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LOW PRODUCTIVITY OF BALD EAGLES ON PRINCE OF WALES ISLAND, SOUTHEAST ALASKA

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ABSTRACT.—I investigated reproductive success of Bald Eagles (*Haliaeetus leucocephalus*) on Prince of Wales Island, Alaska from 1991–93. Productivity (0.13 young produced per occupied territory) was the lowest recorded for the species throughout its geographic range. Productivity was not significantly different among different habitats including remote roadless areas vs. roaded and logged areas, which suggested that habitat alterations were not the cause of low productivity. Because nesting densities were high and I observed some effects of proximity of nearest neighbor pairs, I suggest these densities (proximate factor) were affecting productivity through reduced food availability (ultimate factor). However, I could not rule out the effects of environmental contaminants, although this seemed unlikely because of the distance of the island from industrial and agricultural areas. I discuss the various potential causes of this low rate of productivity.

KEY WORDS: *Bald Eagle*; Haliaeetus leucocephalus; *nearest-neighbor effects*; *productivity*; *southeast Alaska.*

Baja productividad de águilas calvas en la isla del Principe de Gales, sureste de Alaska

RESUMEN.—Investigué el éxito reproductivo de las águilas calvas (*Haliaeetus leucocephalus*) en la Isla del Príncipe de Gales, Alaska 1991–93. La productividad (0.13 juveniles producidos por territorio ocupado) fue la mas baja registrada para la especie a lo largo de su rango geográfico. La productividad no fue significativamente diferente entre los diferentes habitats incluyendo áreas remotas y sin carreteras vs. áreas de explotación maderera con carreteras, lo cual sugiere que las alteraciones del habitat no fuera la causa de la baja productividad. Debido a que las densidades de los nidos fueron altas, observe algunos efectos producidos por la proximidad de las parejas vecinas mas cercanas. Sugiero que estas densidades (factor próximo) estaban afectando la productividad reduciendo la disponibilidad de comida (factor último). Sin embargo, no pude medir los efectos de los contaminantes ambientales, aunque posiblemente no hubo debido a la distancia de la isla a las áreas industriales. Discuto las causas potenciales de esta baja tasa de productividad.

[Traducción de César Márquez]

Bald Eagles (*Haliaeetus leucocephalus*) are considered a Sensitive Species in Alaska and are managed under the Bald and Golden Eagle Protection Act (1940) and the Migratory Bird Treaty Act (1918). The most prominent factor for historical population declines in the state was the bounty system which was imposed on the species until 1953; however, populations have increased since mortalities from this system have stopped (Hodges et al. 1979). Southeast Alaska currently has large populations of breeding and wintering Bald Eagles. Alaska is considered a stronghold (Hodges et al. 1979, Hansen 1987) and provides high quality habitat for the species. However, high densities are not necessarily indicative of high quality habitat (Van Horne 1983) or sufficient demographic performance. Evaluating habitat quality should involve examination of the species' reproductive success and/or survival within the area. Habitat quality may also be influenced by human activities, because high quality habitats are often avoided because of the presence of humans (McGarigal et al. 1991).

There were several human activities that may have disturbed Bald Eagles on Prince of Wales Island, including road construction, vehicular traffic, helicopter overflights, and habitat alteration in the form of timber harvest. The purpose of this project was to investigate Bald Eagle productivity on the eastern shoreline of Prince of Wales Island, Alaska, and examine both "natural" and human-related factors that may influence productivity. Specifically, I hypothesized that human activities as a result of logging and road construction were having a detrimental effect on Bald Eagle productivity (Anthony and Isaacs 1989, McGarigal et al. 1991). Because of dense breeding populations, I also predicted that nearest-neighbor interactions may affect productivity (Anthony et al. 1994). Hansen (1987) suggested that food availability has an influence on productivity of Bald Eagles in southeast Alaska, so I was aware of this potential effect. However, prey availability is next to impossible to describe for this species because of their diverse diet of fish, birds, and mammals.

