoa as well as prevalence of each parasite species did not differ between nestling from Isla Garzas and Isla Pelicano (G test, all P >0.26). There was no significant difference between sexes in the prevalence of *Leucocytozoon toddi, Plasmodium polare,* and total prevalence (pooling both species) (G test, all P>0.48). The intensity of haematozoan infections, excluding samples in which no parasite were detected, was very high (average of 128 parasites/2,000 erythrocytes), ranging from 40 to 320 parasites per 2,000 erythrocytes (Table 1). There were no significant differences in the intensity of infection between island and sexes (Mann-Whitney U test, all $P > 0.48$). There was a higher intensity of infection of *Leucocytozoon toddi* than of *Plasmodium polare* when sexes and island were pooled (Mann-Whitney U test, $z = 2.397$, $P = 0.017$, Table 1).

Table 1. Prevalence (percentage of individuals with parasites) and intensity of infection with hematozoa (parasites per 2,000 erythrocytes) in nestling ospreys from Baja California, México

	prevalence		intensity of infection		
	% positive	*n*	mean ± SE	range	*n*
Hematozoa (total)	52.9	51	128.15 ± 13.30	40-320	27
Leucocytozoon toddi	39.2	51	144.00 ± 15.67	40-320	20
Plasmodium polare	13.7	51	82.86 ± 16.57	60-180	7

Most sampled nestlings were weakened, dehydrated or with pale mucous membranes on physical examination. Many of them were apparently affected by malnutrition and anemia or had suffered development constraints (Rivera and Rodríguez-Estrella unpublished data); several died before fledging, which promoted a low breeding success and productivity of the colonies in the study breeding season (Rodríguez-Estrella *et al.*, in this publication). The only ectoparasite found in high numbers was the louse fly *Olfersia fumipennis*, Hippoboscidae (Rodríguez-Estrella and Rivera unpubl. data).

DISCUSSION

We found a very high prevalence of infection with blood parasites (53%) in nestling ospreys, especially for *Leucocytozoon toddi* (39%). This protozoan species is a common blood parasite of Falconiformes and Accipitiformes around the world (Greiner and Kocan 1977, Bennett *et al.* 1982, Ashford *et al.* 1991). To our knowledge, this is the first report of *L. toddi* in the osprey. The other parasite species found that was preliminary identified as *Plasmodium polare* has been previously reported for several raptor species (Greiner *et al.* 1981, Bennett *et al.* 1982) but it has never been found in ospreys. The prevalence of blood parasites reported here may be considered very high according to the published information for raptors (Greiner *et al.* 1975, Peirce 1981, Tella *et al.* 1999). A study that searched for hematozoan parasites on a significant number of nestling ospreys (*n*=30) sampled in nests from Ontario, Canada found no parasite (Miller *et al.* 1997). Other less extensive surveys in ospreys have shown no blood parasite in samples from Europe and North America (Greiner *et al.* 1975, Greiner and Kocan 1977, Bennett *et al.* 1982, Peirce and Marquiss 1983, Krone *et al.* 2001).

The high values of prevalence reported here were found associated with average intensities of infection of 128 parasites per 2,000 erythrocytes, which can be considered severe infections according to the available information for other species (Tella *et al.* 1996, Dawson and Bortolotti 1999, Stuht *et al.* 1999, Krone *et al.* 2001). These data suggest that blood parasites may be causing health problems to nestlings probably associated to low condition and depressed immunity (Atkinson and van Riper 1991, Bennett *et al.* 1993, Valkiūnas 1993). Low condition and anemia are typically associated with leucocytozoonosis in birds (Atkinson and van Riper 1991, Bennett *et al.* 1993) and it may cause high morbidity and mortality (Hunter *et al.* 1997). Avian malaria caused by *Plasmodium* infections may be associated to health problems, including anemia, splenomegaly and myocarditis (Atkinson and van Riper 1991), and may cause death in species or birds not commonly infected with this parasite (Warner 1968, Bennett *et al.* 1993). However, under conditions of abundant food supply, most infections with blood parasites may cause no severe effects on health, as the immune system may be able to successfully fight infection (Atkinson and van Riper 1991). Therefore, the severe infections and associated symptoms of low condition found in osprey nestlings may indicate reduced food availability during the breeding season of 2001 and possibly other related factors such as high breeding density (Tella *et al.* 2001). The fact that no mixed infection with the two blood parasite species was recorded is remarkable because it may indicate competence between intraerythrocytic parasites, which need further examination and research.

The high prevalence and intensity of infection found is not expected according to the potential scarcity of vectors due to the marine environment and the dry conditions around the colonies (Piersma 1997, Jovani *et al.* 2001). The lack of suitable vectors in marine environments or open and arid areas has been argued to explain the absence of blood parasites in several bird species (Blanco *et al.* 1997, Tella *et al.* 1999, Martínez-Abrain and Urios 2002) but it failed to explain presence of blood parasites in other species and particular localities (Bosch *et al.* 1997). The only previous survey of avian blood parasites in Baja California found geographical differences in the prevalence of infection by *Haemoproteus coatneyi* in wintering white-crowned sparrows (*Zonotrichia leucophrys*). These differences were argued to be associated to contrasting environmental conditions affecting both the vectors and the hosts in coastal and inland oases where birds were respectively sampled (Blanco *et al.* 2001). The studied osprey colonies were located far from any source of fresh water where the potential vector of *L. toddi* and *Plasmodium*, such as black flies (Simulidae) and *Culicoides* spp. mosquitoes (Ceratopogonidae) may breed. However, these and other appropriate vectors may be common in mangroves that are about 10 km far from the colonies (pers. obs.). Though the effects of salinity on rates of infection by haematozoa may be less significant compared to those from areas with fresh water (Figuerola 1999), salinity levels in mangroves may be lower than in open sea and suitable vectors may also breed in dead and humid vegetation (Atkinson and van Riper 1991).

As mentioned before, the only ectoparasite found on nestlings in high numbers was the louse fly *Olfersia fumipennis* (Hippoboscidae). Louse flies are blood-sucking parasites that may cause a reduction in their host's body condition (Bize *et al.* 2004) and transmit blood parasites (Sol *et al.* 2000). Several species of *Olfersia* louse flies have been cited as potential vectors of avian protozoan parasites in Hawaiian birds (van Riper 1991). The emergence and abundance of these and other potential vectors need to be assessed in the future to determine their effects on nestling ospreys. Assessing whether louse flies, high blood parasites infestation or both are involved in low condition or depressed immunity of nestling ospreys in Baja California is worthy of further investigation. Given the absence of haematozoa in nestlings from populations where osprey nest solitarily (Miller *et al.* 1997, Krone *et al.* 2001), the role that parasites may play in the transition from colonial to solitary nesting or *vice versa* in this species may be a good study model of the costs associated to the evolution of coloniality in birds.

ACKNOWLEDGEMENTS

We thank L.B. Rivera for sampling blood smears and A. Cota for field assistance. J.M. Godoy determined the sex of nestling ospreys at the Laboratory of Molecular Ecology, Estación Biológica de Doñana. J.L. Tella provided valuable comments on the manuscript. Dra. M.G. López Campos identified the Hippoboscide louse fly at the Laboratory of Acarology, UNAM. We thank M. en C. Diana Leticia Dorantes Salas for helping in the english edition. Consejo Nacional de Ciencia y Tecnología (SEMARNAT-CONACyT C01-0318) and CIBNOR gave financial support.

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Resident and wintering populations of the burrowing owl (*Athene cunicularia*) in México

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ABSTRACT

The burrowing owl was officially listed as a threatened species in México in 1994, but was delisted in 2001. However, little is known of its current status and distribution and only scattered quantitative information of its abundance throughout México exists. There is no published information on estimates and trends of resident and wintering burrowing owl numbers in México. We present our information of burrowing owl local populations in the northwestern states of Chihuahua, Durango, and Sonora, and the Baja California Peninsula. Xerophytic scrub dominates the Durango and Sonora deserts, and a desert thicket dominates the Baja California desert. Sandy-clay and sandy soils are common in the areas where burrowing owls are found. Burrows were located in arroyos, dunes, and valleys, and were originally made by kangaroo rats, fox, badgers, coyotes, and desert tortoises. Our preliminary data indicate the most important threats for burrowing owls in México are habitat loss, burrow destruction by cattle, and poisoning. Official international agreements are needed to establish functioning cooperative programs between official agencies, universities, and research centers of the three countries

included in NAFTA and to find common strategies of natural resource management and conservation that can be presented to the appropriate national agencies within NAFTA. We also propose a study in México, involving local residents, to study the ecology and the threats to burrowing owls during winter seasons in the desert and coastal lowlands. Status, ecological requirements, feeding habits, and threats should be studied simultaneously at several locations. This information is crucial for its conservation.

Key words: burrowing owl, habitat, conservation management, *Athene cunicularia*, Durango, Chihuahua, Sonora, Baja California Peninsula, México

RESUMEN

La lechucita de madrigueras fue considerada como una especie amenazada en México en 1994. Al presente, ha sido sacada de esta lista, aunque se sabe poco sobre su estatus y distribución, existiendo poca información publicada sobre su abundancia en México. No hay información publicada sobre estimaciones en números y tendencias de las poblaciones residentes y migratorias en México. Se presenta información de poblaciones locales en Chihuahua, Durango, y Sonora, y de la península de Baja California. El matorral xerófilo domina los desiertos en Durango y Sonora, y un tipo de matorral desértico particular es el desierto de Baja California. Los suelos arenoso-arcillosos y arenosos son comunes en las áreas donde se han registrado las lechucitas de madrigueras. Las madrigueras donde anidan o pernoctan se han localizado en arroyos

secos, dunas y valles; éstas fueron originalmente construidas por ratas canguro, zorras, tejones, coyotes y tortugas del desierto. Nuestros datos preliminares indican que las amenazas más importantes para las lechucitas de madrigueras en México son la pérdida de hábitat, la destrucción de las madrigueras por el ganado, y el envenenamiento. Se requieren tratados internacionales oficiales efectivos con los que se puedan establecer programas funcionales de cooperación entre las agencias oficiales, universidades, y centros de investigación de los 3 países incluidos en el NAFTA (y la CCA). Es necesario encontrar estrategias comunes para el manejo de recursos y la conservación en particular que se puedan presentar a las agencias nacionales correspondientes dentro del NAFTA. También proponemos un estudio en México que involucre a los residentes de las áreas, para estudiar la ecología y las amenazas que enfrentan las poblaciones de lechucitas de madrigueras durante la estación de invierno en el desierto y zonas costeras. El estatus, requerimientos ecológicos, dieta, y las amenazas deberían ser estudiadas simultáneamente en varias localidades. Esta información es crucial para establecer medidas de conservación.

INTRODUCTION

The burrowing owl (*Athene cunicularia*) ranges from Canada to Argentina, mainly occurring in grasslands and arid lands throughout its territorial range (Haug *et al.* 1993). The burrowing owl is a relatively well-studied species throughout its northern breeding range, but little is known of its wintering grounds (Wellicome and Holroyd 2001). Very little is known of its current status, distribution, and ecology throughout México. There is no published information on estimates and trends of resident and wintering populations in México. Only scattered quantitative information of its abundance exists (Holroyd *et al.* 2001). Estimating population trends is particularly relevant for the burrowing owl because its current status in most of its northern territory is endangered or declining in part of this distribution (see Holroyd *et al.* 2001).

The burrowing owl has been listed as a threatened species in México (NOM-059-ECOL-1994), but has been delisted recently (NOM-059-ECOL-2001). It is unclear whether a population decline has occurred in México and, if it is true, we do not know the extent of this decline. If a population decline existed in México, it is unknown how the decline is happening because this species has been poorly studied. Most works related to this owl in México are anecdotal, mainly distributional records, with only a few referring to its ecology (see Clark *et al.* 1997). For instance, we found only one publication on productivity and feeding habits (Rodríguez-Estrella 1997).

Without adequate information, it is not possible to determine the current status and population trends of resident and wintering populations in México. This information is crucial if we want to take actions to stop or reduce further declines in burrowing owl populations.

In this paper, we present information on the current knowledge of northern México's burrowing owl populations and discuss the areas where resident and migrant populations have been found. Few studies have previously been done with Mexican resident populations (Rodríguez-Estrella 1994, 1997). The relative importance of México for wintering burrowing owls had been previously recognized (James and Ethier 1989, Enriquez-Rocha 1997, Valdez and Holroyd 2000).

METHODS

Our accounts on habitats, breeding, and winter distribution of burrowing owls were based on an extensive search of the literature and field studies made in different locations over about 10 years time. Partial information on their ecology has been published (Rodríguez-Estrella *et al.* 1983, Rodríguez-Estrella and Ortega 1993, Rodríguez-Estrella 1997, Valdéz 2003; a detalilled description of the studied areas and methods can be found in these publications).

RESULTS

Information on burrowing owls in México

According to the literature, museum specimens, and recent scattered surveys, the burrowing owl seems to be widely distributed in México, especially in northern arid regions, and is common in a few localities (Fig. 1, Table 1). Unfortunately, only a few studies have described their habitat. For example, Enriquez-Rocha (1997) and Enriquez-Rocha *et al.* (1993), in an extensive work, compiled and analyzed data on 279 burrowing owls in 27 museum collections (21 outside of México), and found that they were widely distributed, present in 28 of 32 states of México. However, accurate

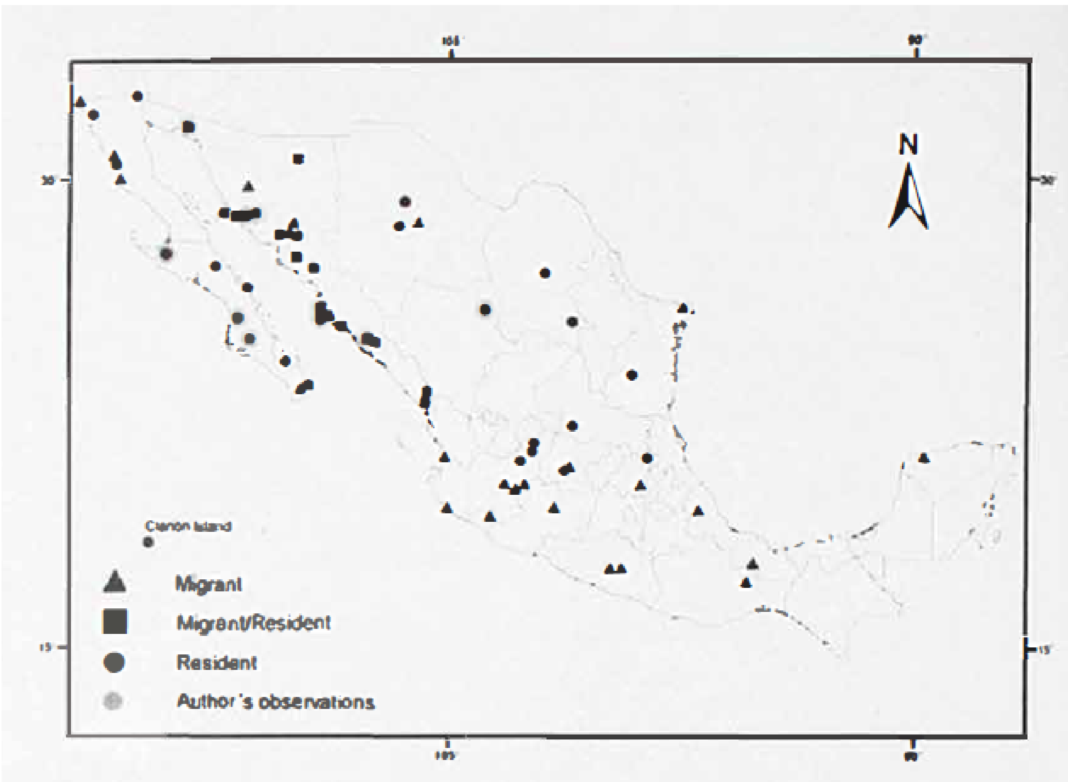

Figure 1. Resident and wintering populations of burrowing owls in México. Data comes from museum specimens, literature, and authors' records.

information is not available, the data does not specify the habitat type where the specimens were found.

In our surveys of Durango, Sonora, and Baja California, we can now provide a general assessment of the status of the burrowing owl in those localities of northern México States where we studied their populations in a brief period of time. We can also evaluate the habitats where they occur seasonally.

Table 1. Distribution of burrowing owls in México from 1 (Macouzet 1993); 2 (Rodríguez-Estrella 1997); 3 (Rodríguez-Estrella *et al.* 1983); 4 (Valdez 2003); * (Authors' observations); KU (Colección de Aves y Mamíferos del Valle de Cuatrociénegas; MVZ (Museum of Vertebrate Zoology, University of California, Berkeley); MZFC (Museo de Zoología de la Facultad de Ciencias, UNAM); MCZ (The Museum of Comparative Zoology, Harvard University); CAS (California Academy of Sciences, San Francisco). The high number of records given in Palacios *et al.* (2000) for the peninsula of Baja California are not included in this table, but in Appendix 1.

state	location	museum	status
Baja California	San Ramon, mouth of Río Santo Domingo	MVZ	Resident ?
	Alamo River, 20 mi SW Pilot Knob	MVZ	Resident ?
	Tijuana	MVZ	Migrant ?
	No Location	MVZ	Migrant ?
	Guadalupe	MCZ	Resident ?
	San Quintin	MCZ	Resident ?
	El Rosario	MCZ	Migrant ?
	San Pedro Nolasco	CAS	Resident ?
	Clarion	MCZ	Resident
Baja California Sur	No Location	MVZ	Resident ?
	Arroyo Malarrimo	*	Resident
	Arroyo San José de Castro	*	Resident
	Cd. Constitución	*	Mig/Res
	Eureka	MCZ	Mig/Res
	San Javier	MCZ	Mig/Res
	La Paz	MCZ	Migrant
	Miraflores	MCZ	Migrant
	Ildefonso	MCZ	Mig/Res
	Llanos de Hyrais	*	Mig/Res
Chihuahua	Chihuahua	MCZ	Migrant ?
	Cerro Campana	MVZ	Resident ?
	Laguna Bustillos	1	Resident?
Coahuila	Cuatrociénegas - 14.4 km E, 1.8 km S from Cuatrociénegas	KU	Resident
	Saltillo	1	Resident ?
Colima	Plains of Colima	MCZ	Migrant ?
Durango	Mapimi	2	Resident
Guerrero	Chilpancingo	1	Migrant ?
	Omilteme	MVZ	Migrant ?
	Chilpancingo	MCZ	Migrant ?
Guanajuato	Valencianita (Irapuato)	1	Migrant

Table 1. *Continued.*

state	location	museum	status
Hidalgo	Actopan	1	Migrant ?
	San Salvador	1	Resident?
Jalisco	El Guayabo (Pegueros)	4	Migrant
	Paso deTrujillo (San Juan de Los Lagos)	4	Migrant
	Potrero La Cantera (Encarnación de Díaz)	4	Migrant
	Chamela	1	Migrant ?
	La Barca	1	Migrant ?
	Lago Chapala	1	Migrant ?
Michoacán	Pátzcuaro	1	Migrant ?
	Escuinapa	MCZ	Migrant ?
Morelos	El Cedral	1	Migrant ?
	Alejandra	1	Migrant ?
Nayarit	Las Varas	1	Migrant ?
ND	Clarion	MCZ	Migrant ?
Oaxaca	Tutla	1	Migrant ?
	San Pablo	1	Migrant ?
	Villa de Mitla	1	Migrant ?
Sinaloa	16 km SE Topolobampo	MZFC	Mig/Res
	Ahome	MZFC	Mig/Res
	Boca del Río Sinaloa	MZFC	Mig/Res
	Culiacan	MZFC	Mig/Res
	Chele	MZFC	Mig/Res
	Escuinapa	MZFC	Mig/Res
	Estación Biteruto, before El Tamarindo, near San Blas	*	Mig/Res
	Road to El Maviri SW from Topolobampo	*	Mig/Res
	Ahome	CAS	Migrant ?
San Luis Potosí	San Luis Potosí	MCZ	Resident
Sonora	Arenas, near	MZFC	Mig/Res
	Bacuachi	MZFC	Mig/Res
	Pinacate	3	Mig/Res
	Bahía Kino	MZFC	Mig/Res
	Cd. Obregón	MZFC	Mig/Res
	Isla San Esteban	MZFC	Mig/Res
	La Bonancita	MZFC	Mig/Res
	Las Arenas	MZFC	Mig/Res
	Tesia	MZFC	Mig/Res

Table 1. *Continued.*

state	location	museum	status
	Road to Puerto Libertad	*	Mig/Res
	Bacuachito	MCZ	Migrant ?
	Bonancita	MCZ	Migrant ?
	Arenas	MCZ	Migrant ?
Tamaulipas	Cd. Victoria	1	Resident
	Altamira	MCZ	Migrant ?
	Matamoros	MCZ	Migrant ?
Veracruz	Achotal	1	Migrant ?
	Mountains of Coatepec	MCZ	Migrant ?
Yucatán	San Ignacio	MCZ	Migrant ?
Zacatecas	La Cinta (Mpio de Pinos)	4	Migrant ?

1. Existing ecological information about burrowing owls in México

Durango: The northeastern part of this state is part of the Chihuahuan Desert. Information on its summer and winter status in the Mapimi Biosphere Reserve is available. Breeding performance, nest-habitat preferences, kinds of nest-burrows, diet during the breeding season (Table 2), and threats (Table 3) have already been described (Rodríguez-Estrella 1997, Rodríguez-Estrella and Ortega 1993, Table 2). Currently, analyses of the winter diet and use of burrows are in progress (Rodríguez-Estrella, Holroyd, and Uranga unpubl. data).

Chihuahua: New information on occurrence, habitat characteristics, and limited data on diet during the winter in the grasslands of Chihuahua has been published elsewhere (i.e. poisoning, habitat loss, grazing; Chávez-Ramírez 1990) (Fig. 1, Table 1). The important threats to burrowing owls have been previously defined (Chávez-Ramírez

1990).

Sonora: We have information of a population located in northwestern Sonora, the Pinacate area within the Sonora Desert. Only limited information about occurrence, habitat characteristics, diet, and threats is available (Rodríguez-Estrella *et al.* 1983, Hiraldo, Delibes, Rodríguez-Estrella, and Donázar, unpubl. data; Table 3).

Table 2. Habitat characteristics of burrowing owl populations of northern México. The status and productivity are given for known populations.

area	Habitat	status	Productivity
Durango (Mapimí) 20,000 Ha	Xerophytic scrub desert: *Larrea, Hilaria, Prosopis.* Soils: Sandy-clay. Topography: valleys with small hills, arroyos. Precipitation: 230 mm. Temperature: 11-28°C. Known nesting burrow preferences: Kangaroo rat, fox, badger, coyote, and desert tortoise burrows	stable ± 40 pairs	1.2 + 1.1 fledglings/ attempts
Sonora (Pinacate)	Xerophytic scrub: *Croton, Larrea, Baccharis, Ambrosia, Fouquieria.* Soils: Sand Topography: valleys, dunes, arroyos. Precipitation: 50-120 mm. Temperatures: 10-30°C. Nest burrow preferences: unknown, possibly fox, coyote, and kangaroo rat burrows	stable ± 15 pairs	?
Baja California (Vizcaino)	Desert thicket: *Asclepias, Fouquieria Larrea, Encelia, Ambrosia.* Soils: Sandy Topography: gentle hills, dunes, arroyos. Precipitation: 92 mm. Temperatures: 18-22°C. Nest burrow preferences: fox, badger, coyote, and kangaroo rat burrows	stable ± 10 pairs	?

Baja California Peninsula: the burrowing owl is a widespread, but uncommon resident throughout the length of the peninsula (Palacios *et al.* 2000). The population in the Vizcaino Desert in the center of the peninsula has been studied during all seasons and information is available on occurrence, nest habitat preferences, burrow types, feeding habits during the breeding and wintering periods (Table 2), and threats (Table 3). Wintering owls have also been found throughout the peninsula (Palacios *et al.* 2000, Rodríguez-Estrella, unpubl. data; Fig. 1).

Xerophytic scrub dominates the Chihuahuan and Sonoran Deserts and a subtropical desert chaparral dominates the southern third of the Baja California Peninsula (Table 2). Sandy-clay and sandy soils are common in the areas where burrowing owls are found. Burrows were located in arroyos, dunes, and valleys, originally constructed by kangaroo rats *Dipodomys* spp., foxes *Urocyon cinereoargenteus* and *Vulpes macrotis*), badgers *Taxidea taxus*, coyotes *Canis latrans*, and desert tortoises *Gopherus flavomarginatus* (Table 2).

