Presented at the 38th North American
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COMPARATIVE PRODUCTIVITY OF SIX BALD EAGLE POPULATIONS

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Charles L. Broley (1958) reported a drastic decline in a bald eagle (Haliaeetus leucocephalus) population during the late 1950's. He documented a marked reduction in the number of breeding pairs and the reproductive rate of the remaining pairs. In response to increasing concern for the future of the species, the National Audubon Society began to investigate the bald eagle over most of its range in 1960. The studies reported here have been closely coordinated with, or are integral parts of, a long term program to determine the status and examine the ecology of the bald eagle.

Knowledge pertaining to the bald eagle has been meager except for the findings of Francis H. Herrick (1924, 1932, 1933, 1934).

Herrick's monumental contribution, with the casual effort of others, has helped to sketch an outline but many gaps exist. Bald eagles build large conspicuous nests, usually in trees and to a lesser extent along cliffs or on sea stacks. The usual clutch size is two eggs but one and three eggs are common with clutches of four having been reported by oologists. After an incubation period of 34 or 35 days (Herrick, 1934) the young remain in the nest 10 to 12 weeks before fledging. After leaving the nest young eagles depend on parental care for several weeks and often return to the nest for food. Broley's (1947) banding results indicated that young eagles may move long distances after becoming self sufficient.

It is impossible to ascertain the "normal" reproductive rate of the bald eagles due to the lack of definitive studies. Two studies, however, offer some insight of what it might have been in past years. The first by W. Bryant Tyrrell (1936) was conducted during a single year near Chesapeake Bay. His observations on 53 active nests revealed that 46, or 87 percent, were successful with 95 young produced, for a reproductive rate of 2.1 young per successful nest and 1.8 young per active nest. Broley's (1947) work from 1939 through 1946 also exhibited a high success rate with 448 productive nests in 619 attempts for a success rate of 72 percent over a six year period. Analysis of Broley's figures for 384 of these attempts, which he reports in more detail, indicates that on the average 1.66 young were produced from each successful nest and 1.23 from each active nest. Both the percentages for successful nestings and the number of young raised reported by Tyrrell and Broley are higher than any found during the present investigations.

It is of course possible that prior to 1946 productivity was higher than has been recognized but a bias has been noted by the present authors which might explain the high success rates reported in the above works. Tyrrell worked entirely from the ground, traveling by car, boat and afoot. He started late in the season and located nests over an extended period. Broley was interested in banding young birds and often depended on other persons for information pertaining to the earlier stages of the breeding season. Because of these circumstances eagles failing early in their cycle could have been overlooked and nests recorded as unoccupied for that year. This would inflate the rate of success. Broley's figures, gathered over several years and based, in part, on actual climbs to the nests, probably show less bias. They are indeed closer to the upper limits of production reported in the present paper.

Methods and Definitions

The same basic methods of gathering data were used in the studies reported here. During the earlier work in Maine, Michigan, and Wisconsin, nests were located and checked from the ground but light aircraft were used in these areas after 1962 and throughout the studies in Florida and Alaska. The type of plane varied with time and location but observations were made at low altitude and at slow speed. This provided an excellent opportunity to observe nest contents which are quite difficult to see from the ground. Incubating eagles pay little attention to fixed-wing aircraft so it was often impossible to see eggs. If an adult was on the nest in a typical incubating posture, eggs were assumed to be present.

At least two checks of the nests were made during each nesting season. The first was made early in the breeding cycle to determine which territories contained adults at nests, and the second at a stage when fledglings 6 to 10 weeks old could be distinguished. Little mortality of young birds occurs after this period so nestlings counted during the second visit were assumed to have fledged.

Because of the difficulty in working with bald eagles, whose nests are often inaccessible, some of the usual methods of reporting reproductive success, such as the number of young produced from a known number of eggs, become impractical. Thus, a clear understanding of the terms used to report nest status in this paper is essential.

