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Status of Nesting Ospreys in Coastal Baja California, Sonora and Sinaloa, Mexico, 1977 and 1992–1993.

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Abstract.—We used a double-sampling technique (air + ground surveys), with partial double coverage and an additional adjustment for lack of nesting synchrony in southern latitudes, to estimate the size of the osprey (*Pandion haliaetus*) nesting population in the study area in 1992–1993. The osprey population was previously surveyed in 1977 by the same authors, although their published findings were not adjusted for early or late nests missed. An estimated 810 ± 55 (95% C.I.) pairs were nesting at the *time of the aerial survey* in 1977, but the population increased 68% to an estimated 1,362 ± 278 pairs at the *time of the aerial survey* in 1992–1993 (Baja California surveyed in 1992, Sonora and Sinaloa in 1993). The new adjustment for nesting chronology to estimate the total nesting population (including early and late nests missed) adds 19% to the *time of the aerial survey* population estimates for both 1977 and 1992–1993. The surveyed area was divided into seven regions for summary purposes in 1977; the same as in 1992–1993. The distribution of nesting pairs was similar during both time periods, except two range expansions to the north, which we attributed to the presence of artificial structures in flat terrain with no suitable cacti. The estimated number of nesting pairs on the Pacific side of Baja California (focused on Scammon's and San Ignacio Lagoons) more than doubled, while the population did not increase on the Gulf of California side of Baja California. Osprey pairs nesting on the Midriff Islands in the Gulf of California increased 64%—those nesting on islands nearer Baja California remained generally the same, and those on islands nearer Sonora showed the most increase. The nesting population in Sonora and Sinaloa also more than doubled with a higher rate of increase in Sinaloa. The use of human-made structures for nest sites is still small (only 6%). This population still nests primarily on cliffs (40%), cacti (37%), and the ground (16%).

Seventy-six years ago the osprey (*Pandion haliaetus*) was reported as a common coastal resident along both the Pacific and Gulf sides of Baja California and practically all the adjacent islands (Grinnell 1928). Based on field surveys in 1977, the first regional nesting population estimate was made with about 174 pairs along the Pacific side of Baja California, 255 pairs along the Gulf side, 187 pairs on the Midriff Islands and 194 pairs in coastal Sonora and Sinaloa (Henny and Anderson 1979). The objective of this report was to compare the distribution and abundance of ospreys breeding in 1977 with our findings in 1992–1993 when we

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repeated the survey. Other local studies were also incorporated into our overall assessment.

Methods

We subdivided our large study area into seven regions: basically a northern and southern portion of both the Pacific Ocean side and the Gulf of California side of Baja California, the Midriff Islands in the middle of the Gulf of California, and coastal Sonora and coastal Sinaloa. 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 to the shoreline, we flew transects at increasing distances landward from the shore looking for osprey nests until no more were observed. Generally, we did not find nesting pairs more than 2 km landward from the shoreline (the two most inland nests we located were 7 and 9 km inland, both near Scammon's Lagoon and on human-built structures).

We located osprey nests in 1992–1993 from a twin engine fixed-wing aircraft with excellent visibility and a Global Positions System (GPS) (Partenavia PN68TC). The survey was flown at an altitude of 60–100 m between 20 March and 2 April. Coastal Baja California and adjacent islands were surveyed in 1992, but a factory recall of an engine part (aircraft had just received new engines) during the survey delayed our aerial survey of coastal Sonora, Sinaloa and adjacent islands until 1993. The GPS allowed us to record the location of each occupied nest in 1992 and 1993. No GPS was available during our 1977 survey which was flown at the same time (24 March to 1 April). A pilot and two observers (same as in 1977, CJH and DWA) were present in the plane, and about 80 h of flying time were logged during both surveys.

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.

Since it is costly and time-consuming to conduct the ground or boat survey of the double survey, we surveyed all of the study area by air but covered about 7–8% of the population from the ground, to develop a partial double-survey population estimate and its associated variance. The ground studies, conducted by individuals involved with other studies, were generally made by boat, although one area was surveyed on foot and 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 aerial survey* by use of a modification of the Petersen Estimator (see Henny and Anderson 1979). 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

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

Year nest substrate	Air (s_a)	Ground (s_g)	Both (m)	Total est. (N)	Visibility rate (N/s_a)
1977					
Cliffs	88	121	74	143.89	1.64[a]
Cactus	7	9	6	10.50	1.50
Cliffs & 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 & Cactus (combined)	48	70	41	81.95	1.71

[a] Values for three locations sampled in 1977 were 1.54, 1.75 and 1.77.
[b] Combined information for both 1992 and 1993.

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 wks 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. For this study, the nests on cliffs and cacti were combined because of their similar Visibility Rates (Table 1). A comparison of the maximum number of occupied nests seen from both air and ground with the estimated number of nests (N) occupied at the *time of the aerial survey* suggests that about 6.1% in 1977 and 3.6% in 1992–1993 were undetected by both air and ground counts. Visibility Rates for cliffs and cactus (combined) in 1977 and for this survey in 1992–1993 were similar (1.63 and 1.71), which suggests that the Visibility Rate had minimal influence on the percent change in the osprey population estimates.

