Differential Reproductive Success of Ospreys in New Jersey

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Abstract: To determine factors responsible for low productivity of ospreys (Pandion haliaetus) nesting along Delaware Bay, we compared their reproductive success to birds nesting along the Atlantic Coast during 1987 and 1988. Productivity of ospreys nesting along Delaware Bay was lower because 50% of all nests initiated failed, whereas only 21% of Atlantic Coast nests failed. Only 50% of all eggs laid in the Bay colony hatched, compared to 69% in the Atlantic Coast colony. Nestling mortality was similar between colonies (26 vs. 18% for Delaware Bay and Atlantic Coast, respectively) but 21% of those young hatched near the Bay were probably preyed upon by great horned owls (Bubo virginianus). Although Delaware Bay ospreys spent considerably more time away from their nests, presumably foraging, than did Atlantic Coast birds, adults from both colonies spent similar amounts of time feeding young, which suggests that food stress did not influence productivity. High frequency of unhatched eggs and thinner eggshells (8% below pre-DDT levels vs. 3% for Atlantic Coast eggs) of ospreys along Delaware Bay suggests possible exposure to environmental contaminants that may reduce hatching success.

Osprey populations in eastern North America have steadily recovered from severe declines that occurred before the early 1970's (Henny et al. 1977; Spitzer et al. 1977, 1983). Productivity and population sizes are approaching those that existed before the widespread use of organochlorine pesticides (Spitzer et al. 1978, Wiemeyer et al. 1989). Similarly, New Jersey’s osprey population, although strongly affected by these persistent pesticides (Henny 1983), has steadily increased in productivity and population size since the mid-1970’s.

In contrast, ospreys that nest along the New Jersey side of Delaware Bay continue to produce few young and have not increased in number, although suitable habitat and nesting structures exist along the Bay. Productivity of ospreys near Delaware Bay (\(x = 0.69\) young/occupied nest, \(n = 157\)) was well below that of New Jersey’s Atlantic Coast population (\(x = 1.23, n = 1,046\)) from 1978 to 1988 (L. J. Niles and R. J. Steidl, unpubl. data). Further, productivity is below the level thought necessary to maintain a stable population (Henny and Wight 1969, Spitzer et al. 1983).

In 1987 and 1988, we compared reproductive success of the Delaware Bay osprey colony to a recovering colony nesting along New Jersey’s Atlantic Coast. To determine factors limiting osprey productivity and population growth along the Bay, we examined nesting success, timing of reproductive failure, feeding and nest attendance rates, food accessibility, and eggshell thickness of both colonies.

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STUDY AREA

Our study took place at 2 colonies, one located along Delaware Bay and the other along the Atlantic Coast. The Delaware Bay site was defined by all active nests along the New Jersey side of the Bay. The Atlantic Coast site was chosen by selecting areas representative of common coastal habitats containing a large number of accessible nests.

Human use of both nesting areas differed markedly. Atlantic Coast areas received intensive use from summer vacationers, including recreational boaters and anglers. This high use coincided with the middle through the end of the ospreys’ breeding season. Delaware Bay received almost no recreational use and was virtually free from human disturbance.

Delaware Bay Site.—Delaware Bay is a 215-km-long estuary, of which about 120 km has salinity >0.5 ppt. The Bay is characterized by high turbidity and lack of human development along the coastline, though the extreme upper reaches are densely populated. The population and industrial centers of Philadelphia, Trenton, and Wilmington are based along the Bay’s main influent source, the Delaware River. At the Bay study site, ospreys nest along tidal, saline regions of the Bay. Here, dominant plant species include common reed (Phragmites australis) and salt-marsh cordgrasses (Spartina patens, alterniflora, and cynosuroides), with a few trees and scattered patches of marsh elder (Iva frutescens). Much of the land surrounding this portion of the Bay is agricultural.