Breeding bald eagles occupy a definite territory containing one to several nests for which they show a high degree of tenacity over a period of years (Howell, 1954, 1958, 1968, and Howell and Heinzmann, 1967). The following terms and definitions are based on those discussed at the Bald Eagle Symposium held in 1965 at Port Clinton, Ohio and first committed to paper by Postuaplsky (1967).

The terms <u>active territory</u> and <u>active nest</u> are used here to indicate the same condition: the presence of a pair of eagles during the breeding season, in a territory which contained a nest. If a nest was occupied by an incubating eagle, or if eggs or young were seen, the presence of an adult pair was assumed. A successful nest is a nest from which at least one young fledged. Only those territories whose outcome in a given year was known are included.

The intensity of coverage in the six areas differed. Because of the high number of active territories (about 200) located within the large Kodiak National Wildlife Refuge and the limitations of manpower and equipment, only about 20 percent were sampled. In the Everglades National Park repeated coverage over an extended period of time and the low rate of new nest discoveries indicated that probably at least 95 percent of the nests occurring in the area were censused. The diminishing rate of discovery of new sites as the study progressed in Wisconsin, Michigan and Maine also indicated that samples approached the actual number of breeding pairs. For an overall average, however, the coverage throughout the time reported in this paper in the latter areas is estimated at 80 percent of the actual population.

This study included a total of 2036 nesting attempts over a 7 to 12-year period.

Results

At the inception of the Bald Eagle Project, one of the first tasks was to ascertain the distribution of nesting and wintering populations. The results of these surveys have been published in various progress reports (Sprunt and Cunningham, 1961, 1962; Sprunt and Ligas, 1963, 1966). Information for the eastern half of the United States showed that significant breeding populations could still be found in Florida, the Chesapeake Bay area, Maine, and the western Great Lakes States. Alaska, particularly southeastern Alaska, supported, probably as it always had, the largest breeding population of the species.

It became evident that eagles were reproducing at different rates according to locality so detailed studies were undertaken in specific areas with pertinent findings presented in Figure 1 and Table 1.

Eagles on the Kodiak National Wildlife Refuge were chosen as an example of Alaskan populations. They nest here in cottonwood trees bordering lakes and streams and along seaside cliffs or rocky islets (Troyer and Hensel, 1965). This large eagle population is believed to represent as nearly a normal situation as presently exists for this species. A productivity sample for this group is in Table 2.

One of the more surprising discoveries was that populations nesting fairly close together, or even contiguously, were reproducing at quite different rates. This is clearly demonstrated by the populations of the western Great Lakes States. Three discrete populations were recognized in Michigan and Wisconsin. One is located in the northern two tiers of counties in Wisconsin, away from the shores of the Great Lakes. This population was still reproducing at a rate presumed to be close to normal (Table 3).

A second population is located in the inland (again, away from the immediate shores of the Great Lakes) portion of the Lower Peninsula of Michigan. Reproductive success of this population was considerably lower than that noted in Wisconsin (Table 4).