Scammon's and San Ignacio Lagoon and vicinities included large numbers of ospreys in 1992 in relatively small areas. Therefore, we relied upon detailed counts throughout the nesting season of those areas by Castellanos and Ortega-Rubio (1995) and Castellanos et al. (1999) from 1993, and Danemann (1994) from 1989. These two lagoons accounted for 20% of the osprey population in our study area and were treated as total counts. For the other portions of the study area, nests occupied at the *time of the aerial 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 and cliff nests was used. We believe nests in man-

groves 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 not detailed in our earlier report (Henny and Anderson 1979), but is described below. 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:

- N population size in area covered by ground and air
- 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
- T = N+M, population total

Estimation formulae used in the study were:

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

The variance comes from the theoretical formula for the Lincoln-Peterson estimator.

$$\hat{V}(\hat{N}) = \frac{\hat{N}}{m}[\hat{N} - (s_a + s_g - m)]$$

The covariance was obtained by another large sample method often called the delta-method.

$$\widehat{Cov}(\hat{N}, \hat{M}) = C\hat{V}(\hat{N})/s_a$$

$$\hat{V}(\hat{M}) = \frac{C^2}{m}\left(\frac{s_g - m}{m}\right)\left[1 + \left(\frac{s_g - m}{m}\right)\right] + \hat{M}\left(\frac{s_g - m}{m}\right)$$

$$\hat{V}(\hat{T}) = \hat{V}(\hat{N}) + \hat{V}(\hat{M}) + 2\,\widehat{Cov}(\hat{N}, \hat{M})$$

To obtain the overall total estimate and its variance, we add the individual estimators $\hat{T}$ and $\hat{V}(\hat{T})$ over all strata. The estimated standard error (SE) of $\hat{T}$ is thus $\sqrt{\hat{V}(\hat{T})}$.

It would be useful to provide an estimate of the variance associated with the seven regional estimates. This can be accomplished by assuming that the relative variance by region is the same as that for the total population. So, if the total has $\hat{N}$ and SE, obtain CV = SE/$\hat{N}$ and for any subset of the data with estimated population size X, take its SE to be: SE(X) = X*CV. For this study, CV = 0.1019. Such SE's on $\hat{N}$ by region would be useful, but not perfect. $\hat{N}$ ± 95% C.I. for each region in 1992–1993 are shown in the last table presented.

Table 2. Number of occupied Osprey nests from ground counts at Ballena Islands, San Ignacio Lagoon, Mexico, 1989 (summary from Danemann, pers. comm.).

Time period	Number occupied nests		
	South section	North section	Total
13–18 Jan	41	10	51
6–13 Feb	86	16	102
15–21 Feb	100	19	119
8–15 Mar	100	22	122
17–23 Mar	98	22	120[a]
7–14 Apr	77	21	98
16–22 Apr	71	19	90
3–9 May	35	16	51
4–13 June	9	2	11
Total Occupied (Whole Season)	110	33	143

[a] Most closely relates to time period of aerial survey with 120/143 = 83.9% of total nests occupied at that time, or an adjustment factor of 1.19 (143/120).

Generally, in more northern latitudes where this type of survey approach was first conducted (Henny et al., 1974; Henny and Noltemeier, 1975), the nesting cycle was synchronized; however, this 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 what percentage of the total breeding population was nesting at a certain time, and that a further refinement may be made of the population estimate obtained from the earlier study and subsequent studies. To better address the issue of survey timing and nest occupancy in the region, we 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 (Table 2). 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. Because of this lack of nesting synchrony, there would be no survey time when all nests for the year were occupied. A final adjustment of population estimates for both the 1977 (not previously adjusted for lack of nesting synchrony) and 1992–1993 will be made here based upon this new information, and the double-adjusted estimates (for birds missed that were nesting at the *time of the aerial 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 both survey time periods (1977 and 1992–1993). The double-adjustment for asynchrony of nesting does not influence the percent change over time, but only total population estimates.

