

DIFFERENCES IN DISTRIBUTION OF BREEDING, NONBREEDING, AND MIGRANT BALD EAGLES ON THE NORTHERN CHESAPEAKE BAY¹

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Abstract. We compared the distributions of resident breeding, resident nonbreeding, and northern and southern migrant Bald Eagles (*Haliaeetus leucocephalus*) on the northern Chesapeake Bay from 1984–1988. Breeding eagles were dispersed throughout most of the study area and were resident all year. Dispersion of Chesapeake nonbreeding eagles was similar to the dispersion of breeding birds on the northern Chesapeake in summer and winter. Chesapeake nonbreeding eagles moved throughout most of the bay, $\leq 5\%$ of radio-tagged eagles were off the bay during any month. Radio-tagged northern migrants arrived in late fall ($\bar{x} = 21$ December, $n = 7$, range = 61 days) and departed in early spring ($\bar{x} = 27$ March, $n = 14$, range = 43 days). In contrast to local eagles, northern migrants were concentrated almost exclusively on Aberdeen Proving Ground, Maryland. Radio-tagged southern migrants arrived throughout April–August ($\bar{x} = 6$ June, $n = 11$, range = 94 days) and departed from June–October ($\bar{x} = 3$ September, $n = 22$, range = 119 days). Southern migrants were more dispersed than the northern migrants but less dispersed than the resident eagles. Northern Chesapeake eagle abundance peaked twice annually; in winter (e.g., 261 eagles, December 1987), due to the presence of northern eagles, and in summer (e.g., 604 eagles, August 1988), due to the presence of southern birds.

Key words: *Abundance; Bald Eagle; Chesapeake Bay; distribution; habitat; Haliaeetus leucocephalus; Maryland; migration; population dynamics.*

INTRODUCTION

Bald Eagle (*Haliaeetus leucocephalus*) assemblages may include breeding birds associated with nest sites, mature or immature birds that are summering or wintering away from their breeding areas, resident immature birds, and resident mature birds without mates or breeding sites. The Chesapeake Bay, for example, is used by eagles from three geographically-isolated breeding populations in the northeastern, southeastern, and mid-Atlantic regions of the United States (Broley 1947, McCollough 1986).

Local and migratory eagles may have different distributions because of different resource requirements, differing abilities to find or use local resources, or because of social interactions, such as territoriality. Movements of individuals with-

in each group continuously alter the distribution of that group. Description of distribution and movement patterns of resident and migrant, and breeding and nonbreeding eagles is the first step toward understanding their respective resource needs. In this paper, we describe the dynamics of eagle distribution on the northern Chesapeake Bay, test the hypothesis that resident breeding, resident nonbreeding, and migrant eagles have different distributions, and describe eagle abundance in light of the movements of eagles in the various groups.

STUDY AREA

The study area (Fig. 1) was the Chesapeake Bay and shoreline habitats from the Bay Bridge at Annapolis to the Conowingo Dam on the Susquehanna River, encompassing 3,512 km². The area included 2,472 km of bay, river, and creek shoreline and extended inland to the head of all major tributaries except the Susquehanna and Chester rivers.