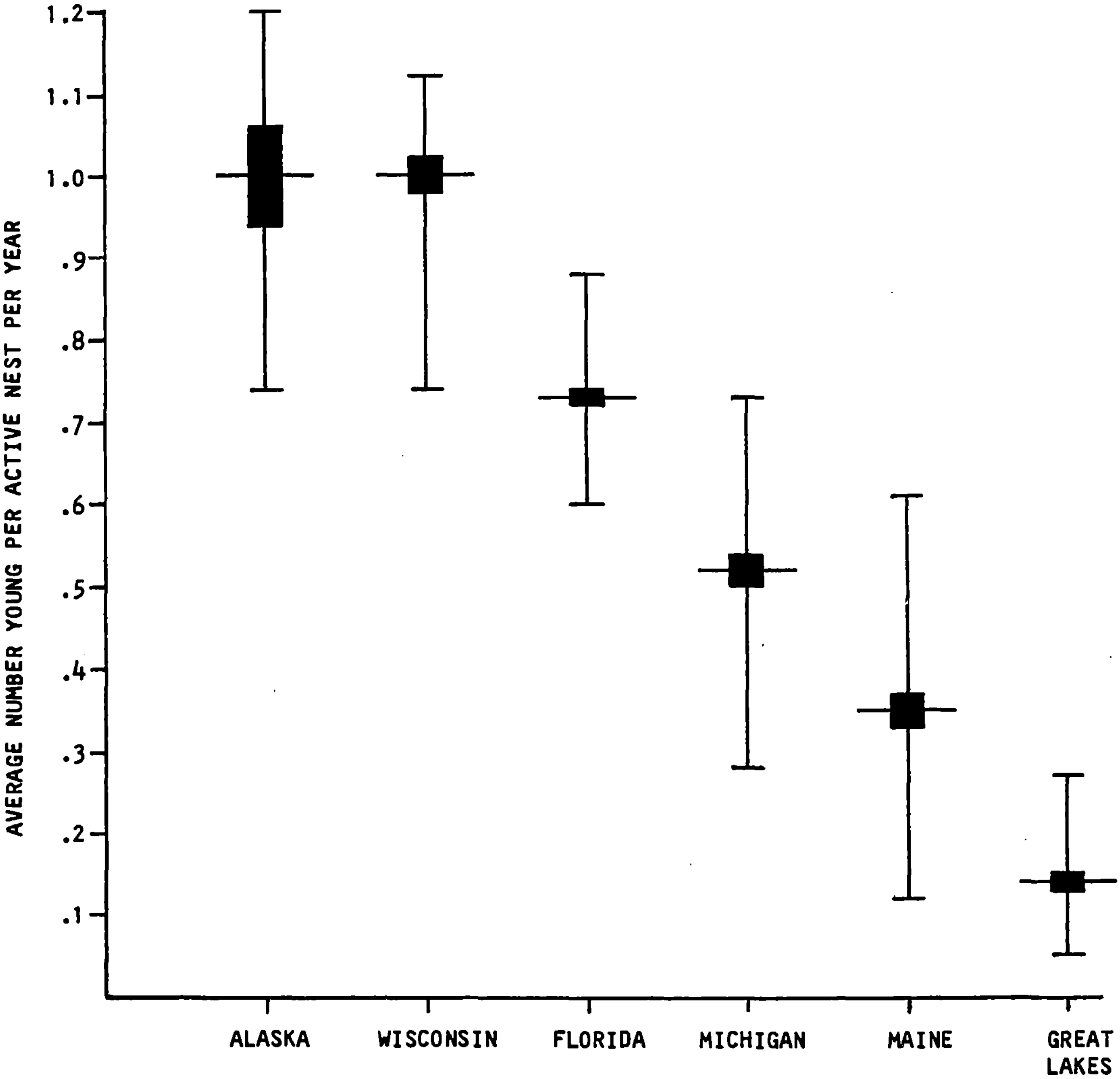

FIGURE 1. COMPARATIVE REPRODUCTIVE SUCCESS OF SIX BALD EAGLE POPULATIONS.

Rectangles represent standard errors of the means, vertical lines the observed ranges.

TABLE 1. COMPARATIVE PRODUCTIVITY OF SIX BALD EAGLE POPULATIONS

Population	Percent Nests Fledging Following Number Young 0	1	2	3	Total Number Nests	Number Years Data	Percent Nests Successful	Av.No.Yng. Successful Nest	Av.No. Yng.Active Nest/Yr.	Standard Error[5]
Alaska[1]	37	27	35	2	312	7	63	1.60	1.00	0.06
Wisconsin	34	33	30	3	492	9	66	1.55	1.00	0.02
Florida[2]	50	29	20	1	592	12	50	1.45	0.73	0.01
Michigan[3]	63	24	11	2	243	10	37	1.39	0.52	0.02
Maine	73	20	7	0	241	9	26	1.29	0.35	0.02
Great Lakes Shores[4]	90	8	3	0	156	10	10	1.31	0.14	0.01