Results

Distribution and Abundance

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

Northwest Baja California, L.C.—The region extends from the U.S.-Mexico

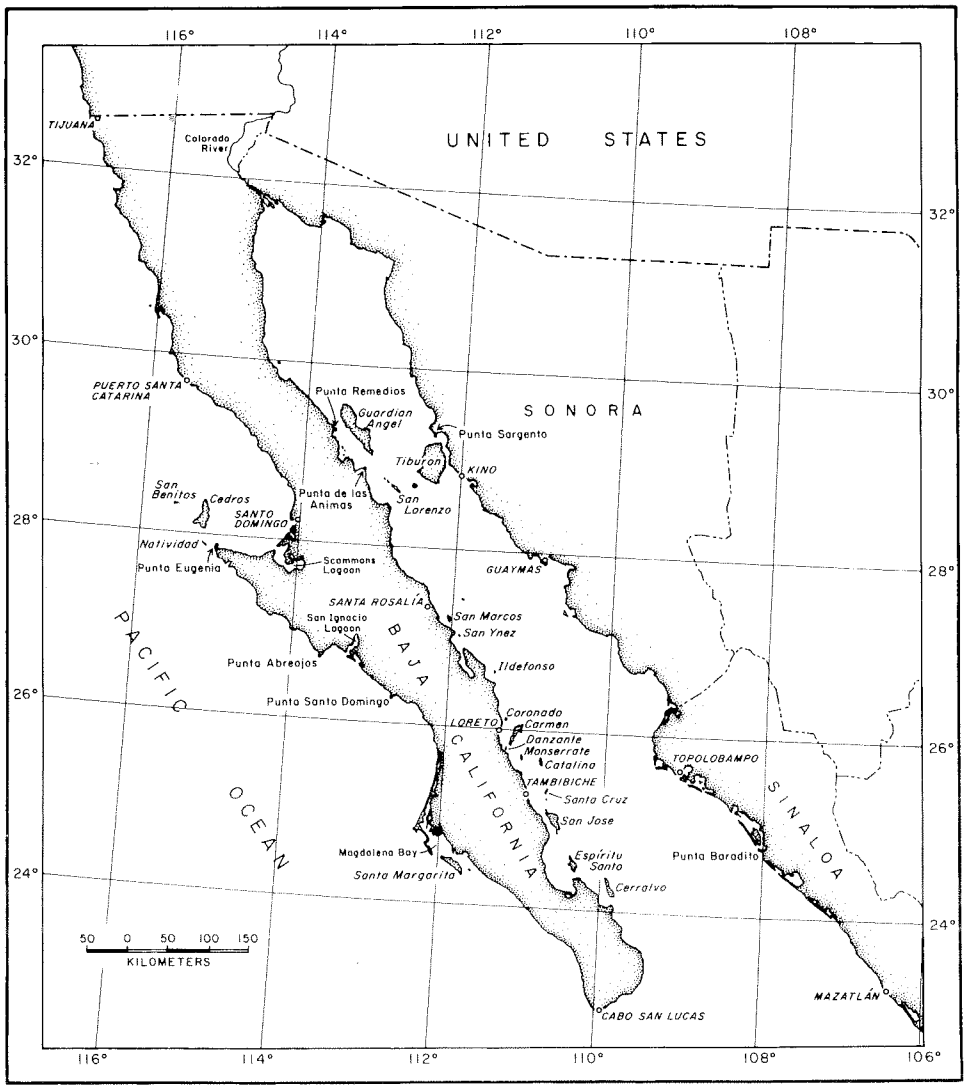

Fig. 1. The Baja California and Gulf of California study area for ospreys.

border south to and including Scammon's Lagoon, and west to Punta Eugenia, including Natividad, Cedros, and San Benitos Islands (Fig. 1). The San Benitos Islands were not surveyed in 1977, although population information for 1973 was available. The total population in the region was estimated at 138 nesting pairs in 1977, but increased to 227 pairs in 1992 (Table 3). No nesting pairs were observed between the border and Desembarcadero de Santa Catarina in either 1977 or 1992. The first nesting pair was observed near Santa Catarina at 29° 35′ N; 115° 22′ W. However, from this point south to Morro Santo Domingo, an estimated 20 pairs were nesting on cliffs in 1977, but 31 pairs were nesting in 1992.

Scammon's Lagoon has been part of the El Vizcaino Biosphere Reserve since

Table 3. Distribution and abundance of occupied opsprey nests at the *time of the aerial survey* on the Pacific side of Baja California in 1977 and 1992.

Location	1977[a]	1992					
	Total estimate	Cliff	Cactus	Ground	Other	Max. observed	Total estimate
Northwest Baja, L.C.							
Puerto Santa Catarina to Morro Santa Domingo	19.5	30.8	—	—	—	18	30.8
Scammon's Lagoon and vicinity	50.1	—	—	68.0[b]	58.0[b]	126[b]	126.0[b]
Punta Mallarrimo to Punta Eugenia	—	5.1	3.4	—	1.7	6	10.2
Natividad Island	22.8	8.6	—	—	—	5	8.6
Cedros Island	19.6	18.8	—	—	—	11	18.8
San Benitos Islands	26.0[c]	32.5	—	—	—	19	32.5
Subtotal	138.0	95.8	3.4	68.0	59.7	185	226.9
Southwest Baja, L.C.							
Punta Eugenia to Punta Abreojos	1.6	3.4	—	—	1.7	3	5.1
San Ignacio Lagoon	27.3	—	—	143.0[d]	—	143[d]	143.0[d]
Punta Santo Domingo to Cabo San Lucas	6.5	13.7	29.1	—	6.8	29	49.6
Subtotal	35.4	17.1	29.1	143.0	8.5	175	197.7
Grand Total	173.4	112.9	32.5	211.0	68.2	360	424.6

Note: No adjustment of aerial survey population estimates was made here from nesting chronology.
[a] From Henny and Anderson (1979).
[b] From Castellanos and Ortega-Rubio (1995) and Castellanos et al. (1999) for 1993.
[c] Not surveyed in 1977, data for 1973 (Jehl 1977).
[d] From Danemann (1994) for 1989.

Table 4. Osprey nesting pairs in Scammon's Lagoon and vicinity 1946–1993 (from Castellanos and Ortega-Rubio 1995).

Year	No. pairs	Natural nests	Artificial structure
1946[a]	27	27	0
1971[b]	30	30	0
1977[c]	50	NA	(14)[d]
1980	71	58	13
1981	76	60	16
1982	86	62	24
1993	126	68	58

[a] Kenyon (1947), [b] Jehl (1977), [c] Henny and Anderson (1979), [d] At least 14 nests were on artificial structures.

1988 (Castellanos et al. 2002) and has a fairly long history of osprey studies by a number of scientists with the population now actively protected (V. Sanchez, pers. comm.) and steadily increasing from 27 nesting pairs in 1946 to 126 nesting pairs in 1993 (Table 4).

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. This appeared to be an "overflow" from the population increase in Scammon's Lagoon, and this apparent spread of nesting osprey has continued almost to Ensenada by 2002 (E. Palacios, pers. comm.). The islands north of Punta Eugenia (Natividad, Cedros and San Benitos) all contained nesting ospreys during both surveys, but fewer were found on Natividad in 1992, a similar number on Cedros in 1992, but more were found on San Benitos Islands in 1992. The total estimate for these islands declined slightly from an estimated 68 nesting pairs in 1977 to 60 in 1992.

Southwest Baja California, L.C.—This region extends south from Punta Eugenia along the Pacific Coast to Cabo San Lucas. In San Ignacio Lagoon, an estimated 27 pairs were nesting on two small islands (Ballenas) in 1977 (Table 3), but Reitherman and Storrer (1981) reported 129 occupied nests only 4 years later in 1981, therefore, either many ground nests were missed in 1977, or something was atypical that year in San Ignacio Lagoon. Gustavo Danemann (pers. comm.) mentioned fisherman's dogs on the islands in 1991, which could certainly disrupt ground nesting ospreys during any specific year, as well as storms and extremely high winds. The extremely high nest density on the islands in 1992 made it impractical to count occupied nests because birds flew and their association with a nest could not be determined with accuracy. Although our counting technique for a dense colony was inadequate, we counted ospreys at 85 nests, and no ospreys at 50 nests. Therefore, for this report we used the 1989 complete count of Danemann (1994) based upon many visits (143 occupied nests) to the two islands (Table 2). As with Scammon's Lagoon, San Ignacio Lagoon is also part of the large El Vizcaino Biosphere Reserve established after our 1977 surveys.

