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Population Size and Trends for Nesting Ospreys in Northwestern Mexico: Region-wide Surveys, 1977, 1992/1993 and 2006

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Open-File Report 2007–1298

U.S. Department of the Interior
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Suggested citation:
Henny, C.J., Anderson, D.W., Vera, A.C., and Carton, J-L. E., 2007, Population Size and Trends for Nesting Ospreys in Northwestern Mexico: Region-wide Surveys, 1977, 1992/1993 and 2006: Reston, Virginia, U.S. Geological Survey, Open-File Report 2007-1298, p. 15.

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Charles J. Henny[1], Daniel W. Anderson[2], Aradit Castellanos Vera[3] and Jean-Luc E. Cartron[4]

Abstract

We used a double-sampling technique (air plus ground survey) in 2006, with partial double coverage, to estimate the present size of the osprey (*Pandion haliaetus*) nesting population in northwestern Mexico. With the exception of Natividad, Cedros, and San Benito Islands along the Pacific Coast of Baja California, all three excluded from our coverage in 2006 due to fog, this survey was a repeat of previous surveys conducted by us with the same protocol in 1977 and 1992/1993 (Baja California surveyed in 1992, Sonora and Sinaloa 1993), allowing for estimates of regional population trends. Population estimates at the "time of aerial survey" include those nesting, but missed from the air. The population estimate for our coverage area in 2006 was 1,343 nesting pairs, or an 81% increase since 1977, but only a 3% increase since 1992/1993. The population on the Gulf side of Baja California generally remained stable during the three surveys (255, 236 and 252 pairs, respectively). The overall Midriff Islands population remained similar from 1992/1993 (308 pairs) to 2006 (289 pairs), but with notable population changes on the largest two islands (Isla Angel de la Guarda: 45 to 105 pairs [+ 60 pairs]; Isla Tiburon: 164 to 109 pairs [- 55 pairs, or -34%]). The estimated osprey population on the Sonora mainland decreased in a manner similar to adjacent Isla Tiburon, i.e., by 26%, from 214 pairs in 1993 to 158 pairs in 2006. In contrast, the population in Sinaloa, which had increased by 150% between 1977 and 1993, grew again by 58% between 1993 and 2006, from 180 to 285 pairs. Our survey confirmed previously described patterns of rapid population changes at a local level, coupled with apparent shifts in spatial distribution. The large ground nesting population that until recently nested on two islands in San Ignacio Lagoon was no longer present on the islands in 2006, but an equivalent number of pairs were found to the north and south of the lagoon, nesting in small towns and along adjoining power-lines, with no overall change in population size for that general area (198 pairs in 1992; 199 in 2006). Use of artificial nesting structures was 4.3% in 1977 and 6.2% in 1992/1993, but jumped to 26.4% in 2006. Use of power poles poses a risk of electrocution to ospreys as well as causes power outages and fires; modification of power poles to safely accommodate osprey nests has been successful in many countries.

Introduction

The Baja California and Gulf of California region harbors a large resident osprey (*Pandion haliaetus*) population (Henny and Anderson 1979, 2004, Cartron et al. in press). An early qualitative assessment of that population was provided by Grinnell (1928), but only for the Pacific and Gulf sides of Baja California and adjacent islands. For decades thereafter, the status and distribution of the osprey along the eastern side of the Gulf of California remained essentially unknown, with only a few reports of the species' occurrence on offshore islands (see Cartron et al. 2006, in press).

Based on aerial and ground surveys conducted in 1977, Henny and Anderson (1979) provided the first osprey population estimates for the entire Baja California and Gulf of California region and for each of seven subregions, including coastal Sonora and coastal Sinaloa along the eastern side of the Gulf of California (Figure 1). At the time, Henny and Anderson (1979) envisioned that the regional osprey population could be monitored on a long-term basis to serve as

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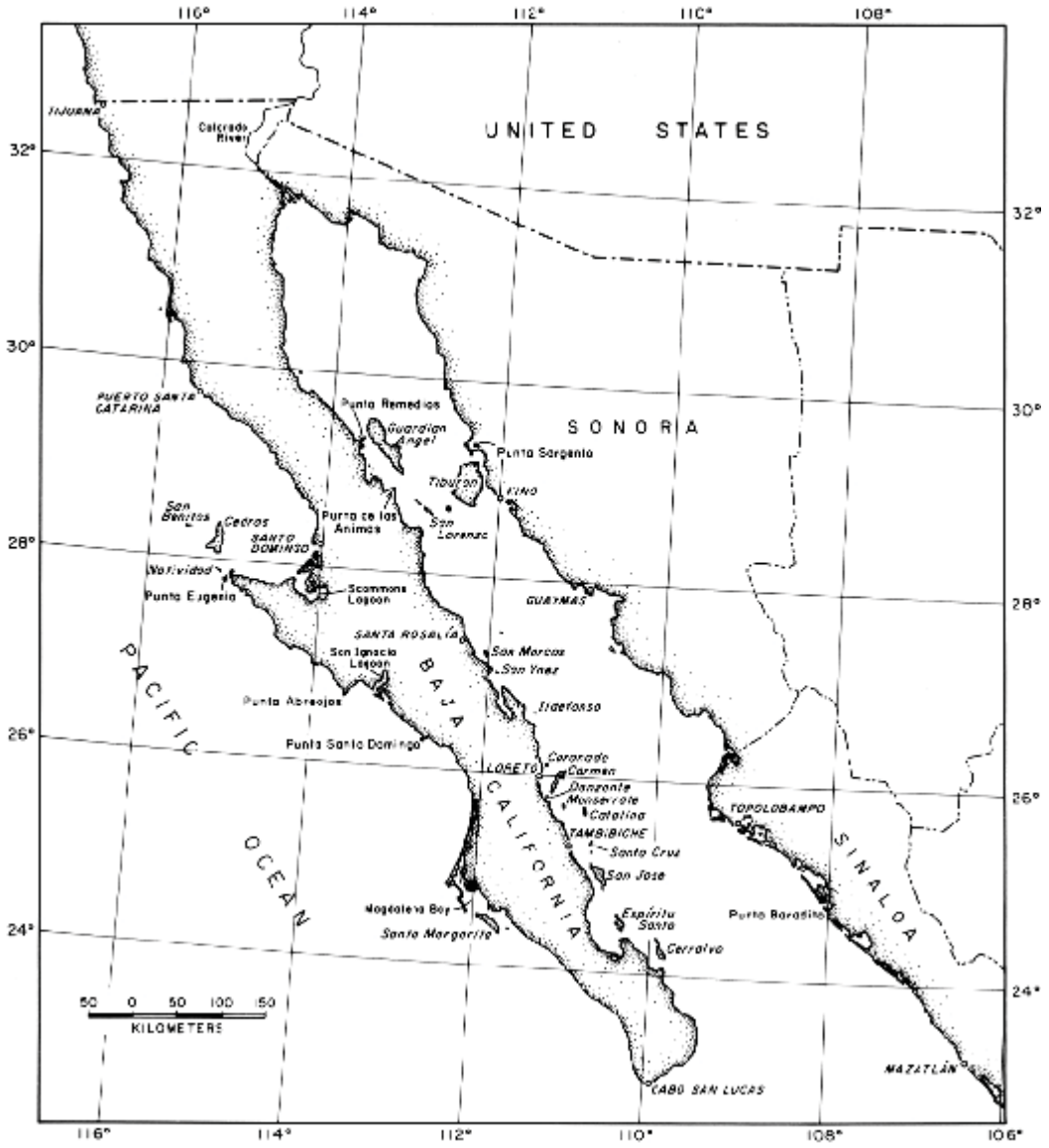
Figure 1. The Baja California and Gulf of California study area for ospreys