STUDY AREA

I conducted surveys of Bald Eagles and described productivity on the east side of Prince of Wales Island, Alaska The coastline in this region is variable. Some areas are very convoluted with many small bays and peninsulas, as well as numerous offshore rocks and islets. Other areas are essentially straight shorelines with few prominent points and steep slopes descending directly to the shoreline. Vegetation consists of forests dominated by Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). The study area consisted of shoreline between Mills Bay on the south and Lake Bay on the north, and small islands near the shoreline also were included in the study. In 1992, I expanded the study area to include Rose, Berry, Round, and the east side of Stevenson Islands (hereafter referred to as islets). Rivers or streams that support runs of salmon (*Oncorhynchus* spp.) within or near this area include Lake Bay, Coffman, Chum, Eagle, Ratz, Little Ratz, Sal, Cobble, Slide Creeks, and the Thorne River.

METHODS

Surveys. Surveys were conducted from April through September 1991–93 by foot, from vehicles, sea (14′ Gregor welded and 18′ Alumaweld boats), and air (Hughes 500D helicopter). Occupancy and productivity of nests were determined with two aerial surveys each year with four people on board the helicopter. One person recorded data while the others watched for eagles or nests. Locations of all eagles and nests were plotted on U.S. Geological Survey 1:63 360 maps or U.S. Forest Service maps of the study area. The first survey flight was conducted during the egg laying and incubation periods (7–8 May 1991, 6–7 May 1992, 3 May 1993) to determine occupancy of nesting territories. The second flight was conducted during the late nestling stage (3 and 8 July 1991, 28–30 July 1992, 3–4 August 1993) to determine productivity. In addition, a third survey flight was flown on 15 August 1991 to verify productivity at several nests. I also supplemented aerial surveys at as many nest sites as possible throughout the breeding season using boats or foot travel.

Terminology used in this paper follows that of Postupalsky (1974). A territory was occupied when two adults were observed in association with a nest or when an adult was observed on a nest. If an adult was observed on a nest in incubating posture or with young nestlings, a breeding attempt took place in the territory (Steenhof 1987). A territory was successful if fledglings, or nestlings near fledgling age, were observed. For the purposes of analysis, any occupied site that failed to produce fledglings was considered a failure.

Nearest-Neighbor Interactions. Because breeding populations were dense, I was interested in conspecific nearest-neighbor interactions and its potential influence on Bald Eagle productivity as described for Oregon (Anthony et al. 1994). Accordingly, I determined a Universal Transverse Mercator (UTM) location for each territory for each year. The location of occupied nests, if known, was used for the territory location. If no occupied nest was known for the territory, I used a nest within the area where eagles were frequently observed. If I failed to identify an occupied nest or breeding attempt within the area, I approximated a central point for all eagle observations within the territory during that year. I calculated the distance to the nearest occupied territory using the UTM locations for each territory occupied during a given year. I also calculated the distance to the second nearest territory, which was added to the nearest territory distance to provide the "total neighbor distance." The nearest and total neighbor distances were used to evaluate the potential effect of nearest-neighbors on productivity.

Statistical Analyses. For each year and for all years combined, I calculated three measures of productivity. Breeding success was defined as the percent of occupied sites that produced young, and productivity as the number of young fledged per occupied site. I also calculated the number of young fledged per successful site. Habitats surrounding nests were classified as unroaded and unlogged, roaded but unlogged, unroaded but logged, roaded and logged, and islet nests. Unroaded and unlogged habitats were those that had no roads or past logging history within ~1.6 km of the occupied nest or territory center. In contrast, roaded or logged habitats had roads or past logging history within 1.6 km of the nest or territory center. All logging activities were of the form of clearcut harvests. Chi-square tests or Fisher's exact test were computed to determine if the proportion of successful nests was significantly different among years. Analysis of variance was used to test for differences in the number of young produced per site among years and habitats. I used an alpha of 0.10 to determine significance for all statistical tests, because I wanted to minimize the probability of a Type II statistical error and maximize

Table 1. Occupancy and productivity of Bald Eagle nests on Prince of Wales Island, Alaska, 1991–93.

	1991	1992	1993	ALL YEARS
Sites surveyed	109	109	109	327
Occupied[a]	91 (84%)	98 (90%)	78 (72%)	267 (82%)
Breeding attempt[b]	47 (52%)	62 (63%)	41 (53%)	150 (56%)
Successful[b]	10 (11%)	10 (10%)	11 (14%)	31 (11%)
# Young fledged	11	10	13	34
# Young/occupied site	0.12	0.10	0.17	0.13
# Young/successful site	1.10	1.00	1.18	1.10

[a] Percent is based on number of sites surveyed.
[b] Percent is based on number of sites occupied.

power to detect any possible differences (Sokal and Rohlf 1981).