With the exception of San Ignacio Lagoon, only eight additional pairs were estimated nesting in this region in 1977. An estimated 55 pairs nested there in 1992, with most nesting south of Punta Santo Domingo (Table 3). A small concentration of osprey (8 pairs observed, estimated 14 pairs) were located in cacti

between 25° 48′ N and 25° 54′ N, and another concentration was found in the Magdalena Bay/Almejas Bay region (19 pairs observed, estimated 32 pairs) and included nests on cliffs, cacti, and power poles. The most southern occupied nest on the Pacific side of Baja in 1992 was in a cactus at 23° 49′ N; 110° 43 W which was about 120 km south of Magdalena Bay.

Northeast Baja California, L.C.—An estimated 117 pairs of ospreys were nesting in this region along the Gulf from the mouth of the Colorado River south to Santa Rosalia in 1977, and a similar estimated 106 pairs in 1992 (Table 5). The terrain from the Colorado River south to Puertecitos was very flat and contained very few cacti suitable for nesting sites (such as the giant cardon, *Pachycereus pringlei*). The next series of occupied osprey nests in 1992 was in the San Luis Archipelago. The small number of osprey nests in 1992 (four observed pairs, estimated seven pairs) is in stark contrast to the 60–75 nesting pairs reported on the small archipelago by Bancroft (1927, 1932). He also stated that the archipelago was the location for the most northern nesting of the species in the region, as we observed also in 1992, except for one lone nest on an artificial structure on top of a building where a tripod structure was placed with a nesting platform (30° 45′ N; 114° 42′ W). The apparent reduction in the nesting population was most pronounced (37 pairs in 1977 to 24 pairs in 1992) in the northern portion of the region (Colorado River to Punta Remedios). In 1977, about half of the pairs were concentrated on a group of small islands (Miramar, Lobos, Encantada, San Luis, Pumice), but only seven pairs were estimated on these islands in 1992. The San Luis area has been subject to considerable human activity and disturbance, but recently (mid-1990s) has begun to receive patrolling and posting by Mexican wildlife officials (DWA, field notes).

Bahia de los Angeles and Bahia de las Animas located between Punta Remedios and Punta de las Animas contained an estimated 57 pairs in 1977 and an estimated 46 pairs in 1992. Declines were apparent on the small islands (Smith, la Ventana, Cabeza de Caballo, Mitlan, Islas de los Gemelos) in Bahia de los Angeles (35 to 29 pairs) and elsewhere (22 to 17 pairs). The southernmost portion of the region (Punta de las Animas to Santa Rosalia), which is a remote part of the coast, showed a population increase from 23 pairs in 1977 to an estimated 36 pairs in 1992. Cardon cacti became more important as a nesting substrate in the more southern portion of the region.

Southeast Baja California, L.C.—The coastal region south of Santa Rosalia to Cabo San Lucas contained an estimated 137 pairs in 1977 and a similar 130 pairs in 1992 (Table 5). The estimated number of occupied nests between Santa Rosalia and Loreto was also down from 1977 (66 to 50 pairs), and again is more subject to human activities (larger towns, etc.). Occupied nests in 1992 were again concentrated in and around Conception Bay, another rapidly developing tourist area (Carabias-Lillo et al. 2000, Ezcurra et al. 2002). The islands of Coronado, San Marcos and Santa Ynez again had nesting ospreys in 1992, but none were found on Ildefonso. On 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. Tortuga Island was not surveyed in 1977, but only two occupied nests were observed there in 1992.

Between Loreto and Tambibiche an estimated 42 pairs were nesting in 1977, but an estimated 50 pairs in 1992. In 1977, an estimated 16 pairs nested along

Table 5. 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 and 1992.

Location	1977	1992					
	Total estimate	Cliff	Cactus	Ground	Other	Max. observed	Total estimate
Northeast Baja, L.C.							
Colorado River to Punta Remedios	37.4	22.2	—	—	1.7	14	23.9
Punta Remedios to Punta de las Animas							
Los Angeles Bay Islands[a]	35.0	29.3	—	—	—	26	29.3
Other Locations	22.1	17.1	—	—	—	10	17.1
Punta de las Animas to Santa Rosalia	22.8	18.8	17.1	—	—	21	35.9
Subtotal	117.3	87.4	17.1	—	1.7	71	106.2
Southeast Baja, L.C.							
Santa Rosalia to Loreto	65.6	41.0	—	1.7	6.8	29	49.5
Loreto to Tambibiche	42.4	49.6	—	—	—	29	49.6
Tambibiche to Cabo San Lucas	29.3	30.8	—	—	—	18	30.8
Subtotal	137.3	121.4	—	1.7	6.8	76	129.9
Grand Total	254.6	208.8	17.1	1.7	8.5	147	236.1
Midriff Islands							
Guardian Angel	40.8	44.5	—	—	—	26	44.5
San Lorenzo, San Lorenzo Norte, Partida, Salispuedes, Raza	52.2	51.3	1.7	—	—	31	53.0
Tiburon[b]	71.8	46.2	118.0	—	—	96	164.2
San Estaban, Turner, Cholla[b]	22.8	46.2	—	—	—	27	46.2
Grand Total	187.6	188.2	119.7	—	—	180	307.9

Note: No adjustment of aerial survey population estimates was made here for nesting chronology.

[a] In 1993, the total estimate for Los Angeles Bay Islands was 25.2 occupied nests (max number observed 23).