Table 3. Threats to burrowing owl populations in some regions of México.

population	threats
Durango	Loss of habitat, burrow destruction by cattle, pesticides in areas with intensive agriculture in central Durango
Sonora	Destruction of burrows by cattle, pesticides in areas with intensive agriculture, loss of habitat in central and southern coastal Sonora, probably sport hunting
Baja California	Probably pesticides in areas with intensive agriculture; in northern populations, possibly loss of habitat and destruction of burrows by cattle

2. Loss and degradation of habitat, a potential problem leading to population decline

México has one of the highest rates of loss of biodiversity in Latin America from loss and degradation of habitats (SEMARNAT 2003). Although little information is available on habitat preferences of burrowing owl populations in México, we frequently found them in the xerophytic scrub habitats of northern México during the breeding and wintering seasons (Table 1). We also found owl pairs among dune vegetation near the coast (Table 1, Fig. 2). However, burrowing owls use a variety of habitats, from undisturbed areas to disturbed grassland and cultivated areas (Figs. 1 and 2).

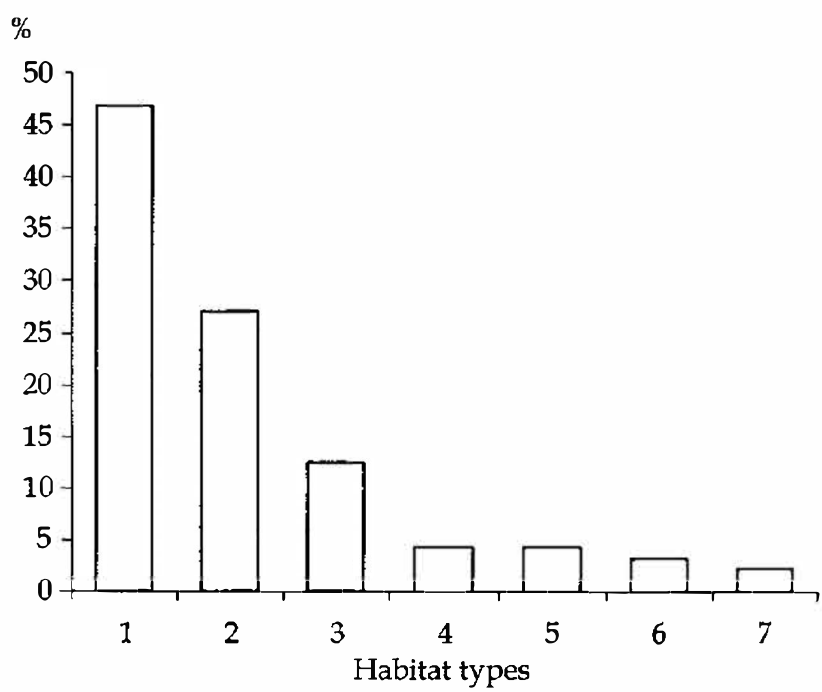

Figure 2. Habitats where burrowing owls have been recorded in México, both during resident and migration periods. 1. suburban and cultivated areas; 2. sarcocaulescent scrub, thorn scrub, and subtropical, tropical deciduous wooded savanna, riparian woodlands, and xerophytic desert scrub; 3. microphyllous scrub, gypsophilous and halophilous vegetation, halophilous vegetation and vegetation associated with sandy soils; 4. tropical medium-height forest, cloud forest, pine forest, and tropical rainforest; 5. chaparral and coastal sage scrub; 6. grassland and open areas; 7. mangrove

Xerophytic scrub in México is being converted to agricultural and ranching uses and coastal vegetation is also lost to tourist facilities. The grassland vegetation has been heavily disturbed by cattle raising and agriculture (SEMARNAT 2003). It is expected that this dramatic change will affect distribution of the burrowing owl, including a decline in the number of resident and migrating populations (see Holroyd *et al.* 2001). In spite of continual habitat losses, xerophytic scrub covers a very large area of northern México and, in many areas, is well preserved. This may assure stability of many burrowing owl populations in the short to medium term. Studies of habitat preferences of resident and wintering populations in México are still needed to determine which areas are at risk, so that most populations will be conserved. Also, studies on habitat use of burrowing owls in agriculture and town locations could help to determine the risks owl populations will face in the near future. Of particular concern is the high number of records of burrowing owl in, or near agricultural and town locations (Fig. 2); populations should be evaluated in these areas.

3. Identifying wintering areas, understanding wintering ecology, and establishing international agreements

Most burrowing owl populations seem to be resident, but researchers demonstrated that populations from the USA and Canada overwinter in México (James and Ethier 1989, Holroyd and Trefry 1998). Overwintering populations have been recorded in Guanajuato, Tamaulipas, Coahuila, Chihuahua, the Baja California and Veracruz (Holroyd *et al.* 2001, Palacios *et al.* 2000). Most wintering populations have been recorded and collected in central and southern México (Fig. 1, Table 1). At present, international agreements between México, USA, and Canada have been few and have not had continuity, although international agreements officially exist in all countries.

Very little information has been published on the ecology and threats to burrowing owl populations in México. Our preliminary data indicate that the most important threats are habitat loss, burrow destruction by cattle, and poisoning. However, the information available is limited and obtained only on a local scale. Data on degradation of habitats for breeding and wintering populations on a regional scale is needed. Information of the effects of pesticides and contaminants and land-use changes where burrowing owls are present is also needed.

Specific information on the effects of human activity and environmental factors on the biology and habitat use of burrowing owls is lacking. Some raptors may take advantage of areas containing crop fields, particularly migrant species in their wintering areas, to exploit abundant food sources (i.e. insects, rodents) (Rodríguez-Estrella *et al.* 1998). However, intensive cultivation of grasslands is recognized as a cause of declining owl populations (Haug *et al.* 1993). We found some pairs of burrowing owl nesting at the edge of crop fields, where they fed on small mammals and invertebrates (e.g., near Ciudad Constitución, Baja California Sur). Information on owls during overwintering is increasing, but is still very scarce. Particular studies on the effects of land use changes and habitat degradation on burrowing owl resident and withering populations are urgently needed.

Any conservation plan for burrowing owls in México requires baseline information on distribution, habitat preferences, feeding habits, and identification of threats on the local and regional level on a seasonal and long-term basis and different spatial scales. We also need information on the economic needs of landowners. This information is crucial for conservation programs. More detailed information can be found in Holroyd *et al.* (2001).

Another important issue needed for conservation is to establish more international agreements. One important step to achieve this is to establish functional cooperative programs between government agencies, universities, and research centers of the three NAFTA nations, and to find common strategies for natural resources management and conservation that can be presented jointly to the appropriate national agencies in these countries. Conservation of burrowing owls throughout their range depends on the evaluation of threats at a regional scale, giving solutions at this scale.

We propose an international study in México, including Canada, USA, and México research teams to study the ecology and threats facing burrowing owls during the winter (see Holroyd *et al.* 2001). The study could start in northern México and spread through the central desert areas and coastal lowlands. Status, ecological requirements, feeding habits, and threats could be studied simultaneously at several locations. Geographical Information Systems will help with spatial analysis. Modeling of human-related factors to determine the effects of human activities (agriculture, deforestation, ranching, poisoning) on burrowing owl populations could help us understand the threats of these activities on the persistence of the species at the regional scale.

CONCLUSION

Little is known of the status and distribution of burrowing owl populations in México, and only scattered quantitative information of abundance throughout its range exists. Conservation of northern migrant populations in México depends primarily on the knowledge of the habitats that owls are using in the winter. Since 1992 (Lincer 1997), little has been added to our understanding of breeding and wintering burrowing owl populations in México. However, we propose that the burrowing owl be officially listed again as a threatened species in Mexico. Its decline in Canada and in the northern populations of the USA justify this proposal because we need to establish conservation actions at regional scale, including Mexico, for wintering populations of this species.

ACKNOWLEDGMENTS

We thank A. Cota for field assistance. G. Arredondo drafted the Figure 1. Consejo Nacional de Ciencia y Tecnología (SEMARNAT-CONACyT C01-0318) and CIBNOR gave financial support. BG received a CONACyT scolarship grant for completing his Bachelnr's Thesis.

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Apendix 1. Historical and recent records of burrowing owls on the peninsula of Baja California and Sonora, México. Modified from Palacios *et al.* 2000. The "?" indicates the status is not completelv confident.

state	location	status	vegetation
Colorado Delta Region			
BC	Alamo River	Migrant?	Riparian
	Ejido Hermosillo	Migrant?	Agricultural
	Mexicali	Resident	Agricultural
	Colonia Robledo	Resident	Agricultural
	Cerro Prieto	Resident	Agricultural
	Between ejidos Nayarit and Sonora	Migrant?	Agricultural
	Río Hardy	Migrant/Resident	Riparian
	Cucapa Indigena	Migrant/Resident	Riparian
	Between Rancho El Caiman and Highway	Resident?	Riparian
	Ejido Monterrey	Resident?	Riparian
	El Mayor	Resident?	Agricultural
	Yuri Muri. south of Mexicali	Resident?	Agricultural
	San Felipe road	Resident?	Desert
SON	N of Estación Coahuila	Resident	Agricultural
	Mexicali Valley	Migrant?	Agricultural
	Ciénaga de Santa Clara	Resident	riparian
	Bordo Lerma	Migrant?	Agricultural
	Colorado delta region	Uncommon	Desert & agricultural
Northwestern Baja California			
BC	Rancho Neji	Resident?	Riparian
	Tecate	Resident?	Agricultural
	Tijuana	Migrant?	Coastal sage scrub
	Playas de Tijuana	Resident	Coastal sage scrub
	Rosarito	Resident	Coastal sage scrub
	San Antonio de Las Minas	Migrant?	Agricultural
	Between El Tigre and San Antonio de Las Minas	Resident?	Agricultural
	N of Ensenada	Resident?	Coastal sage scrub
	Mounth of Arroyo Ensenada	Migrant?	Coastal sage scrub
	Sand Dunes	Migrant?	Sand Dunes
	Laguna El Ciprés	Resident	Agricultural
	El Ciprés Airport	Resident?	Agricultural
	On road to Punta Banda, just south of Ensenada	Migrant?	Irrigation Dike
	Meneadero	Resident?	Agricultural
	Estero Punta Banda	Migrant/Resident	Wetland

Appendix 1. *Continued.*

state	location	status	vegetation
	Valle de Maneadero	Resident	Agricultural
	Punta Banda, between La Bufadora and Villarino	Migrant?	Chaparral/grass edge
	Ojos Negros	Resident	Riparian
	Real del Castillo	Resident	Riparian
	Marsh north of Ojos Negros	Resident	Agricultural
	Santo Tomas	Resident?	Agricultural
	N of San Vicente	Resident	Agricultural
	7 km N of San Vicente	Resident	Agricultural
	San Antonio del Mar	Resident	Coastal sage scrub & Agricultural
	Punta Colonet	Resident?	Coastal sage scrub
	San Telmo	Resident?	Agricultural
	Bocana de Santo Domingo	Resident?	Riparian
	Field northeast of Laguna Figueroa	Resident?	Agricultural
	Laguna Figueroa south	Resident?	Wetland
	Bahía de San Quintín	Resident?	Coastal sage scrub-Desert
	San Quintín valley	Resident?	Agricultural
	San Quintín	Resident	Agricultural
	Mouth of Cañón de Agua Chiquita	Resident	Coastal sage scrub
	Bahía de San Quintín. Muelle Viejo	Resident	Coastal sage scrub
	Bahía de San Quintín, saltpond	Resident	Coastal sage scrub
	Bahía de San Quintín. Punta Azufre	Resident	Wetland
	San Quintin, English Graveyard	Resident	Wetland
	Bahia San Simon north	Resident	Wetland
Central Desert of Baja California			
BC	El Rosario	Migrant?	Desert
	Near San Fernando	Resident?	Desert
	"San Jabier" (San Javier)	Resident?	Desert
Vizcaino Desert			
BCS	Guerrero Negro	Resident	Desert
	E shore of Estero San Jose, W Guerrero Negro	Resident	Old Salt Works
	Estero de San José W of Guerrero Negro	Resident	Old Salt Works
	Laguna San Ignacio	Resident	Desert and Wetland
	Laguna San Ignacio. El Cardón	Resident	Desert
	Laguna San Ignacio, El Delgadito	Resident	Wetland
	Isla Pelícanos	Migrant	Desert
	Road to Punta Abreojos	Resident	Desert

Appendix 1. *Continued.*

state	location	status	vegetation
	Loreto	Resident?	Desert
	Bahía Magdalena	Resident	Desert
Cape Region			
BCS	La Paz	Migrant	Desert
	19 km N of La Paz	Migrant	Desert
	Ejido Chametla	Migrant	Desert
	Ejido Alfredo V. Bonfil	Migrant	Abandoned field
	3 Km N of El Centenario	Migrant	Desert
	Todos Santos	Migrant	Desert
	Miraflores	Migrant	Subtropical deciduous scrub
	Eureka	Migrant	Subt. deciduous scrub
	San José del Cabo	Migrant	Subt. deciduous scrub
	Cabo San Lucas	Migrant	Subt. deciduous scrub
Offshore islands of Baja California peninsula (including those belonging to Sonora)			
BC	Los Coronados	Resident?	
	Todos Santos	Not Uncommon	
	San Martin	Migrant?	
	Guadalupe	Resident?	
	San Jerónimo	Resident?	
	San Benitos	Not Common	
	Cedros	Migrant?	
	Natividad	Resident	
BCS	Magdalena	Resident?	
	Santa Margarita	Resident?	
	Angel de la Guarda	Resident?	
	Piojo	Resident?	
	Cardonosa	Resident?	
	Rasa	Resident?	
	Salsipuedes	Resident?	
	San Lorenzo Norte Las Animas	Resident?	
	Tortuga	Migrant?	
	San Ildefonso	Migrant?	
	Cerralvo	Resident?	
	Coronados	Migrant?	
SON	San Esteban	Common Winter Visitant	
	Tiburón	Common Winter Visitant	
	San Pedro Mártir	Resident?	

Raptor and raven electrocutions in northwestern México: a preliminary regional assessment of the impact of concrete power poles

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Javier Bruno Granados Ruíz

ABSTRACT

Recent research has shown that concrete power poles with steel cross-arms are responsible for large numbers of raptor and raven electrocutions in northwestern Chihuahua. Monitoring of raptor and raven mortality in that area is important, but there is also a need for information regarding the numbers of concrete power poles and their impact in other parts of México. From February 2002 through March 2004, we conducted power-line surveys in Chihuahua, Sonora, and Baja California Sur. In Chihuahua, most areas we inspected had either wooden poles or concrete poles that had been retrofitted with wooden cross-arms, perch guards, or polyvinyl chloride (PVC) covering. Only the northwestern part of the state was found to have large numbers of non-retrofitted concrete poles, along with important bird mortality (chiefly of Chihuahuan ravens [*Corvus cryptoleucus*] and red-tailed hawks [*Buteo jamaicensis*]), including along power lines never before surveyed. In Sonora,

concrete poles were found to be widespread, but as in Chihuahua many of them had been retrofitted. We found a total of 10 dead birds (2 turkey vultures [*Cathartes aura*] and 8 ravens) under non-retrofitted poles in the northeastern part of the state. Five dead birds including 2 red-tailed hawks were also detected under non-retrofitted poles of a power line in coastal west-central Sonora. In Baja California Sur, few power lines with concrete poles were observed, and of these, only 1 yielded an electrocuted bird, a common raven (*Corvus corax*). The results of our surveys suggest that prior to the retrofitting effort now taking place, bird electrocutions on concrete poles were very widespread, affecting much of Sonora and Chihuahua, and some areas of Baja California Sur. With many concrete poles now retrofitted, raptor and raven mortality should be lower along power lines of northwestern México, but more surveys are needed to verify the effectiveness of all retrofitting techniques and materials.

Key words: *Aquila chrysaetos*, *Buteo jamaicensis*, *Buteo regalis*, concrete poles, electrocutions, ferruginous hawk, golden eagle, raptors, ravens, red-tailed hawk.

RESUMEN

Investigaciones recientes han demostrado que los postes de concreto con brazos de acero cruzados en líneas eléctricas, son responsables de un gran número de electrocuciones de rapaces y cuervos en el noroeste de Chihuahua. El monitoreo de la mortalidad de las rapaces y del cuervo en esta área es importante, pero también existe una necesidad de contar con información disponible del número de postes de

concreto y su impacto en otras partes de México. De febrero de 2002 a marzo de 2004 se realizaron muestreos en líneas de transmisión en Chihuahua, Sonora y Baja California Sur. En Chihuahua, muchas áreas fueron inspeccionadas buscando si tenían postes de madera o de concreto que hubiesen sido modificados con brazos cruzados de madera, perchas de guardia, o cubiertos de PVC. Sólo en la parte noroeste del estado se encontró un gran número de postes de concreto no modificados, junto con una importante mortandad de aves (principalmente del cuervo de Chihuahua [*Corvus cryptoleucus*] y del halcón cola roja [*Buteo jamaicensis*]), incluyendo líneas de transmisión nunca antes muestreadas. En Sonora, los postes de concreto fueron ampliamente utilizados, pero muchos de ellos fueron modificados, como en Chihuahua. Se encontró un total de 10 aves muertas (2 zopilotes auras [*Cathartes aura*] y 8 cuervos) en postes no modificados en el noreste del estado. Se detectaron 5 aves muertas, incluyendo 2 halcones cola roja, a lo largo de una línea de transmisión no modificada, muestreada en la parte costera del oeste-centro de Sonora. En Baja California Sur, se encontraron pocos postes de concreto y de éstos, sólo 1 tenía por debajo un ave muerta electrocutada, un cuervo (*Corvus corax*). Los resultados de nuestros muestreos muestran que, previo a los esfuerzos de modificación de postes que tienen lugar ahora, las electrocuciones de las aves en postes de concreto eran ampliamente distribuidas, afectando partes de Sonora y Chihuahua, y en menor extensión a Baja California Sur. Con la gran cantidad de postes de concreto ahora modificados, la mortandad de rapaces y cuervos en líneas de transmisión del noroeste de México debe ser menor, pero se necesitan más muestreos para verificar la efectividad de todas las técnicas de modificación y de los materiales utilizados.

INTRODUCTION

Power poles are an important cause of raptor mortality throughout much of the world (e.g., Markus 1972, Haas 1980, Ledger and Annegarn 1981, Ferrer and Hiraldo 1991, LaRoe *et al.* 1995, Ferrer and Janss 1999, Harness and Wilson 2001). In the western U.S., most poles are built with wood, which under dry weather conditions is a non-conductive material. As a result, electrocutions on wooden poles occur typically when a bird spans the distance between 2 energized wires. In contrast, México has since the 1970s often been using poles that are conductive, as they are made of concrete and fitted with steel cross-arms (Cartron *et al.* 2005). A bird perched on the steel cross-arm of a concrete pole is grounded and need only touch 1 energized wire to be electrocuted. For that reason the risk of electrocution is higher on this type of pole. It may be further compounded by relatively high voltage (34.5 kV in the Janos – Casas Grandes area; see further on) used along distribution power lines of México (Cartron *et al.* 2005). Higher voltage results in arcing over larger distances, and thus the possibility exists that on a concrete pole, a bird can be electrocuted by simply perching very close to an energized wire without actually touching it. Finally, much of northern México is characterized by an arid climate. The lack of tall vegetation at low and middle elevations increases the likelihood that raptors and other birds will use power poles as perches (APLIC 1996).

In March 2002, a workshop was organized in México City to present and discuss information on the impact of power lines on birds in México. Biologists from México and the U.S. as well as representatives of the *Comisión Federal de Electricidad* (CFE) attended the workshop. Other than the research conducted in northwestern Chihuahua (Cartron *et al.* 2000, 2005), there was virtually no information available on bird electrocutions on concrete poles from anywhere in México.

In northwestern Chihuahua, electrocuted raptors have been reported since 1999, chiefly from the Janos – Casas Grandes (JCG) prairie dog town complex and surrounding area (Cartron *et al.* 2005). More than 20 raptor species occur in that area (Manzano-Fischer *et al.* 1999, in press), which also has a large number of concrete poles. Most recently, monthly surveys were conducted in the JCG area from December 2000 through November 2001 (Cartron *et al.* 2005). The remains of 178 birds (52 raptors, 123 ravens, 2 great blue herons [*Ardea herodias*], 1 unidentified) were found during those surveys, all but one at the base of concrete poles. The remains of only 12 dead birds were discovered elsewhere in northwestern Chihuahua, but surveys outside the prairie dog town complex area were very limited. In all survey locations, many, if not most, of the remains bore signs of electrocution (e.g., singed feathers). Those that did not were typically old and/or incomplete remains. Another important finding was that double dead-end poles with double cross-arms (Fig. 1) were associated with higher mortality compared to all other types of concrete poles

(Cartron *et al.* 2005).

At the time of Cartron *et al.*'s (2005) monitoring effort, CFE began to retrofit some of the concrete power poles in the JCG area. What remained unclear, even despite the workshop, was whether CFE was engaged in similar retrofitting efforts elsewhere in Chihuahua or even in other parts of México. In the JCG area, retrofitting consisted of replacing steel cross-arms with longer cross-arms made out of wood.

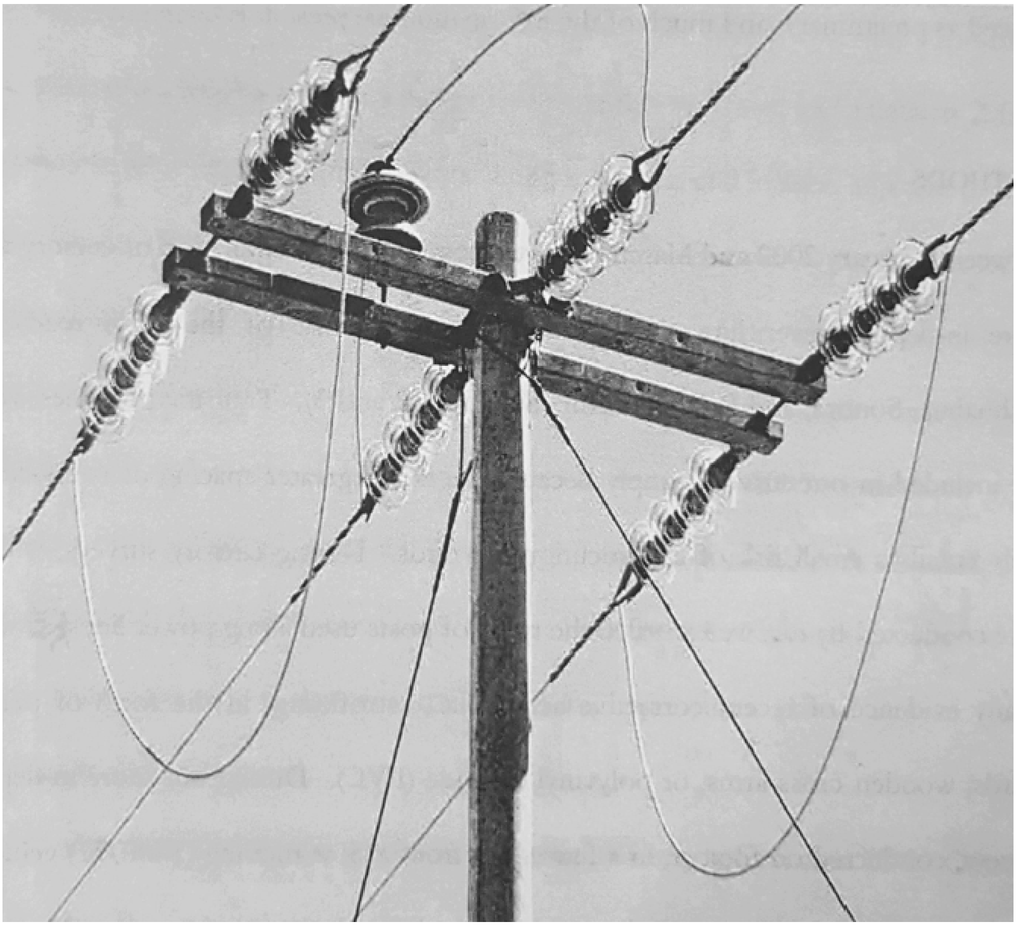

Figure 1. Double dead-end pole with double cross-arms.

In this chapter, we report the results of power-line surveys we conducted from February 2002 to March 2004 in Chihuahua, Sonora, and Baja California Sur. The 3 main objectives of the study were to 1) gather information on the number and location of concrete power poles in those 3 states; 2) assess the magnitude of the retrofitting effort at a regional scale; and 3) search for electrocuted birds under non-retrofitted concrete poles. Although not the principal focus of this study, we also continued to monitor power lines in the JCG general area. This study should be viewed as preliminary, and much of the information we present is qualitative.