Nested analysis of variance (ANOVA) was used to test for differences in nearest and total neighbor distances using SAS (SAS Institute 1989). For both nearest neighbor distances, I compared active versus inactive nests and successful versus unsuccessful nests within years. Because sample sizes were unequal for many groupings of nest sites, Satterthwaite's approximation to the F statistic was used for both tests of activity nested within years (Sokal and Rohlf 1981). The standard simple approximation of the F statistic was used for both tests of success nested within years. I transformed both nearest and total neighbor distances using the square root transformation so the frequency distributions were normally distributed. Productivity at territories on the more remote islets was examined, because I hypothesized that these territories may not be influenced by nearest-neighbor interactions. A chi-square test of independence was used to compare breeding success at remote islets with that of nests in the remainder of the study area.

RESULTS

Productivity. I identified 109 breeding territories within the study area and 267 breeding attempts (territory occupancy) during the three years. Of these, 62 (57%) were occupied all three years, 34 (31%) were occupied for two years, and 13 (12%) were occupied in only one year. Ninety-one territories were occupied in 1991, and 47 (52%) breeding attempts were identified. Eleven young fledged from 10 successful nests. I identified 98 occupied territories in 1992, and 62 (63%) of these had breeding pairs. Ten young fledged from 10 successful nests. Seventy-eight territories were occupied in 1993, and 41 (53%) had breeding pairs. Thirteen young fledged from 11 successful nests. Productivity was extremely low for all years. The proportion of nests that were successful was not significantly different among years ($\chi^2 = 0.695$, df $= 2$, $P = 0.7065$) and averaged only 11% (Table 1). The number of young fledged per occupied site was not significantly different among years ($\chi^2 = 1.286$, df $= 2$, $P = 0.5257$) and averaged only 0.13 (Table 1). For all years, an average of 1.1 young fledged per successful nest (Table 1).

Timing of Nesting Failures. In 1991, 14 of the 29 breeding pairs (48%) failed by the early nestling stage. Of the 12 territories that were still occupied and could be monitored, eight succeeded in fledging young. In 1992, 19 territories failed to produce young, and 12 (63%) were still occupied on 27 May. Of these 12, only three were still occupied on 10 June, and all three were successful in fledging young. Therefore, 47% of failures occurred within the two-week period at the beginning of June, which corresponded with the late incubation period. The cause of nesting failures was not determined because I did not climb nest trees to inspect nests according to Anthony et al. (1994).

Influence of Habitat Condition on Productivity. Because there were no significant differences in productivity among years, data for different years were combined for this analysis. Productivity for the different habitat conditions also was extremely low, but there were significant ($P < 0.05$) differences among the habitat conditions. Productivity of islet territories was significantly higher ($P < 0.05$) than those in unroaded and unlogged, and in roaded and logged territories (Table 2). Overall, productivity of islet nests was the highest of all of the habitat conditions. Productivity of territories in unroaded and unlogged areas was not significantly ($P > 0.05$) higher than that of other habitats. When all territories that were either roaded or logged were combined (Table 2), there was no significant ($P > 0.17$) difference in productivity of this group of territories and that of sites in unroaded and unlogged sites. However, productivity of islet nests was significantly ($P = 0.0031$) higher

Table 2. Productivity of Bald Eagle nest sites on Prince of Wales Island in relation to habitat condition.

Habitat Condition	No. Occupied Sites	Breeding Success (%)	Young Fledged/ Occupied Site[a]
A. Separate analysis:			
Unroaded, unlogged	149	6	0.07[a]
Roaded, unlogged	5	0	0.00[a]
Unroaded, logged	22	18	0.18[a]
Roaded, logged	42	12	0.12[a]
Newly roaded and logged	36	22	0.25
Islets (undisturbed)	13	38	0.38
B Combined analysis:			
Unroaded, unlogged	149	6	0.07[a]
Roaded or logged	105	16	0.17[a]
Islets (undisturbed)	13	38	0.38

[a] Means with the same superscripts are not significantly ($P > 0.10$) different as determined by analysis of variance and a Bonferoni mean separation test.