[b] Survey conducted in 1993.

mainland cliffs or on immediately adjacent rocks, while in 1992 an estimated 17 pairs nested in the same locations. The slight increase took place on the islands with Carmen, Danzante, Monserrate, and Santa Catalina listed in order of importance.

The southernmost portion of the region (Tambibiche to Cabo San Lucas) contained an estimated 29 pairs in 1977 with about half the nests along the shoreline and the rest on islands with Cerralvo and Espiritu Santo most important. In 1992, the estimated 31 pairs included 12 along the shoreline and 19 on islands. Islands with occupied nests included Cerralvo, Santa Cruz (and a small island immediately to the south), San Jose and Espiritu Santo. None of these islands had more than three nests observed (estimated five nests) in 1992. The most southern nesting pair was found on a tower at the southern end of Isla Cerralvo (24° 09′ N; 109° 52′ W).

Midriff Islands.—An estimated 188 pairs of ospreys nested on the islands in this region located at about latitude 29° N Latitude in the Gulf of California in 1977; however, an estimated 308 pairs were present in 1992 or 1993 (islands nearer Sonora surveyed in 1993) (Table 5). The estimated numbers nesting on Guardian Angel (41 pairs in 1977 vs. 45 pairs in 1992) and the chain of islands to the south (Partida, Raza, Salsipuedes, San Lorenzo Norte and, San Lorenzo) (52 pairs in 1977 vs. 53 pairs in 1992) were basically identical during both survey years. In contrast, on the eastern side of the Gulf of California, the large island of Tiburon contained an estimated 72 pairs in 1977, but more than doubled to 164 pairs in 1993, while the population on the nearby San Esteban, Turner and Cholla doubled from an estimated 23 pairs to 46 pairs in 1993. The population increase on Tiburon was equally apparent for nests on cliffs (estimated 20 to 46 pairs) and nests in cardon cacti (52 to 118 pairs). Van Rossem (1932) noted ospreys nesting at frequent intervals along the Tiburon coast, but provided no quantitative information. Tershy and Breese (1997) report the osprey as a rare visitor on San Pedro Martir, probably because of the lack of shallow water; the island was not surveyed in 1977 or in 1992–1993.

Coastal Sonora.—An estimated 124 pairs of ospreys were nesting in coastal Sonora in 1977, but the number increased to an estimated 214 pairs in 1993 (Table 6). The extreme northern coastal area is flat with no cacti, then cardon began appearing sporadically. Further south along the coast, there are a few sandy cliffs and, eventually, some rocky cliffs. Some pairs were nesting in the cliffs, but most pairs were in cardon cacti. The first nest we located in 1993 was south and east of Puerto Penasco at 31° 12′ N; 113 04′W and found on a metal power pole about 1.5 km inland. Mellink and Palacios (1993) reported an osprey nest in the same general area in 1982, and reported several nests along the railroad between Lopez Collada and Sahuaro in 1991 and 1992 (unsure how many occupied). The nests were on power line towers or telephone poles, suggesting that artificial structures promoted ospreys colonizing the area where no natural nest sites were available (land flat and no suitable cacti). The power line towers were constructed in 1978 and 1979 (Mellink and Palacios 1993). Then, a series of 11 nests were observed (estimated 19 nests) in cardon cacti between 30° 55′ N and 30° 23′ N. These were followed by a series of eight nests observed (estimated 14 nests in cliffs between latitude 30° 17′ N and 30° 07′ N). From 30° N to Punta Sargento, an estimated 72 pairs were nesting and nearly all were in cacti. From Punta

Table 6. Distribution and abundance of occupied osprey nests at the *time of aerial survey* in coastal Sonora and Sinaloa in 1977 and 1993.

	1977	1993					
Location	Total estimate	Cliff	Cactus	Mangrove	Other	Max. observed	Total estimate
Coastal Sonora							
Colorado River to Punta Sargento[a]	78.4	17.1	87.2	—	1.7	62	106.0
Punta Sargento to Sinaloa border	45.6	15.4	87.2	—	5.1	76	107.7
Subtotal	124.0	32.5	174.4	—	6.8	138	213.7
Coastal Sinaloa							
Sonora border to Topolobampo	6.5	—	10.3	1.7	1.7	8	13.7
Topolobampo to Punta Baradito[b]	61.9	—	152.2	13.7	—	97	165.9
Punta Baradito to Mazatlan	1.6	—	—	—	—	—	0
Subtotal	70.0	—	162.5	15.4	1.7	105	179.6
Grand Total	194.0	32.5	336.9	15.4	8.5	243	393.3

Note: No adjustment of aerial survey population estimates was made here for nesting chronology.
[a] Includes Hamerstrom ground counts (36 pairs) behind Punta Sargento in 1977 (see Henny and Anderson 1979).
[b] Mainly on outer barrier islands: San Ignacio, Macapule and Altamura.

Sargento south to the Sinaloa border, the population more than doubled from an estimated 46 pairs in 1977 to 108 pairs in 1993. The nests south of Punta Sargento in 1993 included a concentration in the Kino Estero, but also a fairly even distribution south to Guaymas. A portion of the Sonora population (El Desemboque to the town of Kino) was studied by Cartron (2000) from 1992 to 1997. He reported a population increase in his study area from 1992 to 1996 (25 to 34 pairs observed, but thought several nests were missed the first year) and then a decline in 1997 to 29 pairs when production was extremely poor. Only one nest was south of Guaymas where the dominant species of cactus in our survey area changed from saguaro (*Cereus giganteus*) that would support a nest to organpipe (*Cereus thurberi*) that would not. The lone nest was on a tower (26° 18′ N; 109° 15 W).

