AN ENDANGERED OSPREY POPULATION: ESTIMATES OF MORTALITY AND PRODUCTION[1]

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MANY ornithologists have noted declines in Osprey (*Pandion haliatus carolinensis*) populations in the United States since the beginning of the twentieth century (Bent, 1937; Stone, 1937; Kenyon, 1947; Ames and Mersereau, 1964; Schmid, 1966; and others). The acceleration of these declines in the last 15 to 20 years is causing much concern among conservationists. It is axiomatic that, assuming no permanent emigration, a decline in population size results from (1) increased mortality, (2) decreased productivity, or (3) a combination of both of these.

This paper reports on estimates of mortality rates derived from reports of band recoveries from a segment of the northeastern population of Ospreys banded in New York and New Jersey from 1926 to 1961. Although these estimates do not necessarily reflect the mortality rates now being sustained by this population, they show the amount of production per nest needed to maintain the population and bring into focus the dynamics of the decline that has taken place.

ANALYSIS PROCEDURES

Recovery records of 330 Ospreys banded as nestlings in New York and New Jersey were obtained from the Bird Banding Laboratory of the U.S. Fish and Wildlife Service in Laurel, Maryland. New York bandings yielded 186 recoveries (56 per cent), New Jersey bandings 144 recoveries (44 per cent). Of these recoveries 225 were considered suitable for migration anlaysis and 290 for mortality analysis (life tables). In the migration analysis we used only records that included the exact date (month, day, and year) of recovery. For constructing life tables (mortality or survival) based on band recoveries, the status of the bird (dead or alive) when recovered must be known. Before being rectified by the 1965 revision of the banding codes, 20 of the 55 "how obtained" codes in the "Bird banding manual" failed to mention whether the bird was dead or alive. This rendered 35 recoveries (10.6 per cent) useless for life tables.

Five banded birds recovered in July during their first few weeks out of the nest were also discarded from the analysis because an initial date of 1 August was chosen. This date was selected for three reasons: (1) 96 per cent of the 1st-year recoveries occurred in the period August through the following July, (2) banding records should account for mortality from the time of departure from the nest which young Ospreys did at approximately this time, and (3) production data from nesting studies could thus be compared directly with the estimated production necessary to offset the annual mortality shown by recovery analysis.

[1] Technical Paper No. 2463, Oregon Agricultural Experiment Station, Corvallis.

TABLE 1

GEOGRAPHIC AND TEMPORAL DISTRIBUTION OF OSPREY RECOVERIES IN FIRST 2 YEARS OF LIFE

	1st year of life									2nd year					
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Mar.	May	June	Aug.	Oct.	Apr.	May	June	July
Me.	–	0,1[1]	–	–	–	–	–	–	–	–	–	–	–	0,1	–
N.H.	0,1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Vt.	–	0,1	–	–	–	–	–	–	–	–	–	–	–	–	–
Mass.	–	–	–	–	–	–	–	–	–	–	–	–	0,1	–	–
N.Y.	0,6	1,4	0,2	–	–	–	–	–	–	–	–	–	–	0,1	0,2
N.J.	10,3	5,1	1,0	–	–	–	–	–	–	–	–	–	–	–	–
Ind.	–	0,1	–	–	–	–	–	–	–	–	–	–	–	–	–
Pa.	–	1,3	0,1	1,0	–	–	–	–	–	–	–	–	–	–	–
Dela.	–	1,0	–	–	–	–	–	–	–	–	–	–	–	–	–
Md.	–	1,2	4,1	1,0	–	–	–	–	–	–	–	–	–	–	–
Va.	–	6,2	1,2	–	–	–	–	–	–	–	–	–	1,1	–	–
W.V.	0,1	2,3	–	–	–	–	–	–	–	–	–	–	–	–	–
Ky.	–	0,1	–	–	–	–	–	–	–	–	–	–	–	–	–
N.C.	1,0	4,5	0,4	0,1	–	–	–	1,0	–	–	–	–	–	–	1,0
S.C.	–	2,2	–	–	1,0	–	–	–	–	–	–	–	–	–	–
Ga.	–	0,1	0,1	1,0	–	–	–	–	–	–	–	1,1	1,1	–	–
Fla.	–	0,4	4,2	1,0	–	–	0,1	–	–	–	–	–	–	–	–
Ala.	0,1	0,1	0,1	–	–	–	–	–	–	–	–	–	1,1	0,1	–
Cuba	–	–	2,0	–	1,2	–	–	–	–	–	0,1	–	–	–	–
P.R.	–	–	1,0	1,0	–	–	–	–	–	–	–	–	–	–	–
Haiti	–	–	0,1	–	–	–	–	–	–	–	–	–	–	–	–
Panama	–	–	–	–	1,0	–	–	–	–	–	–	–	–	–	–
Ecuador	–	–	–	–	1,0	–	–	–	–	–	–	–	–	–	–
Ven.	–	–	–	–	1,0	1,0	–	1,0	–	–	–	–	–	–	–
Guiana	–	–	–	–	1,0	–	–	–	–	–	–	–	–	–	–
Colombia	–	–	–	–	–	–	–	1,0	1,0	–	0,1	–	–	–	–
Peru	–	–	–	–	1,0	–	–	–	–	–	–	–	–	–	–
Brazil	–	–	–	–	–	–	–	–	–	0,1	–	–	–	–	–
TOTALS	11, 12	23, 32	13, 15	5,1	7,2	1,0	0,1	3,0	1,0	0,1	0,2	1,1	3,4	0,3	1,2
Found dead	19	20	10	4	2	–	1	1	–	1	1	–	1	1	2
Shot	4	35	18	2	7	1	–	2	1	–	1	2	6	2	1