Table 3. Mean (±SE) nearest and total neighbor distance (m) for all activity categories of Bald Eagle nests on Prince of Wales Island, 1991–93.[1]

Category	N	Nearest-Neighbor	Total Neighbor
1991	91	1130 (59)	2992 (135)
Unoccupied	44	1172 (75)[a]	3058 (173)[a]
Breeding attempt	47	1090 (92)[a]	2929 (207)[a]
Failed	81	1089 (58)[b]	2918 (133)[b]
Successful	10	1461 (259)[c]	3584 (586)[b]
1992	98	1048 (60)	2764 (127)
Unoccupied	36	952 (92)[a]	2560 (192)[a]
Breeding attempt	62	1104 (78)[a]	2883 (165)[a]
Failed	88	1081 (65)[b]	2810 (137)[b]
Successful	10	764 (117)[c]	2360 (281)[b]
1993	78	1341 (69)	3547 (159)
Unoccupied	37	1341 (112)[a]	3467 (245)[a]
Breeding attempt	41	1341 (86)[a]	3618 (208)[a]
Failed	67	1310 (77)[b]	3488 (173)[b]
Successful	11	1528 (145)[c]	3904 (388)[b]
All years combined	267	1162 (37)	3070 (82)
Unoccupied	117	1158 (55)[a]	3034 (121)[a]
Breeding attempt	150	1164 (50)[a]	3098 (112)[b]
Failed	236	1148 (39)[b]	3040 (86)[c]
Successful	31	1260 (119)[c]	3303 (271)[d]

[1] Means for nests with breeding attempts vs. those without and successful vs. failed comparisons were significantly ($P < 0.10$) different when followed by different letters. All comparisons were made within a column.

than that of territories in unroaded and unlogged areas for the combined analysis.

Nearest-Neighbor Analysis. Nearest-neighbor distances between all territories averaged 1162 m (range = 175–3937) for all years combined (Table 3). There were no significant ($P > 0.10$) differences between nearest-neighbor distances for nests with breeding attempts vs. those without or successful vs. unsuccessful nests for all years combined (Table 3). However, nearest-neighbor distance between nest with breeding attempts vs. those without was significant ($F = 7.50$, $P = 0.0795$) within years after annual variation was removed. This was probably the result of nearest-neighbor distances increasing in 1993 because fewer territories were occupied than in 1991 or 1992. There was no significant ($F = 2.74$, $P = 0.2124$) difference in nearest-neighbor distances between successful and failed nests for all years combined; however, the difference was significant ($F = 2.47$, $P = 0.0627$) for within-year comparisons. In 1991 and 1993, successful nests had larger nearest-neighbor distances than failed nests (Table 3). However, successful nests had smaller nearest-neighbor distances than failed nests in 1992.

Total neighbor distances averaged 3070 m (range = 355–8567) for all years (Table 3). Total neighbor distance was significantly different between nests with breeding attempts vs. those without ($F = 11.74$, $P = 0.0493$) when data were combined over all years, but activity was not significantly ($F = 0.72$, $P = 0.5399$) different for

Table 4. Productivity of Bald Eagle populations in North America.

REGION	OCCUPIED SITES	YOUNG FLEDGED/ OCCUPIED SITE	YOUNG FLEDGED/ SUCCESSFUL SITE	STUDY PERIOD	SOURCE
Colorado, Wyoming	85	1.21	1.92	1981–89	Kralovec et al. (1992)
Saskatchewan, Canada	48	1.06	1.82	1984–87	Dzus and Gerrard (1993)
Chesapeake Bay	1448	1.21	1.70	1981–90	Buehler et al. (1991)
Wisconsin	1469	1.30	1.69	1983–88	Kozie and Anderson (1991)
Northwest Ontario	1370	0.80[a]	1.67	1970–80	Grier (1982)
Arizona	45	0.80	1.63	1975–80	Grubb et al. (1983)
Alaska Peninsula, Alaska	43	0.97	1.61	1970	Hehnke (1973)
Kodiak Island, Alaska	312	1.00	1.59	1963–70	Sprunt et al. (1973)
Oregon	606	0.92	1.52	1979–92	Isaacs and Anthony (1992)
Wisconsin	492	1.00	1.52	1962–70	Sprunt et al. (1973)
Texas	193	0.98	1.50	1981–90	Maybie et al. (1994)
Gulkana River, Alaska	274	0.86	1.48	1989–93	Steidl et al. (1997)
Florida	592	0.73	1.46	1961–70	Sprunt et al. (1973)
Yukon Territory, Canada	39	1.05	1.46	1980–82	Blood and Anweiler (1990)
California	140	0.81	1.45	1970–91	Jenkins (1992)
Yellowstone Nat. Park, Wyoming	107	0.41	1.43	1972–79	Alt (1980), Swenson (1975)
Amchitka Island, Alaska	71	0.86	1.42	1972	Sherrod et al. (1976)
Maine	521	0.44[a]	1.35	1972–78	Todd (1979)
San Juan Islands, Washington	275	0.84	1.35	1975–80	Grubb et al. (1983)
New Brunswick, Canada	55	0.73	1.33	1974–80	Stocek and Pearce (1981)
Washington	866	0.87	1.32	1981–85	McAllister et al. (1986)
Prince of Wales Island, Alaska	267	0.13	1.10	1991–93	This study