Coastal Sinaloa.—This region extends from the Sonora border south to Mazatlan. An estimated 70 pairs of ospreys nested along coastal Sinaloa in 1977 and 180 pairs in 1993 (Table 6). From the Sonora border to Topolobampo, an estimated seven pairs nested in 1977, but increased to an estimated 14 pairs in 1993. All of these pairs were nesting on Santa Maria, which is a barrier island south and west of Los Mochis. Most nests were in cacti, although a derelict boat and mangrove tree were also used. South of Topolobampo to Punta Baradito an estimated 62 pairs were nesting in 1977, but the numbers increased to an estimated 166 pairs in 1993. This area was further sub-divided into two areas with the split at 25° 10′ N. From Topolobampo to 25°10′ N, which included the barrier islands of San Ignacio and Macapule, had an estimated 31 pairs nesting in 1977 and an estimated 118 pairs in 1993. South of 25° 10′ N, which included Santa Maria Bay and the barrier island of Altamura, we estimated 31 pairs in 1977, but an estimated 48 pairs in 1993. Carmona and Danemann (1994) studied Santa Maria Bay in 1988, and reported about 40 pairs of nesting osprey which generally supports our observations. Most ospreys at the above two areas were nesting on barrier islands and peninsulas associated with several large bays. Mangroves and other brushy trees were abundant and some of the ospreys nested in them. The species of cacti changed again to a type that branches about 1.5 m above ground (*Pachycereus pecten-aboriginum*), and most nested again in the cactus. The most southern nesting osprey was at 24° 54′ N; 108° 07′ W. During the 1977 survey the most southern occupied nest was south of Punta Barradito at 24° 38′ N, but cacti in this area are sparse and of the wrong shape and the tops of trees will not support a nest. No occupied osprey nests were found south of Punta Baradito in 1993. The terminus of the survey was Mazatlan both years of the survey, and it is possible that a few more scattered nests could be found farther south. However, CJH flew further south along the coast at low altitude to the Guatamala border on another project in January 1983 (Henny and Blus 1986) and saw no osprey nests.

Nesting Sites

Dead trees or trees with dead tops are the "typical" sites for nesting ospreys in the western United States (Henny et al. 1978a, b), but ospreys in more recent years have nested on power poles and transmission towers in response to the shortage of tree sites (Henny and Kaiser 1996). Trees, with the exception of mangroves at more southern latitudes of this study area, were rare. Consequently, the ospreys used different nest sites (Table 7). The proportions of nests found in

Table 7. Types of nest sites selected by ospreys in the study area, 1997 and 1992–1993.

Nest site substrate	Estimated number of occupied nests (%)	
	1977	1992–1993
Cliff	479 (59.1%)	542 (39.8%)
Cacti	213 (26.3%)	506 (37.2%)
Ground	59 (7.3%)	213 (15.6%)
Human-made Structures	35 (4.3%)	85 (6.2%)
Mangrove or Other Trees	24 (3.0%)	16 (1.2%)
Total	810 (100%)	1,362 (100%)

Note: No adjustment of aerial survey population estimates was made here for nesting chronology.

the five categories of nesting substrate (Table 7) varied significantly ($P < 0.01$, Kolmogorou-Smirnov Test) from 1977 to 1992–1993, mainly due to the increase of nests found in cacti and on the ground. Remote, inaccessible cliffs and cacti were still the most important substrates used for nesting during both surveys, as nesting above ground level is critical for ospreys on the mainland where predators are common. Coyotes (*Canis latrans*) were observed throughout the study area, and it was not uncommon to see several each day during our aerial surveys. Both Kenyon (1947) and Jehl (1977) monitored coyote depredation of ground nests, even when nests were located on small islands and Danemann (1994) mentioned fisherman's dogs as well as coyotes as a problem on small islands in San Ignacio Lagoon.

Ground-nesting ospreys were restricted to very small islands at three locations: Scammon's Lagoon, San Ignacio Lagoon and Santa Ynez Island, and were likely much more abundant in the past (e.g., Jehl 1977) and recovering in importance, given recent protection. In the Bahia de los Angeles area, DWA knew of 2–3 ground nests in the mid-1970s, but annual observations since then have yielded no ground nests. Overall, ground nests on islands increased from 1977 to 1992, primarily because of the large population increase at San Ignacio Lagoon. San Ignacio Lagoon is part of the Biosphere Reserve System in Baja California (Anderson et al. 2002) and subject to management and protection since the early 1990s. The use of human-made structures as nest sites also increased (from 35 pairs to 85 pairs) as a result of increased human activity at several locations, including the building of some nesting structures specifically for ospreys at Scammon's Lagoon.

Discussion and Conclusions

Much of our discussion relates to larger regions with 95% C.I. provided (see Table 8), although point estimates are provided for smaller areas. The maximum number of nests observed from each area is shown in Tables as well as the estimated size of that population which provides additional insight into data quality. Comparisons with published results from several areas (e.g., Santa Maria Bay) (Carmona and Danemann 1994) also show good agreement with our estimated values. Furthermore, we do not believe that change in population size between the two survey periods (1977 and 1992–1993) was a function of changes in Visibility Rates, in fact, the Visibility Rates for cliffs and cactus combined were nearly identical for the two surveys, which supports the repeatability of the survey

Table 8. A summary of changes in estimated number of occupied osprey nests in the study area, 1977 and 1992–1993.