[1] The first figure denotes banded in New Jersey; the second banded in New York.

Suitable recoveries for life tables were divided into two categories: (1) birds shot and (2) birds found dead. The recoveries of birds shot included only one banding code (shot), while the found dead category included birds reported under 33 "how obtained" codes. These 33 codes were grouped together because the fate of the bird was known; it was dead.

Mortality was estimated by using composite dynamic life tables (Hickey, 1952). Initially the recovery data from New York and New Jersey were analysed separately, but the similarity in mortality rates and migration routes permitted combining the data from the two states to improve the sample size and reduce the random error.

BREEDING CYCLE AND MIGRATION

The breeding cycle of the New England Ospreys is conveniently summarized by Bent (1937) and Stone (1937), who show that Ospreys appear

TABLE 2

GEOGRAPHIC AND TEMPORAL DISTRIBUTION OF OSPREY RECOVERIES IN THE 3RD AND LATER YEARS OF LIFE

	Third and later years of life											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
Me.	–	–	–	–	–	–	–	–	–	–	0,1	–
Conn.	0,1[1]	–	–	–	–	–	–	–	0,2	–	–	–
R.I.	–	–	–	–	–	–	–	–	0,1	0,1	–	–
N.Y.	0,3	0,1	0,1	0,1	0,1	–	0,1	–	0,8	0,1	0,2	0,6
N.J.	2,0	–	–	1,0	–	–	–	–	3,1	3,0	1,0	1,0
Pa.	1,1	–	–	–	–	–	–	–	–	–	–	–
Dela.	–	–	–	–	–	–	–	–	3,0	–	–	–
Md.	–	–	–	–	–	–	–	1,0	1,1	–	–	–
Va.	–	1,0	–	–	–	–	–	–	1,0	–	0,1	–
N.C.	–	1,0	–	–	–	–	–	–	3,2	1,1	–	–
S.C.	–	–	–	–	–	–	–	1,0	0,1	–	0,1	–
Ga.	–	–	–	–	–	–	–	1,0	–	–	–	–
Fla.	–	–	0,1	–	–	–	–	2,0	–	–	–	–
Cuba	1,1	1,1	–	–	–	–	–	–	–	–	–	–
Virgin Is.	–	–	–	–	–	–	0,1	–	–	–	–	–
Haiti	–	–	–	–	–	0,1	–	–	–	–	–	–
Panama	–	–	–	0,1	–	–	–	–	–	–	–	–
Ven.	–	–	–	–	0,1	–	–	–	–	–	–	–
Colombia	–	–	–	0,1	–	–	–	–	–	–	–	–
Brazil	–	1,0	–	–	–	–	0,1	–	–	–	–	–
TOTALS	4,6	4,2	0,2	1,3	0,2	0,1	0,3	5,0	11,16	4,3	1,5	1,6
Found dead	7	4	2	2	1	–	1	2	15	6	6	5
Shot	3	2	–	2	1	1	2	3	12	1	–	2

[1] The first figure denotes banded in New Jersey; the second banded in New York.

in southern New England regularly during the last week of March, but the greatest numbers arrive during the first week of April. The recoveries of Ospreys banded as nestlings in New York and New Jersey indicate similar arrival times at the nesting areas for adult birds (Tables 1 and 2).