an indicator of ecosystem health and track anthropogenic impacts. Henny and Anderson (2004) repeated their region-wide survey in 1992/1993 (survey split into two years) and documented an important increase in osprey numbers. Beginning in the 1980s, monitoring studies were also conducted on a local scale (e.g., Carmona et al. 1994, Castellanos and Ortega 1995, Cartron 2000, Cartron et al. 2006, Rodríguez-Estrella et al. 2006). Some of these local studies documented sharp fluctuations in the reproductive success of osprey pairs and rapid and pronounced changes in the number of nesting pairs, often with no clear underlying explanation.

In 2006 we conducted a third survey of the osprey population in the Baja California and Gulf of California region. The main objective of this survey was to document any population trend region wide and for each of the seven subregions, using 1977 and 1992/1993 numbers for comparisons. Additional goals of our survey were to assess whether some of the pronounced patterns described at a local level could be detected on a larger scale, whether they could be tied to shifts in the distribution of nesting pairs, and whether they were indicative of wide, naturally-occurring versus human caused changes in the environment of ospreys (see Cartron et al. in press).

Methods

During the aerial survey (total area surveyed from air in 2006, except several islands mentioned later which were covered with fog), we made a single pass along the shore to census rocky or sandy cliffs adjacent to the shoreline or flat terrain with no cacti. In areas where large cactus or mangrove forests existed near the shoreline, we flew transects at increasing distances landward from the shore looking for osprey nests until no more were observed. Emphasis was also placed on locating nests on power poles and other structures in towns. Generally, we did not find nesting pairs more than 2 km landward from the shoreline, but when nests were found on power poles, we extended the survey landward a few extra kilometers.

We located osprey nests in 2006 from a twin engine fixed-wing aircraft with excellent visibility and a Global Positions System (GPS) (Partenavia PN68TC), i.e. the same type of plane used in 1992/1993. The survey was flown at an altitude of 60-100 m between 23 March and 1 April. The GPS allowed us to record the location of each occupied nest in 1992/1993 and 2006. No GPS was available during our 1977 survey. The surveys in 1977 and 1992/1993 were flown at about the same time (24 March to 1 April, and 20 March to 2 April). A pilot and two observers (same as in 1977 and 1992/1993, CJH and DWA) were present in the plane, and about 80 h of flying time were logged during each survey.

We classified nests observed during the aerial survey as occupied if an adult was present on or in the immediate vicinity of the nest, or if young/eggs were seen in the nest. An attempt was made to schedule the aerial survey during the peak of the nesting cycle, although the season is not well synchronized in southern latitudes (but see nesting chronology below). Occupied nests would have been missed if a bird was not at or near a nest when it was surveyed, the nest was abandoned before the area was surveyed, the nest was initiated after the area was surveyed, or we failed to see the nest. Unoccupied nests were also recorded.

Because it is costly and time-consuming to conduct the ground or boat survey portion of the double survey, we surveyed all of the study area by air but covered < 10% of the population from the ground, to develop a partial double-survey population estimate and its associated variance. The ground studies were generally made by boat or from a pickup truck. The ground studies were conducted within a few days to 2 wks of the interval for the aerial survey, and made it possible to compare numbers of occupied nests at the time of census in various areas seen from air, ground, and both air and ground. Comparing data from both counts allowed us to obtain a visibility rate for adjusting aerial counts to the total nesting population at the *time of the survey* by use of a modification of the Petersen Estimator (see Henny and Anderson 2004). We sampled a finite population of size N (N unknown) by use of the two methods. The data were then recorded so that we knew the number of elements s_a, observed by method 1 (aerial survey), the number of elements s_g, observed by method 2 (ground survey), and m, the number of elements observed by both methods. Then,

$$\hat{N} = s_a s_g / m$$

is a reasonably good estimator of N. In this approach we assumed statistical independence of s_a and s_g.

In sampling osprey nests, it was also necessary to assume N was not changing during the time between the ground and air survey. With the ground and aerial counts made within 2 weeks of one another, it is doubtful that significant changes had taken place. Then $\hat{N}/s_a$ is a reasonably good estimator of the aerial Visibility Rate. The aerial count was multiplied by the aerial Visibility Rate to obtain population estimates for areas with only aerial counts. Separate Visibility Rates were initially estimated for nests in cacti, nests on cliffs, and ground nests on small islands. Several nests on other structures (power poles) were included in air: ground comparison study area near Kino in 2006. For this study the nests on cliffs, cacti and other structures were combined because of their similar Visibility Rates (Table 1). Visibility Rates (combined nesting substrates) in 1977, in 1992-1993 and in 2006 were similar (1.63, 1.71 and 1.75), which suggests that the Visibility Rate had minimal influence on the percent change over time in the osprey population estimates.

Scammon's Lagoon and vicinity included large numbers of nesting ospreys in a relatively small area. Therefore, we relied upon detailed ground counts of that area by Castellanos and Ortega-Rubio (1995) and Castellanos et al. (1999) from

Table 1. Number of occupied osprey nests (nesting pairs) seen from the air and ground.