Location	1977[a]	1992–1993[a]	Change
NW Baja, L.C.	138.0 (164.2)	226.9 ± 20.6[b] (246.1)[c]	+64% (+50%)
SW Baja, L.C.	35.4 (42.1)	197.7 ± 11.1[b] (208.1)[c]	+458% (+394%)
NE Baja, L.C.	117.3 (139.6)	106.2 ± 21.6 (126.4)	−9% (−9%)
SE Baja, L.C.	137.3 (163.4)	129.9 ± 26.5 (154.6)	−5% (−5%)
Midriff Is.	187.6 (223.2)	307.9 ± 62.8 (366.4)	+64% (+64%)
Sonora	124.0 (140.7)[c]	213.7 ± 43.6 (254.3)	+72% (+81%)
Sinaloa	70.0 (83.3)	179.6 ± 36.6 (213.7)	+157% (+157%)
Totals	810 (957)	1,362 ± 278 (1,570)	+68% (+64%)

[a] First estimate refers to those nesting at the *time of the aerial survey* including those missed by aerial survey; estimate in ( ) refers to double-adjusted population estimate which includes those that were not nesting at the time of the survey due to asynchronized nesting season at more than southern latitudes (initial estimate × 1.19, see Table 2).

[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 were used for Scammon's Lagoon, San Ignacio Lagoon, and behind Punta Sargento, thus that portion was not adjusted for asynchronized nesting season.

method for nesting ospreys (Table 1). We found that the general distribution of ospreys in our survey area had not changed appreciably between 1977 and 1992–1993, although changes in abundance were apparent and variable.

The region of Northwest Baja has the best documented changes in osprey population numbers over time in Mexico. Prior to our 1977 survey (Henny and Anderson 1979), most of the quantitative studies of osprey in Mexico were restricted to portions of Northwest Baja, and Jehl (1977) reviewed these studies. The four most northern islands or groups of islands (Los Coronados, Todos Santos, San Martin and San Geronimo) are of interest, because the last pair nested there in 1971. Los Coronados historically had no nesting records, but ospreys were common on the other three islands. However, by the 1920s ospreys were gone from Todos Santos and San Geronimo, and reduced to only one pair by 1969–1971 on San Martin. San Martin had about 30 pairs nesting on the ground in 1913. None of these more northern islands had nesting ospreys during our surveys in 1977 and 1992. These extirpations were concomittant with extirpations on islands off southern California (Kiff 1980).

As we mentioned in our earlier report, the road system heading south from Tijuana (where nesting ospreys are no longer present) was along the coast, but further south the main road was inland away from the coastline. Osprey pairs were only found nesting along the coast after the road veered inland away from the coast. Inland nests near the main highway are rare, but include the famous and well-known osprey nest on the sign near Guerrero Negro and another near Villa Jesus Maria. Both are right over or very near the main road and about 7–9 km from water. We know of no other nests this distance from water.

Most of the osprey increase in Northwest Baja occurred in Scammon's Lagoon and the adjacent areas to the north and west. Scammon's Lagoon was originally developed in 1953 for salt production, and now has one of the worlds largest salt-production companies (Castellanos et al. 1999). In earlier years, the nesting pairs were on the ground on three small islands in the lagoon, but more recently, utility

poles (some modified with platforms above the electric wires) in the town of Guerrero Negro, plus towers, nesting platforms built for ospreys, pilings, and channel markers (associated with development of salt industry) have become important (Castellanos and Ortega-Rubio 1995) just as elsewhere (Henny and Kaiser 1996). Nesting platforms were first constructed in the Scammon's Lagoon area in 1982 and were used immediately (Castellanos and Ortega-Rubio 1995). The presence of wildlife officials actively involved with ospreys in Guerrero Negro in 1992 was a noticeable change from 1977. Furthermore, osprey nests on power poles in the city of Guerrero Negro were common and protected, and none were present during the 1977 survey. Permanent and successful use of utility poles by ospreys began in 1984 as a result of three factors: law enforcement, environmental education programs, and utility pole modification (extension platforms) (Castellanos et al. 1999). West of Scammons Lagoon in 1977 we reported that populations on Natividad, Cedros and San Benitos, which are generally more distant from human populations, appeared to be stable. The overall osprey population on the three islands in 1992 was down slightly; the decline was more pronounced at Natividad, which is the closest to the mainland and had the most human activity, e.g., many roads were evident on the island in 1992.

We provide an additional estimate of the size of populations (using a double-adjustment including nesting asynchrony) which may be considered preliminary, and is only mentioned from here onward. The percentage change in population estimates was not influenced by the nesting asynchrony adjustment, because the same adjustment was used for all data. However, the size of the population was increased except in areas where detailed nesting studies were conducted. The estimated population in Northwest Baja increased 50% from 1977 to 1992 (Table 8). The osprey population in Southwest Baja also increased dramatically from 1977 (42 pairs) to 1992 (208 pairs) (Table 8), with most of the change the result of the tremendous increase in San Ignacio Lagoon. Historically, Huey (1927) did not report ospreys nesting on Ballenas Islands in San Ignacio Lagoon in 1927 (visited islands on 12 April), although the date of visit was well within the nesting cycle (Table 2). Huey did report seeing ospreys. However, Bancroft (1927) reported them abundant at both San Ignacio and Scammon's Lagoons (uncertain of year). There is some indication that a portion of the increase from 1977 to 1992 in the lagoons may not be real because of the much larger nesting osprey population (129 pairs) counted in the lagoon only four years after our initial survey (Reitherman and Storrer 1981). Storms (winds), dogs on the islands or other factors may have resulted in lower counts at the time of our survey in 1977 or we may have just missed some ground nests. Now the osprey nesting on the two small islands in San Ignacio Lagoon, which were well studied by Reitherman and Storrer (1981) and Danemann (1994), may have the highest density in the world! At both Scammon's Lagoon and San Ignacio Lagoon, the ospreys probably also benefitted from the additional presence of wildlife officials involved with the gray whales (*Rhachianectes gibbosus*) that calve in both lagoons and an island-protection program run by the Guerrero Negro group. Another nesting concentration in the region was found in the Magdalena Bay/Almejas Bay region where the only nesting bald eagles (*Haliaeetus leucocephalus*) in Baja California are now located (Henny et al. 1993). We are aware that in the late 1970s and 1980s, about 25–30 osprey pairs were shot and nests removed from structures near the town of

San Carlos (Magdalena Bay) (J.E. Mendoza, pers. comm.), and it might be that the increased population around Magdalena Bay represents a local population recovery.