Incubation, which is apparently performed solely by the female, lasts about 28 days and the earliest date on which newly hatched young were found in Massachusetts was 25 May; the latest date for unhatched eggs was 18 June (Bent, 1937). Bent further notes that the young in Massachusetts usually do not leave the nest until the first week of August or possibly later. Stone (1937) reports seeing young in the nest being fed by the parents in New Jersey from 3 July to 26 August but has also seen young leave the nest as early as 2 August. He adds that the young regularly return to the nest to roost long after they first take wing. Nestlings in this study were banded in June (15 per cent), July (80 per cent), and August (5 per cent).

According to Ferguson and Ferguson (1922), the fall migration of Ospreys near Fishers Island, New York (12 miles west of Gardiners

Island, the principal banding area) begins about 1 September, but the birds are seen as late as 22 November. The greatest numbers of Ospreys passed through Cape May, New Jersey during the 2nd and 3rd weeks of September, 1935 (Allen and Peterson, 1936). The latest date for Ospreys at Cape May was 6 November for the period 1918 to 1935 (Stone, 1937). The recoveries of birds banded in New York and New Jersey (Table 1) show that some immatures start southward by the end of August and most young Ospreys have left the state in which they were banded by 31 October.

Worth (1936) summarizes the distribution of recoveries from Ospreys banded in Delaware, New York, and New Jersey up to July 1935, and Gillespie (1960) those from 16 seasons (1926–41) of banding in Cape May County, New Jersey, and Delaware. They both note recoveries from the West Indies and South America. First-year birds were found as far south as Cuba, Haiti, and Puerto Rico by 1 November (Table 1). The paucity of banded birds recovered in the United States after 1 January shows that almost all the population winters south of the United States. The fact that only two banded birds were reported in the United States (one in North Carolina and one in Florida) from 1 January of their 2nd calendar year until 1 April of their 3rd calendar year suggests that Ospreys do not return north to breed as 1-year-olds. Both recoveries were a considerable distance south of their natal area.

Osterlof (1951) notes the failure of Swedish Ospreys (*P. h. haliatus*) to leave the wintering area during the first summer. Bent (1937) published indirect evidence that Ospreys do not migrate north to nest as 1-year-olds. He notes that in the European Osprey "the throat and upper breast are pale brown, sometimes tinged with rusty, forming a broad pectoral band" and adds that "very few American birds even approach this condition; these may be the younger birds, for I believe that the breast becomes whiter with advancing age." Brasher (1936) states that the young of the American Osprey are also marked with buffy and brownish on the neck and underparts. Bent (1937) probably saw no birds in the rusty brown condition because few 1-year-olds remain in the United States after 1 December of their 1st year. Similar findings have been reported for 1-year-old White Storks (*Ciconia ciconia*) banded in Germany (Libbert, 1954) and for Common (*Sterna hirundo*) and Arctic Terns (*Sterna paradisea*) by Austin and Austin (1956).

Some Ospreys return north to their natal area in the United States as 2-year-olds (3rd calendar year of life) (Table 1). These birds first appear in April as evidenced by two banded birds shot in Georgia. Note that 8 of 13 2-year-old Ospreys recovered during the breeding season (May,

June, and July) were randomly distributed south of the natal area (Table 1). Two-year-old Swedish Ospreys are also found in the more northern latitudes and quite randomly distributed throughout western Europe (Osterlof, 1951). He further states that 2-year-olds do not breed although a few reach the breeding area. This is also assumed to be true for the American Osprey.

The paucity of recoveries from 3-year-old and older American Ospreys from outside the breeding area suggests that the species begins breeding at age 3. All recoveries of 3rd-year Swedish Ospreys were in the breeding area and ⅔ of them were within 100 km of the banding locality (Osterlof, 1951). On the basis of these data, it is assumed that all Ospreys 3 years old and older attempt to nest.