Year nest substrate	Air (s_a)	Ground (s_g)	Both (m)	Total est. ($\hat{N}$)	Visibility Rate ($\hat{N}/s_a$)
1977					
Cliffs	88	121	74	143.89	1.64[a]
Cactus	7	9	6	10.50	1.50
Cliffs and Cactus (combined)	95	130	80	154.38	1.63
Scammon's Lagoon (ground nests)	26	23	22	27.18	1.05
1992, 1993					
Cliffs (LA Bay)[b]	32	43	25	55.04	1.72
Cactus (Kino)	16	27	16	27.00	1.69
Cliffs and Cactus (combined)	48	70	41	81.95	1.71
2006					
Cliffs (LA Bay)	25	37	22	40.22	1.61
Cactus and Other (Kino and vicinity)	23	33	18	42.17	1.83
All Combined	48	70	40	84.00	1.75

[a] Values for three locations sampled in 1977 were 1.54, 1.75 and 1.77

[b] Combined information for both 1992 and 1993

1993 for our earlier survey and counts by Castellanos (unpublished data) from 2004 for this survey. This lagoon accounted for about 9% of the osprey population throughout our whole study area. For our study area, nests occupied at the *time of the survey*, but believed to have been missed by both air and ground surveys, were included in estimates presented here. However, occupied nests abandoned before the survey, or initiated after the survey, are not included in our initial population estimates (but see nesting chronology below). No Visibility Rates were available for nests in mangroves; therefore, the combined value for cacti, cliffs and other nests was used. We believe nests in mangroves were more difficult to locate from the air, thus, nesting pairs in mangroves in coastal Sinaloa and perhaps Magdalena Bay (although none were located) may be underestimated. In the text, we refer to *observed* occupied nests (nesting pairs) when raw counts are used and *estimated* occupied nests (nesting pairs) when Visibility Rate adjusted counts are used. For simplicity in the text, we will refer to either observed nesting pairs or estimated nesting pairs.

The variance estimate was detailed in our earlier report (Henny and Anderson 2004), and will not be described here. Basically, let there be two similar areas with populations of sizes N, and M. It is assumed that the aerial visibility of nests is the same in both areas. In one area both air and ground counts are made. A critical assumption is that the air and ground counts are statistically independent. In the second area only aerial counts are made.

Using the following notation:

- $\hat{N}$ population size in area covered by ground and air
- $\hat{M}$ population size in area covered by air only
- s_a nests seen by air in air-ground area
- s_g nests seen by ground in air-ground area
- m nests seen by both air and ground methods
- C aerial count of nests outside of air-ground area, a binomial random variable
- $\hat{T}$ = N+M, population total

Estimation formulae used in the study were:

$$\hat{N} = s_a s_g / m \qquad \hat{M} = C s_g / m \qquad \hat{T} = \hat{N} + \hat{M}$$

Generally, in more northern latitudes where this type of survey approach was first conducted (Henny et al., 1974), the nesting cycle was more synchronized; however, this tight synchrony does not occur in Mexico. Jehl's (1977:243) statement citing Kenyon (1947) regarding ospreys in Scammon's Lagoon is typical, "nests there contained all stages from fresh eggs to flying young." Henny and Anderson (1979) noted that more research on nesting season chronology was needed throughout the study area to evaluate the percentage of the total breeding population that was nesting at a certain time. To better address the issue of survey timing and nest occupancy in the region, Henny and Anderson (2004) used detailed studies of ospreys in San Ignacio Lagoon (26° 54′ N; 113° 09′ W) by Danemann (1994). He provided information on the number of nests occupied on two small islands (Ballenas) between mid-January and early June 1989 (see Table 2 in Henny and Anderson [2004]). Our surveys in late-March approached the peak of occupancy, although only 83.9% of the total nests occupied for the season were occupied at that time (used multiplication factor of 1.19 times estimated occupied nests *at time of the survey*). Because of this lack of nesting synchrony, there was no survey time when all nests for the year were occupied. A final adjustment of population estimates for 1977, 1992/1993,

and 2006 is made here based upon Danemann's studies at San Ignacio Lagoon, and the double-adjusted estimates (for birds missed that were nesting at the *time of the surveys* and for those nesting earlier or later) will only be presented in the last Table. Future studies may show variability in nesting chronology among regions, but only one detailed chronology dataset currently exists. The same adjustment for nesting chronology was used for all regions and all survey time periods (1977, 1992/1993 and 2006).

Results

Using seven designated regions, we summarize our results as follows:

Northwest Baja California, Lower California (L.C.)

The region extends from the U.S.-Mexico border south to and including Scammon's Lagoon, and west to Punta Eugenia, including Natividad, Cedros, and San Benito Islands (Figure 1). No nesting pairs were observed between the border and Desembarcadero de Santa Catarina in either 1977 or 1992 with the first nesting pair observed near Santa Catarina at 29° 35′ N; 115° 22′ W. From this point south to Morro Santo Domingo, an estimated 20 pairs were nesting in cliffs in 1977 with an estimated 31 pairs nesting in cliffs in 1992. However, by 2006 the nesting range extended north of Santa Catarina to 29° 52′ N; 115° 4′ W where a nest was built on a platform near a house, while a few other nests were on cliffs (Table 2). The estimated nesting population between Santa Catarina and Morro Santo Domingo was essentially unchanged at 32 pairs in 2006.

Scammon's Lagoon has been part of the El Vizcaino Biosphere Reserve since 1988 and has a long history of osprey studies (see summary 1946-1993 in Henny and Anderson [2004]). Basically, the population increased from 27 pairs nesting on the ground on small islands in 1946, to 50-86 nesting pairs between 1977 and 1982 when artificial structures (channel markers, power poles, platforms, etc.) became important nesting substrates, and then further increased to 126 in 1993 and 120 in 2004 (including 30 in the town of Guerrero Negro) when artificial nesting structures became even more important.

No nesting pairs were observed to the west along "Scavenger's Beach" between Scammon's Lagoon and Punta Eugenia in 1977, but an estimated 10 pairs were present in 1992. Henny and Anderson (2004) referred to this as an apparent "overflow" from the population increase at Scammon's Lagoon. However, in 2006 only 2 pairs were estimated in the area. Due to fog in 2006, Natividad, Cedros and San Benito Islands (where an estimated 68 and 60 nesting pairs were present during the two earlier surveys) could not be surveyed. The estimated osprey population in Northwest Baja, L.C. (excluding the islands mentioned above) increased from 1977 (70 pairs) to 1992 (167 pairs), but showed little change between 1992 and 2006 (160 pairs) (Table 2).