Ospreys, once abundant along the New Jersey side of Delaware Bay (Stone 1937, Mills 1977), currently nest along only 1 area of southwestern Salem County. One nest along the Bay was in a dead tree, whereas the remainder were atop 500-kilovolt transmission towers, 50–75 m tall, emanating from a nuclear-powered electric generating station. Ospreys built nests on cross-supports about ⅔ of the way up transmission towers.

Atlantic Coast Site.—The Atlantic Coast study site, along the northern portion of New Jersey’s Cape May peninsula, consisted of 3 areas within 4 km of the Atlantic Ocean: Avalon, Marmora, and Great Egg Harbor River. The Avalon and Marmora sites are salt-marsh estuaries supporting typical salt-marsh vegetation dominated by cordgrasses. Great Egg Harbor River is an estuarine river draining acidic waters from the Pine Barrens to Great Egg Harbor Bay. The study area along the river was also dominated by cordgrasses (Spartina spp.). The coastline east of these marshes is heavily developed, and most land west of the marshes is forest swamp, with little residential or industrial development.

Most of the nests we studied along the Atlantic Coast were atop man-made structures built specifically for ospreys (82%), that consisted of 1 or 4 3-m-long cedar poles erected in the marsh with a 1- × 1-m oak pallet nailed to the poles. The remainder of the nests studied were built in trees (13%) or atop duck-hunting blinds (5%).

METHODS

Reproductive Success.—For Delaware Bay in 1988 and the Atlantic Coast in 1987 and 1988, we visited nests weekly beginning in late March when ospreys arrived and began courtship, and we continued visits through fledgling dispersal. We climbed to nests to determine contents from egg laying until nestlings were about 45 days old. After birds fledged, we used a spotting scope to observe young until dispersal or 1 September, whichever came first. In 1987, we inspected Delaware Bay nests 4 times, twice by helicopter during incubation, once by climbing to nests during peak hatching, and once again to band young when they were 3–4 weeks old. Data on number of eggs laid, hatching success, and egg and young survival are therefore incomplete for this colony in 1987.

Nest Attendance and Feeding Rates.—Time-lapse movie cameras with solar on-off switches (Temple 1972) were installed at 3 nests in each colony during 1988. Each camera exposed 1 frame every 70–90 seconds and operated from hatching until nestlings were about 45 days old, thereby providing almost complete coverage during this period. Because of the volume of film collected (>125,000 frames), we subsampled each film by randomly selecting 1 complete day for each 6–7-day interval (approx 750 frames). To determine if colonies differed in the amount of time ospreys spent foraging and the amount of prey delivered to their nests in 1988, we compared (1) the percentage of time-lapse film frames when adults were absent from the nest, (2) those in which young or adults were actively feeding or handling prey atop the nest, and (3) the proportion of our nest visits when only 1 adult was present at the nest; we assumed the other was away foraging (Jamieson et al. 1982).
**Food Accessibility.**—We used Secchi disk measurements of water transparency to compare food accessibility between foraging areas surrounding colonies in 1988 (Vana-Miller 1987). Because all sites were tidal, measurements were standardized by taking readings from 1000 to 1500 hours, within ±2 hours of high tide, with little or no wind, and not within 3 days of rain. We measured water transparency monthly from April through August at 20 sampling stations along both Delaware Bay and Atlantic Coasts.

**Eggshell Thickness.**—During 1985–88, we collected all eggs that remained >1 week after all other eggs hatched within these colonies. After opening eggs by scoring the equator with a scalpel, we stored egg contents in jars washed with nitric acid and rinsed with hexane. Eggshells were then rinsed in tap water, air dried for >3 months, weighed to the nearest 0.001 g, and measured for thickness to the nearest 0.01 mm with a dial-gauge micrometer. We compared eggshell thickness to pre-DDT thickness of 0.505 mm for Atlantic Coast ospreys (Anderson and Hickey 1972). We also measured length and breadth of eggs and calculated the Ratcliffe Thickness Index by dividing shell mass (g) by length (mm) × breadth (mm) of the egg (Ratcliffe 1980:213).