METHODS

Between February 2002 and March 2004, we conducted a combination of cursory and more in-depth power line surveys along or near some of the main roads of Chihuahua, Sonora, and Baja California Sur (Figs. 2 and 3). Transmission lines were not included in our surveys simply because the much greater spacing of conductors likely entails a small risk of electrocution for birds. During cursory surveys, which were conducted by car, we recorded the types of posts used along power lines, as well as any evidence of recent corrective action (i.e., retrofitting) in the form of perch guards, wooden cross-arms, or polyvinyl chloride (PVC). During our more in-depth surveys, conducted on foot or, in a few cases, from a slow-moving (5 km/hr) vehicle driven directly under the power line, we searched for electrocuted raptors. Most of the in-depth surveys were along power lines with non-retrofitted concrete poles, but we also inspected a few power lines with wooden poles or concrete poles retrofitted with wooden cross-arms. Every set of remains found under a pole was examined for signs of electrocution, primarily singed feathers. We recorded the location of every set of remains using a Garmin hand-held GPS unit.

Surveys in Chihuahua were conducted on 9-11 February, 26-28 April, 5-8 June, 25-26 July, 28 October, and 11-12 November 2002, and on 18 March 2004. They were conducted directly along Mexican Highway 23 (between Palomas and Highway 2), Highway 16 between Ojinaga and Cd. Chihuahua, Highway 45 north of Cd. Chihuahua, Highway 10 from near Buenaventura to Janos, and Highway 2 from its junction with Highway 23 to the border with Sonora, and in areas adjacent to these main roads (Fig. 2). In total, these surveys spread over a total distance of approximately 1,000 km of roads and covered much of the eastern, central, and northwestern parts of the state. In the JCG prairie dog town complex area (west of Highway 10 and south of Highway 2; see Cartron *et al.* 2005), vegetation types included open grassland, mesquite (*Prosopis* sp.) grassland, shrublands dominated by mesquite or *Ephedra*, and agricultural fields. Elsewhere in Chihuahua, some of the same vegetation types also occurred, with mesquite-yucca (*Yucca* sp.) or yucca grasslands also widespread.

Power-line surveys in northeastern Sonora were conducted on 28-29 October 2002 (Fig. 2). In northern and west-central Sonora they were conducted on 18-20 March 2004. The combined road distance over which these surveys were conducted

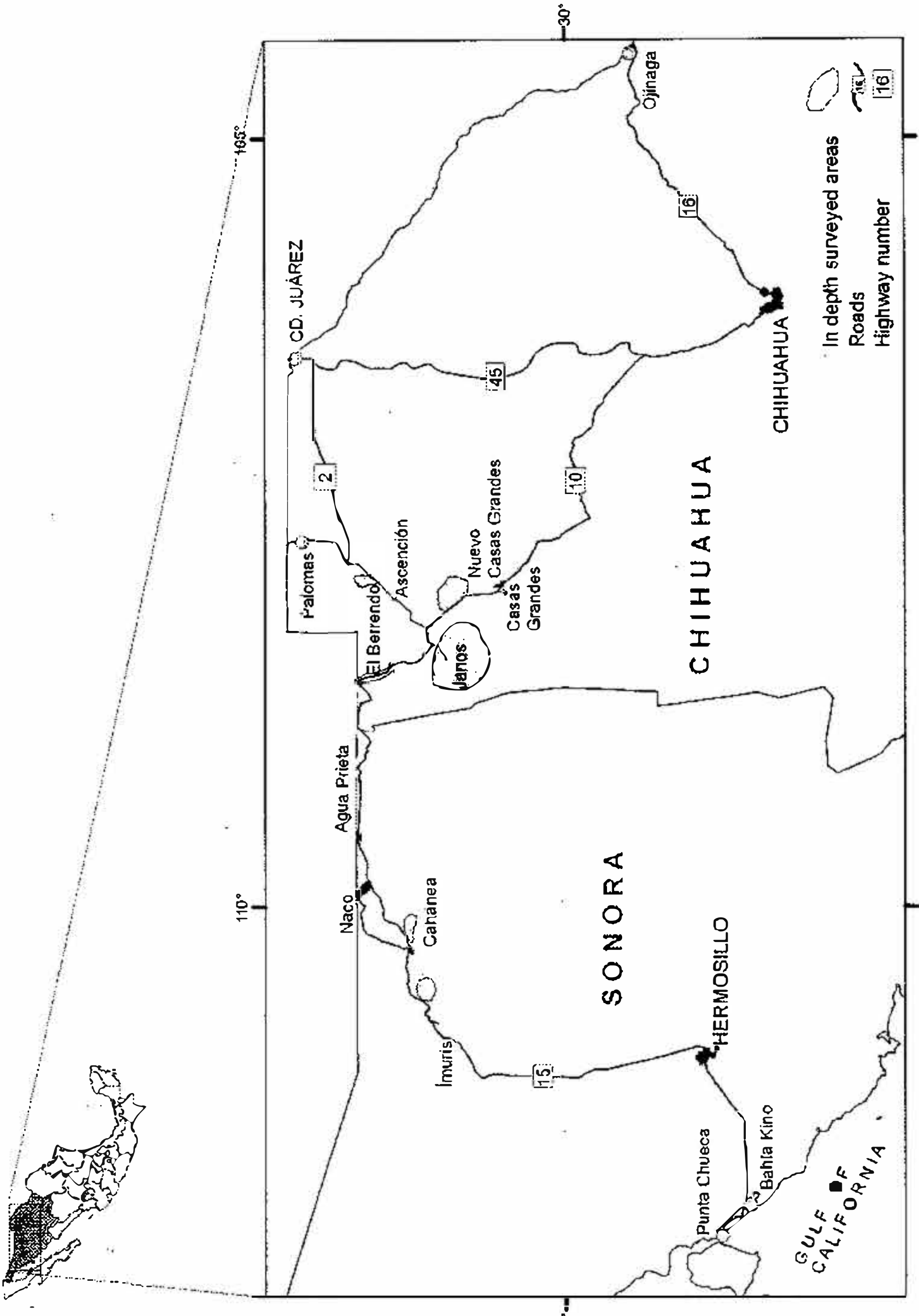

Figure 2. Chihuahua and Sonora, with main roads and areas selected for 'in-depth' surveys.

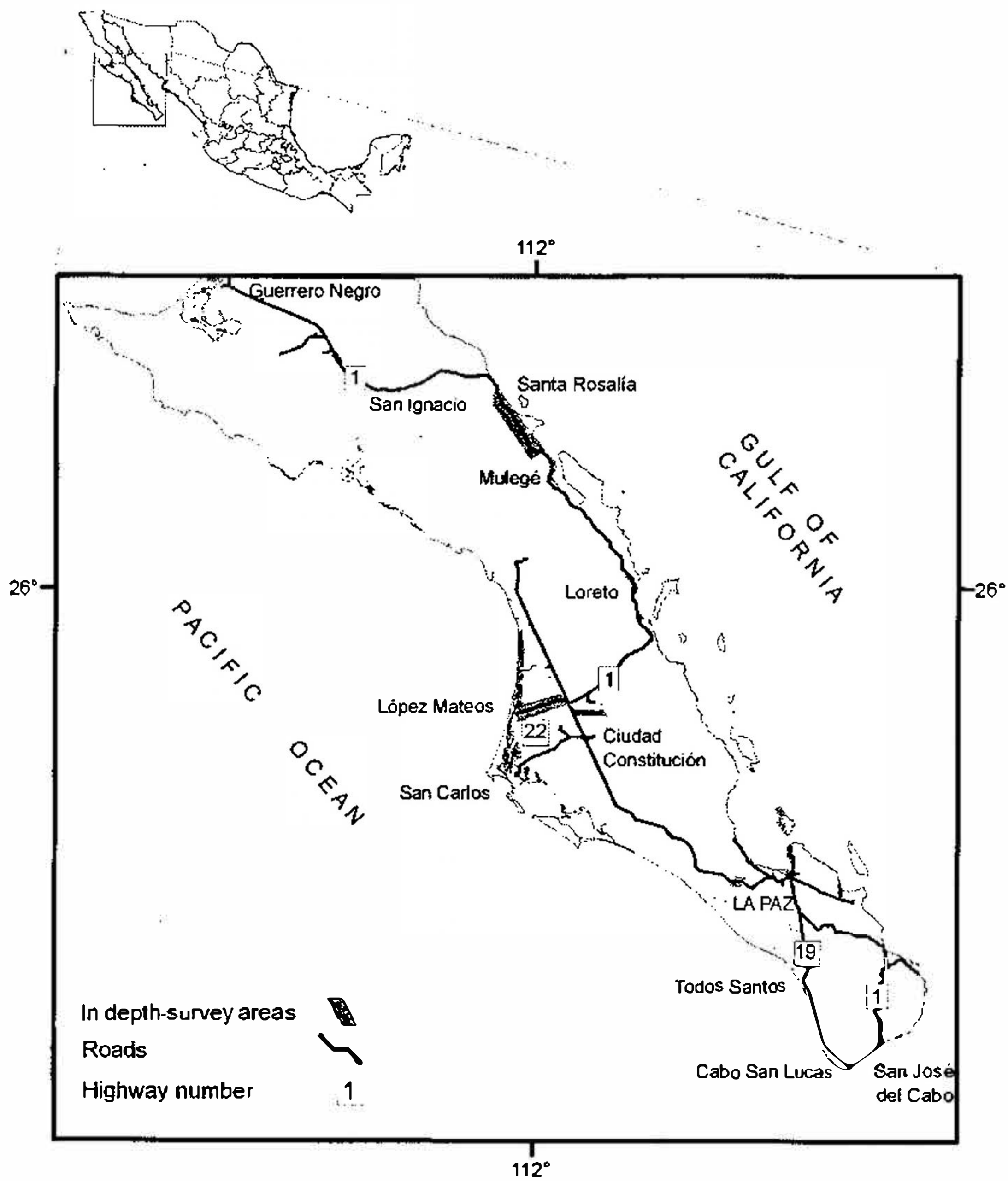

Figure 3. Baja California Sur with main roads and areas selected for 'in-depth' surveys.

totaled approximately 600 km. The vegetation varied widely based in part on elevation. In the northeastern part of the state, some of the areas we inspected had mesquite grasslands or shrublands. In west-central Sonora, a power-line survey was conducted in the vegetational subregion of the Sonoran Desert designated by Shreve (1951) as the Central Gulf Coast. The vegetation was dominated by cacti (e.g., *Pachycereus pringlei*, *Stenocereus gummosus*, *S. thurberi*, *Lophocereus schottii*, *Opuntia fulgida*) and arborescent shrubs (*Cercidium* sp., *Olneya tesota*, *Prosopis* sp.).

All work in Baja California Sur was conducted between 11 April and 26 May, 2003 (Fig. 3). In most places the landscape was dominated by 1.5 to 2 m tall microphyllous Sonoran desert vegetation that included *Atamisquea emarginata, Yucca valida,* and *Pachycereus pringlei.* In the Vizcaino Desert (another subdivision of the Sonoran Desert), the vegetation tended to be smaller and consisted chiefly of *Encelia palmieri, Lycium californicum, Atriplex policarpa,* and *Errazurizia megacarpa.* We first conducted a preliminary inspection of power lines from Cabo San Lucas north to the Vizcaino Desert to locate concrete poles, for a total travel distance of 1,419 km. We then initiated in-depth surveys for electrocuted birds along power lines with concrete poles. Collectively, power lines with concrete power poles spread over a total distance of 189 km. Raptors present in survey areas in Baja California Sur and their use of power poles are presented in Appendix 1.

RESULTS

Distribution of concrete poles

In Chihuahua, concrete poles with steel cross-arms were found to be widespread. The power line along Highway 23 (the road from the border town of Palomas to Highway 2; Fig. 2) consisted entirely of concrete poles, most of them tangent units (Fig. 4), with also some double poles (for a discussion of pole configurations see APLIC 1996 and Cartron *et al.* 2005). We counted approximately 370 poles, none of them retrofitted. Highway 2 from the junction with Highway 23 west to the border with Sonora had several stretches of power lines with a total of > 400 concrete poles (mostly tangent poles but also some double dead-end units). Initially, none of these poles was retrofitted. However, on 28 October 2002, white PVC covering was observed around the conductors on tangent poles west of Janos. Finally, non-retrofitted concrete poles were found in the JCG prairie dog complex area and east of Highway 10 between Nuevo Casas Grandes and Janos. All these concrete poles were located along power lines supplying electricity to small rural communities (e.g., ejidos; Tables 1 and 2).

Elsewhere, we did not detect any power lines with more than a few scattered non-retrofitted concrete poles. Power lines along Highway 16 consisted almost entirely of wooden poles. In the vicinity of Cd. Chihuahua and along Highway 10 near Nuevo Casas Grandes, concrete poles numbered in the hundreds (the exact number of poles was not counted). However, most of them had been retrofitted with wooden cross-arms (Cd. Chihuahua and vicinity) or with perch guards (Nuevo Casas Grandes area).

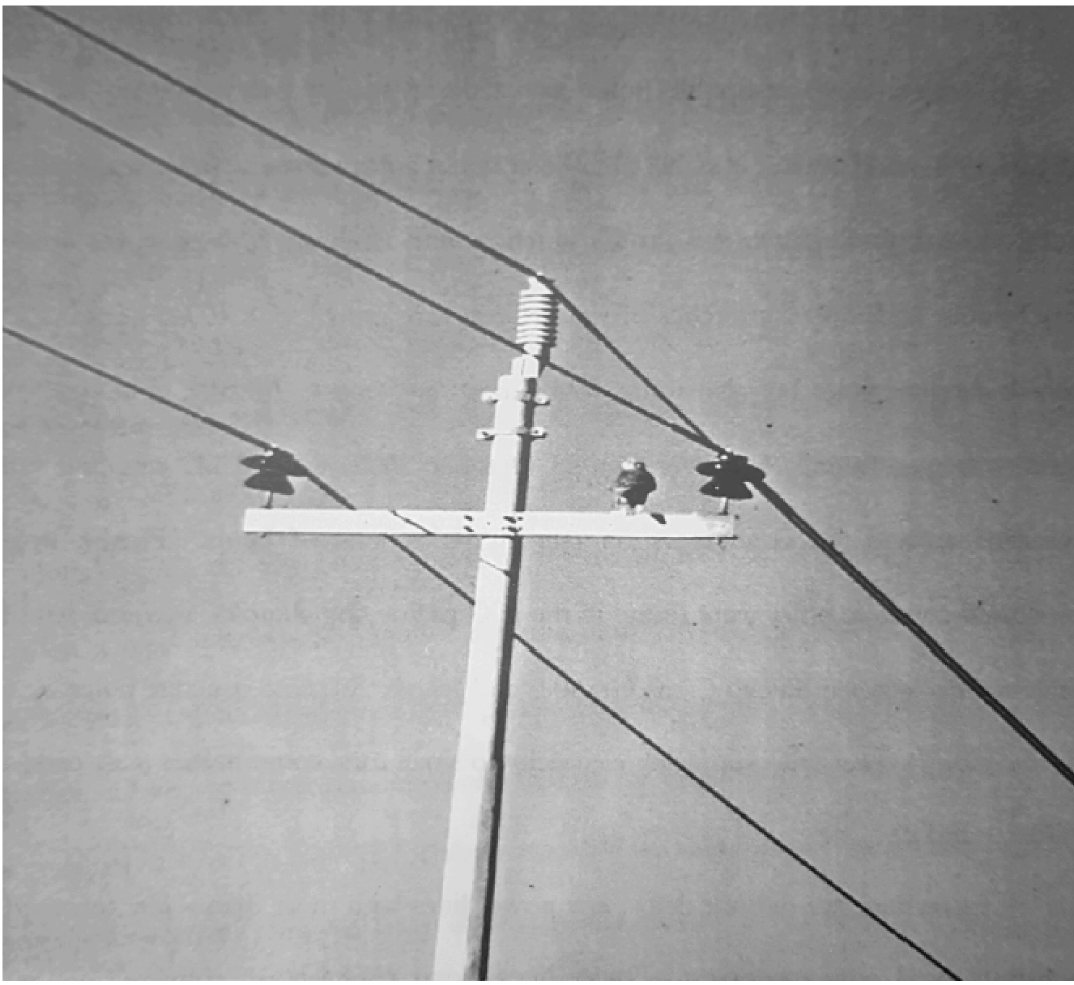

Figure 4. Tangent unit with perched raptor.

Table 1. Characteristics of areas where in-depth power-line surveys were conducted in the Janos-Casas Grandes prairie dog town complex area of northwestern Chihuahua, with associated mortality findings.

location	date of survey	surrounding vegetation	number and configuration of inspected power poles	findings[1]
Casa de Janos	February 10, 2002 April 27, 2002 November 12, 2002	Grassland and fields	53 (36 tangent, 5 double dead-end) concrete poles	1 (0) red-tailed hawk (November 02)
El Cuervo	February 9, 2002 April 26, 2002 June 5, 2002 November 11, 2002	Grassland, mesquite grassland, and crop fields, with numerous active prairie dog burrows	389 (271 tangent) concrete poles	1 (1) turkey vulture (April 02) 1 (0) red-tailed hawk (April 02) 8 (7) Chihuahuan ravens (April 02) 2 (1) Chihuahuan ravens (June 02) 2 (1) turkey vultures (November 02) 1 (0) golden eagle (November 02) 1 (0) ferruginous hawk (November 02) 1 (1) red-tailed hawk (November 02) 5 (5) Chihuahuan ravens (November 02)
Ignacio Zaragoza	February 10, 2002 April 27, 2002 November 12, 2002	Grassland, barren soil, shrubland, with some prairie dog burrows	98 (6 tangent, 78 retrofitted tangent) concrete poles	1 (1) Chihuahuan raven (April 02)
North access road to San Pedro	February 10, 2002 April 27, 2002 June 5, 2002 November 11, 2002 March 18, 2004	Grassland	64 (50 tangent) concrete poles	1 (0) red-tailed hawk (June 02) 1 (1) unidentified eagle (November 02) 1 (1) American kestrel (March 04)

Table 1. *Continued.*

location	date of survey	surrounding vegetation	number and configuration of inspected power poles	findings[1]
Pancho Villa	February 10, 2002	Grassland with creosote and mesquite shrubs and some prairie dog burrows	121 (22 tangent, 96 retrofitted tangent) concrete poles	No remains
Power line southwest of San Pedro	February 10, 2002 April 27, 2002 June 5, 2002 November 12, 2002 March 18, 2004	Low shrubland with *Ephedra* and nearby field at one end	40 (30 tangent, 3 double dead-end) concrete poles	2 (2) Chihuahuan ravens (April 02) 3 (3) Chihuahuan ravens (June 02) 1 (1) red-tailed hawk (June 02) 1 (0) raven (March 04) 2 (2) Chihuahuan ravens (March 04) 1 (1) red-tailed hawk (March 04)
Power line west of Buenos Aires	November 12, 2002	Grassland and fields	21 (18 tangent) concrete poles	1 (1) unidentified eagle
North-south road at western end of road to Ignacio Zaragoza	February 10, 2002 April 27, 2002 November 12, 2002	Mesquite shrubland	46 (18 tangent, 28 retrofitted tangent) concrete poles	1 (1) Chihuahuan raven (November 02)

[1] The number of dead birds showing signs of electrocutions is given in parentheses.

Table 2. Characteristics of areas where in-depth power-line surveys were conducted in (northwestern) Chihuahua outside of the Janos-Casas Grandes prairie dog complex, with associated mortality findings.

location	date of survey	surrounding vegetation	number and configuration of inspected power poles	findings[1]
Colonia Hidalgo, north of Nuevo Casas Grandes, east of Highway 10	June 7, 2002	Crop fields with human dwellings	62 (60 tangent, 2 double dead-end) concrete poles	2 (2) red-tailed hawks
Ejido Hidalgo, north of Nuevo Casas Grandes, east of Highway 10	June 7, 2002 July 26, 2002	Mesquite shrubland	102 (48 tangent, 7 double dead-end) concrete poles[2]	1 (1) Chihuahuan raven (June 02) 3 (0) red-tailed hawks (July 02) 1 (0) great blue heron (July 02)
El Berrendo, near state limit with Sonora, north of Highway 2	April 28, 2002	Mesquite grassland	19 (16 tangent, 3 double dead-end) concrete poles	No remains
Hacienda Corralitos, east of Highway 10	June 6, 2002	Mesquite-yucca grassland, mesquite shrubland, and crop fields	135 (12 double dead-end) concrete poles	1 (1) Chihuahuan raven 1 (1) unidentified hawk
Rancho de Toritos, northeast of Ascensión, north of Highway 2	October 28, 2002	Creosote shrubland	22 (20 tangent, 2 double dead-end) concrete poles	No remains
Rancho Mary Paz, west of Janos along Highway 2	April 28, 2002	Mesquite shrubland	10 (8 tangent, 2 double dead-end) concrete poles	No remains

[1] The number of dead birds showing signs of electrocutions is given in parentheses. [2] Tally for the June survey; in July 2002, surveys were extended farther to the east along an offshoot of the power line surveyed a month before.

In northeastern, northern, and west-central Sonora, concrete power poles were also widespread (although generally not as numerous as wooden poles). Along Highway 2 in northeastern Sonora, the cross-arms were typically covered with yellow PVC covering. Non-retrofitted poles were still present along Highway 2 to Naco, and along power lines originating from Highway 2 and supplying electricity to rural communities in the general area of Cananea (Fig. 2, Table 3). Most concrete poles were tangent structures, but 1 power line in the area of Ejido Zaragoza, just east of Cananea, had concrete poles with lower and upper cross-arms. Stretches of power lines with concrete poles, most of them tangent units, were also observed between Imuris and Hermosillo along Mexican Highway 15, in the Hermosillo area, and between Hermosillo and Bahía Kino. A power line from Bahía Kino to the Seri Indian village of Punta Chueca had concrete poles. They consisted chiefly of tangent poles retrofitted with wooden cross-arms. A total of 23 double dead-end units were counted along this power line, and none of them had been retrofitted. An offshoot of the Bahía Kino – Punta Chueca power line was observed on private property. It had concrete tangent poles with steel cross-arms.

In Baja California Sur, most of the power poles we observed were made of wood. Our preliminary surveys, most of them along Highway 1, led to the discovery of only 608 concrete poles fitted with steel cross-arms. Stretches of power lines with concrete poles were located mainly in the northern part of the State, between Mulegé and Santa Rosalía; concrete poles were also observed between Loreto and Mulegé and between San Ignacio and Vizcaíno (Fig. 3, Table 4). Few concrete poles were observed along power lines between La Paz and Ciudad Constitución and between La Paz and Cabo San Lucas (Fig. 3, Table 4). Most concrete poles were tangent units. Only 30 double dead-end units were counted along all surveyed power lines, and none of them had been retrofitted. Interestingly, between Villa Insurgentes and López Mateos, 15 concrete poles were fitted with platforms for ospreys (*Pandion haliaetus*) to perch and build their nests. In-depth surveys were conducted everywhere concrete power poles were found but also included a total of 295 wood poles (Table 4).

Table 3. Characteristics of areas where in-depth power-line surveys were conducted in Sonora, with associated mortality findings.

location	date of survey	surrounding vegetation	number and configuration of inspected power poles	findings[1]
Ejido Cuitaca (about 25 km west of Cananea)	October 29, 2002	Mesquite shrubland	11 (11 tangent) concrete poles (interspersed with wooden poles)	2 (2) turkey vultures
Ejido Zaragoza (about 15 km east of Cananea)	October 29, 2002	Mesquite grassland	94 (88 tangent) concrete poles	5 (3) ravens 2 (1) Chihuahuan ravens
Pueblo Naco, along Highway 2 (about 5 km west of Agua Prieta)	October 29, 2002	Mesquite grassland	20 (19 tangent) concrete poles	1 (0) raven
Road from Bahía Kino to Punta Chueca	March 18, 2004	Sonoran Desert (Central Gulf Coast subdivision)	23 (23 double dead-end) concrete poles (interspersed with retrofitted tangent poles)	2 (0) red-tailed hawks 3 (0) unidentified birds

[1] The number of dead birds showing signs of electrocutions is given in parentheses

Table 4. Characteristics of areas where in-depth power line surveys were conducted in Baja California Sur, with associated mortality findings. Vegetation characterization follows Wiggins (1980) and (INEGI 1981).

survey area	date of survey	surrounding vegetation	number and type of poles	findings[1]
Road from La Paz to Cd. Constitución	April 11, 2003 May 9, 2003	Sonoran desertscrub, sarcocaulescent vegetation association	35 (2 double dead-end, 33 tangent) concrete poles	1 (1) common raven
	April 11, 2003 May 9, 2003	Sonoran desertscrub, sarcocaulescent vegetation association	35 (33 tangent, 1 double dead-end) wooden poles	No remains
Cd. Constitución	April 11, 2003 May 9, 2003	Urbanized area, with nearby fields	10 (2 tangent, 3 double dead-end) concrete poles	No remains
	April 11, 2003 May 9, 2003	Cultivated area	10 (7 tangent, 3 double dead-end) wooden poles	No remains
Road to Puerto San Carlos	April 11, 2003 May 9, 2003	Sonoran desertscrub, sarcocaulescent vegetation association	10 (10 tangent) concrete poles	No remains
	April 11, 2003 May 9, 2003	Sonoran desertscrub, sarcocaulescent vegetation association, containing a large area of creeping devil cactus (low-tall vegetation)	46 (46 tangent) wooden poles	No remains
Deviation road to Ejido 419	May 9, 2003	Sonoran desertscrub, sarcocaulescent vegetation association and cultivated area	155 (149 tangent, 6 double dead-end) wooden poles	No remains

Table 4. *Continued.*

survey area	date of survey	surrounding vegetation	number and type of poles	findings[1]
Road to López Mateos	April 11, 2003 May 9, 2003	Cultivated area and Sonoran desertscrub, sarcocaulescent vegetation association	147, (132 tangent, 15 with platforms) concrete poles	No remains
	April 11, 2003 May 9, 2003	Sonoran desertscrub, sarcocaulescent vegetation association and cultivated area	49 (42 tangent, 6 double dead-end) wooden poles	No remains
Road from Vizcaíno to San Ignacio	May 24, 2003	Sonoran desertscrub, sarcocaulescent vegetation association, non-thorny scrub, with small cultivated areas	63 (63 tangent) concrete poles	No remains
Road from Mulegé to Loreto	May 26, 2003	Sonoran desertscrub, sarcocaulescent vegetation association	83 concrete poles	No remains
Road from Santa Rosalía to Mulegé	May 26, 2003	Sonoran desertscrub, sarcocaulescent vegetation association	260 (260 tangent) concrete poles	No remains

Search for electrocuted raptors

In the JCG area, we found a total of 39 dead birds (14 raptors) during 5 rounds of surveys from February 2002 through March 2004 (Table 1). No remains were found in February 2002. In April 2002, however, we found a total of 13 dead birds under concrete poles of the area. Eleven of the 13 dead birds were Chihuahuan ravens (*Corvus cryptoleucus*); the other 2 birds were a red-tailed hawk (*Buteo jamaicensis*) and a turkey vulture (*Cathartes aura*). Ten of the 11 ravens and the turkey vulture had singed feathers. Seven of the ravens and the turkey vulture were found under 8 double dead-end units. No dead bird was found at any of the retrofitted concrete poles we surveyed.