Southwest Baja California, L.C.

This region extends south from Punta Eugenia along the Pacific Coast to Cabo San Lucas. In 1977, only 35 pairs of osprey were estimated nesting in the region with the majority (27 pairs) nesting on the ground on two small islands (Ballenas) in San Ignacio Lagoon (Table 2). However, Reitherman and Storrer (1981) reported 129 occupied nests on the two islands only 4 years later in 1981. Danemann (1994) visited the islands regularly between January and June 1989 and counted 143 occupied nests (total count). During the 1992 survey of the lagoon, we counted ospreys at 85 nests, and no ospreys at 50 nests, but our counting technique for the dense colony was inadequate, especially when many birds were flying. Therefore, although the nesting colony remained large in 1992, we opted to use the 1989 complete count of Danemann in the report. Excluding San Ignacio Lagoon, only 8 additional pairs were estimated nesting in the region in 1977 and 55 additional pairs in 1992, with most nesting south of the lagoon (Table 2).

In contrast to the two earlier surveys, the San Ignacio Lagoon nesting colony of ospreys was no longer present in 2006. Roberto Carmona (personal communication) made a ground count on the islands in 2006 and reported only three occupied nests. Therefore, we did not fly low over the islands and only saw one flying osprey from our higher-altitude flyover. Where did the San Ignacio Lagoon birds go, and when did they depart the lagoon? Basically, we believe they began nesting on power poles and other artificial structures in nearby towns in the region. In 1992, an estimated 8 pairs were nesting on artificial structures in the region (Henny and Anderson 2004); but by 2006, the number increased to an estimated 175 pairs (Table 2). The towns with nesting pairs (from highest counts to lowest counts) and distance (north or south) away from San Ignacio Lagoon included: Puerto San Carlos (south 263 km), Punta Abreojos (north 46 km), Puerto Adolfo Lopez Mateos (s. 217 km), La Bocana (n. 56 km), Las Barrancas (s. 139 km). Other towns in the region with fewer numbers included: El Datil (s. 48 km), San Juanico (s. 98 km), military base on Isla Santa Margarita (s. 301 km), Bahia Tortugas (n. 192 km) and Punta Prieta (n. 90 km). The total estimated population in the region in 1992 was 198 pairs, and remained unchanged at 199 pairs in 2006, but with a major redistribution to towns both north and south of the lagoon.

Northeast Baja California, L.C.

An estimated 117 pairs of ospreys nested in this region along the Gulf from the mouth of the Colorado Rivers south to Santa Rosalia in 1977, 106 pairs in 1992, and 126 pairs in 2006 (Table 3). The terrain from the Colorado River south to

Table 2. Distribution and abundance of occupied osprey nests at the "time of the aerial survey" on the Pacific side of Baja California in 1977, 1992 and 2006.

Location	1977	1992	2006					
	Total Estimate[a]	Total Estimate[b]	Cliff	Cactus	Ground	Other	Max. Observed	Total Estimate
Northwest Baja, L.C.								
U.S. Border to Puerto Santa Catarina	0	0	5.25	0	0	1.75	4	7.0
Puerto Santa Catarina to Morro Santa Domingo	19.5	30.8	26.25	0	0	5.25	18	31.5
Scammon's Lagoon and vicinity[c]	50.1	126.0	0	0	18.00	102.00	120	120.0
Punta Mallarrimo to Punta Eugenia	0	10.2	0	0	0	1.75	1	1.8
Natividad Island	22.8	8.6						NS[d]
Cedros Island	19.6	18.8						NS
San Benitos Islands	26.0	32.5						NS
Subtotal	138.0 (69.6)[e]	226.9 (167.0)[e]	31.50	0	18.00	110.75	143	160.3
Southwest Baja, L.C.								
Punta Eugenia to Punta Abreojos	1.6	5.1	14.00	0	0	54.25	39	68.3
San Ignacio Lagoon	27.3	143.0	0	0	3.00[f]	0	3	3.0
El Datil to Cabo San Lucas	6.5	49.6	7.00	0	0	120.75	73	127.8
Subtotal	34.5	197.7	21.00	0	3.00	175.00	115	199.0
Grand Total	173.4 (104.1)[e]	424.6 (364.7)[e]	52.50	0	21.00	285.75	255	359.3

[a] From Henny and Anderson (1979)

[b] From Henny and Anderson (2004)

[c] Ground count by Aradit Castellanos Vera 5-7 Feb 2004

[d] NS = not surveyed in 2006 due to fog

[e] Value in ( ) estimate without Natividad, Cedros and San Benito Islands (comparable to 2006 total estimate)

[f] Ground count by Roberto Carmona, 25 Jan 2006

Table 3. Distribution and abundance of occupied osprey nests at the "time of the aerial survey" on the Gulf side of Baja California and Midriff Islands in 1977, 1992 and 2006.

Location	1977	1992	2006					
	Total Estimate[a]	Total Estimate[b]	Cliff	Cactus	Ground	Other	Max. Observed	Total Estimate
Northeast Baja, L.C.								
Colorado River to Punta Remedios	37.4	23.9	21.00	3.50	0	5.25	17	29.8
Punta Remedios to Punta de las Animas								
Los Angeles Bay Islands	35.0	29.3[c]	40.22	0	0	0	39	40.2[d]
Other Locations	22.1	17.1	21.00	0	0		12	21.0
Punta de las Animas to Santa Rosalia	22.8	35.9	24.50	8.75	0	1.75	20	35.0
Subtotal	117.3	106.2	106.72	12.25	0	7.00	88	126.0
Southeast Baja, L.C.								
Santa Rosalia to Loreto	65.6	49.5	42.00	0	0	14.00	32	56.0
Loreto to Timbabichi	42.4	49.6	36.75	0	0	1.75	22	38.5
Timbabichi to Cabo San Lucas	29.3	30.8	22.75	0	0	8.75	18	31.5
Subtotal	137.3	129.9	101.50	0	0	24.50	72	126.0
Grand Total	254.6	236.1	208.22	12.25	0	31.50	160	252.0
Midriff Islands								
Guardian Angel	40.8	44.5	105.00	0	0	0	60	105.0
San Lorenzo, San Lorenzo Norte, Partida,								
Salispuedes, Raza	52.2	53.0	36.75	0	0	0	21	36.8
Tiburon	71.8	164.2[e]	40.25	66.50	0	1.75[f]	62	108.5
San Estabon, Turner, Cholla[g]	22.8	46.2[e]	39.00	0	0	0	29	39.0
Grand Total	187.6	307.9	221.00	66.50	0	1.75	172	289.3

[a] From Henny and Anderson (1979)

[b] From Henny and Anderson (2004).