[a] The population in this study area has been influenced by organochlorine contaminants.

within-year comparisons (Table 3). This result corresponded with the nearest-neighbor analyses and was probably the result of larger total neighbor distances being observed in 1993, because fewer sites were occupied than in 1991 or 1992. Total neighbor distance for all years combined was significant ($F = 6.17$, $P = 0.0864$) when comparing successful vs. unsuccessful nests within years. However, total neighbor distance did not differ according to success within-year ($P = 0.2571$).

I monitored nesting success of Bald Eagles on small islets in 1992 and 1993, because there was usually only one occupied territory per islet. Territories at these islets produced young more often than territories within the remainder of the study area ($\chi^2 = 90.6$, df = 1, $P = 0.0019$). Of the 13 occupied territories on islets, 5 (38%) were successful in producing at least one young. At "nonislet" territories, only 26 of 252 (10%) occupied territories were successful. Mean nearest-neighbor distance at islet territories was 1369.9 m, as compared to 1151.3 m at "nonislet" territories. Mean total neighbor distance at islet territories was 3521.5 m, compared to 3046.4 m at "nonislet" territories.

DISCUSSION

Productivity of Bald Eagles on Prince of Wales Island, Alaska, was extremely low for all three years and in all habitat conditions. The average number of young produced per occupied site (0.13) was the lowest reported for this species throughout its geographic range (Table 4). In addition, the number of young fledged per successful nest (1.10) was also the lowest recorded for Bald Eagles, including other areas in Alaska. Hansen et al. (1984) studied productivity of Bald Eagles in the Chilkat River Valley from 1979–83 and found that 32% of occupied territories were successful in producing young with mean productivity rate of 0.42 young per occupied site. Steidl et al. (1997) reported higher mean productivity (0.86 young/occupied site) on the Gulkana River of central Alaska.

Potential causes of nesting failures that can reduce productivity of Bald Eagle populations include human disturbance, contaminants, nestling mortality, infertile eggs, food stress, weather, nearest-neighbor effects, or the failure to lay eggs (Anthony et al. 1994). Of these causes, human disturbance, contaminants, nearest-neighbor interactions, and/or food stress were considered to be the most likely factors to cause the extremely low productivity of Bald Eagles on Prince of Wales Island. I found no evidence for human disturbance being a major influence on productivity, because nesting failures occurred along remote as well as human occupied shorelines during all three years. In addition, nest sites that were successful in producing young were associated with shorelines with human activities as frequently as those that were associated with uninhabited shorelines. Also, low productivity was prevalent in unroaded and unlogged as well as human inhabited areas. Consequently, my data do not support the original hypothesis that human disturbance (i.e., logging or road construction) had an effect on productivity of Bald Eagles on Prince of Wales Island.

My analysis of nearest-neighbor distances suggested that nearest-neighbor interactions may have influenced productivity. The higher nearest-neighbor distance for successful versus failed sites in 1991 and 1993, and the higher productivity of "islet" versus "nonislet" territories (large vs. small nearest-neighbor distances) support this explanation. The extremely low success rates of eagles within our study area prevented us from conducting nearest-neighbor analyses comparable to those of Anthony et al. (1994) for Oregon. However, they observed negative effects of nearest-neighbor pairs at greater distances (<3200 m) than those among most pairs on this study area ($\bar{x}$ = 1162 m, range = 175–3967 m). Therefore, it is possible that Bald Eagles on Prince of Wales Island were nesting so densely that all nests were subjected to nearest-neighbor interactions, which acted as a proximate effect on productivity.