In June 2002, our surveys yielded a total of 7 dead birds, 2 red-tailed hawks and 5 Chihuahuan ravens (Table 1). One of the 2 red-tailed hawks and 4 of the 5 Chihuahuan ravens had singed feathers. Two of the dead birds (1 red-tailed hawk and 1 Chihuahuan raven) were found under double dead-end units.

In November 2002, dead birds consisted of 1 immature golden eagle (*Aquila chrysaetos*), 2 unidentified eagles, 1 ferruginous hawk (*Buteo regalis*), 2 red-tailed hawks, 2 turkey vultures, and 6 Chihuahuan ravens (Table 1). The 2 unidentified eagles, 1 of the 2 turkey vultures, 1 red-tailed hawk, and all 6 ravens had singed feathers. In addition to the dead birds, an injured red-tailed hawk was observed along one of the power lines we surveyed.

In March 2004 an American kestrel (*Falco sparverius*) with singed feathers was found under 1 of 64 concrete poles along 1 power line with tangent units and double poles (Table 1). Along a second power line, a total of 4 dead birds were discovered, 1 red-tailed hawk, 2 Chihuahuan ravens, and 1 raven that could not be identified to species. Both Chihuahuan ravens and the red-tailed hawk had singed feathers. The 3 ravens were found under the same pole, a double dead-end unit.

Outside of the JCG prairie dog complex area, our in-depth surveys were restricted to an area east of Highway 10 between Nuevo Casas Grandes and Janos, and to a few power lines branching off the main line along Highway 2 (Table 2). We found a total of 9 dead birds, all of them east of Highway 10: 5 red-tailed hawks, 1 unidentified hawk, 2 Chihuahuan ravens, and 1 great blue heron. No dead bird was discovered during in-depth surveys along Highway 2. However, cursory surveys along that same road led to the discovery in February 2002 of 1 great horned owl (*Bubo virginianus*, under a wooden pole fitted with a steel cross-arm) and 1 unidentified raven (under a double dead-end concrete pole).

The 9 dead birds east of Highway 10 were found during surveys conducted in June and July 2002. In June, we discovered 2 red-tailed hawks (both with singed feathers) under the same concrete tangent structure in the area of Colonia Hidalgo. In the vicinity of Ejido Hidalgo, 1 Chihuahuan raven with singed feathers was found at a tangent structure. Finally, at Hacienda Corralitos, an unidentified hawk and a Chihuahuan raven both had singed feathers. The raven was found under a double dead-end pole (this type of configuration was represented in all 3 of the areas surveyed east of Highway 10). In July the same areas were revisited, leading to the discovery of 3 red-tailed hawks and a great blue heron, none of them with visible signs of electrocution.

In northeastern Sonora in October 2002, we found a total of 10 dead birds along 3 power lines surveyed on foot. The remains of 2 turkey vultures, both of them with singed feathers, were discovered under 1 of 11 concrete poles (a tangent structure) near Ejido Cuitaca, west of Cananea. About 15 km east of Cananea, an inspection of 94 concrete poles near Ejido Zaragoza yielded a total of 7 ravens, 4 of which had singed feathers. Of these 7 ravens, 2 were identified as Chihuahuan ravens. The others were too incomplete or old to identify to species. Along Highway 2 to Naco, 1 set of old raven remains was discovered under 1 of 20 concrete poles we inspected. None of the poles along the 3 power lines were double dead-end units, and the 10 dead birds were found under poles with a variety of configurations.

In west-central Sonora, a total of 5 sets of bird remains were found under 5 of the 23 double dead-end poles along the power line to Punta Chueca. Among the remains were those of 2 red-tailed hawks. The other 3 sets of remains could not be identified, although 1 appeared to belong to a raptor species. None of the remains showed any signs of electrocution, but all except 1 of the 2 red-tailed hawks were old.

In Baja California Sur, we found the remains of only 1 common raven (*Corvus corax*) beneath a tangent concrete pole. No other dead bird was discovered during our surveys. The raven seemed to have died several months prior to the survey. It presented singed feathers.

DISCUSSION

While we were conducting this study, other people observed additional dead birds under concrete poles in the JCG area. Reports of dead birds included those of 2 golden eagles in February and March 2002 (J. Harris, pers. comm.), as well as 2 more golden eagles, 3 ferruginous hawks, and 1 turkey vulture in January 2003 (J. Watson, pers. comm.). Together with the results of this and earlier studies (Cartron *et al.* 2000, 2005), those additional findings by others bring the total of dead birds discovered since January 1999 under concrete poles to 292 (112 raptors, 178 ravens, and 2 great blue herons) in the JCG area. Elsewhere in Chihuahua (along Highway 23 and along Highway 2, as well as east of Highway 10), 22 (13 raptors, 8 ravens, and 1 great blue heron) dead birds have now been found under concrete poles. For all of northwestern Chihuahua, a total of 316 dead birds have been documented to date. To this total could be added a raven discovered in 2001 under a double wooden pole (Cartron *et al.* 2005) and the great horned owl discovered (in this study) under a wooden pole fitted with a steel cross-arm (along Highway 2).

In this study, no dead bird was found in central or eastern Chihuahua. In some of the areas we explored, either there were no distribution lines or all poles were wooden. However, the presence of perch guards on poles along Highway 10 and new wooden cross-arms in the vicinity of Cd. Chihuahua suggest that in those areas, bird electrocutions were sufficiently frequent as to warrant the cost of retrofitting poles. Together with findings of dead birds through much of northwestern Chihuahua, evidence of retrofitting in other parts of the state thus suggests a widespread problem of bird electrocutions until the recent past. Based on this and earlier studies, it is likely that most electrocutions statewide were associated with 2 species, the red-tailed hawk and the Chihuahuan raven. To date, golden eagle, bald eagle (*Haliaeetus leucocephalus*), and ferruginous hawk mortality has been recorded only in the JCG prairie dog town area. As these 3 species are federally listed in México, the U.S., or both, this last pattern emphasizes the need to focus retrofitting efforts on the JCG area in particular. During this study, a long stretch of the power line crossing the largest prairie dog town in the complex was retrofitted using wooden cross-arms (retrofitting occurred after our last survey of that power line). However, many power lines with concrete poles have not yet been retrofitted. That is the case in particular with 1 small power line near San Pedro. Over a 6-month period, 1 dead bird was discovered per every 2 poles, on average (see Cartron *et al.* 2005).

Our study is the first to document raptor and/or raven electrocutions in Sonora and Baja California Sur. None of the birds discovered in west-central Sonora showed signs of electrocution. However, most of the remains were old, and because they were found under double dead-end poles with double cross-arms, electrocution is a likely cause of the observed mortality. In northeastern Sonora, 2 of us (JLEC and RR) interviewed several CFE engineers and technicians, who confirmed a past history of bird electrocutions along Highway 2. According to these CFE employees, the incidence of bird electrocutions has decreased drastically since PVC has been used around steel cross-arms. Near Agua Prieta, use of PVC along Highway 2 began in 1999 or 2000, while in the Cananea area it dated back to the year of our survey (2002). As in Chihuahua, the wide distribution of concrete poles, evidence of retrofitting in several of the areas that we visited, and findings of dead birds all suggest an important problem of bird electrocutions on concrete poles through much of Sonora. Only in Baja California Sur did our surveys suggest that, although bird electrocutions occur on concrete poles, their incidence is likely fairly low. This may be simply because the number of concrete power poles in Baja California Sur is low. It may also be due to the high density of cardon cacti in the surrounding vegetation in many areas. Because these cacti stand approximately 8 m tall, power poles are not the only vantage points available to raptors and ravens, in contrast to survey areas in northeastern Sonora and in Chihuahua. In Baja California, conservation strategies should include maintaining a high number of cardons around concrete poles in order to avoid electrocutions.

Our methodology did not allow us to compare the incidence of bird electrocutions as a function of pole configuration. However, Cartron *et al.* (2005) established that the incidence of bird electrocutions was disproportionately high at double dead-end poles. As shown by our study, these poles are widely distributed, and thus they should be a priority of all remaining retrofitting efforts. Additional power-line surveys are needed to evaluate the impact of concrete poles in areas that have not yet been checked, and to monitor the success of retrofitting. International funding to help retrofit all power lines in the JNC area would also be beneficial. Retrofitting in the area is occurring, but at a slow pace. Meanwhile, conservation sensitive species such as the ferruginous hawk and the golden eagle continue to experience important mortality at least locally.

ACKNOWLEDGMENTS

We thank Erika Marcé, Nikolai Manning, Jorge Arturo Ramírez, Ilyana Ruíz, and Sergio Avila for assistance in the field; Jim Watson, Ana Davidson, and John Harris for communicating to us their findings of dead raptors not discovered by us; the *Comisión Federal de Electricidád* (CFE), and in particular engineers Alfonso Sánchez and Lucio Bermúdez, for information on power lines and retrofitting efforts in northeastern Sonora. This study was funded through a grant from the Edison Electric Institute, with help from Scott Berger, Public Service Company of New México (PNM). CIBNOR and Consejo Nacional de Ciencia y Tecnología – SEMARNAT (project 2002-C01-0318), México, also supported this work.

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Appendix 1. List of raptor species in Baja California Sur (Migratory status: Res=Resident; Mig=Migratory). All species were recorded perching on cardon cacti except ferruginous hawk.

species	english common name	mexican common name	status
Cathartes aura[1]	turkey vulture	zopilote aura	Res/ Mig
Pandion haliaetus[1]	osprey	águila pescadora	Res/Mig
Elanus leucurus	white-tailed kite	milano cola blanca	Res
Haliaeetus leucocephalus	bald eagle	águila cabeza blanca	Res
Circus cyaneus	northern Harrier	gavilán rastrero	Mig
Accipiter striatus	sharp-shinned hawk	gavilán pecho rufo	Mig
Accipiter cooperii	Cooper's hawk	gavilán de Cooper	Mig
Parabuteo unicinctus[1]	Harris's hawk	aguililla rojinegra	Res
Buteo lineatus[1]	red-shouldered hawk	aguililla pecho rojo	Mig
Buteo swainsoni	Swainson's hawk	aguililla de Swainson	Mig
Buteo albonotatus	zone-tailed hawk	aguililla aura	Res/Mig
Buteo jamaicensis[1]	red-tailed hawk	aguililla cola roja	Res/Mig
Buteo regalis	ferruginous hawk	aguililla real	Mig
Aquila chrysaetos[1]	golden eagle	águila real	Res
Caracara cheriway[1]	crested caracara	Caracara, quebrantahuesos	Res
Falco sparverius[1]	American kestrel	cernícalo Americano	Res/Mig
Falco columbarius	merlin	halcón esmerejón	Mig
Falco peregrinus[1]	peregrine falcon	halcón peregrino	Res/Mig
Falco mexicanus	prairie falcon	halcón mexicano	Res/Mig

[1] Recorded perching on poles.

Current curatorial and bibliographic knowledge of Mexican Falconiformes

Patricia Ramírez-Bastida
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ABSTRACT

As part of the 'Atlas of Mexican Birds', we obtained information about specimens of raptor housed in 29 scientific collections in México, North America, and Europe. Also, we searched 235 references on Falconiformes in México published from 1848 to 1999. We compared the known range of species with museum records. Bibliographic information was organized by species, date of publication, and subject. Thirty species had specimens in museums from more than 75% of the states in which they have been recorded; the remaining species had a very scattered representation in collections. For 13 species, we recorded localities that fall outside of known distribution ranges. A low number of raptor specimens by states is the general pattern. Only the states of Chiapas, Oaxaca, Tamaulipas, and Veracruz had specimens of more than 30 species represented in collections. Aguascalientes, Distrito Federal, Hidalgo, Estado de México, Morelos, Quintana Roo, Tlaxcala, and Zacatecas had less than 6 raptors represented in collections. Bibliographic information has increased since the end of the 1970's and deals with a wide variety of subjects, from distribution records and species lists to breeding biology, food habits,

parasites, and systematic. Bibliographies are concentrated in a few noticeable taxa, like osprey, red-tailed hawk, crested caracara, aplomado falcon, and peregrine falcon, all with more than 10 references. In contrast, bi-colored hawk, black-collared hawk, red-shouldered hawk, great black hawk, Mississippi kite, white hawk and 11 more species have one or no citations. These analyses showed that scientific efforts should be driven to lesser known species and areas.

Key words: México, raptors, museum collections, bibliography, distribution.

RESUMEN

Como parte del Atlas de Aves de México, se obtuvo la información de ejemplares de aves rapaces mexicanas, depositadas en 29 museos de México, Estados Unidos, Canadá, Inglaterra, Francia y Austria, así como de 235 artículos sobre aves en México, de 1848 a 1999. Se comparó la distribución conocida de las especies, con los estados de los cuales se tienen ejemplares; la bibliografía se organizó por especie, década y tema. Treinta especies presentan colectas en más del 75% de los estados en que se han registrado, el resto tiene una representación más incompleta; existen además ejemplares de al menos 13 especies, cuya referencia de localidad queda fuera de la distribución reconocida. El análisis de las localidades y el número de ejemplares por especie, muestra baja representatividad en general. Sólo Chiapas, Oaxaca, Tamaulipas y Veracruz tienen ejemplares de más de 30 especies, mientras que Aguascalientes, Distrito Federal, Hidalgo, Estado de México, Morelos, Quintana Roo, Tlaxcala y

Zacatecas, tienen colectas de 6 o menos especies. Respecto a la bibliografía, los estudios sobre rapaces se han incrementado desde finales de 1970s, con temas que van desde nuevos registros y listados avifaunísticos hasta estudios de reproducción, hábitos alimenticios, efecto de pesticidas, endopatásitos y taxonomía, entre otros. Sólo *Pandion haliaetus, Buteo jamaicensis, Caracara plancus, Falco femoralis* y *Falco peregrinus* tienen 10 o más referencias en la bibliografía. Este tipo de análisis brinda pautas para dirigir estudios hacia las especies y localidades poco conocidas.

INTRODUCTION

Knowledge of the avifauna of México is still incomplete. Many areas are poorly surveyed and precise distribution and basic biology of many species is still unclear. Scientific collections are critical for understanding of biodiversity, biogeography, and systematics, thanks largely to the large number of specimens accumulated in the world's major natural history museums. However, recent revisions suggest that specimen representation is scattered, uneven, and inadequate for developing studies dealing with distribution, systematics, and many aspects of the biology of species (Peterson *et al.* 1998). This is true also for raptors (Order Falconiformes), one of the most conspicuous and studied group of birds, with 39 species of Accipitridae and 12 species of Falconidae in México (A.O.U. 1998).

This contribution results from seven years of compilation of information on Mexican specimens to produce an 'Atlas of the Birds of México' (Peterson *et al.* 1998, Navarro *et al.* 2002, 2003), and analyzes the current knowledge of Mexican raptors based on museum specimens and bibliographic information.

METHODS

The information presented is based largely on museum specimens, collection catalogs, and databases from 28 institutions in Canada, United States, México, United Kingdom, France, The Netherlands, and Austria (Appendix 1). We also include records obtained from published scientific papers. The bibliographic information was obtained from an accessory database that is being prepared at the Museo de Zoología, Facultad de Ciencias, Universidad Nacional Autónoma de México. This database is under construction and is being updated almost daily, now containing more than 5100 references. For both specimen data and bibliographic records, localities were referenced for use in a geographic information system and maps at a scale of 1:250,000 (INEGI 1982).

More than 5300 specimen records were assembled, as well as more than 600 species/locality records in 235 references about diurnal raptors of México from 1848 to 1999 (Rodríguez-Yáñez *et al.* 1994, Navarro *et al.* 2003), that are available at the following URL: (http://osuno.fciencias.unam.mx/laboratorios/Mzoologia/Aves/inicial.htm).

Records were organized to find geographic patterns of knowledge according to decade of record, species, and state. The known distribution of each species, as proposed by Howell and Webb (1995), was overlapped with the primary point records from our databases. Bibliographies were analyzed according to subject, species, and state. For purposes of the present analyses, we use an alternative species-level nomenclature for Mexican birds (Navarro and Peterson 2004), that applies the evolutionary species concept.

RESULTS

Collections with largest numbers of Mexican specimens are outside México; the most important are the Moore Laboratory of Zoology, US National Museum, Western Foundation of Vertebrate Zoology, and British Museum (Appendix 1). This makes extensive foreign searches, especially since the two Mexican collections included in the database contain only 19 (38%) of the species and 97 (1.8%) of the specimens.

Figure 1 shows the numbers of specimens by decade of collection. From 1931 to 1970, the collection of specimens was most intense, with more than 52% percent of the specimens recorded. This is surely due to an increased interest of North American researchers to develop fieldwork in México, and the time when major Mexican bird collections (e. g. Moore Collection, Field Museum) were constructed.

Specimen representation by species, even for the wide-ranging and most common ones, is uneven, and for 41 species, there are less than 100 specimens in all collections (Fig. 2). Some species are very poorly represented in spite of a wide

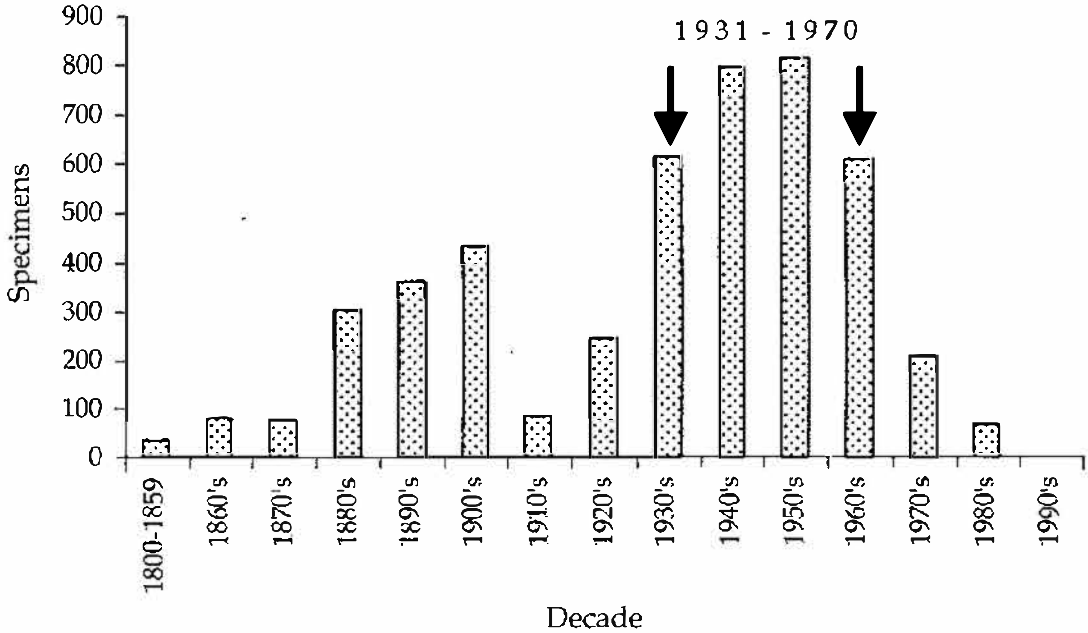

Figure. 1. Specimens of diurnal raptors collected (in ten year intervals), with 2389 specimens collected. The total number of specimens is 5389, 528 of which did not have precise locality.

distribution within the country, such as the swallow-tailed kite (11 specimens), Mississippi kite (3), black-collared hawk (16), and northern goshawk (10). In contrast, the American kestrel *Falco sparverius* is represented by almost 900 specimens (Appendix 2). Obviously, this reflects the apparent commonness of each species as well as some population and geographical trends of the species within México, although this figure is gradually changing because of habitat perturbation and land use modifications by humans (Rodríguez-Estrella 1997).

The geographical representation of localities by species is also not

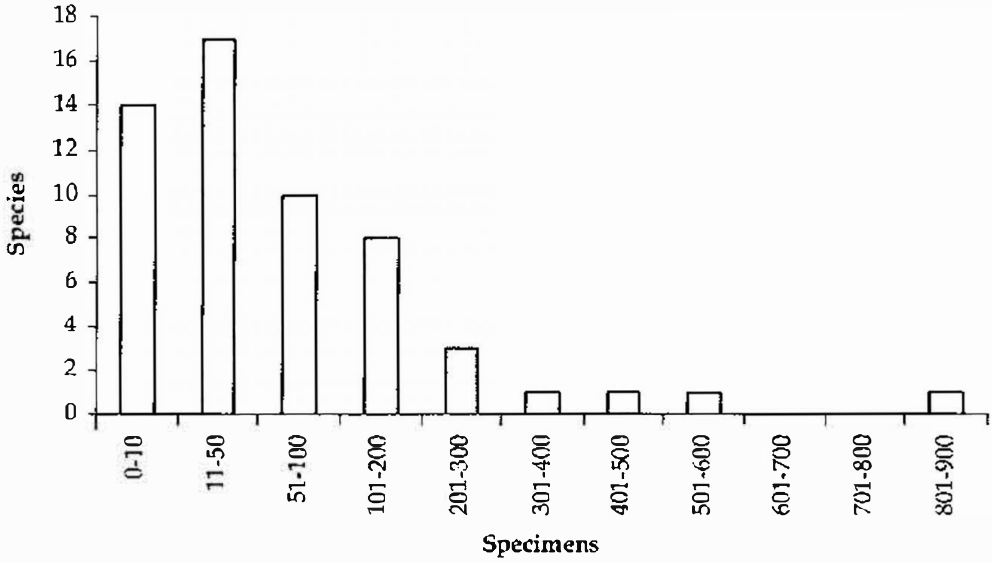

Figure. 2. Number of specimens by species.

homogeneous. Especially in central México, specimen numbers are low, while states close to the USA border and tropical regions of the southeast have experienced more intense collecting activities (Fig. 3). This coincides with a general pattern of ornithological knowledge in México–best known states are those close to the formerly dominant research groups (North American institutions) or hold important habitats and species like the tropical lowlands or where easy access to regions within the state is known. This affects the general picture of a raptor's distribution because of its intrinsic heterogeneity. Figure 4 shows the species richness by state, following Howell and Webb (1995). A general trend is that northern México holds significantly lower species richness than the tropical lowlands of the south. The Baja California Peninsula, Coahuila, and central México have the lowest diversity, with less than 22 species recorded, while Oaxaca (45 species), Chiapas (45 species), and Veracruz (42) are the richest diversity, a pattern repeated for many plant and animal taxa (Ramamoorthy *et al.* 1993).