**Statistical Analyses.**—To compare reproductive and eggshell parameters between colonies, we used Wilcoxon 2-sample tests (using an approximation to the normal distribution, Z, when n was >20) and G-tests of independence for 2-way contingency tables. Water transparency was compared between colonies with Z-tests for large samples. Because time-lapse film data were collected from the same pairs through the season and therefore not independent through time, we compared the frequency of behaviors between colonies at each week with Z-tests for proportions. To control for experimentwise error rate, we divided α by the number of weeks (0.05/7 = 0.007). All statistical tests were 2-tailed with 1 degree of freedom unless otherwise stated.

Because of small sample sizes in some of our comparisons, there was considerable risk of committing Type II errors. We evaluated this possibility if P values were >0.05 and <0.10 by estimating the power of the test (power = 1 − β, where β is the probability of committing a Type II error) based on methods described in Cohen (1988). Power values range from 0 to 1 and represent the probability of detecting a significant difference if one exists, given sample size, variance, and α (Cohen 1988, Forbes 1990).

**RESULTS**

During 1987 and 1988, we observed 62 nesting attempts, 24 along Delaware Bay and 38 along the Atlantic Coast. During 1987, we collected only fledging and nest success data for the Bay colony (n = 12). These totals exclude 1 renesting attempt within each colony during 1988. There were no significant differences in any reproductive parameters between years for the Atlantic Coast colony and for fledging data from the Bay colony (Z < 1.17, P > 0.24, for all comparisons), so we pooled both years of data for each colony.

**Egg Laying, Survival, and Hatching Success**

Ospreys nesting along Delaware Bay were less successful than those along the Atlantic Coast in all postlaying parameters except for the proportion of eggs that disappeared before hatching, which was similar between colonies (Table 1). This disparity in success was not related to differences in clutch sizes, as these were also similar between colonies (Delaware Bay \( \bar{x} = 3.17 \pm 0.17 \) [SE], n = 12; Atlantic Coast \( \bar{x} = 3.00 \pm 0.08, n = 35; Z = 0.97, P = 0.33 \) [excludes 3 nests from the Atlantic Coast that failed after laying only 1 egg]). Bay nests hatched a lower proportion of eggs than did Atlantic Coast nests due to a greater proportion of addled eggs in the Bay colony and not due to the number of eggs that disappeared before hatching of the first egg within a clutch (Table 1).

Although nests within both colonies lost similar numbers of eggs during incubation, these eggs are important in calculating nest success, so we also calculated hatching success based only on eggs that survived the entire incubation period. This value, which we termed hatchability, was also lower for the Delaware Bay colony (Table 1). Delaware Bay nests did not differ from Atlantic Coast nests in the proportion of nests hatching ≥1 egg (\( G = 2.27, P = 0.13 \)).

**Nestling Survival, Nest Success, and Productivity**

The proportion of young fledged per egg laid was lower for Delaware Bay nests than for nests along the Atlantic Coast because of the greater proportion of addled eggs from Delaware Bay (\( G = 4.37, P = 0.037 \) (Table 1). The proportion
Table 1. Reproductive parameters of Delaware Bay (1988) and Atlantic Coast (1987–88) osprey colonies in southern New Jersey.