We divided the study area into four parts for

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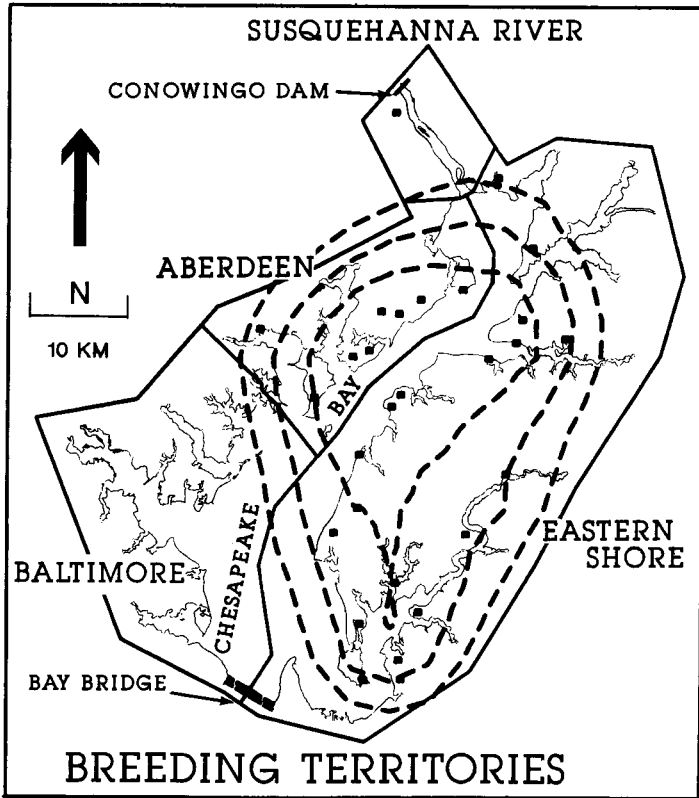


FIGURE 1. Four major divisions of the study area (Aberdeen, Baltimore, Eastern Shore, and Susquehanna River areas; solid lines), Bald Eagle breeding territories in 1988 (squares), and harmonic-means activity-area model 50%, 80% and 95% distribution contours (dashed lines).

analysis based on land ownership patterns and habitat homogeneity within each area (Fig. 1). Shoreline lengths for the four areas were 1,212 km, 699 km, 483 km and 78 km for the Eastern Shore, Baltimore, Aberdeen, and Susquehanna River areas, respectively. Habitat on the study area included coastal lowland oak-gum (*Quercus* spp.-*Liquidambar styraciflua*) forests on Aberdeen, agricultural fields with scattered oak-gum woodlots on the Eastern Shore, upland and lowland oak-gum-hickory (*Carya* spp.) forests along the Susquehanna River valley, and a largely urban-suburban setting near Baltimore.

METHODS

BALD EAGLE DISTRIBUTION

Breeding eagles. We monitored the distribution of breeding adults using records obtained from the Maryland Department of Natural Resources

(G. D. Therres, Md. Dep. Nat. Res., pers. comm.) and by conducting aerial nest searches in fixed-wing aircraft.

Radio-telemetry. We monitored the distribution and movements of nonbreeding eagles and the movements of one breeding eagle using radio-telemetry. We trapped 31 nonbreeding eagles using floating noose-fish (Cain and Hodges 1989) and padded leghold traps (Young 1983) and radio-tagged 28 northern Chesapeake eaglets at 8–10 weeks of age during 1984–1987.

Eagles were equipped with 65-g radio transmitters with solar-charged nickel-cadmium batteries (Telemetry Systems, Inc., Mequon, Wis.) and had an expected life of three to five years. We mounted radios dorsally on the eagle using a brown 1-cm wide teflon ribbon harness (Bally Ribbon Mills, Bally, Pa.).

We tracked eagles two to three times weekly from fixed-wing aircraft and recorded locations

to the nearest 25 m on 7.5-min U.S. Geological Survey (USGS) topographic maps. When more than 10 radio-tagged eagles were on the study area, we randomly selected 10 eagles for visual relocation on each flight and ascribed the rest to our four general locations (Fig. 1).

We compared relative use of general areas based on the number of radio-tagged eagle locations per area per flight and the number of locations per flight per shoreline km for each area. We used a general linear model by ranks in a two-way analysis (Hettmansperger and McKean 1978) to test for differences in Chesapeake eagle use by area and seasons. We used the χ^2 approximation of the Kruskal-Wallis test in a one-way analysis (Hollander and Wolfe 1973) to test for differences in migrant eagle use among areas in the primary season that northern eagles were present (winter) and southern eagles were present (summer). We used the multiple response permutation program (MRPP, Zimmerman et al. 1985) to test for differences among the distributions of Chesapeake breeding sites, Chesapeake nonbreeding eagle locations, and migrant eagle locations. We further evaluated distributional differences among eagle groups by conducting harmonic-means activity-area analyses (Dixon and Chapman 1980), using computer software developed by Coleman and Jones (1988). We used the 50% contour of the harmonic means model to indicate high activity areas and the 95% contour to show the breadth of the distribution.