Food stress is likely the ultimate factor influencing productivity on Prince of Wales Island and may result in nearest-neighbor interactions. Our limited data indicate that many of the nests failed during the egg-laying and incubation stages, which is a pattern associated with food-stressed populations (Newton 1979). Also, the spatially variable groupings of successful nests that I observed each year suggested local prey availability in these areas. Some of these groupings were in close proximity to streams with abundant salmon runs, which may have provided the necessary prey resources for successful reproduction. However, salmon were not present in streams until later in the summer after nesting failures have occurred. Other anadromous fishes such as eulachon (*Thaleichthys pacificus*), sand lance (*Ammodytes hexapterus*), and herring (*Clupea pallasi*) are some of the first foods available to eagles after the long winter, and their runs are highly variable spatially (P. Schempf pers. comm.). Consequently, the abundance of these fishes in space and time may influence Bald Eagle productivity. This is a hypothesis for future work and testing.

Several studies in Alaska have indicated that Bald Eagle productivity is controlled by prey abundance and/or availability. In southeastern Alaska, Hansen (1987) found that placing prey within Bald Eagle nesting territories increased their productivity. Hansen and Hodges (1985) attributed variability in breeding rates of Bald Eagles to variability in prey abundance. Lastly, Steidl et al. (1997) suggested that most variation in reproductive success of Bald Eagles along the Gulkana River in central Alaska was attributable to prey availability. The low productivity of Bald Eagles on Prince of Wales Island may be due to low prey abundance or availability (ultimate factor) and is displayed through nearest-neighbor interactions (proximate factor).

I could not rule out the possibility of environmental contaminants having an effect on productivity of Bald Eagles on Prince of Wales Island. This seemed unlikely because the area is remote from industrial and agricultural areas, the source of many pesticides that have been shown to effect Bald Eagle populations (Wiemeyer et al. 1984). However, elevated levels of DDE, PCBs, dioxins, or furans have been reported in waterfowl (Whitehead et al. 1990), seabirds (Elliott et al. 1989a), Great Blue Herons (*Ardea herodias*) (Elliott et al. 1989b), and Bald Eagles (Elliott et al. 1996) along the coast of British Columbia, Canada. The source of DDE and PCBs in these species of birds is unknown; however, the source of dioxins and furans is usually from pulp and paper mills that use bleaching processes to produce paper. These two compounds are reported to be some of the most toxic substances to birds, and effects on reproduction have been documented in laboratory experiments on wood ducks (White and Seginak 1994) in concentrations of parts per trillion. In addition, Estes et al. (1997) and Anthony et al. (1999) have recently found elevated levels of DDE and PCBs in Bald Eagles in the western Aleutian Islands of Alaska. Consequently, environmental contaminants may be accumulating in food chains and affecting Bald Eagle reproduction on Prince of Wales Island. The possible effect of environmental contaminants on productivity of bald eagles should be investigated by collecting eggs from nests over a 2–3 yr period (Wiemeyer et al. 1984, Anthony et al. 1993).

I may have studied the Bald Eagles on Prince of Wales Island during a time when productivity was extremely low because productivity may have improved. Continued monitoring of reproductive success on the island would help answer this question. Monitoring trends of prey populations, particularly salmon, herring, sand lance, eulachon, and smelt, could be important also. The timing, location, and magnitude of these runs may explain the clumped but sparse nature of successful breeding attempts of Bald Eagles that varies among years on the island. Data on eagle productivity and characteristics of anadromous fish runs over several years will be necessary to determine if any relation exists between the two, but such information could be valuable in determining the cause(s) of low productivity on Prince of Wales Island.

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LITERATURE CITED

ALT, K.L. 1980. Ecology of the breeding Bald Eagle and Osprey in the Grand Teton-Yellowstone National Parks Complex. M.S. thesis. Montana State Univ, Bozeman, MT U.S.A.

ANTHONY, R.G. AND F.B. ISAACS. 1989. Characteristics of Bald Eagle nest sites in Oregon. *J. Wildl. Manage.* 53. 148–159.