[c] Total estimate for 1993 was 25.2.

[d] Used adjustment factor determined for LA Bay Islands in 2006

[e] Aerial survey conducted in 1993

[f] Only tree nest in Midriff Islands (near a well)

[g] Includes ground count by Tad Pfister in 2006 (4 occupied nests)

Puertecitos is flat and contains few cacti suitable for nesting sites (such as the giant cardon, *Pachycereus pringlei*). The osprey breeding range has extended north from the tripod nesting structure placed on top of a building (30° 45′ N; 114° 42′ W) first observed in 1992 and still occupied in 2006. The most northern nest is now (2006) on a power pole at San Felipe (31° 03′ N; 114° 49′ W), with two additional nests observed north of the tripod nesting structure (another power pole at 30° 56′ N; 114° 43′ W, and a cactus at 30° 46′ N; 114° 42′ W). Bancroft (1927, 1932) stated that historically the San Luis Archipelago (29° 57′ N to 30° 06′ N) was the location of the most northern nesting of the species in the region with about 60-75 nesting pairs. The estimated number of nesting pairs at the Archipelago in 1977 declined to 16 pairs, than further declined to 7 pairs in 1992 and remained unchanged at 7 in 2006.

Bahia de los Angeles and the nesting population on the small islands have been a focal point for osprey studies for many years. The estimated population on the islands was 35 pairs in 1977, 29 pairs in 1992 and 40 pairs in 2006, with the pattern over time paralleling that observed for the whole region, except perhaps for the southernmost part of the regions (Punta de las Animas to Santa Rosalia) which is a more remote area. Isla Tortuga was not surveyed in 1977 and 2006 (fog), but 2 occupied nests were located in 1992. The southern area showed an increase from an estimated 23 pairs in 1977 to 36 pairs in 1992 and then stabilized at 35 pairs in 2006.

Southeast Baja California, L.C.

The coastal region south of Santa Rosalia to Cabo San Lucas contained an estimated 137 pairs in 1977, 130 pairs in 1992 and 126 pairs in 2006 (Table 3). The islands along the coast listed in order of importance (nesting pairs) included Carmen, San Marcos, Cerralvo, Santa Cruz, Coronado and Santa Catalena; and those with only one nest located include Monserrat, San Jose, Partida, Espirita Santo and three small near-shore islands. These islands accounted for an estimated 70 of the 126 nesting pairs in the region in 2006. Isla Santa Ynez, where five occupied nests were observed on the ground and one on a fishing shelter in 1977, only one occupied nest was observed on the ground and one on a tower in 1992, but none were observed in 2006. A new southern record for nesting osprey in Baja California was located on a rock pinnacle about 53 km northeast of San Jose del Cabo at 23° 26′ N; 109° 25′ W. The previous southern record for the Gulf side was at the southern end of Isla Cerralvo in 1992 (24° 09′ N; 109° 52′ W), and for the Pacific Side in a cactus in 1992 at 23° 49′ N; 110° 43′ W.

Midriff Islands

These islands are located in the Gulf of California in the vicinity of 29° N Latitude (Table 3). An estimated 188 pairs nested on the islands in 1977, 308 pairs in 1992/1993 and 289 pairs in 2006. The two largest islands, Guardian Angel and Tiburon on opposite sides of the Gulf accounted for an increasing percentage of the total during the surveys; an estimated 113 pairs (60% of the total) in 1977, 209 pairs (67.8%) in 1992/1993 and 214 pairs (73.8%) in 2006. But, perhaps more intriguing is the relative importance of the two islands during the interval of surveys: Guardian Angel accounted for an estimated 21.7% of the population in the region in 1977, 14.5% in 1992/1993, and 36.3% in 2006. Conversely, Tiburon Island accounted for an estimated 38.3% of the population in 1977, 53.3% in 1992/1993 and 37.5% in 2006. The other islands on the Baja California side (San Lorenzo, San Lorenzo Norte , Partida, Salispuedes, Raza) showed a consistent decline as a percentage of the total in the region (1977, 27.8%; 1992/1993, 17.2%; 2006, 12.7%), while on the Sonora side (San Estabon, Turner, Cholla) remained fairly consistent (1977, 12.2%; 1992/1993, 15.0%; 2006, 13.5%). Tershy and Breese (1997) report the osprey as a rare visitor on San Pedro Mártir; the island was not surveyed in 1977, 1992/1993 or 2006.

Coastal Sonora

An estimated 124 pairs nested in the region in 1977, 214 pairs in 1993 and 158 pairs in 2006 (Table 4). The highest population estimate for Sonora occurred in 1993, but was followed by a general decline in 2006, which appeared more precipitous south of Punta Sargento. Cartron (2000) reported some years with extremely poor reproduction in his study area in coastal Sonora. The extreme northern portion of the region is flat with no cacti; then cardon appear sporadically. Further south along the coast, there are a few sandy cliffs and, eventually, some rocky cliffs. Some pairs nested in the cliffs, but most pairs in the region were in cardon cacti. The most northern occupied nest located in 2006 along the mainland of Mexico was on a power pole at 31° 18′ N; 113° 13′ W. Another nest was on a platform at 31° 16′ N; 113° 27′ W with two other nests on fake (wooden or plastic) cactus at 31° 14′ N; 113° 13′ W. These were all located in the vicinity of Puerto Peñasco which is an area of rapid and extensive development. These nests were all north of the previous northern nesting record in the region in 1993 which was south and east of Puerto Peñasco at 31° 12′ N; 113° 04′ W and located on a metal power pole. Mellink and Palacios (1993) reported an osprey nest in the same general location in 1982, and reported several nests along a railroad between Lopez Collada and Sahuaro in 1991 and 1992. All of the specific nests mentioned above were on artificial structures which strongly supports the concept that ospreys colonized this area with few natural nest sites available (land flat and no suitable cacti) because of the artificial nest sites. The power line towers were constructed shortly after our first survey in 1978 and 1979 (Mellink and Palacios 1993). No osprey in Sonora were nesting on artificial structures in 1977, but increased to 3.2% in 1993 and 16.7% in 2006.

Table 4. Distribution and abundance of occupied osprey nests at the "time of the aerial survey" in coastal Sonora and Sinaloa in 1977, 1993 and 2006.