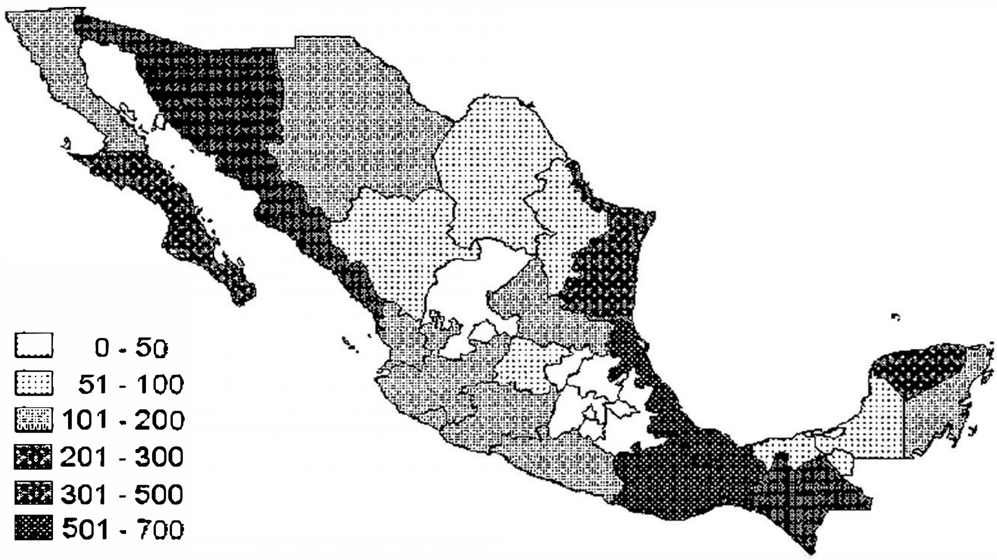

Figure. 3. Number of specimens by state.

Comparison of species richness and number of specimen records suggests an interesting pattern. In general, specimen representation on a state-wide basis is low (Fig. 5). Most of the states have less than 75% of their raptor species represented in any collection; only some states along the coasts and Guanajuato have more than 75% of their raptor avifauna substantiated with a specimen. The states of Chiapas, Oaxaca, Tamaulipas, and Veracruz have more than 30 species each collected, while states in central México (Aguascalientes, Distrito Federal, Hidalgo, Estado de México, Morelos, Querétaro, and Tlaxcala) have 6 or less species each in collections. For 528 specimens no location was obtained given the inaccuracy of locality data (for example, 'México' or 'Baja California').

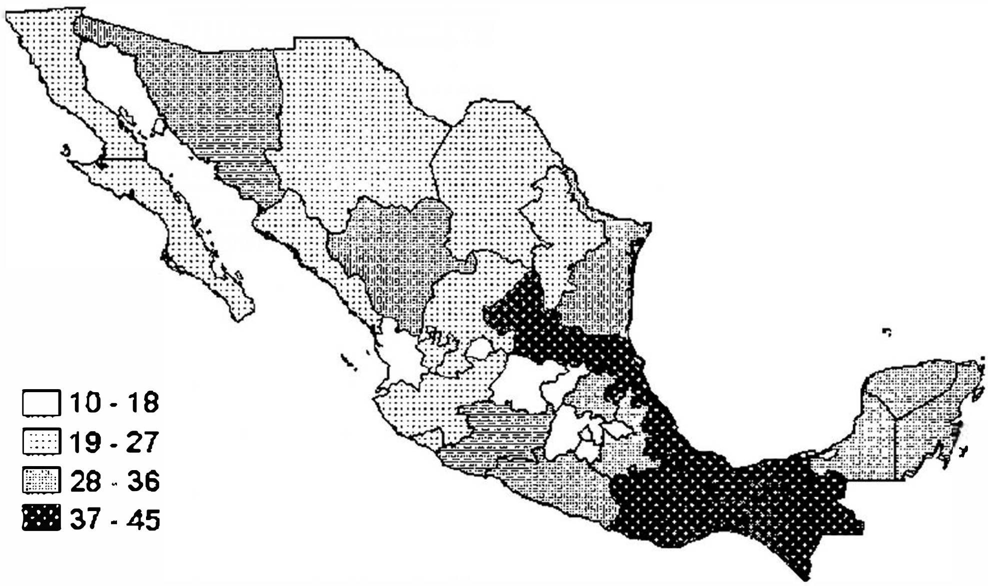

Figure 4. Species richness of diurnal raptors in each state.

For 24 species, specimens from more than 75% of the states are known to be present (e. g., bicolored hawk, *Accipiter bicolor*, Cooper's hawk, *A. cooperi*; sharp-shinned hawk, *A. striatus*; white-tailed hawk, *Buteo albicaudatus*; common black-hawk, *Buteogallus anthracinus*; plumbeous kite, *Ictinia plumbea*; Harris's hawk, *Parabuteo unicinctus*, and bat falcon, *Falco rufigularis*). Of course, species with more restricted ranges are likely to have specimens from most of their geographical area, like the Cozumel Island roadside hawk (an endemic; *Buteo gracilis*), gray-headed kite (*Leptodon cayenensis*), Chiapas black hawk (restricted to the mangrove) (*Buteogallus subtilis*), and white hawk

(*Leucopternis albicollis*). For 13 species, we found unpublished records that expand their known geographical distribution (Appendix 2).

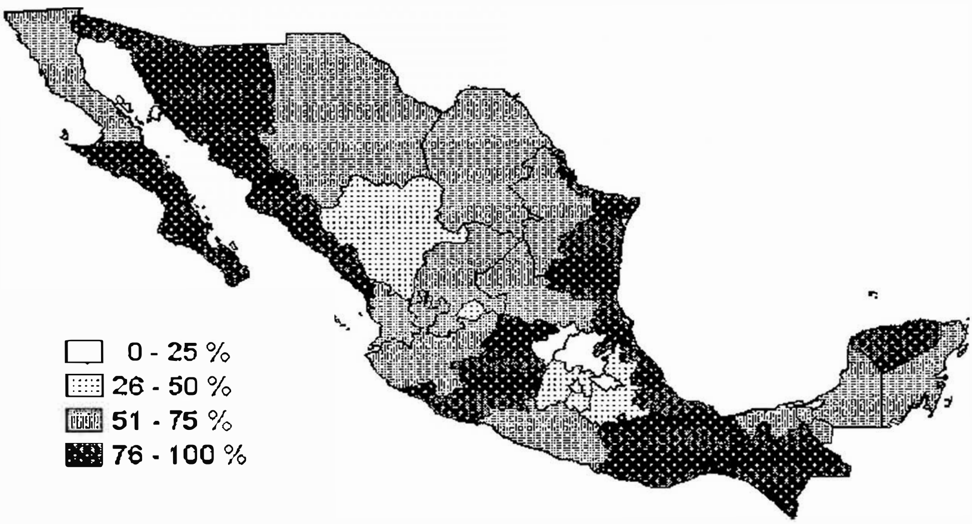

Figure 5. Representativeness of species by state. Percentage represents the number of species with specimens/ total number of species known in the state.

References about Mexican raptors are not abundant. It is noteworthy that studies on various aspects of raptors' biology have increased since the 1970s. Thematic subjects of publications are varied, ranging from new locality records of species and lists of raptors in avifaunal surveys, to breeding biology, food habits, toxicology, parasites and systematics (Fig. 6). Publications devoted specifically to raptors (particular studies) are few, compared with those that indicate the presence of some species in a given area, which are dominant in the literature, followed by systematics, breeding biology, ecology, and life histories. However, most publications are devoted only to a small set of species (e.g., peregrine falcon and osprey, Appendix 2).

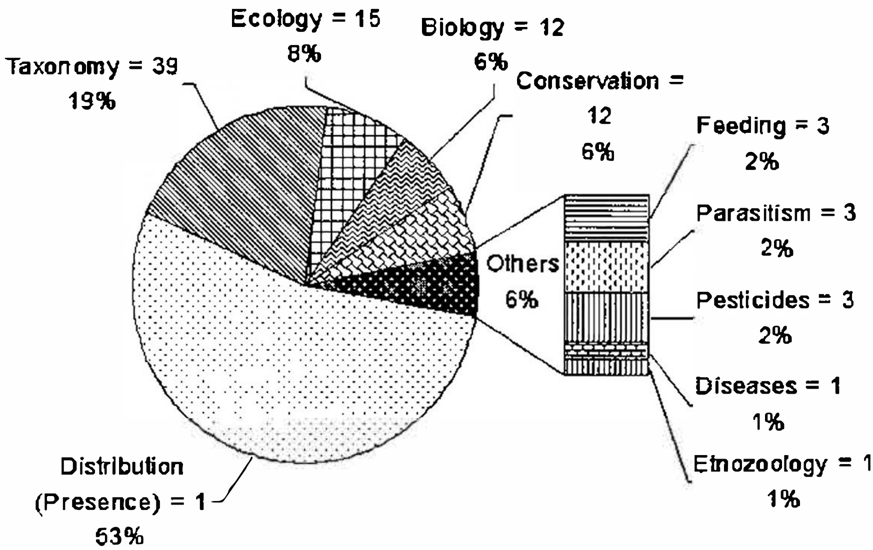

Figure. 6. Bibliographic subjects found in 235 references about diurnal raptors of México from 1848 to 1999.

Some examples illustrate how the lack of information in some instances is critical for the understanding of geographic patterns, ecology, and conservation of species. The known distribution of golden eagles is based on bibliographic records, which expanded greatly with the specimens collected in Guerrero and Oaxaca (Fig. 7), suggesting that further work is needed to assess its complete distribution and seasonality.

The extreme uneveness of information is clear if we compare the ferruginous hawk (*Buteo regalis*) with the American kestrel (*Falco sparverius*). For the former, only

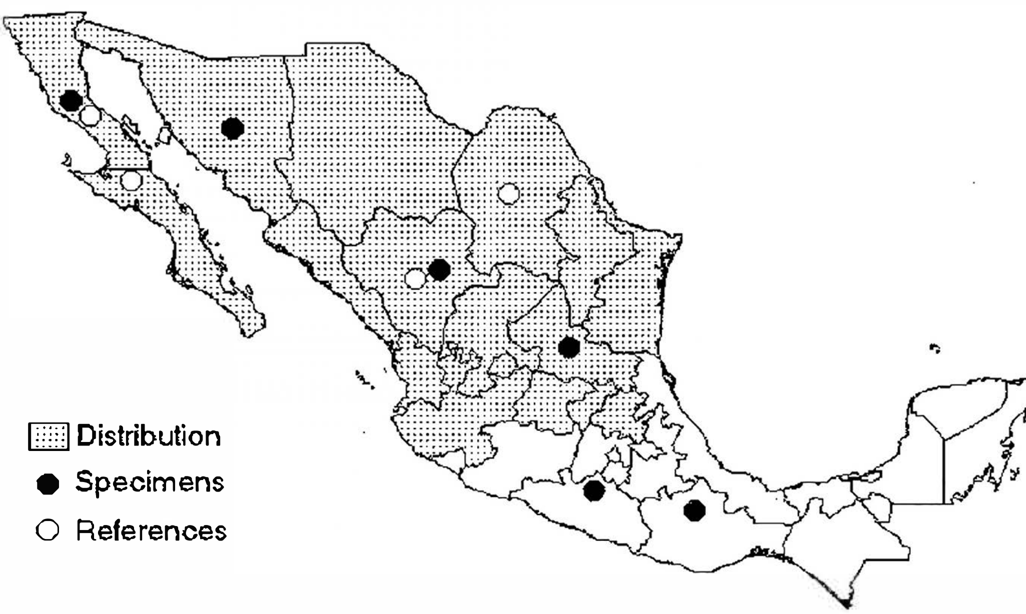

Figure. 7. Contrasts among known distribution, bibliographic references, and collected specimens for the golden eagle.

five specimens and two bibliographic references from México are known (Russell and Lamm 1978, Wilbur 1987), against the 899 specimens and 46 bibliographic references about the kestrel. Other examples are the possibly extirpated red-throated caracara (*Daptrius americanus*) with only two specimens and no references, and the black-and-white hawk-eagle (*Spizastur melanoleucus*) with 13 specimens, no references, and only one published sighting (Amadon and Eckelberry 1955, Appendix 2). Both species are in a priority conservation status in national lists (NOM-ECOL-059-2001), although this is based only on the scarce and unpublished data from experienced researchers and the meager bibliography.

DISCUSSION

Research in many key areas of knowledge about diurnal raptors is strongly needed. Areas, such as systematics, biodiversity conservation, geographic patterns, patterns of endemism, geographic variation, genetics, breeding biology, and ecological links of species, rely on information from scientific collections and bibliographics (e.g. Peterson *et al.* 2001).

Presently, declining populations of some species from habitat destruction, use of pesticides, and natural rarity of some top order predators, among other reasons, have generated that many species are now considered of conservation concern within México and internationally. In fact, 44 of the 51 species in México are so categorized (Collar *et al.* 1994, NOM-ECOL-059-2001). This has resulted in legal restrictions on collecting specimens for study or capture for aviaries and zoos. However, efforts should be made to surprising specimens that die from power line accidents, road kill, and those captured illegally for falconry or as pets.

Given that raptors are a taxon of special interest to many research groups and amateur birdwatchers, it is strange that most bibliographic references are devoted to a small set of species of special concern in the past or present. Examples are the peregrine falcon and the golden eagle, for which extensive conservation programs were developed in the United States and Canada and extended to México as part of their distribution. Raptors avifauna of México is extremely rich, and efforts should be devoted to study the many rare or endangered tropical raptors, e.g. the *Spizaetus,* *Spizastur*, *Micrastur* genera and the important raptor communities in arid lands (Rodríguez-Estrella and Rivera-Rodríguez, in this publication).

Major taxonomic revision is needed for this group to assess species limits (Rojas-Soto and Navarro, in this publication), phylogenetic relationships, genetic structure of populations, and migration and range expansion patterns, e.g. the white-tailed kite (Eisenmann 1971, Fuller *et al.* 1998).

Although our results will be affected as more information and specimens becomes available (e. g. Rodríguez-Estrella *et al.* 1991, Figueroa *et al.* 1998, Morales-Pérez 1998, Rojas-Soto *et al.* 2002, Puebla-Olivares *et al.* 2002, Peterson *et al.* 2003), this analysis gives a general clue to species and localities in need of more attention. Some of the areas with low numbers and diversity may correspond to less studied areas. Ornithologists working in México should engage in collaborative efforts to obtain a better understanding of México's diurnal raptors.

ACKNOWLEDGMENTS

We deeply thank Town Peterson for his continuous support, and the curators and collection managers of many museums for providing access to their collections. We also thank the comments of several anonymous reviewers. Alejandro Gordillo and team provided georeferences for the museum specimen localities. Gabriela Meza, Alejandro Villafranco, Diego Carmona, Gabriela García Deras, Esteban López, Laura López, and many other students helped in the search for bibliographic information.

Financial support was obtained from the Mexican Consejo Nacional de Ciencia y Tecnología (CONACyT), the SEMARNAT-CONACyT Sectorial Funds (C01-0265), US National Science Foundation, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), DGAPA-PAPIIT (grants IN218598, IN214200), and the Universidad Nacional Autónoma de México (UNAM). Thanks to Ricardo Rodríguez-Estrella and the Raptor Research Foundation for their support to Patricia Ramírez during the conference on raptors held in La Paz.

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Appendix 1. Falconiformes specimens in 28 museums in North America and Europe. Museums and numbers in bold indicate better representation of number of species and number of specimens.

MUSEUM	Number of species	Number of specimens
Academy of Natural Sciences, Philadelphia	17	**49**
American Museum Of Natural History, New York	**36**	**283**
Bell Museum of Natural History, University of Minnesota	31	123
British Museum of Natural History, London	45	516
Carnegie Museum of Natural History, Pittsburgh	29	114
Delaware Museum of Natural History, Wilmington	**32**	152
Denver Museum of Natural History	8	15
Field Museum of Natural History, Chicago	**43**	**276**
Los Angeles County Museum of Natural History	19	78
Louisiana State University Museum of Zoology, Baton Rouge	**44**	**432**
Moore Laboratory of Zoology, Occidental College, Los Angeles	**37**	855
Museo de Zoología, Universidad Nacional Autónoma de México	16	45
Museum Nationale d'Histoire Naturelle, París	14	34
Museum of Comparative Zoology, Harvard University	**38**	**401**
Natuurhistorische Museum, Leiden	15	22
Peabody Museum, Yale University	27	103
Royal Ontario Museum, Toronto	24	53
San Diego Natural History Museum	20	168
Southwestern College, Winsfield, Kansas	24	55
Texas Cooperative Wildlife Collections, Texas A&M University	5	9
US National Museum of Natural History, Washington, D.C.	**49**	757
Universidad Michoacana de San Nicolás de Hidalgo, Morelia	13	52
University of Arizona Zoological Collections, Tucson	10	12
Cowen Vertebrate Museum, University of British Columbia	8	34
University of California, Los Angeles	15	78
Natural History Museum, University of Kansas, Lawrence	**37**	163
Western Foundation of Vertebrate Zoology, Camarillo, CA	**41**	**491**
Total	55	5 389

Appendix 2. Specimen records in museums and bibliographic information on Falconiformes. The "?" in the Specimens in museums column indicates the number of specimens without a known locality of collection. The Mexican states of collection in bold indicate specimens collected in states where the distribution of the species is not recognized by Howell and Webb (1995).

species	specimens in museums (first and last year)	mexican states where collected[1]	(%) states where collected and distributed	bibliographic topics2 (first and last year)	sightings (first and last year)
osprey *Pandion haliaetus*	124 + 2 ? (1859 – 1981)	2,3,8,16,18,20,23,24,26 27, 28,30,31	40.6	BI, CS, DI, EC, FE, PA, RE 16 (1947 – 1995)	48 (1950 – 1995)
gray-headed kite *Leptodon cayanensis*	42 (1864 – 1973)	4,8,20,23,27,28,30,31	100	none	1 (1960)
hook-billed kite *Chondrohierax uncinatus*	88 + 1 ? (1895 – 1985)	4,6,8,11,12,14,16,18,19 20,23,24,27, 28,30,31	84.2	DI, EC, FE, RE, TA 8 (1934 – 1992)	8 (1938 – 1967)
swallow-tailed kite *Elanoides forficatus*	10 + 1 ? (1875 – 1967)	5,8,20,28,30	41.7	BI, DI 1 (1998)	6 (1952 – 1957)
white-tailed kite *Elanus leucurus*	82 (1866 – 1982)	8,16,20,23,27,28,30	25	DI, FE 2 (1971 – 1991)	10 (1960 – 1993)
snail kite *Rostrhamus sociabilis*	49 + 1 ? (1894 – 1969)	4,8,20,23,27,30	75	TA 1 (1933)	4 (1933 – 1993)
double-toothed kte *Harpagus bidentatus*	42 (1877 – 1974)	11,20,23,27,30	62.5	DI, TA 2 (1961 – 1992)	3 (1958 – 1967)
Mississippi kite *Ictinia mississippiensis*	3 (1888 – 1959)	27,28,30	33.3	DI 1 (1998)	3 (1955 – 1966)
Plumbeous kite *Ictinia plumbea*	62 + 2 ? (1869 – 1975)	4,8,20,23,25,27,28,30	80	none	5 (1947 – 1955)
bald eagle *Haliaeetus leucocephalus*	5 + 1 ? (1897 – 1905)	2	12.5	CS, DI, FE, RE 8 (1978 – 1996)	4 (1905 – 1993)
black-collared hawk *Busarellus nigricollis*	16 (1868 – 1963)	8,11,20,24,27,30	54.6	BI 1 (1989)	3 (1955 – 1990)

Appendix 2. *Continued.*

species	specimens	states	(%) states	topics	sightings
northern Harrier *Circus cyaneus*	99 + 4 ? (1859 – 1989)	All except 4,5,10,11,17,22,23,27	75	none	17 (1926 – 1995)
sharp-shinned hawk (part) *Accipiter striatus*	293 + 9 ? (1858 – 1985)	All except 1,4,13,21, 23,27,29	78.1	BI, DI, TA 3 (1888 – 1952)	17 (1938 – 1993)
sharp-shined hawk (part) *Accipiter chionogaster*	5 (1949 – 1962)	8	50	none	4 (1955 – 1976)
Cooper's hawk *Accipiter cooperi*	143 + 11 ? (1858 – 1989)	All except 4,8,13,21,27	90	DI, EC, TA 4 (1888 – 1990)	19 (1954 –1995)
bicolored hawk *Accipiter bicolor*	37 + 1 ? (1859 – 1963)	4,8,20,23,25,28, 30,31	72.7	DI, EC 2 (1975)	4 (1913 – 1967)
northern goshawk *Accipiter gentilis*	10 (1888 – 1984)	7,11,14,24,26	62.5	TA 2 (1938 – 1992)	1 (1938)
crane hawk *Geranospiza caerulescens*	54 + 3 ? (1968 – 1965)	6,8,11,18,20,21,23,24,2 5,26,28,30,31	76.43	BI, TA 2 (1921 – 1954)	2 (1955 – 1960)
white hawk *Leucopternis albicollis*	45 (1888 –1976)	8,20,27,30	100	FE 1 (1962)	3 (1959 – 1967)
northern goshawk *Accipiter gentilis*	10 (1888 – 1984)	7,11,14,24,26	62.5	TA 2 (1938 – 1992)	1 (1938)
crane hawk *eranospiza caerulescens*	54 + 3 ? (1968 – 1965)	6,8,11,18,20,21,23,24,2 5,26,28,30,31	76.43	BI, TA 2 (1921 – 1954)	2 (1955 – 1960)
gray hawk *Asturina plagiata (nitida)*	502 + 10 ? (1853 – 1983)	All except 1,2,3, 5, 9, 12,13,22,29,32	100	DI, RE 3 (1929 –1963)	13 (1947 – 1989)
common black-hawk *Buteogallus anthracinus*	233 + 3 ? (1863 – 1989)	4,6,7,8,10,11,12,14,16, 18,19,20,21,23,24,25,2 6,27,28,30,31.	91.3	DI, TA 3 (1937 – 1995)	17 (1954 – 1993)
mangrove black-hawk *Buteogallus subtilis*	3 + 1 ? (1951 – 1980)	8	100	none	none

Appendix 2. *Continued.*

species	specimens	states	(%) states	topics	sightings
great black-hawk *Buteogallus urubitinga*	118 + 1 ? (1863 - 1974)	4,6,7,8,11,14,16,20,23, 24,25,26,27,28,30,31	80	BI 1 (1992)	2 (1957 -1993)
Harris's hawk *Parabuteo unicinctus*	166 + 4 ? (1894 - 1969)	2,3,5,6,9,10,12,14,16,1 8,19,20,24,25,26,28,30, 31,32	79.2	DI, RE 4 (1978 - 1998)	11 (1947 - 1993)
gray hawk *Asturina plagiata (nitida)*	502 + 10 ? (1853 - 1983)	All except 1,2,3, 5, 9, 12,13,22,29,32	100	DI, RE 3 (1929 -1963)	13 (1947 - 1989)
solitary eagle *Harpyhaliaetus solitarius*	6 + 1 ? (1947 - 1959)	20,26	18.2	BI, CS, DI, RE, TA 5 (1948 - 1997)	1 (1954)
roadside hawk (part) *Buteo magnirostris*	486 + 12 ? (1855 - 1989)	4,6,8,11,14,16,19,20,21 23,25,27,28, 30,31	88.2	DI, TA 7 (1873 - 1963)	10 (1913 - 1993)
roadside hawk (part) *Buteo gracilis*	15 + 6 ? (1885 - 1971)	23	100	none	none
red-shouldered hawk (part) *Buteo lineatus*	21 (1863 - 1956)	6,12,14,19,25,28,30	36.8	TA 1 (1912)	3 (1955 - 1993)
red-shouldered hawk (part) *Buteo elegans*	1 (1906)	2	25	none	none
broad-winged hawk *Buteo platypterus*	76 (1889 - 1941)	5,8,11,20,24,28,30	38.9	DI 2 (1957 - 1979)	9 (1955 - 1966)
short-tailed hawk *Buteo brachyurus*	36 + 1 ? (1864 - 1972)	4,6,8,11,13,16, 20,23,24,25,28, 30,31	56.5	DI, TA 3 (1960 - 1997)	6 (1967 - 1993)
Swainson's hawk *Buteo swainsoni*	27 (1891 - 1975)	2,5,7,10,16,19,20,21, 24,25,26,30	41.4	DI, EC 4 (1941 - 1998)	15 (1947 - 1993)
white-tailed hawk *Buteo albicaudatus*	84 + 7 ? (1837 - 1989)	6,8,10,11,12,14,16,18,2 0,23,24,25,26,27,28,30, 31,32	90	none	9 (1947 -1993)