1. Kodiak Island

2. Everglades National Park

3. Lower Peninsula only, excluding nests on Great Lakes

4. Michigan and Wisconsin shorelines, including Isle Royale

5. Adjusted using "finite population correction" (Snedecor and Cochran, 1967)

TABLE 2. PRODUCTIVITY OF BALD EAGLES AT THE KODIAK REFUGE, ALASKA

Year	Number Active Territories	Number Successful Nests	Percent Successful Nests	Total Number Young	Av. No. Young Fledged/ Successful Nest	Av. No. Young Fledged/Active Nest	Number and Percent of Nests Fledging Following Number of Young							
							0	%	1	%	2	%	3	%
1963	76	49	66	81	1.65	1.06	27	36	20	26	26	34	3	4
1964	45	22	50	37	1.68	0.82	23	51	8	18	13	29	1	2
1965	35	19	54	26	1.37	0.74	16	46	12	34	7	20	0	0
1966	39	24	63	38	1.58	0.97	15	38	10	26	14	36	0	0
1967	54	37	69	63	1.70	1.17	17	32	11	20	26	48	0	0
1968	35	24	68	42	1.75	1.20	11	31	8	23	14	40	2	6
1969	No data - eggs collected this year													
1970	28	22	79	30	1.36	1.07	6	21	14	50	8	29	0	0
Totals:	312	197	63	317	1.61	1.02	115	37	83	27	108	35	6	2

TABLE 3. BALD EAGLE PRODUCTIVITY IN WISCONSIN

Year	Number Active Territories	Number Successful Nests	Percent Successful Nests	Total Number Young	Av. No. Young Fledged/ Successful Nest	Av. No. Young Fledged/Active Nest	Number and Percent of Nests Fledging Following Number of Young: 0	%	1	%	2	%	3	%
1962	25	17	68	28	1.65	1.12	8	32	6	24	11	44	0	0
1963	38	24	63	40	1.69	1.05	14	37	9	24	14	37	1	3
1964	27	17	63	24	1.41	0.89	10	37	10	37	7	26	0	0
1965	35	21	60	26	1.24	0.74	14	40	16	46	5	14	0	0
1966	63	43	68	70	1.63	1.11	20	32	19	30	21	33	3	5
1967	72	49	68	70	1.43	0.97	23	32	30	42	17	24	2	3
1968	67	46	69	73	1.59	1.09	21	31	20	30	25	37	1	1
1969	83	60	72	93	1.55	1.12	23	28	33	40	21	25	6	7
1970	82	47	57	78	1.66	0.95	35	43	19	23	25	30	3	4
Totals:	492	324	66	502	1.55	1.02	168	34	162	33	146	30	16	3

TABLE 4. PRODUCTIVITY OF BALD EAGLES IN THE INLAND LOWER PENINSULA OF MICHIGAN

Year	Number Active Territories	Number Successful Nests	Percent Successful Nests	Total Number Young	Av. No. Young Fledged/ Successful Nest	Av. No. Young Fledged/Active Nest	Number and Percent of Nests Fledging Following Number of Young: 0	%	1	%	2	%	3	%
1961	20	7	35	10	1.42	0.50	13	65	4	20	3	15	0	0
1962	24	8	33	12	1.50	0.50	16	66	4	17	4	17	0	0
1963	21	5	23	6	1.20	0.28	16	76	4	19	1	5	0	0
1964	26	11	57	19	1.72	0.73	15	58	4	15	6	23	1	4
1965	28	9	32	12	1.33	0.42	19	68	6	21	3	11	0	0
1966	27	12	44	16	1.33	0.59	15	56	9	33	2	7	1	4
1967	30	11	36	15	1.36	0.50	19	63	8	27	2	7	1	3
1968	26	10	38	15	1.50	0.57	16	61	6	23	3	12	1	4
1969	22	9	40	11	1.22	0.50	13	59	7	32	2	9	0	0
1970	19	9	47	11	1.22	0.58	10	53	7	37	2	11	0	0
Totals:	243	91	37	127	1.39	0.52	152	63	59	24	28	11	4	2

The third population consists of those nesting close to the shores of the Great Lakes proper and where breeding eagles probably draw a large proportion of their food from the lakes. Production of young eagles is lower in this group of nesting pairs than in any other so far studied (Table 5).