Radio-tagged eagle movements were monitored off the study area by using monthly relocation flights on the remainder of the Chesapeake Bay and the lower portions of its tributaries from September 1986–August 1988. We conducted a two-way analysis of variance of the number of days eagles spent on the northern Chesapeake and the lower Chesapeake each month to determine whether eagle use changed among months and between years. We tested for differences in the frequency of movement between areas, among months and between years using log-linear analyses. An α -value of 0.05 was used for determining goodness of fit of the various log-linear models.

Shoreline surveys. We surveyed the same 614 km of contiguous shoreline monthly in fixed-wing aircraft from September 1985–August 1988 to estimate eagle abundance. We excluded the intensively-developed Baltimore area because we

never located radio-tagged eagles there, no nesting occurred there, and because of federal flight rules. We also excluded the Chester river drainage because of time constraints after a trial survey indicated the Chester river was similar in eagle use to the remainder of the Eastern Shore. Surveys began at about 30 min after sunrise and were flown along the shoreline at 150 km/hr, 50 m above the water and 50 m offshore. The same pilot and an experienced front-seat observer spotted eagles; a back-seat observer recorded locations on 7.5-min USGS topographic maps.

Shoreline surveys included breeding adults and nonbreeding adults. We estimated the number of nonbreeding eagles on each survey by subtracting from the survey total any adults (up to two) observed within 3 km of occupied nests (81% of the locations of one radio-tagged adult were within 3 km of its nest). Nonbreeding adults may have been located within 3 km of nests and counted as breeding birds, thus this approach underestimated the number of nonbreeding birds.

We did not see every eagle on the study area during each survey because (1) they were on the survey route but obscured by foliage (visibility bias, Caughley 1974, Grier 1977); or (2) they were on the study area but off the survey route. We estimated the total number of eagles on the study area at the time of each survey by estimating the percent of eagles missed for each month and adjusting the survey upward accordingly. We estimated visibility bias for each month of the year using data from radio-tracking birds on the shoreline survey route. We noted the percent of radio-tagged eagles spotted on the first pass along the shoreline and assumed that those spotted on the first pass would have been spotted on a single-pass shoreline survey (Table 1). Because use of the radio-telemetry gear probably increased the likelihood of spotting an eagle on the first pass along the shoreline, this approach underestimated the number of eagles missed on shoreline surveys.

To account for birds on the study area but off the survey route, we divided monthly survey totals by the monthly percent of radio-tagged eagle locations that occurred on the shoreline survey route (Table 1). The estimate of nonbreeding eagles was added to the number of known breeding birds on the study area to yield the total population estimate. We used Page's (1963) nonparametric test for ordered alternatives to test the

TABLE 1. Monthly values of visibility bias (1/percent of eagles seen on surveys) and survey route coverage (1/percent of eagles on survey route) coefficients and the product of these coefficients used to extrapolate aerial shoreline survey data to total eagle abundance, northern Chesapeake Bay, Maryland, 1985–1988. Visibility bias and survey coverage correction factors were estimated from radio-telemetry data.