MORTALITY AND LONGEVITY

The first month after leaving the nest appears to be the most critical period for hawks and owls (Craighead and Craighead, 1956: 241). Hickey (1952: 86) calculated a 33 per cent mortality of fledgling Marsh Hawks (*Circus cyaneus*) between the time the young leave the nest and 1 August. Craighead and Craighead (1956: 241) state that young birds of prey usually remain in the vicinity of the nest and frequently return to the nest at night. They further note that at this stage young birds of prey are easily shot and sometimes entire broods are destroyed. Young Ospreys remain in the nest about 8 weeks, and during this period considerable mortality occurs. Bent (1937) notes that nests occupied by brooding birds in May were often empty and deserted long before the time for the young to have flown. Very few young Ospreys were shot in the state in which they were banded; most 1-year birds seem to be shot on their migration south (Table 1).

We consider that a life table based solely on recoveries of birds shot overestimates the 1st-year mortality rate, because shooting apparently accounts for a relatively small portion of the overall mortality and immatures are much more susceptible to gun pressure than adults. Moffitt (1935) was the first of many to note a differential vulnerability that favors the shooting of immatures, in this case Canada Geese (*Branta canadensis*). Our hypothesis that immature Ospreys similarly are more vulnerable to shooting than adults are is supported by the fact that 52 per cent of the found dead Osprey recoveries occur in their first year as compared to 63 per cent of the shot recoveries. If hunting accounted for 80 to 90 per cent of the annual Osprey mortality as it does in some goose populations (Rienecker, 1965; Henny, 1967), shot recoveries would provide a reasonable estimate of the overall mortality. As this is not the case in Ospreys, we conclude that the number of birds found dead each year, or a com-

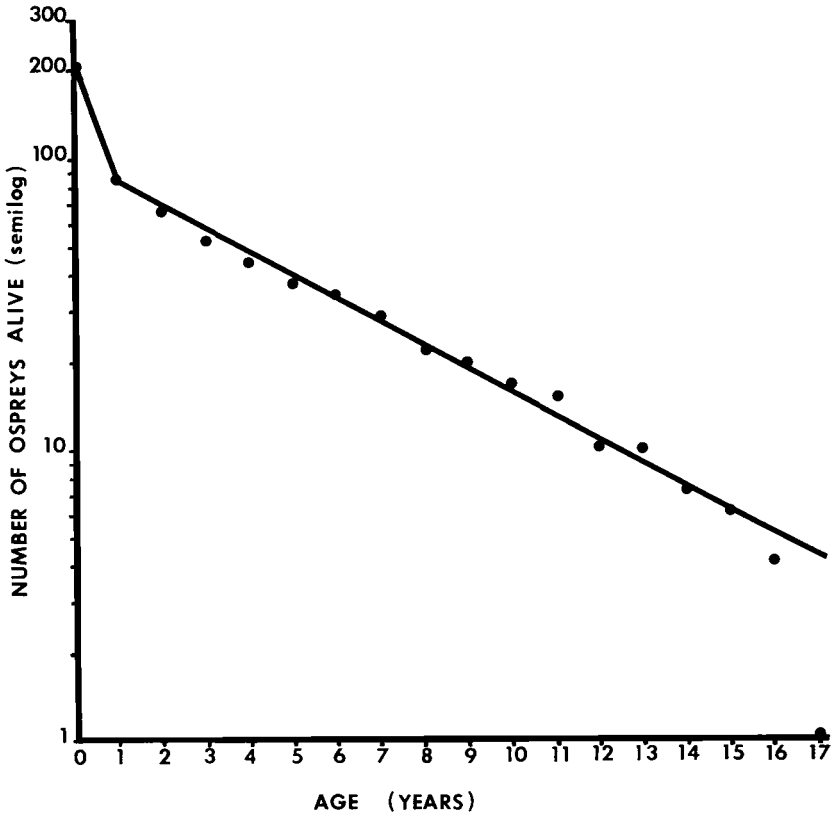

Figure 1. Number of Ospreys alive at the beginning of each year. Data are a composite from birds banded in New York and New Jersey, 1926–1947.

bination of birds in shot and found dead categories will yield the most accurate estimate of the mortality in the population.