Appendix 2. *Continued.*

species	specimens	states	(%) states	topics	sightings
zone-tailed hawk	67 + 2 ?	2,3,5,7,8,12,14,20,24,2	43.8	RE	13
Buteo albonotatus	(1858 - 1964)	5,26,28,30,32		3 (1981 -1989)	(1947 - 1989)
red-tailed hawk	282 + 14 ?	All except	81.2	DI, EC, ET, TA	25
Buteo jamaicensis	(1859 - 1990)	1,13,22,23,27,29		10 (1898 - 1996)	(1898 - 1993)
ferruginous hawk	5	2,7,12,32	30.8	none	3
Buteo regalis	(1902 - 1941)				(1978 - 1987)
rough-legged hawk	none	none	0	none	2
Buteo lagopus					(1978)
harpy eagle	4	20,30	50	BI, DI	1
Harpia harpyja	(1868 - 1962)			7 (1878 - 1998)	(1993)
golden eagle	7	2,10,11,20,25,26	35.3	BI, DI	30
Aquila chrysaetos	(1893 - 198?)			5 (1942 - 1994)	(1962 - 1991)
black-and-white hawk-eagle	12 + 1 ?	8,20,28,30,31	41.7	none	1
Spizastur melanoleucus	(1877 - 1967)				(1955)
black hawk-eagle	17	4,8,20,23,27,30	54.6	BI, TA	4
Spizaetus tyrannus	(1896 - 1969)			2 (1950 - 1992)	(1957 - 1993)
ornate hawk-eagle	38 + 2 ?	4,6,8,20,21,23,25,28,30	71.4	BI, DI, RE, TA	4
Spizaetus ornatus	(1863 - 1974)	,31		8 (1935 - 1992)	(1955 - 1993)
barred forest-falcon	90 + 5 ?	4,8,11,20,21,23,25,30	80	BI	4
Micrastur ruficollis	(1890 - 1989)			1 (1848)	(1957 - 1992)
black-and-white hawk-eagle	12 + 1 ?	8,20,28,30,31	41.7	none	1
Spizastur melanoleucus	(1877 - 1967)				(1955)
Collared forest-falcon	115 + 4 ?	4,6,8,11,13,1416,18,20,	88.2	BI, RE	2
Micrastur semitorquatus	(1868 - 1974)	24,25,27,28, 30,31		2 (1957 - 1990)	(1960 - 1976)
red-throated caracara	3	8,30	66.7	none	none
Daptrius americanus	(1941 - 1947)				
caracara	13	2	100	BI, TA	none
Caracara lutosus	(1875 - 1906)			3 (1876 - 1933)	

Appendix 2. *Continued.*

species	specimens	states	(%) states	topics	sightings
crested caracara *Caracara cheriway (plancus)*	210 + 4 ? (1860 - 1989)	All except 2,5,7,9,13,15,22,23,29	82.8	BI, CS, DI, EC, FE, RE, TA 10 (1858 - 1998)	21 (1898 - 1990)
laughing falcon *Herpetotheres cachinnans*	134 + 1 ? (1863 - 1980)	4,6,8,11,14,16,20,23,24 ,25,26,27,30, 31	70	BI, RE, TA 6 (1918 - 1999)	5 (1955 - 1990)
American kestrel (part) *Falco sparverius*	882 + 17 ? (1853 - 1989)	All except 29	96.9	BI, CS, DI, EC, RE TA 9 (1892 - 1997)	37 (1950 - 1995)
American kestrel (part) *Falco tropicalis*	3 (1904 - 1947)	8	100	none	none
Merlin *Falco columbarius*	57 (1853 - 1965)	2,3,5,6,7,8,12,14,16,18 19,20,22,24,26,28,31, 32	56.3	DI, FE, RE, TA 5 (1927 - 1991)	16 (1934 - 1993)
aplomado falcon *Falco femoralis*	36 + 1 ? (1866 - 1972)	10,11,18,20,24,25,26,2 7,28,30,31	47.8	CS, CT, DI, EC, FE, PA, RE 14 (1948 - 1998)	1 (1990)
bat falcon *Falco rufigularis*	174 + 4 ? (1853 - 1974)	4,6,8,10,11,13,14,16,18 19,20,23,24, 5,26,27,28,30,31	90.5	BI, CT, EC, FE, RE 7 (1937 - 1991)	5 (1952 - 1990)
orange-breasted falcon *Falco deiroleucus*	2 (1908 - 1947)	8,28	33.3	DI 1 (1975)	none
peregrine falcon *Falco peregrinus*	76 + 3 ? (1865 - 1980)	2,3,4,5,7,8,12,14,16,19, 2024,25,26, 28,30,31	50	BI, CS, CT, DI, EC, FE, PA, RE, TA 28 (1937 - 1998)	24 (1950 - 1993)
prairie falcon *Falco mexicanus*	24 + 1 ? (1860 - 1967)	1,2,5,7,13,10,26,32	53.3	DI, RE 2 (1942 - 1991)	4 (1955 - 1993)

[1] Mexican States: 1. Aguascalientes, 2. Baja California Norte, 3. Baja California Sur, 4. Campeche, 5. Coahuila, 6. Colima, 7. Chihuahua, 8. Chiapas, 9. Distrito Federal, 10. Durango, 11. Guerrero, 12. Guanajuato, 13. Hidalgo, 14. Jalisco, 15. México, 16. Michoacán, 17. Morelos, 18. Nayarit, 19. Nuevo León,; 20. Oaxaca, 21. Puebla, 22. Querétaro, 23. Quintana Roo, 24. Sinaloa, 25. San Luís Potosí, 26. Sonora, 27. Tabasco; 28. Tamaulipas, 29. Tlaxcala, 30. Veracruz, 31. Yucatán, 32. Zacatecas. [2]Topics in Bibliography: BI=Biology; CS=Conservation; CT=Contamination; DI=Distribution; DS=Disease; EC=Ecology; ET=Ethnozoology; FE=Feeding; PA=Parasitism; RE=Reproduction; TA=Taxonomy.

Taxonomy, distribution and conservation of owls in the neotropics: a review

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ABSTRACT

The majority of owl species are distributed in tropical areas. For the neotropics, the 75 owl species represent 35% of the owls of the world. The taxonomy and classification of neotropical owls have been unclear and difficult, especially in the Strigidae family; 14 genera are represented in the neotropics, with five endemic to the region. Genera with the most species are *Megascops* (26), *Glaucidium* (16), and *Strix* (10). Some 34 (45%) of the neotropical species are considered endemic or quasi-endemic, having distributions limited to one to three countries. Our ecological knowledge of tropical species is limited; early reports reflect brief notes on taxonomy, distribution, or natural history and recent studies have been mainly undertaken in northern (México) and southern (Argentina and Chile) regions. While habitat loss and fragmentation have been the main threats for many forest raptors, other factors, such as pesticides, species trade, exotic species on islands, collisions with power lines, automobiles, or fences, and local traditions seriously threaten owls in some regions. Herein, we present an overview of taxonomic issues, general distributions, a perspective on our level of ecological knowledge, endangered species, and discussion of the threats to neotropical owls. We also offer a listing of important literature for México on the 32 species found there.

Key words: neotropic owls, taxonomy, distribution, conservation, endangered species, México.

RESUMEN

La mayoría de las especies de búhos se encuentran distribuidas en áreas tropicales. Setenta y cinco especies se distribuyen en la región neotropical, las cuales representan el 35% de las especies de búhos en el mundo. La taxonomía y clasificación de estas especies ha sido poco clara y difícil, especialmente para la familia Strigidae. Catorce géneros se encuentran representados en los neotrópicos, de los cuales 5 son endémicos de la región. Los géneros con el mayor número de especies son *Megascops* (26 especies), *Glaucidium* (16 especies), y *Strix* (10 especies). Existe una alta tasa de endemismos en los neotrópicos, ya que 34 especies (45%) están restringidas a 1 o 3 países. El conocimiento ecológico de estos búhos tropicales es restringido frecuentemente a breves notas en taxonomía, distribución o historia natural. Estudios recientes se han realizado principalmente en la parte norte (México) y sur (Argentina y Chile) de la región. La pérdida del hábitat y la fragmentación han sido las principales amenazas para muchas especies de rapaces. Sin embargo, existen otros

factores como plaguicidas, tráfico de especies, introducción de especies exóticas en islas, colisiones con cables de luz, con automóviles o cercas de púas, y creencias culturales que están amenazando a los búhos en algunas regiones. Aquí presentamos una revisión de la taxonomía, de distribución, conocimiento biológico, especies amenazadas y factores que amenazan a estas especies en los neotrópicos. También presentamos una lista de la literatura que se ha publicado para las especies de búhos en México.

INTRODUCTION

Owls represent 2.35% of all bird species, with the majority of owls occurring in tropical regions. Some 83 species are associated with mature and old-growth forests around the world, and 70 are tropical species (Marcot 1995). Recent studies offer important new taxonomic information (e.g., Wink and Heidrich 1999, Penhallurick 2002), and add new insights on the distribution of owls. Currently, 75 species are reported for the neotropics, representing 35% of the world's known 212 species (König *et al.* 1999). In México, there are 32 species, representing a surprising 42.6% of neotropical species. In large measure, our biological information on neotropical owls is limited to only brief and incomplete notes of their natural history, taxonomy, and distribution. Without basic ecological and biological information, it is very difficult to know the actual status and trends of owl populations in this region. Thiollay (1994) reported that the Strigiformes, like other diurnal raptors, are among the most endangered and neglected groups of tropical birds. In this paper, we present a review of the taxonomy of neotropical owls, their general distributions in neotropical countries, our level of ecological knowledge, and a discussion of endangered owls, including the threats to their survival. For the 32 owl species in México, we list the current literature to support our overall understanding of owls and provide a baseline for further work. Our major goal here is to synthesize information and encourage research on owls in the neotropics.

REVIEW OF LITERATURE

All the sources of information in this review came from the neotropical owl literature assembled by the authors. Information on distribution of owls (see Table 1) was obtained from field guides of neotropical countries (e.g., De Schauensee and Phelps 1978, Stiles and Skutch 1989, Howell and Webb 1995). Information about the countries used in Fig. 2 and human population density came from Simielli (1998).

TAXONOMY AND CLASSIFICATION OF NEOTROPICAL OWLS

Morphological characteristics (e.g., external ear openings, color patterns), analysis of recorded vocalizations, phylogenetic studies, and geographic isolation have been used to identify and describe owls at the species and subspecies level. However, the taxonomy of owls has been challenging, mainly for the Strigidae family (Sibley 1996). Although there have been significant advances in recent years (Wink and Heidrich

1999), it has been difficult to accurately assess variations that exist in species within complex genera, such as those that are highly variable in plumage color, vocalizations, and with extensive geographic ranges (Marshall 1967, König 1994).

Using mitochondrial DNA (cytochrome b gene) evidence, Wink and Heidrich (1999) examined owl taxa from 15 genera worldwide and offered important new data on taxonomic diversity. For the neotropics, they recognized several species in the *Glaucidium brasilianum* complex (e.g., *G. ridgwayi*) and additional species in *Pulsatrix* (short-browed owl *P. pulsatrix*), *Bubo* (Magellan horned owl *B. magellanicus*), and *Strix* (Chaco owl *S. chacoensis*), and five additional species in the genus *Megascops* (formerly *Otus*). In México, the Oaxaca screech-owl *Megascops lambi* was added and *Glaucidium brasilianum* was changed to *G. ridgwayi*.

Recently new world owls of the genus *Otus* have been reclassified to the genus *Megascops* (Banks *et al.* 2003), based on mitochondrial DNA and vocal differences with old world *Otus* species. *Megascops* has more species (26) in the neotropics than other genera. The genera *Megascops* is very complex because it shows geographic variations in plumage color and vocalizations (Marshall 1967). Such variations are the result of parallel or convergent evolution (Norberg 1987). The genus *Glaucidium* has similar complexity (Robbins and Stiles 1999) with 16 species in the neotropics. Taxonomic and distributional revisions for both genera have occurred in the last 60 years (Moore and Peters 1939, Buchanan 1964, Johnson and Jones 1990, Howell and Robbins 1995, König *et al.* 1999).

Other genera have had taxonomic revisions in recent years. For instance, the burrowing owl *Athene cunicularia* was reclassified within the monotypic genus *Speotyto* (Clark 1997). However, studies based on features of anatomy, behavior, vocalization, and osteology recommend reclassification to the genus *Athene* (AOU 1998, König *et al.* 1999). The striped owl *Rhinoptynx clamator* (also named *Asio clamator*) was placed in the genus *Pseudoscops* (Sibley 1996, AOU 1998). However, mtDNA and structural features again recommend its return to the genus *Asio* (König *et al.* 1999). Sibley (1996) and König *et al.* (1999) recommend that genus *Ciccaba* be placed in genus *Strix*. Support for this position is derived from DNA/DNA-hybridization techniques, which indicates that it is not a recognizable genus (Sibley and Monroe 1990). Further, using morphological measurements (degree of external ear asymmetry) Norberg (1977, 2002) recommended that all species in the genus *Ciccaba* be placed in genus *Strix*.

Some completely new genera and species have been described recently (König 1994). O'Neill and Graves (1977) described the long-whiskered owlet *Xenoglaux lowery*. Fitzpatrick and O'Neill (1977) described the cinnamon screech-owl *Megascops petersoni* and offered systematic notes on the Colombian screech-owl *Megascops colombianus* and the rufescent screech-owl *Megascops ingens*. Vielliard (1989) described the Amazonian pygmy-owl *Glaucidium. hardyi*, Robbins and Howell (1995) described the subtropical pygmy-owl *G. parkeri*, and Robbins and Stiles (1999) described the cloud forest pygmy-owl *G. nubicola*.

Our understanding of neotropical owl taxonomy continues to change at a brisk rate. Additional field recordings of owl vocalizations and distributions, DNA studies, and specimen-based museum investigations will further clarify neotropical owl systematics and provide a more solid taxonomic foundation for their conservation.

DISTRIBUTION OF NEOTROPICAL OWLS

Neotropical owls include 14 of the 26 genera in the world; 6 of these are endemic to the neotropics (*Megascops, Gymnoglaux, Lophostrix, Pseudoscops, Pulsatrix, Xenoglaux*). The genera with the most species are *Megascops* (26), *Glaucidium* (16), and *Strix* (10). México has 3 endemic genera (*Megascops, Lophostrix, Pulsatrix*), and the genera with more species is *Megascops* (8), *Glaucidium* (6), and *Strix* (5) species.

In general, the most current maps showing regional distribution are found in del Hoyo *et al.* (1999) and König *et al.* (1999). There are 7 owl species having very wide distribution in the neotropics: barn owl (*Tyto alba*), burrowing owl (*Athene cunicularia*), striped owl (*Asio clamator*), great horned owl (*Bubo virginianus*), short-eared owl (*Asio flammeus*), spectacled owl (*Pulsatrix perspicillata*), and mottled owl (*Strix virgata*); all of them found in México. There are 12 owls having restricted disttibutions, endemic to a portion of only one country: México has 5 endemic species, Perú has 2, Cuba has 2, and Jamaica, Dominican Republic, and Puerto Rico have one each. There are 13 other species with distributions restricted to portions of two countries, most of them are in South America (Table 1), and 9 species are distributed in only a portion of three countries. In this tabulation, 34 of the 75 neotropic species (45%) are endemics or quasi-endemics (species having distributions restricted to two or three countries, Escalante *et al.* 1993) (Table 1). This rate of endemism is consistent with that of other raptors in tropical areas (Bildstein *et al.* 1998).

BirdLife International defines a restricted-range species as one that, in historical times, has had an overall range of under 50,000 km^2 (del Hoyo *et al.* 1999:29). There are 11 neotropic species fitting this description: ashy-faced barn-owl (*Tyto glaucops*), bearded screech-owl (*Megascops barburus*), Colombian screech-owl (*M. colombianus*), cinnamon screech-owl (*M. petersoni*), Puerto Rican screech-owl (*M. nudipes*), Jamaican owl (*Pseudoscops grammicus*), white-chinned owl (*Pulsatrix koeniswaldiana*), fulvous owl (*Strix fulvenscens*), Cape pygmy-owl (*Glaucidium hoskinsii*), Tamaulipas pygmy-owl (*G. sanchenzi*), and long-whiskered owlet (*Xenoglaux loweryi*) (del Hoyo *et al.* 1999).

México and Perú have the highest number of species (32 each). In México, five of its 32 owl species are endemic and two are quasi-endemic (species having distributions restricted to two or three countries, Escalante *et al.* 1993) (one species is shared with Guatemala and one with United States). This country has the highest number of owl endemic species in the region; 2 are *Megascops* species and 3 are *Glaucidium* species (Table 1). In Perú, two of the 32 species are endemic and five are

Table 1. Owl species distribution per country in the Neotropics.

no.	scientific name	common name	Snst	México	Guatemala	Belize	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Colombia	Venezuela	Ecuador	Perú	Bolivia	Brazil	Paraguay	Uruguay	Argentina	Chile	Cuba	Puerto Rico	Jamaica	Dom.Rep./Haiti	Surinam	Guyana	French	Lesser Antilles	Bahamas I.	Total
1	*Tyto alba*	common barn owl	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	27
2	*Tyto glaucops*	ashy-face barn-owl	?																						E						1
3	*Otus flammeolus*	flammulated screech-owl	H	X	X		O																								3
4	*Megascops kennicottii*	western screech-owl	L	X																											1
5	*Megascops asio*	eastern screech-owl	L	X																											1
6	*Megascops lambi*	Oaxaca screech-owl		E																											1
7	*Megascops cooperi*	Pacific screech-owl	M	X	X		X	X	X	X																					6
8	*Megascops trichopsis*	whiskered screech-owl	H	X	X		X	X	X																						5
9	*Megascops barbarus*	bearded screech-owl	M	E	E																										2
10	*Megascops clarkii*	bare-shanked screech-owl	H							X	X	X																			3
11	*Megascops seductus*	balsas screech-owl	M	E																											1
12	*Megascops choliba*	tropical screech-owl	L							X	X	X	X	X	X	X	X	X	X	X						X	X	X	X		15
13	*Megascops koepckeae*	Maria Koepcke's screech-owl	M												E	E															2

Table 1. *Continued.*

no.	scientific name	common name	Snst	Méx	Guat	Bel	Sal	Hon	Nic	C. R.	Pan	Col	Ven	Ec	Perú	Bol	Bra	Par	Uru	Arg	Chile	Cuba	P. R.	Jam	D.R./H	Sur	Guy	French	L. A.	B. I.	Total
14	*Megascops roboratus*	Peruvian screech-owl	M											E	E																2
15	*Megascops hoyi*	montane forest screech-owl														E				E											2
16	*Megascops ingens*	rufescent screech-owl	H									X	X	X	X	X															5
17	*Megascops marshalli*	cloud forest screech-owl	H												E																1
18	*Megascops colombianus*	Colombian screech-owl	H									X		X	X																3
19	*Megascops petersoni*	cinnamon screech-owl	H											E	E																2
20	*Megascops watsonii*	tawny-bellied screech-owl	H									X	X	X	X	X	X									X	X	X			9
21	*Megascaps usta*	southern tawny-bellied screech-owl									X			X		X															3
22	*Megascops atricapilla*	black-capped screech-owl	L														X	X	X	X											4
23	*Megascops sanctaecaterinae*	long-tufted screech-owl															X		X	O											3
24	*Megascops vermiculatus*	vermiculated screech-owl								X	X	X	X	X																	5
25	*Megascops roraimae*	Roraima screech-owl											E				E														2

Table 1. *Continued.*

no.	scientific name	common name	Snst	Méx	Guat	Bel	Sal	Hon	Nic	C. R.	Pan	Col	Ven	Ec	Perú	Bol	Bra	Par	Uru	Arg	Chile	Cuba	P. R.	Jam	D.R./H	Sur	Guy	French	L. A.	B. I.	Total
26	*Megascops guatemalae*	Middle American screech-owl	M	X	X	X	X	X	X	X																					7
27	*Megascops napensis*	Rio Napo screech-owl										X		X	X	X															4
28	*Megascops nudipes*	Puerto Rican screech-owl	M																				E								1
29	*Megascops albogularis*	white-throated owl	H									X	X	X	X	X															5
30	*Gymnoglaux lawrencii*	Cuban screech-owl	M																			E									1
31	*Lophostrix cristata*	crested owl	H	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X			17
32	*Pseudoscops grammicus*	Jamaican owl	L																					E							1
33	*Bubo virginianus*	great horned owl	L	X	X	X	X	X	X	O	O	X	X	X	X	X	X	X	X	X	X					X	X	X			21
34	*Bubo magellanicus*	Magellan horned owl													X	X				X	X										4
35	*Pulsatrix perspicillata*	spectacled owl	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X						X	X	X	X		20
36	*Pulsatrix pulsatrix*	short-browed owl															E			E											2
37	*Pulsatrix koeniswaldiana*	white-chinned owl	H														X	X		X											3
38	*Pulsatrix melanota*	band-bellied owl	M									O		X	X	X															4

Table 1. *Continued.*

no.	scientific name	common name	Snst	Méx	Guat	Bel	Sal	Hon	Nic	C. R.	Pan	Col	Ven	Ec	Perú	Bol	Bra	Par	Uru	Arg	Chile	Cuba	P. R.	Jam	D.R./H	Sur	Guy	French	L. A.	B. I.	Total
39	*Strix occidentalis*	spotted owl	M	X																											1
40	*Strix fulvescens*	fulvous owl	H	X	X		X	X																							4
41	*Strix varia*	barred owl	M	X																											1
42	*Strix virgata*	mottled owl	M	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X						X	X	X	X		20
43	*Strix rufipes*	rufous-legged owl	M													X		X		X	X										4
44	*Strix chocoensis*	chaco owl																E		E											2
45	*Strix hylophila*	rusty-barred owl	H														X	X		X											3
46	*Strix albitarsus*	rufous-banded owl	M									X	X	X	X	X															5
47	*Strix nigrolineata*	black and white owl	M	X	X	X	X	X	X	X	X	X	X	X	X																12
48	*Strix huhula*	black-banded owl	M									X	X	X	X	X	X	X		X						X	X	X			11
49	*Glaucidium hoskinsii*	Cape pygmy-owl		E																											1
50	*Glaucidium gnoma*	northern pygmy-owl	M	X	X	O	X	X																							5
51	*Glaucidium nubicola*	cloud forest pygmy-owl										E		E																	2
52	*Glaucidium siju*	Cuban pygmy-owl	M																			E									1
53	*Glaucidium sanchezi*	Tamaulipas pygmy-owl		E																											1
54	*Glaucidium palmarum*	Colima pygmy-owl		E																											1

Table 1. *Continued.*

no.	scientific name	common name	Snst	Méx	Guat	Bel	Sal	Hon	Nic	C.R.	Pan	Col	Ven	Ec	Perú	Bol	Bra	Par	Uru	Arg	Chile	Cuba	P. R.	Jam	D.R./H	Sur	Guy	French	L. A.	B. I.	Total
55	*Glaucidium griseiceps*	Central American pygmy-owl		X	X	X	X	X	X	X	X			X																	9
56	*Glaucidium minutissimum*	least pygmy-owl	M														X	X		O											3
57	*Glaucidium hardyi*	Amazonian pygmy-owl	H										X		X	X	X									X	X	X			7
58	*Glaucidium parkeri*	subtropical pygmy-owl												E	E																2
59	*Glaucidium jardinii*	Andean pygmy-owl	M							X	X	X	X	X	X																6
60	*Glaucidium bolivianum*	Yungas pygmy-owl													X	X				X											3
61	*Glaucidium peruanum*	Peruvian pygmy-owl	M											E	E																2
62	*Glaucidium nanum*	Austral pygmy-owl																		E	E										2
63	*Glaucidium brasilianum*	ferruginous pygmy-owl	L									X	X	X	X	X	X	X	X	X	X					X	X	O	X		14
64	*Glaucidium ridgwayi*	Ridgway's pygmy-owl		X	X	X	X	X	X	X	X	X																			9
65	*Glaucidium tucumanum*	chaco pygmy-owl														X		X		X											3
66	*Xenoglaux loweryi*	long-whiskered owlet	H												E																1

Table 1. *Continued.*

no.	scientific name	common name	Snst	Méx	Guat	Bel	Sal	Hon	Nic	C. R.	Pan	Col	Ven	Ec	Perú	Bol	Bra	Par	Uru	Arg	Chile	Cuba	P. R.	Jam	D.R./H	Sur	Guy	French	L. A.	B. I.	Total
67	*Micrathene whitneyi*	elf owl	M	E																											1
68	*Athene cunicularia*	burrowing owl	M	X	X	X	X	O	X	O	O	X	X	X	X	X	X	X	X	X	X	X			X		X		X		22
69	*Aegolius acadicus*	northern saw-whet owl	M	X																											1
70	*Aegolius ridgwayi*	unspotted saw-whet owl	M	X	X		X	X	X	X	X																				7
71	*Aegolius harrisii*	buff-fronted owl	H									X	X	X	X	X	X	X	X	X											9
72	*Asio stygius*	Stygian owl	M	X	X	X	X	X	X		O	X	X	X		X	X	X		X		X	X		X						17
73	*Asio otus*	long-eared owl	M	X																		O	X								3
74	*Asio clamator*	striped owl	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X	X	X		22
75	*Asio flammeus*	short-eared owl	L	X	O					X		X	O	X	X	X	X	X	X	X	X	X	X		X	X	X	O	X	O	21
		Total		32	20	13	18	17	15	18	16	27	22	29	32	26	23	19	10	25	8	7	5	2	6	12	13	12	8	2	

O=Recorded less than 10 times (casual, uncertain or accidental), X=Resident, E=Endemic; Snst=Sensitivity L (low), M (medium); H (high); ? (unknown); blank (sp not recorded by Stotz *et al.* 1996) quasi-endemic (four species shared with Ecuador and one species with Bolivia). In Ecuador, with 29 species, five are quasi-endemic (four shared with Perú and one with Colombia). Colombia has 27 species, one quasi-endemic species shared with Ecuador. Bolivia has 26 species, with two quasi-endemic (one shared with Perú and one with Argentina); and Argentina has 25 species, four are quasi-endemic (two shared with Bolivia, one with Paraguay, and one with Chile) (Table 1). The variation in the number of endemic and quasi-endemic owl species together was highly and positively explained by the variation of the total number of owl species per country (R^2=0.83; ANOVA, F=56.64; d.f.=2,23; P<0.0001; Fig. 1). However, when the analysis was done separately this relationship is relatively less evident for endemic (R^2=0.28; ANOVA, F=4.41; d.f.=2,23; P<0.023; Fig. 1), than for quasi-endemic species (R^2=0.69; ANOVA, F=26.05; d.f.=2,23; P<0.0001; Fig. 1).