In contrast to the osprey population increase on the Pacific side of Baja California, the osprey population on the Gulf of California side appeared unchanged or in a slow, but general decline in both the northern (−9%) and southern regions (−5%) (Table 8). No lagoons with small islands are found along the Gulf side, and lagoons were the primary focus for population increases on the Pacific side. The Pacific side of Baja California, which had fewer nesting pairs than the Gulf side in 1977 (206 vs. 303), had more nesting pairs in 1992 (454 vs. 281) (Table 8).

The Midriff Islands showed an interesting dichotomy, 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 between 1977 and 1992 (93 pairs vs. 98 pairs) (Table 5), while those closer to Sonora (Tiburon, San Estaban, Turner and Cholla) all showed major increases (95 pairs vs. 210 pairs). All islands in the Gulf of California are part of a Biosphere Reserve, called "Islands of the Sea of Cortez," for the protection of animals and plants (Alvarez-Castañeda 1997). Patrol of the islands by reserve personnel of the wildlife service only began near the end of 1997, so the islands have a long history of use without formal supervision, with most supervision restricted to the islands with the most tourist activity (Alvarez-Castañeda and Oretega-Rubio 2003). Other Midriff Islands are fortunately part of a developing management plan (Carabias-Lillo et al. 2000, Ezcurra et al. 2001, Anderson et al. 2002) and will receive more protection in the future.

The estimated nesting osprey population along mainland Mexico (Sonora and Sinaloa to Mazatlan) more than doubled (224 pairs to 468 pairs) between 1977 and 1993 (Table 8). The increase was more pronounced in Sinaloa than in Sonora. The largest increase occurred in Sinaloa on the outer barrier islands of San Ignacio, Macapule and Altamura. The increase was the greatest on San Ignacio Island (different from San Ignacio Lagoon discussed earlier). Most nests were located in cacti and apparently near abundant fish populations in adjacent bays and estuaries. Carmona and Danemann (1994) mentioned the possibility of agricultural pesticides flowing into the bays and estuaries from streams that drain farmlands. The increase in osprey populations in coastal Sinaloa from 1977 to 1993 may be the result of reduced use or termination of the use of persistent pesticides, but no pesticide residue data from osprey eggs were ever collected in coastal Sinaloa. If DDT/DDE was involved in an earlier osprey population decline in Sinaloa, that we would now be seeing a recovery from, reduced productivity would have occurred (Wiemeyer et al. 1988). Unfortunately, in addition to the lack of pesticide studies, there were no osprey production studies from this region to evaluate the possible influence of pesticides in earlier years. Our explanation for the observed increase is therefore problematic.

Nest sites used by the ospreys in Mexico include some structures made by humans, and although the percentage is increasing, it remains small (6%, Table 7) except in Scammon's Lagoon (46%, Table 3). It is anticipated that ospreys will continue to adjust to these structures, and they will become more important in Mexico over time just like they have in other parts of the world. At many locations in the United States and elsewhere, the percentage of nests on human-made structures is extremely high, e.g., 85% along Willamette River in western Oregon

(Henny and Kaiser 1996). As the ospreys begin nesting on power poles or transmission towers, the utility companies will need to address the issue of power outages caused by nests as well as osprey electrocutions. Modifications of nests on power poles with pole top extension platforms are already occurring at some locations. The science of managing osprey nests on power poles is rapidly developing at the present time in the United States and elsewhere (APLIC 1996).

In summary, the osprey population (double adjusted) increased from an estimated 957 pairs in 1977 to an estimated 1,570 pairs in 1992–1993 (Table 8) and major increases seemed to be focused in areas where wildlife personnel had a presence (in some cases not specifically assigned to ospreys), although a general population increase occurred at all regions except the Gulf coast of Baja California. This atypical pattern of population change along the Gulf coast of Baja California should be used to focus additional investigations in that region. A management plan and proposed Bahia de los Angeles National Park (G. Danemann, pers. comm.) in the near future should be helpful. A check of occupied vs. unoccupied nests in a 1992 sample observed from the air on both coasts of Baja California showed nearly equal numbers, but near La Paz on Espiritu Santo and Cerralvo the ratio was skewed heavily toward unoccupied nests (1 vs. 16 and 3 vs. 11, respectively). Is this the result of an earlier nesting season at 24° N. Latitude, or was there possibly a disturbance issue related to human activity from LaPaz? Anderson et al. (1976) brought up the issue of increased human activity in the Gulf of California and its potential effect on vulnerable seabirds. Interest in this subject has increased in recent years (e.g., Tershy et al. 1999, Lopez-Espinosa 2002). We are convinced that human activity has increased tremendously from 1977 to 1992, especially along the Gulf side of Baja California. This increase has taken place in the form of more tour boats, kayaks, and increased construction, although we do not have quantitative data. Ospreys are generally a tolerant species of humans and their activities and habituate to them. However, there are critical times in the nesting cycle (which is much longer in Mexico than farther north due to the lack of nesting synchrony) when presence of humans can prevent eggs from being incubated, the very young from being shaded by the parents from the hot sun, or young becoming more vulnerable to predators such as common ravens (*Corvus corax*), yellow-footed gulls (*Larus livens*), and other species. When official wildlife management presence has occurred, sometimes not even related to ospreys, we have observed ospreys prosper.

This survey data is now more than 10 years old, and there is no guarantee that the osprey populations of the various regions continued to increase or even remain stable after 1992–1993. It is anticipated that another survey will be conducted in the near future.

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