The effect of band loss on estimates of mortality rates has been the topic of many recent papers (Hickey, 1952; Berger and Mueller, 1960; Paynter, 1966; Martinson and Henny, 1967; Ludwig, 1967). Loss of bands soon after banding and before the bird has become accustomed to the band is classified as "initial loss," and is usually a result of the bird pulling the band off with its bill. Ludwig (1967) watched a Herring Gull (*Larus argentatas*) remove a band only 2 hours after the band was applied. This initial loss of bands immediately after banding has no effect on mortality rates estimated from recoveries (Martinson and Henny, 1967). On the other hand, band losses from wear after the band has been on the bird for a considerable time do bias mortality rates considerably. Ludwig

TABLE 3
OSPREY MORTALITY RATES FROM RECOVERIES OBTAINED BY TWO METHODS[1]

Years of life	Found dead			Combined		
	No. of recoveries	Alive at beginning	Survival rate	No. of recoveries	Alive at beginning	Survival rate
1	52	101	48.5	118	206	42.7
2	8	49		20	88	
3	8	41		15	68	
4	7	33		8	53	
5	3	26		7	45	
6	1	23		3	38	
7	3	22	2nd through	6	35	2nd through
8	3	19	18th year	6	29	18th year
9	1	16	83.8 ± 2.1[2]	2	23	81.5 ± 1.8[2]
10	3	15		3	21	
11	1	12		2	18	
12	2	11		4	16	
13	0	9		1	12	
14	2	9		2	11	
15	2	7		3	9	
16	1	5		2	6	
17	3	4		3	4	
18	1	1		1	1	

[1] Found dead, and shot and found dead combined. As the oldest Osprey recovered here was 18 years old, by using 1947 as the last year of banding, the complete life span of the banded cohort was assumed to be reached by 1965. Recoveries include the year 1965.

[2] Standard error of the mean calculated by Haldane's (1955) method.

(1967) shows that loss of bands from wear begins to bias Ring-billed Gull (*Larus delawarensis*) data severely 4.5 years after bands are applied and accelerates through the 5th year to a constant rate of 38 per cent of the remaining bands per year from 6 years onward.

That band loss is of little if any moment in the Osprey recovery data is readily shown by plotting on semilogarithmic paper the number of birds alive at the beginning of each year as derived from the combined found dead and shot data (Figure 1). Assuming constant mortality among adults, loss of bands at a gradually increasing rate would cause the points to deviate from a straight line. As a straight-line relationship exists after the 1st year of life in Figure 1; we may conclude that either (1) band loss is negligible, or (2) band loss occurs at a constant rate throughout the population's life span. In either case the recovery data show the adult annual mortality rate to remain a constant 18 per cent from the 2nd through the 18th year.

The recovery data for Ospreys banded in New York and New Jersey between 1926 and 1947 are arranged in two composite dynamic life tables (Hickey, 1952), separated on the basis of how the recoveries were obtained (Table 3). Because of the relatively small number of Ospreys

TABLE 4

COMPOSITE DYNAMIC MORTALITY RATE ESTIMATES FOR OSPREYS BANDED AS NESTLINGS[1]

Year	Number banded	Years of life														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1948	145	7	1	–	–	2	–	–	–	–	–	–	–	–	–	–
1949	113	7	–	1	–	–	1	2	–	–	–	–	1	–	–	1
1950	107	7	–	–	–	1	–	–	–	–	2	1	–	–	–	–
1951	69	4	–	1	–	2	1	–	–	–	1	–	–	–	–	
1952	68	4	–	1	1	–	–	–	–	–	–	–	–	–		
1953	79	4	–	1	–	–	–	–	–	–	–	–	–			
1954	96	2	2	1	3	–	1	–	–	–	1	–				
1955	64	2	–	–	1	–	–	–	–	–	–					
1956	52	2	–	1	1	1	–	–	–	–						
1957	56	6	1	1	–	–	–	–	–							
1958	38	1	–	–	–	–	1	–								
1959	9	–	–	1	–	–	–									
1960	34	1	–	–	–	–										
1961	14	–	–	–	–											
TOTALS	944	47	4	8	6	6	4	2	0	0	4	1	1	0	0	1
No. available		944	944	944	944	930	896	887	849	793	741	677	581	502	434	365
Rec./1000		49.79	4.24	8.47	6.36	6.45	4.46	2.25	–	–	5.40	1.48	1.72	–	–	2.74
Alive at start		93.36	43.57	39.33	30.86	24.50	18.05	13.59	11.34	11.34	11.34	5.94	4.46	2.74	2.74	2.74
Mortality rate				1st year = 53.3				2nd through 15th = 19.6						Overall = 29.6		
Survival rate				1st year = 46.7				2nd through 15th = 80.4 ± 2.0						Overall = 70.4 ± 2.0		

[1] Banded between 1948 and 1961. Both shot and found dead recoveries are combined.

banded between 1948 and 1961, the shot and found dead recoveries were combined in Table 4. The rates of survival for the first year of life ranged from 48.5 per cent (found dead 1926–47) to 42.7 per cent (combined 1926–47). The estimated rate of average annual survival for adults (years 2–18) was between 83.8 ± 2.1 and 80.4 ± 2.0 per cent. The overall annual rate of survival for the population ranged 74.9 ± 2.2 per cent (found dead, 1926–47) to 69.8 ± 1.8 per cent (combined 1926–47).