<table>
<thead>
<tr>
<th>Reproductive parameters</th>
<th>Delaware Bay</th>
<th>Atlantic Coast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest</td>
<td>12</td>
<td>38</td>
</tr>
<tr>
<td>Eggs laid</td>
<td>38</td>
<td>108</td>
</tr>
<tr>
<td>Eggs hatched</td>
<td>19</td>
<td>74</td>
</tr>
<tr>
<td>% hatchability</td>
<td>50.0</td>
<td>68.5</td>
</tr>
<tr>
<td>Eggs disappeared before hatching</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>% egg hatchability</td>
<td>15.8</td>
<td>13.0</td>
</tr>
<tr>
<td>Eggs addled</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>% addled</td>
<td>34.2</td>
<td>18.5</td>
</tr>
<tr>
<td>Young disappeared or died</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>% fledged</td>
<td>26.3</td>
<td>17.6</td>
</tr>
<tr>
<td>Young fledged</td>
<td>14</td>
<td>61</td>
</tr>
<tr>
<td>% fledged of eggs laid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% fledged of young hatched</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young fledging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% nesting any eggs</td>
<td>36.8</td>
<td>56.5</td>
</tr>
<tr>
<td>Nests fledging any eggs</td>
<td>8</td>
<td>33</td>
</tr>
<tr>
<td>Nests fledging young</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>% fledged of young hatched</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a Hatchability = no. eggs hatched/(no. eggs laid – no. eggs that disappeared before hatching).  
*b Includes data from both 1987 and 1988, n = 24.

Food Accessibility, Nest Attendance, and Feeding Rates

Water transparency is an indicator of fish accessibility to piscivorous birds that depend primarily on vision to obtain food (Eriksson 1985). A difference in water transparency of foraging areas indicates a difference in the ease in which ospreys can locate fish (Vana-Miller 1987, Spitzer 1989). Water transparency (cm) of osprey foraging areas measured during 1988 differed markedly between Delaware Bay and Atlantic Coast colonies (36.1 ± 0.9 and 101.5 ± 4.0, respectively; Z = 16.05, P < 0.0001), which indicates that fish in waters surrounding the Atlantic Coast colony were visible below 1 m, whereas fish near the Bay colony were visible only in the top 36 cm of the water column. Because ospreys can dive to depths of 1 m for prey (Cramp and Simmons 1979:269), their foraging is probably restricted to a smaller volume of water in Delaware Bay than in the Atlantic Coast site.

Colonies differed in the amount of time adults were present at nests in 1988 (Fig. 1). Nest attendance was initially similar between colonies, but as the nestling period progressed, Bay adults spent considerably more time away from nests than did their Atlantic Coast counterparts. Also, osprey adults along Delaware Bay were alone during 22 of 95 of our nest visits (23%, n = 13 nests), whereas Atlantic Coast adults were alone during only 25 of 175 visits (14%, n = 19 nests) (G = 3.27, P = 0.071, power = 0.55). The percentage of frames in which adults and young were actively feeding or handling prey was similar between colonies through the majority of the nestling period (Fig. 1).

Eggshell Thickness

Addled eggs were nearly identical in length, width, and volume measurements between colonies (Z = 0.90, P > 0.60, for all comparisons), but eggshells from Delaware Bay averaged nearly 5% thinner than those from Atlantic Coast eggs when compared to pre-DDT standards.
Table 2. Eggshell thickness and Ratcliffe Index of eggs collected from Delaware Bay (n = 8) and Atlantic Coast (n = 23) osprey colonies after failure to hatch, 1985–88.

<table>
<thead>
<tr>
<th></th>
<th>Delaware Bay</th>
<th>Atlantic Coast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggshell thickness (mm)</td>
<td>0.47 ± 0.01</td>
<td>0.49 ± 0.01</td>
</tr>
<tr>
<td>% thinner than pre-DDT</td>
<td>7.80 ± 2.71</td>
<td>3.14 ± 2.13</td>
</tr>
<tr>
<td>Ratcliffe Index†</td>
<td>2.19 ± 0.07</td>
<td>2.37 ± 0.05</td>
</tr>
</tbody>
</table>

* These values may not be comparable to pre-DDT Ratcliffe Indices because eggs were opened using different techniques.