	Visibility bias			Survey coverage			Total correction factor
	<i>n</i>	% seen	Correction factor	<i>n</i>	% on route	Correction factor	
January	8	75.0	1.33	82	54.9	1.82	2.42
February	32	71.9	1.39	105	66.7	1.50	2.09
March	51	66.7	1.50	159	57.2	1.75	2.63
April	22	45.5	2.20	89	55.1	1.81	3.98
May	31	45.2	2.21	116	69.0	1.45	3.20
June	20	35.0	2.86	120	65.0	1.54	4.40
July	28	42.9	2.33	214	50.9	1.96	4.57
August	29	31.0	3.23	210	58.1	1.72	5.56
September	13	46.2	2.16	121	61.2	1.64	3.54
October	44	52.3	1.91	167	63.5	1.58	3.02
November	32	53.1	1.88	106	64.2	1.56	2.93
December	31	64.5	1.55	52	55.8	1.79	2.77

hypothesis that the eagle population increased each September–August survey year. We then used Wilcoxon signed-rank tests to compare individual pairs of years.

IDENTIFYING EAGLE ORIGIN

To examine differences in distribution between Chesapeake Bay-hatched birds and migratory birds, we classed each radio-tagged eagle based on its origin. We knew the origin of the 28 eagles we radio-tagged as Chesapeake nestlings. Additionally, we trapped seven free-flying eagles that previously had been banded as nestlings (five from Chesapeake nests, one from Maine, and one from South Carolina). We also tracked 22 eagles that had been radio-tagged as nestlings in Florida (P. B. Wood and M. W. Collopy, Univ. Florida, pers. comm.). We classed origin of the unbanded eagles we trapped as northern, Chesapeake Bay, or southern based on the similarity of the timing and direction of their migratory movements to the movements of eagles of known origin. Winter-trapped eagles that left the bay in February–April and returned in November–January were classed as northern birds. Summer-trapped eagles that left the bay in August–October and returned in spring–summer were classed as southern birds. Eagles trapped during any time of the year that were located on the bay throughout the year were classed as Chesapeake Bay birds. We did not use size to discriminate among eagles of different origins because Chesapeake and Florida eagles overlapped in size (Buehler et al., unpubl.

data). We trapped 24 previously unbanded eagles and classified 12 as southern, four as Chesapeake Bay birds, and eight as northern birds.

RESULTS

EAGLE DISTRIBUTION

Breeding birds. There were 12 known breeding areas (24 adults) on the northern Chesapeake in 1984, increasing to 28 areas (56 adults) by 1988 (Fig. 1). Aberdeen and the Eastern Shore had similar breeding densities (eight Aberdeen breeding areas in 1988, one nest/60.5 shoreline km and 19 Eastern Shore breeding areas, one nest/63.9 shoreline km). The 50% contour of the harmonic-means model of the distribution was centered between the Eastern Shore and Aberdeen areas. The Susquehanna River Valley had one active territory (1 nest/78 shoreline km), whereas no nesting activity was observed along 699 km of Baltimore shoreline.

Nonbreeding birds. Northern Chesapeake use by Chesapeake nonbreeders differed among areas and seasons ($P < 0.001$, 0.001, locations, locations/km, respectively, Table 2). The Chesapeake nonbreeding eagle distribution was more concentrated on the Susquehanna area in fall than was the breeding distribution ($P < 0.01$) and the nonbreeders were more concentrated on the Aberdeen area in spring than was the breeding distribution ($P < 0.01$, Table 3, Figs. 1, 2). Summer and winter Chesapeake nonbreeding distributions, in contrast, differed from each other ($P <$

TABLE 2. Mean number of radio-tagged eagle locations per flight and number/shoreline km by season and geographic area of the northern Chesapeake Bay, Maryland, 1984–1988, by eagle origin.