Florida has more breeding bald eagles than any state except Alaska. In the Everglades National Park a population of approximately 50 to 55 pairs has been studied perhaps more thoroughly than any other breeding group. The availability of personnel and aircraft here led to a more careful assessment of this population than has been possible elsewhere (Table 6).

Another significant breeding population occurs in Maine at the other end of the Atlantic seaboard. Most bald eagles in Maine inhabit estuarine zones with only a remnant number of pairs still in the interior (Table 7).

Two factors were responsible for the observed difference in reproductive rates: (1) in populations with reduced productivity, a lower percentage of pairs produced young annually, (2) successful pairs in more productive populations fledged, on the average, more young annually than those in less productive populations. Both were significantly associated with variability in productivity (2x6 contingency tables, χ^2 = 236.3, 29.8 for factors (1) and (2) respectively, 5 d.f., $p < .001$). Since productivity per active nest is the product of factors (1) and (2), the more important factor is that which has the larger variance. Factor (1) has the larger variance

TABLE 5. PRODUCTIVITY OF MICHIGAN AND WISCONSIN GREAT LAKES BALD EAGLE NESTS

Year	Number Active Territories	Number Successful Nests	Percent Successful Nests	Total Number Young	Av. No. Young Fledged/ Successful Nest	Av. No. Young Fledged/Active Nest	Number and Percent of Nests Fledging Following Number of Young							
							0	%	1	%	2	%	3	%
1961	14	1	7	1	1.00	0.07	13	93	1	7	0	0	0	0
1962	14	1	7	2	2.00	0.14	13	93	0	0	1	7	0	0
1963	20	2	10	4	2.00	0.20	18	90	0	0	2	10	0	0
1964	18	1	6	1	1.00	0.05	17	94	1	6	0	0	0	0
1965	16	1	6	1	1.00	0.06	15	94	1	6	0	0	0	0
1966	25	4	16	5	1.25	0.20	21	84	3	12	1	4	0	0
1967	21	1	5	2	2.00	0.10	20	95	0	0	1	5	0	0
1968	11	3	27	3	1.00	0.27	8	73	3	27	0	0	0	0
1969	12	1	8	1	1.00	0.08	11	92	1	8	0	0	0	0
1970	5	1	20	1	1.00	0.20	4	80	1	20	0	0	0	0
Totals:	156	16	10	21	1.31	0.13	140	90	11	8	5	3	0	0

TABLE 6. PRODUCTIVITY OF BALD EAGLES IN THE EVERGLADES NATIONAL PARK

Year*	Number Active Territories	Number Successful Nests	Percent Successful Nests	Total Number Young	Av. No. Young Fledged/ Successful Nest	Av. No. Young Fledged/Active Nest	Number and Percent of Nests Fledging Following Number of Young							
							0	%	1	%	2	%	3	%
1961	45	20	44	29	1.45	0.64	25	56	11	24	9	20	0	0
1962	45	22	49	30	1.36	0.67	23	51	14	31	8	18	0	0
1963	51	31	61	42	1.35	0.82	20	39	20	39	11	22	0	0
1964	50	28	56	40	1.43	0.80	22	44	18	36	8	16	2	4
1965	50	26	52	41	1.58	0.82	24	48	12	24	13	26	1	2
1966	52	25	48	34	1.36	0.65	27	52	16	31	9	17	0	0
1967	50	27	54	39	1.44	0.78	23	46	16	32	10	20	1	2
1968	47	27	57	35	1.30	0.74	20	43	20	43	6	13	1	2
1969	52	22	42	34	1.55	0.65	30	58	11	21	10	19	1	2
1970	46	24	52	39	1.63	0.88	22	48	9	20	15	33	0	0
1971	51	24	47	35	1.46	0.69	27	53	14	27	9	18	1	2
1972	53	20	38	32	1.60	0.60	33	62	8	15	12	23	0	0
Totals:	592	296	50	430	1.45	0.73	296	50	169	29	120	20	7	1

*Bald eagles in the Park nest during the winter months. Therefore, a reproductive season encompasses 2 calendar years. As shown here, 1960 is actually 1959-1960; 1961 is actually 1960-1961, etc.