———, M.G. GARRETT, AND C.A. SCHULER. 1993. Environmental contaminants in Bald Eagles in the Columbia River estuary. *J. Wildl. Manage.* 57:10–18.

———, R.W. FRENZEL, F.B. ISAACS, AND M.G. GARRETT 1994. Probable causes of nesting failures in Oregon's Bald Eagle population. *Wildl. Soc. Bull.* 22:576–582.

———, A.K. MILES, J.A. ESTES, AND F.B. ISAACS. 1999. Productivity, diets, and environmental contaminants in nesting Bald Eagles from the Aleutian Archipelago *Environ. Toxicol. Chem.* 18:2054–2062.

BLOOD, D.A. AND G.C. ANWEILER. 1990. Nesting chronology and success of Bald Eagles in southwest Yukon *Northwest. Nat.* 71:9–11.

BUEHLER, D.A., J.D. FRASER, J.K.D. SEEGER, G.D. THERRES, AND M.A. BYRD. 1991. Survival rates and population dynamics of Bald Eagles on Chesapeake Bay. *J. Wildl. Manage.* 55:608–613.

DZUS, E.H. AND J.M. GERRARD. 1993. Factors influencing Bald Eagle densities in northcentral Saskatchewan. *J Wildl. Manage.* 57:771–778.

ELLIOTT, J.E., D.G. NOBLE, R.J. NORSTROM, AND P.E. WHITEHEAD. 1989a. Organochlorine contaminants in seabird eggs from the Pacific coast of Canada, 1971–1986. *Environ. Monit. Assess.* 12:67–82.

———, R.W. BUTLER, R.J. NORSTROM, AND P.E. WHITEHEAD. 1989b. Environmental contaminants and reproductive success of Great Blue Herons, *Ardea herodias*, in British Columbia, 1986–87. *Environ. Pollut.* 59:91–114.

———, R.J. NORSTROM, A. LORENZN, L.E. HART, H. PHILIBERT, S.W. KENNEDY, J.J. STEGEMAN, G.D. BELLWARD, AND K.M. CHENG. 1996. Biological effects of poly-chlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in Bald Eagle (*Haliaeetus leucocephalus*) chicks. *Environ. Toxicol. Chem.* 15:782–793.

ESTES, J.A., C.E. BACON, W.M. JARMAN, R.J. NORSTROM, R.G. ANTHONY, AND A.K. MILES. 1997. Organochlorines in sea otters and Bald Eagles from the Aleutian Archipelago. *Mar. Pollut. Bull.* 34:1–5.

GRIER, J.W. 1982. Ban of DDT and subsequent recovery of reproduction in Bald Eagles. *Science* 218:1232–1235.

GRUBB, T.G, R.L. KNIGHT, D.M. RUBINK, AND C.H. NASH 1983. A five-year comparison of Bald Eagle productivity in Washington and Arizona. Pages 35–45 *in* D.M. Bird [ED.], Biology and management of Bald Eagles and Ospreys. Harpell Press, Ste. Anne de Bellevue, Quebec, Canada.

HANSEN, A.J. 1987. Regulation of Bald Eagle reproduction rates in southeast Alaska. *Ecology* 69:1387–1392.

——— AND J.I. HODGES. 1985. High rates of nonbreeding adult Bald Eagles in southeastern Alaska. *J. Wildl. Manage.* 49:454–458.

———, E.L. BOEKER, J.I. HODGES, AND D.R. CLINE. 1984. Bald Eagles of the Chilkat Valley, Alaska: ecology, behavior, and management. Natl. Audubon Soc., New York, NY U.S.A.

HEHNKE, M.F. 1973. Nesting ecology and feeding behavior of Bald Eagles on the Alaska Peninsula. M.S. thesis, Humboldt State University, Arcata, CA U.S.A.

HODGES, J.I., J.G. KING, AND F.C. ROBARDS. 1979. Resurvey of Bald Eagle breeding population in southeast Alaska. *J. Wildl. Manage.* 43:219–221.

ISAACS, F.B. AND R.G. ANTHONY. 1992. Bald Eagle nest locations and history of use in Oregon 1971 through 1992. Oregon Coop. Wildl. Res. Unit, Oregon State University, Corvallis, OR U.S.A.