DISCUSSION

Reproductive success of the Delaware Bay osprey colony has been lower than that of the Atlantic Coast colony since at least 1976 (L. J. Niles and R. J. Steidl, unpubl. data). During 1987–88, Bay nests failed primarily because of low hatching success. Other researchers have suspected egg failure as the principal cause of reproductive failure of ospreys nesting in Yellowstone National Park (Swenson 1979) and California (Levenson and Koplin 1984), but each attributed low hatching success to acute levels of human disturbance that kept incubating adults off nests, causing an increase in embryonic mortality. Thickness of eggshells from the Bay colony does not indicate DDE levels associated with severe reproductive problems (Wiemeyer et al. 1989), and the proportion of eggs disappearing before hatching did not differ between colonies. Therefore, we suggest that egg breakage or changes in water or gas transport across the shell membrane due to eggshell thinning were not the cause of egg failure in the Bay colony. One possibility is that other contaminants, more embryotoxic than DDE, may be responsible for egg failure in the Bay colony. Kubiak et al. (1989) reported that high concentrations of certain PCB's in eggs of Forster's terns (Sterna forsteri) decreased hatchability by 50–75% and also impaired reproductive behaviors of adults.

We are unsure why such a high percentage of eggs laid along Delaware Bay failed to hatch. One possibility is that great horned owls nesting near the Bay colony and occasionally in osprey nests on transmission towers may have kept incubating adults off nests, causing an increase in embryonic mortality. Thickness of eggshells from the Bay colony does not indicate DDE levels associated with severe reproductive problems (Wiemeyer et al. 1989), and the proportion of eggs disappearing before hatching did not differ between colonies. Therefore, we suggest that egg breakage or changes in water or gas transport across the shell membrane due to eggshell thinning were not the cause of egg failure in the Bay colony. One possibility is that other contaminants, more embryotoxic than DDE, may be responsible for egg failure in the Bay colony. Kubiak et al. (1989) reported that high concentrations of certain PCB's in eggs of Forster's terns (Sterna forsteri) decreased hatchability by 50–75% and also impaired reproductive behaviors of adults.

Electrical transmission towers are used for nesting by ospreys and many other raptors throughout their ranges (Henny and Anderson 1979, Van Deale 1980) with no apparent ill effects from the high volumes of electricity carried near their nests. Because the biological effects associated with electrical fields, magnetic fields, and corona of electrical transmission are largely unknown (Lee 1978, 1980), we cannot speculate on the effects these factors might have on reproductive success of ospreys nesting atop transmission towers along Delaware Bay.

Osprey foraging efficiency probably increases with increased water transparency (Vana-Miller 1987). Accordingly, ospreys nesting near Delaware Bay spent substantially more time away from their nests, presumably foraging (Jamieson et al. 1982), than did Atlantic Coast birds, yet
we found no difference in amount of time spent feeding at nests, nor in the number of young fledged by successful pairs. If food availability were a problem near the bay, we might expect large-scale brood reduction as observed in ospreys nesting in areas of low food abundance (Poole 1982, Hagan 1986). Food stress is believed to be responsible for the decline of ospreys nesting along Florida Bay (Kushlan and Bass 1983, Bowman et al. 1989). However, no apparent food-related brood reduction occurred in Delaware Bay nests, and it occurred infrequently in Atlantic Coast nests. If Bay ospreys had been food stressed early in the breeding season, we would have expected either smaller clutch sizes (but see Poole 1985) or a lower percentage of pairs laying eggs (Newton 1979:131). Clutch sizes did not differ between colonies, and all pairs occupying a territory in both colonies laid eggs. Nestling loss that occurred in the Bay colony was due to predation on 4 of 5 nestlings that died during 1988.

We suggest that the combination of poor hatching success and predation, probably by great horned owls, was responsible for limiting productivity of Delaware Bay ospreys. This osprey population has grown little or not at all since the ban of DDT, even though this area seems to have ample undisturbed habitat and available nest structures. We suggest that Bay osprey productivity is not severely inhibited by the Bay’s turbid waters, but this question needs more direct investigation. Factors causing egg failure in the Bay colony remain unknown, but in addition to possible harassment by great horned owls during incubation, Bay ospreys and their prey may be exposed to a variety of industrial contaminants, from the northern portion of Delaware Bay, that may reduce reproductive success.

LITERATURE CITED


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