We consider the combined recoveries for the two time periods (1926–47 and 1948–61) comparable, as recoveries of shot birds constitute 42 per cent of the birds reported between 1926 and 1947 and 39 per cent between 1948 and 1961. The first year survival rates (42.7 vs. 46.7 per cent) indicate little or no change between banding periods. Adult survival rates (81.5 ± 1.8 vs. 80.4 ± 2.0) and overall survival rates (69.8 ± 1.8 vs. 70.4 ± 2.0) are also essentially identical. Thus any decline in the size of the Osprey population between the periods 1926–47 and 1948–61 must result from decreased productivity rather than any increase in postfledging mortality rates.

PRODUCTIVITY OF THE POPULATION

From the data presented in two recent nesting studies (Ames and Mersereau, 1964; Kury, 1966) in Connecticut and Maine from 1957 to 1964, we computed the mean number of young fledged from 239 active nests to be 0.27 per nest. It is of significance to compare this estimate of productivity in Connecticut and Maine with the productivity necessary to balance our estimates of mortality.

Using a method developed by Henny et al. (1969), we may calculate the production requirements for a species that begins breeding at age 3 by the formula:

$$\bar{m} = \frac{1 - s}{s_0 s^2},$$

Where $\bar{m}$ = the average number of female fledglings produced per breeding age female ($2\bar{m}$ = the total number of young produced per breeding female assuming an equal sex ratio of fledglings.)

s = adult annual survival rate, where $s = 1 -$ annual mortality rate.

s_0 = 1st-year survival rate.

To balance the demonstrated mortalities, Table 5 shows that each breeding age female in the population must produce each year between 0.95 and 1.30 young per nest alive on the initial date, 1 August. Obviously current production at 0.27 fledgling per nesting female is considerably below that needed to maintain a stable population.

TABLE 5
PRODUCTION REQUIREMENTS AND RATE OF DECLINE OF OSPREY POPULATIONS

Source of mortality estimate	Found dead recoveries (1926–47)	Combined recoveries (1926–47)	Combined recoveries (1948–61)
Production requirements	0.95	1.30	1.22
Annual rate of decline (u)	–10.5%	–13.4%	–14.1%

FATE OF THE POPULATION

According to Peterson (1968), Gardiners Island (the principal banding area) had about 300 pairs of Ospreys in 1945 and about 20 pairs in 1965. This represents a decline of 12.9 per cent per year over the 20 year period.

From the New York and New Jersey banding data we may compute the expected annual rates of decrease in the population by the methods of Henny et al. (1969). Assuming that all Ospreys 3 years old and older attempt to nest and have a constant fecundity rate, we use the formula:

$$(1 + u)^2(1 + u - s) = \bar{m}s_0s^2,$$

where u equals the per cent change per year in the population.

Table 5 also shows the annual rates of decline based on the same survival and production estimates. These rates of decline agree closely with the average rate calculated from census data for Gardiners Island population between 1945 and 1965. It must be remembered that our estimated annual rates of decline, between 10.5 and 14.1 per cent assume all females 3 years old and older attempt to nest and thus may be minimal.

ACKNOWLEDGMENTS

We wish to acknowledge the invaluable contribution of the 24 ornithologists who banded Ospreys in New York and New Jersey. Special recognition is due S. LeRoy Wilcox whose banding at Gardiners Island, New York since 1928 yielded 43 per cent of the Osprey recoveries for this paper. Other major banders we would like to recognize include J. A. Gillespie, J. A. Jacobs, S. R. Lester, D. W. Warner, J. W. Aldrich, and C. B. Worth. The bandings by these ornithologists are prerequisite to any analysis and we gratefully acknowledge their contribution. Also, we would like to thank W. S. Overton, J. J. Hickey, B. J. Verts, and J. A. Wiens for critically reviewing the manuscript and offering many helpful suggestions. Our work was supported by Grant No. 14-16-008-922 from the Department of the Interior, Bureau of Sport Fisheries and Wildlife.

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