Islands in the neotropics also support a diversity of owls. Five species are endemic to islands: Ashy-face barn-owl in the Dominican Republic, Cuban screech-owl (*Gymnoglaux lawrencii*) and Cuban pygmy-owl (*Glaucidium siju*) in Cuba, Puerto Rican screech-owl in Puerto Rico, and Jamaican owl in Jamaica.

Although the geographic boundaries of countries are largely a political construct, the number of owl species increases with country's area (R^2=0.45; ANOVA, F=18.8; d.f.=1,23; P<0.001; Fig. 2). In addition to species-area relationships, factors such as latitude, habitat variability, and season influence the number of species in the region. Outside of the tropics, species richness has been noted to decrease with latitude (del Hoyo *et al.* 1999, König *et al.* 1999). Variations in topography and vegetation structure also influence species numbers. In particular, as the vast majority (about 91%) of owl species occupy forest or savanna habitats, countries having a variety of forest types (and associated structural conditions) also contain more owl species. México and Perú have the most owl species, followed by Venezuela and Colombia (Table 1). These four countries are highly variable in topography and habitat types (Simielli 1998).

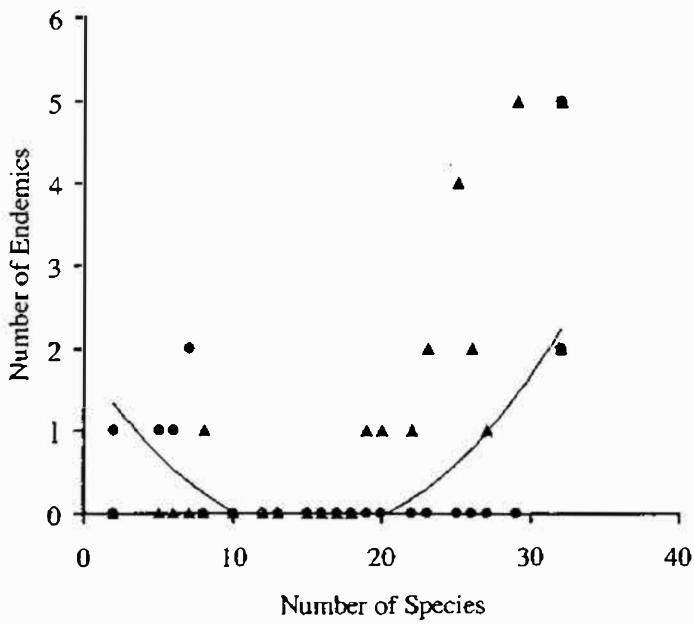

Figure 1. The relationship between the number of endemic and quasi-endemics owl species and the total number of owl species per each Latin America country (N=26). Closed circles represent number of endemics species in individual country (México has the highest number of endemic species). Triangles represent number of quasi-endemics species in each country (Ecuador and Perú have the highest number of quasi-endemics). The number of endemic owl species and the total number of owl species are from Table 1. A polynomial model better explained these relationships (Endemic species= -0.6789+0.04459 [Number of owl species] + 0.0083[Number of owl species - 16.346]2 R^2 = 0.28; F=4.41; d.f. 2, 23; P<0.023) (Quasi-endemic species= - 1.5631+0.1197 [Number of owl species] + 0.0074[Number of owl species - 16.346]2 R^2 = 0.69; F=26.05; d.f. 2, 23; P<0.0001).

Thiollay (1985) stated that biological and ecological information on tropical forest raptors was scarce, and 10 years after of his initial review again concluded that relatively little new information about tropical diurnal raptors had been published (Thiollay 1994). A poorer situation exists for neotropical owls. In his review of South American tropical raptors, Bierregaard (1998) stated: "*...our knowledge of the distribution and natural history of many raptor species, especially owls and forest-dwelling Falconiformes, is rudimentary at best ...... for most species, these data* [on population densities, distribution, and reproductive biology] *are anecdotal or nonexistent.*" Studying owls in the neotropics is not an easy task due to the physically challenging habitats and owls' nocturnal habits. Most of the early neotropical owl studies dealt with taxonomy and range distribution, and were often reported as incidental notes or natural history briefs (e.g., Ridgway 1887, Kelso 1934, Brodkob 1941, Moore 1941). More recently, a limited amount of ecological information for some neotropical owls has been provided in field guides (e.g. De Schauensee and Phelps 1978, Stiles and Skutch 1989, Ffrench 1991, Howell and Webb 1995). General distributional records have been reported for México (Contreras-Balderas 1992, Enríquez *et al.* 1993, Erickson *et al.* 1994).

STATUS OF ECOLOGICAL AND LIFE HISTORY KNOWLEDGE

Some owl species with distributions in both Neotropical and Neartic regions are poorly known in their tropical ranges. For instance, important ecological information

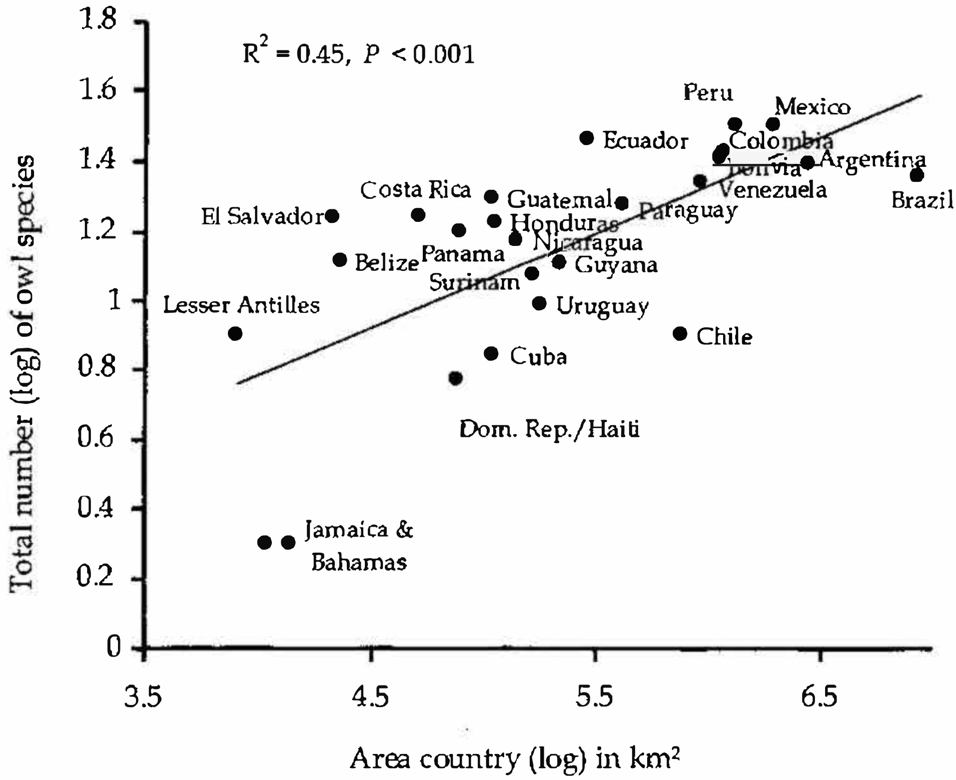

Figure 2. The (log) total number of owl species related with the (log) area in km² of 26 (N) Latin America countries considered by a simple linear regression model (Log of total number of owls species =-0.31+0.274(Log Area [km²]); $R^2 = 0.45$; F=18.8;d.f. 1, 23; P<0.001). Data of country size are from Simielli (1998).

from the Neartic exists for the barn owl (*Tyto alba*, Marti 1992), short-eared owl (*Asio flammeus*, Holt and Leasure 1993), northern saw-whet owl (*Aegolius acadicus*, Cannings 1993), flammulated owl (*Otus flammeolus*, McCallum 1994), eastern screech-owl (*Megascops asio*, Gehlbach 1995a), western screech-owl (*M. kennicottii*, Cannings and Angell 2001), spotted owl (*Strix occidentalis*, Gutierrez *et al.* 1995), and great horned owl (*Bubo virginianus*, McGillivray 1989, Houston *et al.* 1998). However, our knowledge of the ecological requirements, population status, reproductive ecology, or behavior of these species is very limited or absent in the Neotropics.

Natural history studies of neotropical owls have focused mainly on diet in the dry northern (Northern México) and southern (Argentina and Chile) portions of the region with barn owls (Travaini *et al.* 1997, Bellocq 1998, 2000), great horned owls (Yañez *et al.* 1978, Petersen and Petersen 1979, Llinas-Gutiérrez *et al.* 1991, Trejo and Grigera 1998), burrowing owls (Rodríguez-Estrella 1997), and striped owls (Isacch *et al.* 2000). A potential explanation why there are more studies on food habits than on other topics is because pellets disintegrate more slowly in these drier areas, allowing researchers to more readily find pellets from which to examine owl diets. However, two recent studies reported the diet of spectacled owls during the rainy season in southern México (Gómez de Silva *et al.* 1997) and the diet of tropical screech-owls (*M. choliba*) in southeastern Brazil (Motta 2002)

Other studies deal with nesting and reproductive behavior of the tropical screech-owl (*M. choliba*, Thomas 1977) in Venezuela, austral pygmy-owl (*G. nanum*, Jiménez and Jaksic 1989) in Chile, and black-and-white (*Strix nigrolineata*) and mottled owls (*S. virgata*, Gerhardt *et al.* 1991) in Guatemala and Venezuela (Gerhardt *et al.* 1994, Ibañez *et al.* 1992). Recent nest sites and descriptions exist for great horned owls (*B. v. mayensis*, Enríquez and Rangel-Salazar 1996) in México, and bare-shanked screech owls (*M. clarkii*, Enríquez *et al.* 1997) in Costa Rica.

Additional studies on distribution and abundance have been conducted for spotted owl (*S. o. lucida*, Tarango *et al.* 1997, Young *et al.* 1997) and flammulated owl

(*O. flammeolus*, Contreras-Balderas 1992) in México, short-eared and rufous-legged owl (*S. rufipes*, Martínez *et al.* 1997, Martínez and Jaksic 1997) in Chile, and striped owls (Martínez *et al.* 1997) in Argentina. Few studies on the community ecology of owls have recently been published for México (Garza *et al.* 1997), Costa Rica (Enríquez and Rangel-Salazar 1997, 2001), Perú (Lloyd 2003, Borges *et al.* 2004) and Chile (Jaksic *et al.* 2001). Other studies on neotropical owls have been recently published (Diniz-Filho 2000, Rodríguez-Estrella and Careaga 2003, Diniz-Filho *et al.* 2004).

Endangered species

In general, while our knowledge about the conservation status of neotropical populations is limited, we do know that owl abundance and distribution is decreasing in several regions. In these regions, owl species have been added to the endangered species list or have become locally extirpated. As of August 2002, the International Union for the Conservation of Nature (IUCN) listed one species of neotropical owl as endangered (long-whiskered owlet *Xenoglaux loweryi*), five as near threatened (Balsas screech-owl *Megascops seductus*, bearded screech-owl *M. barbarus*, Colombian screech-owl *M. colombianus*, cloud-forest screech-owl *M. marshalli*, spotted owl *Strix occidentalis*), and one as vulnerable (cloud-forest pygmy-owl *Glaucidium nubicola*) (www.birdlife.org). King (1981) cited 13 threatened taxa, 2 of them are subspecies occurring on islands in Latin America: the Tobago striped owl (*A. clamator oberi*) and the Virgin Island screech-owl (*M. nudipes newtoni*). Two species in Puerto Rico are endangered: the short-eared owl and the Puerto Rican screech-owl (Raffaele *et al.* 1989, Moreno 1998). In the West Indies, the Stygian owl needs attention because it is being persecuted by local people (Wiley 1986). Other neotropical owl species considered near-threatened are the unspotted saw-whet owl (*A. ridgwayi*) and buff-fronted owl (*A. harrisi*) (Collar *et al.* 1992, Collar *et al.* 1994 in König *et al.* 1999). Other potentially vulnerable neotropical owl species with uncertain status, little or no ecological data, and restricted distribution include at least the Peruvian (*M. roburatus*), Maria Koepecke's (*M. koepeckeae*), and cinnamon (*M. pertersoni*) screech-owls, and Austral (*G. nanum*), subtropical (*G. parkeri*), and Peruvian (*G. peruanum*) pygmy-owls. In México, in the Diario Oficial de la Federación (2002) (NOM-ECOL-059-2001) 21 owl species were listed (9 threatened, 9 special protection, 2 endangered, and 1 endemic).

Threats in the neotropics

Olson *et al.* (2000) identified the 238 terrestrial, freshwater, and marine eco-regions of the world. They reported 31 terrestrial eco-regions in the neotropics; 15 of these were characterized as "critical or endangered", eight were "vulnerable" and eight were 'relatively stable or intact' (Olson *et al.* 2000). Of major concern in here is that as the eco-regions decline in environmental quality, so do the populations of the species associated with them. Stotz *et al.* (1996) reported 54 owl species for the neotropics, 15 of them were highly sensitive to habitat changes, 28 species had medium sensitivity, 10 had low sensitivity, and the sensitivity for one species was unknown

(Table 1). Only a very few (mostly non-forest) owl species are benefiting from or at least accommodating changes in their habitat. For example, the subspecies *A. otus portoricensis* in Puerto Rico and the barn owl in Chile have apparently benefited from decreases in forest cover, which has improved accessibility to their food (Jaksic and Jiménez 1986). Other species such as great horned owl, short-eared owl, ferruginous pygmy-owl, barred owl, western screech-owl and eastern screech-owl can support some changes in their habitat or are already adapted to human-modified habitats (Marcot 1995, Stotz *et al.* 1996, Rodríguez-Estrella and Careaga 2003).

One of the most serious threats for many species of raptors continues to be the loss of forest (Thiollay 1985, Marcot 1995), including habitat alterations and fragmentation for livestock, wood extraction and agriculture, and natural disturbances (such as hurricanes and droughts). But, while some species can tolerate changes in their habitat or can live in partially urban areas, others still require undisturbed and forested areas for nesting and roosting.

As the human population and its activities represent the threatening factor for neotropical owls and biodiversity in general, we might expect a negative relationship between the status of owl species and human population density. Nine neotropical countries support a human density above the world's average (42 people km^2) and six of them have a greater human density than average for biodiversity hotspots in the world (73 people km^2, Cincontta *et al.* 2000). The Caribbean islands and El Salvador in Central America have a human density 4- to 6-fold the world average, and 2- to 4-

fold above the world average for biodiversity hotspots. We have more to learn about how human-induced environmental changes affect owl populations. For instance, cavity-nesting species have declined in numbers after logging operations in North America (Behrstock 2001). In Nicaragua, whiskered screech-owl (*M. trichopsis*) populations have been negatively affected by deforestation (Martínez 1986). There is some evidence (Parmesan and Yohe 2003) that global warming may alter weather patterns and affect the rate and distribution of habitat-altering storms and weather events that, in turn, affect owl populations. Lynch (1991) studied a bird community in México before and after hurricane Gilberto struck in 1988. In 1988, before the hurricane, Lynch found 14 individual ferruginous pygmy-owls; in 1990 he did not find any pygmy-owls in the study area. Another factor reported for habitat change has been owl species distribution range overlap or species replacement. For instance, the barred owl has been reported occupying spotted owl habitats and in some areas is displacing the latter species (Hamer *et al.* 1994).

Additional, important factors are the introduction of exotic species (mainly on islands) such as rats, cats, pigs, raccoons and their impacts to the more vulnerable ground nesting species (Wotzkow 1994); and trafficking of owl species, illegal hunting, egg and specimen collection, or a combination of these factors (Thiollay 1994, Marcot 1995, Mooney 1998). There are also problems for those species that use urban and farmland areas. In these areas, the most important factors are collisions with automobiles, barbwire fences, power lines, shooting due to perceived damage to farm livestock, and predation from feral and domestic cats.

Pesticides such as insecticides and rodenticides have been reported to threaten and kill raptors and owls because of their high toxicity (Newton 1979, Lacombe *et al.* 1994, Mooney 1998). For instance, pesticides such as organochlorines and cholinesterase-inhibiting pesticides have caused direct mortality in barn, great horned, burrowing, eastern screech-, short-eared, snowy (*Bubo scandiacus*), and barred owls (del Hoyo *et al.* 1999, Mineau *et al.* 1999). Although other studies have concluded that some North American raptors tolerate some pesticides (Blus 1996). Henny *et al.* (1998) reported low concentrations of pesticides in long-eared owl eggs. These pesticides concentrations may cause abnormal eggs, small clutch or poor fledging success (Behrstock 2001). Despite that some pesticides (DDT, aldrin or dieldin) have been banned or severely restricted in the United States since 1976 due to their high toxicity, most are still being used in neotropical areas (Iñigo and Risebrough 1989).

Apparently, nocturnal raptors are less vulnerable to perturbation than diurnal raptors, because of their smaller home ranges and their nocturnal habits (Bierregaard 1998). However, owls face the same threats of diurnal raptors, and there is little evidence why owls would be affected differently. Moreover, owls in many parts of the world are killed as they are considered harbingers of bad luck (Stockton 1983, Enríquez and Mikkola 1997), a cultural situation not affecting diurnal raptors. In several places in tropical Latin America, owls are killed due to local beliefs, myths, or superstitions. For instance, in Haiti, Dominican Republic, Jamaica, and Cuba, these superstitions are well rooted (Wiley 1986). In Puerto Rico, people believe that the Puerto Rican screech-owl damages coffee fruits and is an indicator of misfortune, therefore this owl is frequently shot (Braggi 1983). In Chile, the owl species considered to be bad luck are the barn owl, ferruginous pygmy-owl, and Austral pygmy-owl (Jaksic and Jiménez 1986). The Stygian owl (*A. stygius*) in the West Indies and the spectacled, mottled, and black-and-white owls in Costa Rica are killed as they are considered to be witches and announcers of bad news. In Costa Rica, owls are also perceived to impact farm livestock, as spectacled owls sometimes eat chickens and cats (Enríquez and Rangel-Salazar in press). In El Salvador, nesting Stygian owls are purposefully disturbed by local people (Thurber *et al.* 1987). Despite governmental regulations to protect owls in some countries, these regulations are often not enough to conserve them.

In places as México, some indigenous communities in the highlands of Chiapas use owls as food (PLE pers. obs.). They also use their bones, feathers, or claws for medicine or ritual ceremony. In Puerto Rico the body of the Puerto Rican screech-owl can be used to cure asthma, or the flesh of the burrowing owl is used to increase the appetite for a recovering patient in Uruguay (Mikkola 1999).

The degree of threats to owl populations varies among species, regions, cultures, and countries. The survival of owl populations in the neotropics will ultimately depend on the species' capacity to tolerate the threats imposed by human cultures, conservation and management policies, and education levels in each country.

ADDITIONAL INSIGHTS ON THE OWLS OF MÉXICO

In this section, we offer a listing of the available literature on the 32 owl species found within México (Table 2). We include citations for those studies physically conducted within México, as well as studies conducted outside of México that have produced information directly relevant to México. Our primary focus was to cite sources on studies conducted within México, to provide a baseline for researchers wanting to undertake additional and much-needed work on the owl species found there. While our listing of citations may not be exhaustive, we have attempted to identify the main synthesis publications as well as key literature for the species.

Table 2. Literature on the 32 species of owls found in México. Common and scientific names of owls follow König *et al.* (1999) and Banks *et al.* (2003)

barn owl (*Tyto alba*)	Anderson and Long 1961; Anderson and Ogilvie 1957; Anderson and Nelson 1960; AOU 1998; Baker 1953; Binford 1989; Blake 1972; Bradshaw and Hayward 1960; Brodkorb 1971; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Hardy *et al.* 1990; Howell and Webb 1995; Huey 1926; Hume 1991; Johnsgard 2002; König *et al.* 1999; López-Forment and Urbano 1977; Marti 1992; Miller 1955; Mones 1968; Petersen and Petersen 1979; Ramírez-Pulido and Sánchez-Hernández 1972; Stager 1957; Steadman *et al.* 1994; Voous 1988; Webster 1974.
flammulated scops owl (*Otus flammeolus*)	AOU 1998; Blake 1972; Burton 1973; Contreras-Balderas 1992; Davis 1972; del Hoyo *et al.* 1999; Ely 1962; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Gehlbach 1995a; Hardy *et al.* 1990; Hayward and Verner 1994; Howell and Webb 1995; Hubbard and Crossin 1974; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1957, 1967; McCallum 1994; Miller 1955; Moore and Peters 1939; Navarro 1992; Phillips 1942; Schaldach 1969; Stager 1954; Steadman *et al.* 1994; Sutton and Burleigh 1940; van Hoose 1955; Voous 1988.

Table 2. *Continued.*

western screech-owl (*Megascops kennicottii*)	AOU 1998; Blake 1972; Burton 1973; Cannings and Angel 2001; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gehlbach 1995a; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1957, 1967; Miller and Miller 1951; Moore 1941; Owen 1963; Ridgway 1914; Rodríguez-Estrella and Careaga 2003; Russell and Monson 1998; Voous 1988.
eastern screech-owl (*Megascops asio*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gehlbach 1995a; Hardy *et al.* 1990; Howell and Webb 1995; Huey 1926; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1959, 1967; Miller 1955; Moore and Peters 1939; Owen 1963; Rowley 1984; Steadman *et al.* 1994; Voous 1988; Webster 1974.
Oaxaca screech-owl (*Megascops lambi*)	Binford 1989; Howell and Webb 1995; König *et al.* 1999; Marshall 1967; Marshall *et al.* 1991; Moore and Marshall 1959.
Pacific screech-owl (*Megascops cooperi*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gehlbach 1995a; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1959, 1967; Marshall *et al.* 1991; Moore and Peters 1939.
whiskered screech-owl (*Megascops trichopsis*)	Álvarez del Toro 1971; AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Edwards and Martin 1955; Enríquez *et al.* 1993, 1994; Fleming and Baker 1963; Friedmann *et al.* 1950; Gehlbach 1995a, 1995b; Gehlbach and Gehlbach 2000; Goldman 1951; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1957, 1967; Marshall *et al.* 1991; Miller 1943; Miller 1955; Moore and Peters 1939; Ross 1969; Rowley 1984; Russell and Monson 1998; Schaldach 1963, 1969; Stager 1954; Steadman *et al.* 1994; van Rossem 1938, 1945; Voous 1988; Webster and Orr 1954.
bearded screech-owl (*Megascops barbarus*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; König *et al.* 1999; Marcot 1995; Marshall 1967; Moore and Peters 1939.
Balsas screech-owl (*Megascops seductus*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Johnsgard 2002; König *et al.* 1999; Marshall 1967; Marshall *et al.* 1991; Peterson and Chalif 1973.
Guatemalan screech-owl (*Megascops guatemalae*)	Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Johnsgard 2002; König *et al.* 1999; Marcot 1995; Marshall 1967; Marshall *et al.* 1991; Moore and Peters 1939; Paynter 1955; Storer 1961; Webster 1974.
crested owl (*Lophostrix cristota*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995.