JENKINS, J.M. 1992. Ecology and behavior of a resident population of Bald Eagles. Ph.D. dissertation, Univ. California, Davis, CA U.S.A.

KOZIE, K.D. AND R.K. ANDERSON. 1991. Productivity, diet, and environmental contaminants in Bald Eagles nesting near the Wisconsin shoreline of Lake Superior. *Arch. Environ. Contam. Toxicol.* 20:41–48.

KRALOVEC, M.L., R.L. KNIGHT, G.R. CRAIG, AND R.G. MCLEAN. 1992. Nesting productivity, food habits, and nest sites of Bald Eagles in Colorado and southeastern Wyoming. *Southwest. Nat.* 37:356–361.

MAYBIE, D.W., M.T. MERENDINO, AND D.H. REID. 1994. Dispersal of Bald Eagles fledged in Texas. *J. Raptor Res.* 28:213–219.

MCALLISTER, K.R., T.E. OWENS, L. LESCHNER, AND E. CUMMINS. 1986. Distribution and productivity of nesting Bald Eagles in Washington, 1981–1985. *Murrelet* 67: 45–50.

MCGARIGAL, K., R.G. ANTHONY, AND F.B. ISAACS. 1991. Interactions of humans and Bald Eagles in the Columbia River estuary. *Wildl. Monogr.* No. 115.

NEWTON, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD U.S.A.

POSTUPALSKY, S. 1974. Raptor reproductive success: some problems with methods, criteria, and terminology. *Raptor Res. Rep.* 2:21–31.

SAS INSTITUTE INC. 1989. SAS/STAT user's guide, version 6, 4th Ed. SAS Institute Inc., Cary, NC U.S.A.

SHERROD, S.K., C.M. WHITE, AND F.S.L. WILLIAMSON. 1976. Biology of the Bald Eagle on Amchitka Island, Alaska. *Living Bird* 15:143–182.

SOKAL, R.R. AND F.J. ROHLF. 1981. Biometry: the principles and practice of statistics in biological research, 2nd Ed. W.H. Freeman and Co., New York, NY U.S.A.

SPRUNT, A., IV, W.B. ROBERTSON, JR., S. POSTUPALSKY, R.J. HENSEL, C.E. KNODER, AND F.J. LIGAS. 1973. Comparative productivity of six Bald Eagle populations. *Trans. N. Am. Wildl. Nat. Resour. Conf.* 38:96–106.

STEENHOF, K. 1987. Assessing raptor reproductive success and productivity. Pages 157–170 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird [EDS.], Raptor management techniques manual. Natl. Wildl. Fed., Washington, DC U.S.A.

STEIDL, R.J., K. KOZIE, AND R. G. ANTHONY. 1997. Productivity of Bald Eagles in central Alaska. *J. Wildl. Manage.* 61:1313–1321.

STOCEK, R.F. AND P.A. PEARCE. 1981. Status and breeding success of New Brunswick Bald Eagles. *Can. Field-Nat.* 95:428–433.

SWENSON, J.E. 1975. Ecology of the Bald Eagle and Osprey in Yellowstone National Park. M.S. thesis, Montana State Univ., Bozeman, MT U.S.A.

TODD, C.S. 1979. The ecology of the Bald Eagle in Maine. M.S. thesis, Univ. Maine, Orono, ME U.S.A.

VAN HORNE, B. 1983. Density as a misleading indicator of habitat quality. *J. Wildl. Manage.* 47:893–901.

WHITE, D.H. AND J.T. SEGINAK. 1994. Dioxins and furans linked to reproductive impairment in wood ducks. *J. Wildl. Manage.* 58:100–106.

WHITEHEAD, P.E., J.E. ELLIOTT, R.J. NORSTROM, AND K. VERMEER. 1990. PCDD and PCDF contamination of waterfowl in the Strait of Georgia British Columbia, Canada: 1989–90. *Organohalogen Compounds* 1:459–462.

WIEMEYER, S.N., T.G. LAMONT, C.M. BUNCK, C.R. SINDELAR, F.J. GRAMLICH, J.D. FRASER, AND M.A. BYRD. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in Bald Eagle eggs—1969–1979—and their relationships to shell thinning and reproduction. *Arch. Environ. Contam. Toxicol.* 13:529–549.

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