Location	1977	1993	2006[c]					
	Total Estimate[a]	Total Estimate[b]	Cliff	Cactus	Mangrove[d]	Other	Max. Observed	Total Estimate
Coastal Sonora								
Colorado River to Punta Sargento	78.4	106.0	12.25	66.50	0	15.75	61	94.5
Punta Sargento to Sinaloa Border	45.6	107.7	21.00	31.50	0	10.50	39	63.0
Subtotal	124.0	213.7	33.25	98.00	0	26.25	100	157.5
Coastal Sinaloa								
Sonora border to Topolobampo	6.5	13.7	0	15.75	0	7.00	13	22.8
Topolobampo to Punta Baradito	61.9	165.9	0	243.25	15.75	3.50	150	262.5
Punta Baradito to Mazatlan	1.6	0	0	0	0	0	0	0
Subtotal	70.0	179.6	0	259.00	15.75	10.50	163	285.3
Grand Total	194.0	393.3	33.25	357.00	15.75	36.75	263	442.8

[a] From Henny and Anderson (1979)

[b] From Henny and Anderson (2004)

[c] Survey extended south from Mazatlan to San Blas, Nayarit in 2006, but no nesting ospreys located

[d] Or other trees/bushes

Coastal Sinaloa

In previous surveys, the region extended from the Sonora border south to Mazatlan, but in 2006 the survey extended south from Mazatlan to San Blas, Nayarit, but no nesting ospreys were observed south of Mazatlan (Table 4). An estimated 70 pairs nested in the region in 1977, 180 pairs in 1993, and 285 pairs in 2006. From the Sonora border to Topolobampo, an estimated 7 pairs nested in 1977, 14 pairs in 1993 and 23 pairs in 2006. The majority of the nests were located between Topolobampo and Punta Baradito where an estimated 62 pairs nested in 1977, 166 pairs in 1993 and 263 pairs in 2006. This area was further subdivided into two areas with the split at 25º 10′ N. From Topolobampo south to 25º 10′ N, which included the barrier islands of San Ignacio and Macapule, we estimated 31 pairs nesting in 1977, an estimated 118 pairs in 1993, and 213 pairs in 2006. South of 25º 10′ N, which included Santa Maria Bay and the barrier island of Altamura, we estimated 31 pairs in 1977, 48 pairs in 1993 and 49 pairs in 2006. Carmona and Danemann (1994) studied Santa Maria Bay in 1988 and reported about 40 pairs of nesting osprey which supports our earlier observations. Most ospreys nesting in Sinaloa were nesting on barrier islands and peninsulas associated with several large bays. Mangroves and other brushy trees were abundant and some ospreys nested in them. The species of cacti changed again to a type that branches about 1.5 m above the ground (*Pachycereus pecten-aboriginum*), and most nested again in cactus. The most rapid increase from 1993 to 2006 occurred at the barrier islands of San Ignacio and Macapule. The most southern nesting osprey along the mainland was south of Punta Bardito in 1977 at Ensenada del Pabellón (24º 38′ N) in a mangrove, although an occupied nest was reported on an island in Mazatlan Harbor (~23º 13′ N) in March 1978 (see addendum to Henny and Anderson [1979]). No nests were located south of Punta Baradito in 1993 or 2006 (Figure1).

Nesting Sites

Historically, ospreys at more northern latitudes nested in dead trees or trees with dead tops, but ospreys in more recent years (i.e., beginning in the 1970s) in the western United States nested on power poles and transmission towers and other structures in response to a shortage of suitable trees and the more recent appearance of many potential nesting structures near rivers, bays and estuaries (Henny and Kaiser 1996). In the eastern United States where more artificial structures have been available for a longer time, ospreys began using these structures for nesting much earlier (see Bent 1937). This study area in Mexico, where trees were rare, with the exception of mangroves at more southern latitudes, other options including cliffs, rock pinnacles, cacti and the ground on small islands provided the historic nesting substrates. By 1977, ospreys were using artificial nesting structures, at Scammon's Lagoon primarily; however, towers, pilings, channel markers, debris washed ashore, boats (sunk and aground) and power poles were occasionally used at various locations in the study area (Table 5). The 1992/1993 survey recorded not only an increase in the overall nesting population, but also an increase in the percentage of the population (from 4.3% to 6.2%) nesting on artificial structures. Some artificial structures used in flat terrain with no cacti; i.e., no suitable nesting substrates, resulted in relatively short northward range expansions for the species. By 2006, artificial structures became much more important accounting for 26.4% of all nests, including 79.5% of nests on the Pacific Ocean side of Baja California, but only 6.9% of nests elsewhere. Artificial structures became more important on the Pacific Coast side of Baja California because of two factors: (1) the ground nesting birds on the small islands in San Ignacio Lagoon departed and began nesting on power poles and towers at nearby towns, and (2) development of the salt industry at Scammon's Lagoon beginning in 1953 (Castellanos et al. 1999) resulted in power poles, channel markers and other associated structures being built in the area (including growth of the town of Guerrero Negro). Ospreys already nested on some artificial structures by 1977 which were becoming numerically more important over time (see summary of studies 1946-1993 in Henny and Anderson 2004). At Scammon's Lagoon sometime prior to the 2004 nesting season, a series of platforms/towers were also placed on the three small islands in the lagoon where ospreys traditionally nested on the ground. Thus, in 2004, the complete ground count used for this survey, included 35 pairs nesting on platforms/towers on small islands and 18 on the ground. However, when we flew over the small islands in 2006, all island

Table 5. Types of nest sites selected by ospreys in the study area, 1977, 1992/1993 and 2006.

Nest site substrate	Estimated number of occupied nests		
	1977	1992/1993	2006
Cliff	479 (59.1%)	542 (39.8%)	515 (38.3%)
Cacti	213 (26.3%)	506 (37.2%)	436 (32.5%)
Ground	59 (7.3%)	213 (15.6%)	21 (1.6%)
Artificial Structures	35 (4.3%)	85 (6.2%)	354 (26.4%)
Mangrove/Other Trees	24 (3.0%)	16 (1.2%)	17 (1.3%)
Total	810 (100.0%)	1,362 (100.0%)	1,343 (100.1%)

Note: No adjustment of aerial survey population estimates was made here for nesting chronology, i.e., data reflect "time of aerial survey."

nests were back on the ground because the platforms/towers had fallen down. Thus, the artificial structures count for the latest survey (based on 2004 data at Scammon's Lagoon) was biased high probably by ~ 35 pairs and the ground nests biased low by a similar count. Nevertheless, artificial structures now play an important role, especially along the Pacific Ocean side of Baja California.