Table 2. *Continued.*

crested owl (*Lophostrix cristata*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995.
great horned owl (*Bubo virginianus*)	AOU 1998; Binford 1989; Bailey and Conover 1935; Brodkorb 1943; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Donázar *et al.* 1989; Enríquez *et al.* 1993, 1994; Enríquez and Rangel-Salazar 1996; Hardy *et al.* 1990; Houston *et al.* 1998; Howell and Webb 1995; Huey 1926; Hume 1991; Johnsgard 2002; König *et al.* 1999; Llinas-Gutiérrez *et al.* 1991; McGillivray 1989; Miller 1955; Nelson 1901b; Petersen and Petersen 1979; Rodríguez-Estrella *et al.* 1985; Stager 1954; Steadman *et al.* 1994; Voous 1988; Webster 1974; Webster and Orr 1954; Weick 1999.
spectacled owl (*Pulsatrix perspicillata*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gómez de Silva *et al.* 1997; Hardy *et al.* 1990; Howell and Webb 1995; Johnsgard 2002; König *et al.* 1999; Marcot 1995.
spotted owl (*Strix occidentalis*) (Mexican subspecies is *S. o. lucida*).	Anthony 1893; AOU 1998; Arambula 1994; Block *et al.* 1995; Bryant 1889; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Edwards 1989; Enríquez *et al.* 1993, 1994; Garza *et al.* 1997; Gutiérrez 1994; Gutiérrez *et al.* 1995; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Márquez *et al* 2002; .Peterson and Chalif 1989; Ridgway 1914; Seamans *et al.* 1999; Steadman *et al.* 1994; Tarango 1994; Tarango *et al.* 1997; Tarango *et al.* 2001; Voous 1988; Young *et al.* 1997, 1998.
fulvous owl (*Strix fulvescens*)	Álvarez del Toro 1971; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; König *et al.* 1999; Marcot 1995.
barred owl (*Strix varia*) (Mexican race: *S.v. sartorii*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Garza *et al.* 1997; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Mazur and James 2000; Navarro 1992; Peters 1940; Ridgway 1914; Voous 1988.
mottled owl (*Strix virgata*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995; Steadman *et al.* 1994; Voous 1988; Webster 1974.
black-and-white owl (*Strix nigrolineata*)	AOU 1998; Binford 1989;Blake 1972; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Edwards 1989; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995; Paynter 1955; Peterson and Chalif 1973; Ridgway 1914.

Table 2. *Continued.*

western screech-owl (*Megascops kennicottii*)	AOU 1998; Blake 1972; Burton 1973; Cannings and Angel 2001; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gehlbach 1995a; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1957, 1967; Miller and Miller 1951; Moore 1941; Owen 1963; Ridgway 1914; Rodríguez-Estrella and Careaga 2003; Russell and Monson 1998; Voous 1988.
eastern screech-owl (*Megascops asio*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gehlbach 1995a; Hardy *et al.* 1990; Howell and Webb 1995; Huey 1926; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1959, 1967; Miller 1955; Moore and Peters 1939; Owen 1963; Rowley 1984; Steadman *et al.* 1994; Voous 1988; Webster 1974.
Oaxaca screech-owl (*Megascops lambi*)	Binford 1989; Howell and Webb 1995; König *et al.* 1999; Marshall 1967; Marshall *et al.* 1991; Moore and Marshall 1959.
Pacific screech-owl (*Megascops cooperi*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gehlbach 1995a; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1959, 1967; Marshall *et al.* 1991; Moore and Peters 1939.
whiskered screech-owl (*Megascaps trichapsis*)	Álvarez del Toro 1971; AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Edwards and Martin 1955; Enríquez *et al.* 1993, 1994; Fleming and Baker 1963; Friedmann *et al.* 1950; Gehlbach 1995a, 1995b; Gehlbach and Gehlbach 2000; Goldman 1951; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marshall 1957, 1967; Marshall *et al.* 1991; Miller 1943; Miller 1955; Moore and Peters 1939; Ross 1969; Rowley 1984; Russell and Monson 1998; Schaldach 1963, 1969; Stager 1954; Steadman *et al.* 1994; van Rossem 1938, 1945; Voous 1988; Webster and Orr 1954.
bearded screech-owl (*Megascops barbarus*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; König *et al.* 1999; Marcot 1995; Marshall 1967; Moore and Peters 1939.
Balsas screech-owl (*Megascops seductus*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Johnsgard 2002; König *et al.* 1999; Marshall 1967; Marshall *et al.* 1991; Peterson and Chalif 1973.
Guatemalan screech-owl (*Megascaps guatemalae*)	Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Johnsgard 2002; König *et al.* 1999; Marcot 1995; Marshall 1967; Marshall *et al.* 1991; Moore and Peters 1939; Paynter 1955; Storer 1961; Webster 1974.
crested owl (*Lophostrix cristata*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995.

Table 2. *Continued.*

crested owl (*Lophostrix cristata*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995.
great horned owl (*Bubo virginianus*)	AOU 1998; Binford 1989; Bailey and Conover 1935; Brodkorb 1943; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Donázar *et al.* 1989; Enríquez *et al.* 1993, 1994; Enríquez and Rangel-Salazar 1996; Hardy *et al.* 1990; Houston *et al.* 1998; Howell and Webb 1995; Huey 1926; Hume 1991; Johnsgard 2002; König *et al.* 1999; Llinas-Gutiérrez *et al.* 1991; McGillivray 1989; Miller 1955; Nelson 1901b; Petersen and Petersen 1979; Rodríguez-Estrella *et al.* 1985; Stager 1954; Steadman *et al.* 1994; Voous 1988; Webster 1974; Webster and Orr 1954; Weick 1999.
spectacled owl (*Pulsatrix perspicillata*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Gómez de Silva *et al.* 1997; Hardy *et at.* 1990; Howell and Webb 1995; Johnsgard 2002; König *et al.* 1999; Marcot 1995.
spotted owl (*Strix occidentalis*) (Mexican subspecies is *S. o. lucida*).	Anthony 1893; AOU 1998; Arambula 1994; Block *et al.* 1995; Bryant 1889; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Edwards 1989; Enríquez *et al.* 1993, 1994; Garza *et al.* 1997; Gutiérrez 1994; Gutiérrez *et al.* 1995; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Márquez *et al* 2002; .Peterson and Chalif 1989; Ridgway 1914; Seamans *et al.* 1999; Steadman *et al.* 1994; Tarango 1994; Tarango *et al.* 1997; Tarango *et al.* 2001; Voous 1988; Young *et al.* 1997, 1998.
fulvous owl (*Strix fulvescens*)	Álvarez del Toro 1971; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; König *et al.* 1999; Marcot 1995.
barred owl (*Strix varia*) (Mexican race: *S.v. sartorii*)	AOU 1998; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Garza *et al.* 1997; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Mazur and James 2000; Navarro 1992; Peters 1940; Ridgway 1914; Voous 1988.
mottled owl (*Strix virgata*)	AOU 1998; Binford 1989; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Enríquez *et al.* 1993, 1994; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995; Steadman *et al.* 1994; Voous 1988; Webster 1974.
black-and-white owl (*Strix nigrolineata*)	AOU 1998; Binford 1989;Blake 1972; Burton 1973; Davis 1972; del Hoyo *et al.* 1999; Edwards 1989; Enríquez *et al.* 1993, 1994; Friedmann *et al.* 1950; Hardy *et al.* 1990; Howell and Webb 1995; Hume 1991; Johnsgard 2002; König *et al.* 1999; Marcot 1995; Paynter 1955; Peterson and Chalif 1973; Ridgway 1914.

CONCLUSIONS

With 35% of the world's owls, the neotropical region supports a high degree of owl diversity and endemism. México has the highest number of both species and endemic owls of the neotropics. Although there have been important advances in taxonomy, systematics, and distribution, there are still truly substantial gaps in our understanding of neotropical owl species. The ecological information on neotropical owls is still very incomplete, and the population status is often generalized or even somewhat arbitrary due to our limited knowledge. Most of the published literature on neotropical owls has come from the northern (México) and southern (Argentina and Chile) portions of the region, and generally deals only with few species. And although recently have had a little increase of neotropical owl published papers, we urgently need more biological studies on the poorly known species. We do know that the distribution of owl species has been changing due to the elimination or transformation of their habitats. These habitat changes cause reductions in owl abundance and home ranges, and subsequently in the overall distribution of the species. Few owl species have accommodated these changes and a growing number are endangered, threatened, or vulnerable. Although human activities continue to be the main threat to wildlife, the degree of threat may differ among regions or countries, as human attitudes, land use, conservation policies and education levels vary.

Conservation and management programs for wildlife in general, and owls in particular, will be improved as we gain more biological and ecological information about these species. Being able to protect habitat (and thus species) will continue to be one of the main conservation strategies. Aspects such as survey techniques, abundance, nest and egg descriptions, diet, roosting and nesting sites, demographic aspects, home ranges and seasonal movements, habitat relationships, dispersal of juveniles, genetic population variability, community structure, inter- and intra-specific relationships, and anthropogenic impacts to owl populations are fruitful areas of study. From this information, we can develop and integrate national and international conservation and monitoring programs. Importantly, as we better understand the changing roles that owls play in human cultures, we can build conservation programs around those species for which there is public interest and support.

ACKNOWLEDGMENTS

We would like to thank those who helped us with reviews of the draft manuscript: Bruce G. Marcot, Ana Malizia, Ricardo Rodríguez-Estrella, and an anonymous reviewer. We also thank Bruce G. Marcot, Richard J. Clark, Jane Noll-West, and Mat Seidensticker for helping provide us with Mexican owl citations for Table 2. Financial and logistic support during writing this paper was provide by El Colegio de la Frontera Sur, the Consejo Nacional de Ciencia y Tecnología (grants No. 119647 to PLE and 84108 to JLR), and the Centre for Applied Conservation Research.

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Taxonomic allocation and precision for tropical owl communities: a sampling approach

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ABSTRACT

Owls are difficult to study mainly because of their nocturnal behavior. We propose a sampling approach to study owl densities in tropical rain forests that combines play-back broadcasting with taxonomic allocation of sampling effort based on predicted size of the home range of owl species. We based our sampling approach on the owl assemblage at La Selva Biological Station, Costa Rica. We estimated transect length on an estimated home range of the largest owl species, with the number of stations for broadcasting calls and distance among these stations based on the smallest species. We included insights in sampling owl assemblages in tropical forests in México. A better understanding of the behavioral ecology of tropical owls could improve on this design and reduce potential sources of bias when estimating densities of secretive and vocalizing birds.

Key words: sampling design, allocation effort, owls, tropical forests, play-back technique, calls.

RESUMEN

Las especies de búhos son difíciles de estudiar debido a su comportamiento nocturno. Aquí proponemos una aproximación de muestreo para estimar densidades de búhos en bosques tropicales lluviosos que combina el uso de emisiones auditivas con la asignación taxonómica del esfuerzo de muestreo basado en el cálculo de las áreas de acción de las especies. Basamos nuestra aproximación de muestreo del ensamble de búhos de la Estación Biológica La Selva en Costa Rica. De este lugar, nosotros estimamos la máxima longitud del transecto basada en la estimación del rango hogareño de la especie más grande en el ensamble, y el número de y distancia entre estaciones para la aplicación de las emisiones auditivas basada en el rango hogareño de la especie más pequeña en el ensamble. Incluimos una perspectiva para un muestreo estratificado basado en el tamaño de las especies de ensambles de búhos en bosques tropicales de México. Consideramos que un mejor entendimiento del comportamiento de las especies de búhos en bosques tropicales, podría ayudar a mejorar este diseño y así reducir los posibles sesgos cuando se estiman densidades de organismos sigilosos.

INTRODUCTION

A fundamental goal in avian conservation ecology is to determine whether populations increase or decrease across space and over time and to use appropriate sampling procedures to estimate population densities to predict population trends

(Newton 1998). Birds in particular habitats present a difficult sampling task. Owls inhabiting tropical forests are one of these groups because of our limited understanding of their behavioral ecology (Mikkola 1983, Marcot 1995, König *et al.* 1999).

Most owl species are nocturnal or crepuscular, and this circumstance also contributes to our limited understanding of their behavior and distribution, since observation opportunities are so infrequent (Sparks and Soper 1989). However, counting owl vocalizations has been a successful tool for determining distribution, estimating abundance, and establishing habitat associations (Andersen *et al.* 1985, Hill and Lill 1998a).

The play-back technique has been used to elicit owl calling based on their territorial behavior (Fuller and Mosher 1981, Johnson *et al.* 1981, Marion *et al.* 1981, Martínez and Zuberogöitia 2002). This technique consists of playing pre-recorded vocalizations of territorial calls. Sampling protocols using play-back techniques have mostly focused on estimating population size in temperate forests (Fuller and Mosher 1981, Kochert 1986, Zuberogöitia and Martinez-Climent 2000), with a few studies in tropical forests (Gerthardt 1991, Enríquez and Rangel-Salazar 2001).

While 35% of the owl species occur in the Neotropics, information about their ecology is limited (Enríquez *et al.*, in this publication). In general, owl assemblages have been poorly studied (Korpimäki 1987), and there are no protocols for sampling interacting owl species from tropical bird communities. Studies of owl assemblages in Neotropical ecosystems should help our understanding of limiting factors for tropical owl populations. Sampling protocols for tropical owl assemblages should allow evaluation of single-species densities, as well as owl assemblages as a whole. Here, our goal is to propose a sampling protocol to estimate owl densities in tropical owl assemblages using a taxonomic allocation strategy and to encourage other bird researchers to sample assemblages of interacting owl inhabiting tropical forests of México and Central America.

METHODS: AN EXAMPLE OF SAMPLING A TROPICAL OWL ASSEMBLAGE

Background

Enríquez and Rangel-Salazar (2001) established a sampling protocol for evaluating an owl assemblage from a Neotropical rain forest and obtained information to manage and conserve owls in protected tropical areas. The sequence of broadcasts was random, but they assumed a homogeneous distribution of owls within and among species. This was a preliminary approach since species in an assemblage differ in size, and may differ also in local distribution and abundance (Nee *et al.* 1991, Gaston and Blackburn 2000). An improvement to this procedure would be to recognize differences in spatial distributions among species and allocate sampling efforts according to a taxonomic and size scale.

We propose a sampling design that includes proportional (taxonomic) allocation of sampling effort along line transects based upon estimated size of home range of owls. Time replicates permit calculating population estimates and confidence limits and are important because calling behavior of owls can vary seasonally and be influenced by environmental conditions (Enríquez and Rangel-Salazar 2001).

Proportional (taxonomic) allocation

Proportional (taxonomic) allocation involves assigning sample efforts proportional to the relative abundance of each species. However, knowledge of the size of a population of a species (N_h) and total owl abundance (N) are needed to achieve density estimates. Because estimating N_h and N is often the main goal in sampling design, we obtained preliminary estimates of N_h and N using predicted home range sizes for the various species. Home range is the area normally traveled by an individual owl during activities associated with feeding, roosting, and reproduction (Harested and Bunnell 1979, Basset 1995). To estimate home range of species, we used the allometric model developed by McNab (1963) and Schoener (1968):

$$aW^k$$

where W is the weight of the species and a and k are constants. We used a=0.034 and k=1.31 as constants for birds of prey, as suggested by Harested and Bunnell (1979), and the weight of males for the six species of interest (Table 1).

In birds of prey, females tend to be larger and heavier than males (Snyder and Wiley 1976, Olson *et al.* 1999). However, we used male weights based on the assumption that males establish territories and the sizes of the home range. Territory

Table 1. Estimated number of values for six owl species at La Selva Biological Reserve, Costa Rica.

owl species	english name	weight		HR= (0.034W1.31)		R= SR (A*10000/*P*)		SD (Radious*2)		TL (by 10 stations)		stations		N_h= HR/1513 ha	
		male	female	male	female	male	female	male	female	male	female	distance	number	male	female
Glaucidium griseiceps	Central American pygmy-owl	51	57	5.9	6.8	136.7	147.0	273.3	294.0	2733.1	2939.6	275	10	257.9	222.9
Megascops vermiculatus	vermiculated screech-owl	100	110	14.2	16.1	212.4	226.1	424.8	452.2	4248.1	4521.8	425	6	106.7	94.2
Strix virgata	mottled owl	175	320	29.5	65.0	306.4	455.0	612.9	910.1	6128.9	9100.6	625	4	51.3	23.3
Lophostrix cristata	crested owl	400	600	87.1	148.2	526.6	686.8	1053.3	1373.7	10532.8	13736.7	1050	3	17.4	10.2
Strix nigrolineata	black-and-white owl	435	535	97.3	127.5	556.4	637.1	1112.8	1274.3	11127.7	12742.8	1100	2	15.6	11.9
Pulsatrix perpicillata	spectacled owl	590	980	145.0	281.8	679.3	947.1	1358.6	1894.3	13586.3	18943.0	1350	2	10.4	5.4

HR=home range, R=radious, SD=station distance, TL=transect lenght, Stations=number of stations, N_h=estimated number of individuals of species h and home range can change, depending on season and mating conditions. During breeding season or parental care, the home range could be smaller than at other seasons (Forsman *et al.* 1984). Differences in weight of the sexes tend to increase with species size. The size of a home range may differ within and among species according to sex, habitat type and quality, and landscape characteristics (Schoener 1968).

Transect length and the number of stations per transect could be calculated as a function of the home range of the heaviest owl species and the smallest owl species in the assemblage. Transect length is estimated using twice the station distance:

$$TL = 2\times\left(2\times\sqrt{\frac{HR_{HS}*10000}{\pi}}\right)$$

where TL is the transect length and HR_{HS} is the home range of the heaviest species. The estimated transect length should be reasonable for a survey during one night in a tropical rain forest. The feasibility of using a transect of this estimated length will ultimately depend on the number of stations.

The number of stations along a transect is based upon the transect length (TL) and the home range of the lightest species:

$$NS = \left(\frac{TL}{2\times\sqrt{\frac{HR_{LS}*10000}{\pi}}}\right)$$

where NS is the number of stations along a transect and HR_{LS} is the home range of the lightest species.

A proportional allocation of sampling effort should be based on the number of stations available and restricted by the size of owl species. The estimated number of species ($\hat{N}_h$) in the area is calculated based on the male home range size for the species (HR_h) and the total area. The total number of stations is partitioned among the species based on the estimated population size, using:

$$n_h = \left(\frac{\hat{N}_h}{\sum \hat{N}_h} \right) \times n$$

where n_h is the number of stations for the hth species.

The sequence of broadcasting the various calls should be selected using pseudo-randomization without replacement, starting with the heaviest species and proceeding to the lightest. Once selected, a particular station would not be used for the other species. This procedure should be repeated until all stations are assigned to one or another of the species. For those species with more than one station, the procedure is repeated at each station where the call is planned to be broadcasted. When a station is assigned to a particular species, the stations assigned to a species should be at least as far apart as the station distance estimated for that species. If this is not achieved by random selection, then the selection is ignored and the process repeated until this condition is achieved. Stations would generally be assigned to a different species for each sampling period.

DISCUSSION

Sampling tropical owls is a time consuming activity, and some criterion of efficiency is necessary to design a good sampling protocol before entering the field. The accuracy of the collected data will depend largely on how sampling is conducted and how point values are estimated (see Cochran 1977, Hayek and Buzas 1997). Tropical forest owl assemblages are characterized by a complex of interacting species. We believe that sampling effort should be allocated differently among the community of species. Allocating sampling in a taxonomic manner allows sampling efforts to be invested proportional to the size of the species. Size ranking of a species to establish appropriate distances between broadcasting stations can be troublesome. Most studies that use play-back strategies establish distances among broadcasting locations based on previous studies involving other species or areas (e.g., Clark and Anderson 1997, Zuberogöitia and Martínez-Climent 2000, Enríquez and Rangel-Salazar 2001). Establishing transect length and the number of stations for broadcasting, based on home ranges ranking from larger to smaller species in an area, considers a hierarchical approach to species coexistence (Basset 1995).

The results of a sample should be assessed in terms of potential bias such as species distribution, occurrence, home range, behavior (diurnal or strictly nocturnal), broadcast quality, and equipment used. Estimates of N_h (individuals of species h) and N (estimated number of owls) should be directly related to estimates of home range. Home range of a species depends on a variety of factors such as size, habitat type and quality, landscape characteristics and season (Schoener 1968, Forsman *et al.* 1984). In the tropics, some responses of owls to broadcasted vocalizations showed monthly variation (Enríquez and Rangel-Salazar 1997) associated with illumination, moon phase, time after sunset, and number of days to summer solstice (Enríquez and Rangel-Salazar 2001). Low quality calls, including harsh sounds, different rhythms, or high volumes may reduce the probability of receiving responses, or even worse, cause territories to be abandoned. This last issue may be crucial during the breeding season. Broadcasting calls recorded from different areas may cause different responses as a result of geographic dialects. Individual owls can be identified by their calls, suggesting a high level of sound discrimination (Hill and Lill 1998b). There are also differences in responses among species; some may respond in a cooperative way (male and female together) when defending their territories, while others males and females may respond exclusively to members of their own sex (Appleby *et al.* 1999). Responses may also be dependent on reproductive status, since single individuals do not respond to prerecorded playbacks of territorial intruders, while coupled individuals bravely respond to territorial intruders (Martínez and Zuberogöitia 2002).

Behavioral ecology of owls from the Neotropics is only partially known, which makes designing an efficient sampling protocol difficult. Sampling protocols designed for increasing efficiency and accuracy are essential for increasing our understanding of population size and dynamics. Here, we proposed a sampling protocol to allocate sampling effort among owl species and to efficiently determine the size of an owl assemblage in a tropical forest. Taxonomic allocation of sampling effort, combined with home range estimates and broadcasting calls should result in more reliable information than equal sampling effort per species, particularly if the length of a transect and the distance between stations for broadcasting are based on reasonable estimates of the hypothetical abundance of species. A factor to consider when sampling owls with broadcasting calls is the lack of knowledge of behavioral ecology, which should be a foundation of the design of better sampling protocols. Improved understanding of the natural history and behavior of tropical owls would help to reduce potential sources of bias in estimates of population or assemblage densities.

Insights on sampling owl assemblages in tropical forests in México

México contains 32 owl species (Enríquez *et al.* 1993, 1994) and is considered the richest country on the continent in owl diversity, with five endemic and two quasi-endemic owl species among them (Enríquez *et al.*, in this publication). The majority of owl species in México are distributed in tropical areas, and many of them are closely associated with mature, tropical forests (Marcot 1995). Even with this high owl richness in México, we have limited information and knowledge of their natural history, taxonomy, behavior, and distribution at all geographical levels. Without basic ecological and biological information, it is very difficult to accurately evaluate the true status and trends of owl populations in México.

In general, owl assemblages in tropical lowland forests from southern México through Central America share similar species with little species turnover. For example, all species in the example of the basic sampling protocol by Enríquez and Rangel-Salazar (2001) at La Selva, Costa Rica, are found in México from Southern Veracruz and Oaxaca through the Lacandon Rain Forest of Chiapas (González-García 1993). Even with similar spatial and ecological distributions of the owl species from tropical lowland forests in the region, their abundance vary across the region, resulting in an uneven distribution of individuals across locations (Gaston and Blackburn 2000).

By designing a sampling effort that includes taxonomic (proportional) allocation based upon estimated size of their home range, combined with broadcasting calls, it is possible to test preliminary estimates of N_h and N values of tropical owl assemblages in tropical forests of México. Size of home range is based on local abundance, and distribution is influenced by the body size of the species (Damuth 1991, Nee *et al.* 1991). The most recent information for tropical forest owls in México, including their size and body mass, is found in Olsen *et al.* (1999) and König *et al.* (1999). Calls for broadcasting to owls at particular tropical forest locations could be a difficult task. One approach for recording local calls is to obtain responses to broadcasted calls, using the national sound collection of México (http://www.ecologia.edu.mx/sonidos). Finally, we believe that owls in the tropical forests of México and elsewhere are among the most endangered and neglected groups of tropical birds (Thiollay 1994, Bildstein *et al.* 1998). The challenge to obtain empirical information on distributional abundance to help establish population trends and conserve tropical forest owls in México is current and urgent.

ACKNOWLEDGEMENTS

We thank those people who gave us comments on drafts of this manuscript: B. Hassani, R. Rodríguez-Estrella, and two anonymous reviewers. We also thank R. Barrantes and F. Morales who were involved in the collection of data used in this paper. Financial and logistic support for writing this paper was provided by El Colegio de la Frontera Sur, the Consejo Nacional de Ciencia y Tecnología (Grants No. 84108 to JLR and No. 119647 to PLE), and the Centre for Applied Conservation Research, University of British Columbia.

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This book provides a synopsis of existing information on raptors in México. Studies on the ecology, biology, taxonomy and systematics of raptors (Falconiformes and Strigiformes) are presented throughout the different chapters of the book. This work also presents an analysis of habitats and type of ecosystems where raptor studies are currently performed. Special attention was paid to display the strengths and weaknesses in knowledge of endemic, protected under Mexican law, rare, and sensitive species, and remarking specific challenges. The lack of studies in the most relevant ecosystems for raptors in México is also made evident and discussed. This compiling current work is the first one on Mexican raptors, which attempts to promote, stimulate and encourage more studies on this remarkable group of top predator birds as indicators of habitat quality and functional biological systems.

Ricardo Rodríguez-Estrella, an ecologist who has worked on raptors for the last 20 years, has mainly studied the effects of human activities on their ecology and conservation. His research focuses on basic animal ecology, landscape ecology, and biodiversity conservation through spatial analysis. He has been part of the Board of Directors of the Raptor Research Foundation and a member of the Academia Mexicana de Ciencias.