TABLE 7. PRODUCTIVITY OF BALD EAGLES IN MAINE

Year	Number Active Territories	Number Successful Nests	Percent Successful Nests	Total Number Young	Av. No. Young Fledged/ Successful Nest	Av. No. Young Fledged/Active Nest	Number and Percent of Nests Fledging Following Number of Young							
							0	%	1	%	2	%	3	%
1962	27	8	30	8	1.00	0.30	19	70	8	30	0	0	0	0
1963	32	9	28	12	1.33	0.38	23	72	6	19	3	9	0	0
1964	28	6	21	6	1.00	0.21	22	79	6	21	0	0	0	0
1965	33	4	12	4	1.00	0.12	29	88	4	12	0	0	0	0
1966	28	7	25	11	1.57	0.39	21	75	3	11	4	14	0	0
1967	21	4	19	6	1.50	0.29	17	81	2	10	2	10	0	0
1968	18	9	50	11	1.22	0.61	9	50	7	39	2	11	0	0
1969	24	9	38	12	1.33	0.50	15	63	6	25	3	13	0	0
1970	30	8	27	11	1.38	0.37	22	73	5	17	3	10	0	0
Totals:	241	63	26	81	1.29	0.35	177	73	47	20	17	7	0	0

(.05 versus .02). Therefore the percentage of successful pairs was a more important factor than the number of young per successful nest.

Annual fluctuations in reproductive success in four of the six populations were positively correlated with each other (Table 8). In five of the six possible paired comparisons of reproductive rates between the Alaska, Wisconsin, Great Lakes and Maine populations, the correlation was significant at $p < .10$. The sixth (Wisconsin and Great Lakes) was suggestive of the same generalization. In addition, the reproductive rate in Wisconsin was negatively correlated to that of Florida ($p < .05$).

Discussion

Of the six populations studied, three are declining in numbers and three are apparently stable. The number of breeding pairs comprising the inland Michigan, Maine and Great Lakes populations is declining. This is not apparent from the data presented here but the annual loss of pairs is obvious to investigators in the field. The loss is masked by a number of factors: the number of nests censused each year varied with the intensity of effort and was further affected by such elements as timing and weather. Also, new nests were continuously being found although the number has been sharply reduced in recent years. New nests do not necessarily indicate recent additions to the breeding population; they are quite likely to represent traditional sites not previously located. Eagles sometimes move to

TABLE 8. CORRELATION MATRIX
FOR REPRODUCTIVE SUCCESS IN SIX BALD EAGLE POPULATIONS

	Alaska	Wisconsin	Florida	Michigan	Maine	Great Lakes Shores
Alaska[1]	1	.73*	-.12	-.12	.80**	.71*
Wisconsin[2]		1	-.71**	.03	.77**	.54
Florida			1	-.09	-.39	.11
Michigan				1	.02	-.09
Maine[2]					1	.71**
Great Lakes Shores						1

Degrees of freedom = 8 except where noted

[1] d.f. = 5

[2] d.f. = 7

*$p < .10$

**$p < .05$

alternate nests between seasons and may not be discovered immediately. In areas where coverage is not intensive this can lead to problems in arriving at accurate population estimates.

It appears that in a given population, at least 50 percent of the breeding pairs of bald eagles must be productive and that the population as a whole must produce at least 0.7 young per active nest in order to maintain stability.

Due to the limited number of degrees of freedom (5-8) interpretation of the correlations of annual productivity in the various populations must be considered speculation (Table 8). It appears, however, that several populations, spread over a wide area, may be affected by a common factor. Postupalsky (1967) has commented on an apparent relationship between the severity of the weather during the winter preceding a given breeding season and the overall success of that season.

The marked negative correlation between the productivity of Wisconsin and Florida remains unexplained.

The reasons for the large differences in the reproductive rates of some of the bald eagle populations discussed in this paper have been examined in some detail. The principal factor seems to be the relative contamination of the various populations with hydrocarbon pesticides, principally DDT and its metabolites. The evidence for this will be presented in another paper in the near future.

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