Numerically, the most important nesting substrate throughout the years was cliffs adjacent to the sea (1977, 59%; 1992/1993, 40%; 2006, 38%) both on the mainland and on islands. Sometimes the cliffs consist of large pinnacles or stacks upon which the ospreys build their nests. However, small sandy cliffs contain nesting ospreys in a few areas. Large cacti remained in second place (1977, 26%; 1992/1993, 37%; 2006, 33%), especially in flat terrain, and were numerically most important in Sonora, Sinaloa and Tiburon Island. Mangroves and other trees were generally available only in the southern portion of the study area. Ground nesting ospreys during the studies were restricted to very small islands at three locations: Scammon's Lagoon, San Ignacio Lagoon and Santa Ynez Island. Ospreys were no longer nesting at Santa Ynez Island in 2006, and the population at San Ignacio Lagoon declined from 143 occupied nests in 1989 to 3 in 2006. The Scammon's Lagoon ground nesting population on the small islands was 18 pairs in 2004 with 35 nesting on newly placed platforms on the islands; however, by 2006 all were again nesting on the ground.

Discussion and Conclusions

As in the past, much of our discussion relates to populations in the seven regions with 95% C.I. provided as estimates of precision (Table 6). The maximum number of nests observed for each area is shown in the earlier Tables as well as the estimated size of the population which provides additional insight into data quality. Furthermore, the change in population size between the three survey periods (1977, 1992/1993 and 2006) was not a function of changes in Visibility Rates, in fact, the combined Visibility Rates were very similar for the three surveys (1.63, 1.71 and 1.75), attesting to the consistency of data acquisition with the same two observers. We found that the general distribution of ospreys in the survey area had not changed (with the exception of some short range expansions) between 1977 and 2006, although local and regional changes in abundance were apparent and variable.

The region of Northwest Baja California has the best documented historical changes in osprey population numbers over time in Mexico. These changes were summarized in detail in our earlier reports, but briefly, the four most northern islands or groups of islands (Los Coronados, Todos Santos, San Martín and San Gerónimo) had no nesting ospreys during our three surveys. Los Coronados historically had no known nesting pairs, but ospreys were common on the other three islands. The last pair was observed at San Martin in 1971. These extirpations were concommittant with extirpations on islands off southern California (Kiff 1980). The population is now; however, slowly re-extending its range from the south, and by 2006 the range extended northward from 29° 35′ N; 115° 22′ W to 29° 52′ N; 115° 41′ W (~ 42 km in 14 years, or ~ 3 km/yr). Perhaps, reintroductions from Scammon's Lagoon into this historic range all the way north to California's Channel Islands could expedite the repopulation where osprey have been gone for decades. Scammon's Lagoon is certainly the focal point for osprey in this region and the large population, with most now nesting on artificial structures, stabilized between 1992 and 2006 with much higher numbers than in the

Table 6. A summary of estimated number of occupied osprey nests ± 95% C.I. in the study area, 1977, 1992/1993, and 2006.

Location	1977[a]	1992-1993[a]	2006[a]
NW Baja, L.C.	138.0 (164.2)	226.9 ± 20.6[b] (246.1)[c]	160.3 ± 7.4[bd] (190.8)[d]
SW Baja, L.C.	35.4 (42.1)	197.7 ± 11.1[b] (208.1)[c]	199.0 ± 36.4 (236.8)
NE Baja, L.C.	117.3 (139.6)	106.2 ± 21.6 (126.4)	126.0 ± 23.1 (149.9)
SE Baja, L.C.	137.3 (163.4)	129.9 ± 26.5 (154.6)	126.0 ± 23.1 (149.9)
Midriff Is.	187.6 (223.2)	307.9 ± 62.8 (366.4)	289.3 ± 52.9 (344.3)
Sonora	124.0 (140.7)[c]	213.7 ± 43.6 (254.3)	157.5 ± 28.8 (187.4)
Sinaloa	70.0 (83.3)	179.6 ± 36.6 (213.7)	285.3 ± 52.2 (339.5)
Total	810 (957)	1,362 ± 278 (1,570)	1,343 ± 246[d] (1,598)[d]

[a] First estimate refers to those nesting at the *time of the survey* including those missed by aerial survey; estimate in ( ) refers to double-adjusted population estimate which includes those not nesting at the *time of the survey* due to asynchronized nesting season at southern latitudes (initial estimate X 1.19, see Henny and Anderson 2004).

[b] N ± 95% C.I. for regional population estimates (C.I., assumes variance 0 for total counts at Scammon's and San Ignacio Lagoons)

[c] Complete counts used for Scammon's Lagoon (1993), San Ignacio Lagoon 1989 for 1992 survey, and behind Punta Sargento (1977), thus those portions not adjusted for asynchronized nesting. Ground count at Scammon's Lagoon for the recent survey was conducted over short time interval, therefore, counts adjusted for asynchronized nesting.

[d] Estimated numbers not comparable to earlier years because of fog at several islands (see text)

1940s, or even the 1980s. Unfortunately, we have no recent information to report for the islands to the west (Natividad, Cedros, and San Benito); they were not surveyed in 2006 because of fog.

Perhaps the most dynamic region is Southwest Baja California where ground nesting osprey at San Ignacio Lagoon were at "apparently" low numbers in 1977 (27 pairs), but increased tremendously (129 pairs) by 1981 (Reithermann and Storrer 1981) and where 143 pairs were counted nesting in 1989 (Danemann 1994). When the survey was repeated in 2006, only 3 pairs were likely nesting on the islands, but the numbers lost at San Ignacio Lagoon could be accounted for at nearby towns and associated power lines. In an attempt to understand why the re-distribution occurred, it is first useful to determine when the change occurred. Large counts of nesting ospreys at the towns of Puerto San Carlos and Puerto Adolpho Lopez Mateos were already observed in 2002 by Eduardo Palacios and colleagues (pers. comm.). Thus, we conclude that the osprey redistribution occurred sometime before 2002. These were also two of the three towns in the region with the largest nesting populations in 2006. DWA visited the two islands in San Ignacio Lagoon on 8 May 1998 and recorded "...there were many osprey on the islands nesting, but although I looked, I did not see a single flying osprey young. We did not specifically check osprey nests, but on both islands they were occupying nests in large, typically active numbers." A count by Laura Rivera (personal communication) on April 11, 2001 included 70 pairs and perhaps more were present if some early breeders were missed (see osprey nesting chronology at San Ignacio Lagoon by Danemann in Henny and Anderson [2004]). These observations indicate that osprey had not totally abandoned the islands through 2001, although some loss in numbers apparently occurred. Thus, the major redistribution away from San Ignacio Lagoon to the adjacent towns was perhaps gradual and completed sometime after the 2001 nesting season. The cause remains uncertain and it may not be a single factor. Possibilities for the redistribution include: (1) reduction in fish availability in the lagoon, (2) nests in towns are now more acceptable than 30 years ago due to presence of wildlife personnel and education, e.g., many reports of ospreys shot from power poles in earlier years including at San Carlos (Henny and Anderson 1979), or (3) a combination of the two factors. Disturbance on the islands could be a factor, but not likely, because the area is patrolled by wildlife personnel.

The Gulf Coast of Baja California (North and South) showed the least change over the span of the three surveys, but our initial concern was that it did not respond with a large population increase as recorded for all other regions between 1977 (255 pairs) and 1992/1993 (236 pairs). Furthermore, the population estimate for 2006 was within the same relatively narrow range (252 pairs). Although the population appeared stable during the three surveys in the last 29 years, there is evidence that it was historically much larger at least in the San Luis Archipelago (see earlier discussion referring to Bancroft). This regional population primarily nests on cliffs (82.6%) with artificial structures (12.5%) of minor importance, although nests were occasionally located in towns. The present distribution of the scattered nesting is quite similar to earlier years. However, in contrast to this general concept, the population at Espiritu Santo Island seems quite dynamic with only one pair observed during our 1977 survey, but the number increased sharply beginning in 1984 and peaked in 1986 with 22 occupied nests (Carmona et al. 1994). After 1986, the number of nesting pairs decreased and by 1992 (our second survey) only one pair was again nesting on the island although 16 unoccupied nests were observed. The Espiritu Santo count was back to one pair again in 1999 and 2006 (the last survey). Thus, short-term local changes can certainly occur during the long interval between the regional aerial surveys.

The Midriff Islands in the Gulf of California showed an interesting dichotomy during the 1977 and 1992/1993 surveys, i.e., the islands near the Gulf coast of Baja (Guardian Angel and the series of islands associated with San Lorenzo) maintained nearly identical numbers (93 pairs versus 98 pairs), while those closer to Sonora (Tiburon, San Estaban, Turner and Cholla) showed major increases (95 pairs versus 210 pairs). These findings paralleled those reported for the adjacent mainlands for the same time periods. However, in 2006, the nesting population on the islands nearer Baja California increased to an estimated 142 pairs, while the island population nearer Sonora decreased to 148 pairs. Thus, the size of the two populations was again similar in 2006 (142 and 148 pairs), but at higher numbers than in 1977 (93 and 98 pairs). Factors responsible for the osprey increase in the early 1990s on the islands off the Sonora coast and eventual decrease by 2006 may involve fish availability and associated lower reproductive success. After recording the population shift from San Ignacio Lagoon, it would be tempting to speculate that about 50 pairs moved from islands off the Sonora coast to islands off the Baja California coast, but recall that a 13-14 year interval took place (1992/1993 and 2006) between the two surveys with limited information during the interim. Reduced reproductive success over a long period of time associated with food shortages (as reported along the coast of Sonora by Cartron) could account for the population reduction, and likewise increased reproductive success could also account for the population increase at the other islands.

The estimated osprey population along mainland Mexico (Sonora and Sinaloa) doubled (194 pairs to 393 pairs) between 1977 and 1993 with the increase more pronounced in Sinaloa than Sonora. By 2006, the mainland Mexico population continued to increase (443 pairs), but the increase was solely due to Sinaloa, as the population in Sonora declined (much like the population on the adjacent Midriff Islands). Most of the increase occurred on the relatively remote barrier islands of San Ignacio (different from San Ignacio Lagoon mentioned earlier) and Macapule (estimated 31 pairs in 1977, 118 pairs in 1993 and 213 pairs in 2006). Both of these islands and all others in the area are designated an "Area de Proteccion de Flora y Fauna (Islas e Islotes)" (Carabias-Lillo et al. 2000). Carmona and Danemann (1994) mentioned the possibility of agricultural pesticides flowing into the bays and estuaries from

streams that drain Sinaloa farmlands. The unique pattern of a continued population increase of this barrier island population that nests on natural substrates (cacti and mangrove, 98.7%) may be the result of reduced and/or termination of persistent pesticide use. This location with natural nesting sites seems ideal for ospreys. If DDT/DDE or other persistent pesticides was involved in an earlier (pre-1977) osprey population decline in Sinaloa (the location most likely influenced by agricultural pesticides) then a population recovery and increased productivity (Wiemeyer et al. 1988) would be expected. Unfortunately, no pesticide studies of ospreys and no osprey production studies were conducted in the region to evaluate possible effects of pesticides in earlier years. Our explanation for the observed increase is therefore problematic.

Artificial structures used by ospreys in Mexico increased from 4.3% in 1977 and 6.2% in 1992/1993 to 26.4% in 2006. This increase primarily occurred on the Pacific Ocean side of Baja California, and included many nests on power poles. At many locations in the United States and elsewhere in the world, the percentage of ospreys nesting on artificial nest structures is extremely high, e.g., 85% along the Willamette River in western Oregon (Henny and Kaiser 1996). With many ospreys now nesting on power poles and transmission towers, the utility companies need to address, and in many places have already addressed the issue of power outages cause by nests as well as osprey electrocutions. Modification of some nests on power poles has already occurred at several locations in Mexico. The science of managing osprey nests on power poles is rapidly developing (APLIC 2006) and a recent report is available online: **http://www.aplic.org/SuggestedPractices2006(LR).pdf**.

Acknowledgments

We thank Roberto Carmona and Tad Pfister who provided osprey ground counts for selected sites. Jim Bredy safely piloted the aircraft, especially in areas where fueling stops were limited and planning was critical. The survey was partially funded by the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the University of California, the Instituto Nacional de Ecología, and Comisión Nacional de Áreas Naturales Protegidas. Christine Custer provided useful comments on an early draft of the manuscript. This scientific survey would not have been successfully completed without the approval of La Secretaria de Relaciones Exteriores (Permit No. DAN04059) and the assistance of many wildlife biologists in Mexico.

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