Origin/season	Flights	Geographic area							
		Aberdeen Proving Ground		Eastern Shore		Susquehanna River Valley		Total	
		\bar{x}	\bar{x}/km	\bar{x}	\bar{x}/km	\bar{x}	\bar{x}/km	$\Sigma \bar{x}$	$\Sigma \bar{x}/\text{km}$
Chesapeake^a									
Winter	53	3.30	0.007	2.21	0.002	0.26	0.003	5.77A	0.012A
Spring	53	5.13	0.011	2.79	0.002	0.06	0.001	7.98B	0.014B
Summer	53	6.30	0.013	6.06	0.005	0.70	0.009	13.06C	0.027C
Fall	53	1.96	0.004	3.62	0.003	1.58	0.020	7.16B	0.027C
All seasons	212	4.17A	0.009X	3.67A	0.003Y	0.65B	0.008Z	8.49	0.020
Northern^b									
Winter	53	2.02A	0.004X	0.36B	0.000Y	0.19B	0.002Y	2.57	0.006
Spring	53	0.28	0.001	0.00	0.000	0.04	0.000	0.32	0.001
Summer	53	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Fall	53	0.02	0.000	0.08	0.000	0.00	0.000	0.10	0.000
All seasons	212	0.58	0.001	0.11	0.000	0.06	0.001	0.75	0.002
Southern^c									
Winter	53	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
Spring	53	0.68	0.001	0.00	0.000	0.17	0.002	0.85	0.003
Summer	53	0.83A	0.002X	0.17B	0.000Y	0.55A	0.007Z	1.55	0.009
Fall	53	0.08	0.000	0.00	0.000	0.06	0.001	0.14	0.001
All seasons	212	0.40	0.001	0.04	0.000	0.20	0.003	0.64	0.004

^a Numbers of locations and locations/km of Chesapeake nonbreeding eagles by area and season differed, based on general linear models analysis by ranks (locations, $F = 15.1$, 6, 624 df, $P < 0.001$ [area-season interaction], $F = 79.7$, 2, 630 df, $P < 0.001$ [areas], $F = 14.4$, 3, 630 df, $P < 0.001$ [seasons], locations/km, $F = 26.0$, 6, 624 df, $P < 0.001$ [area-season interaction], $F = 20.8$, 2, 630 df, $P < 0.001$ [areas], $F = 5.8$, 3, 630 df, $P < 0.005$ [seasons]). Within-row and within-column comparisons for Chesapeake origin with the same letter did not differ (Wilcoxon rank-sum pair-wise tests, $P > 0.05$).

^b Numbers of locations and locations/km of northern eagles by area in winter differed, based on the χ^2 approximation of the Kruskal-Wallis test ($\chi^2 = 50.0$, 37.4, 2 df, $P < 0.001$, 0.001, respectively). Within-row comparisons for northern origin with the same letter did not differ (Wilcoxon rank-sum pair-wise tests, $P > 0.05$).

^c Numbers of locations and locations/km of southern eagles by area in summer differed, based on the χ^2 approximation of the Kruskal-Wallis test ($\chi^2 = 14.0$, 22.0, 2 df, $P < 0.001$, 0.001, respectively). Within-row comparisons for southern origin with the same letter did not differ (Wilcoxon rank-sum pair-wise tests, $P > 0.05$).

0.01), but not from the breeding distribution during those seasons ($P = 0.60$, 0.17, respectively).

Northern migrants used Aberdeen in winter more than the Eastern Shore or Susquehanna ($P < 0.001$, 0.001, locations and locations/km, respectively, Table 2). Northern migrants were more concentrated on Aberdeen than were the Chesapeake breeding or nonbreeding eagles, or southern migrants ($P < 0.01$, Table 3, Figs. 1, 2).

Southern migrants used Aberdeen and the Susquehanna most in summer, and the Eastern Shore least, based on locations/flight ($P < 0.001$, Table 2). However, because shoreline length differed among areas, southern migrants use was greatest on the Susquehanna, intermediate on Aberdeen, and least on the Eastern Shore on a locations/km basis ($P < 0.001$). Southern migrants were less dispersed than Chesapeake breeding and Chesapeake nonbreeding eagles ($P < 0.01$, Table 3, Figs. 1, 2). No radio-tagged eagles were found

in the Baltimore area, despite its 699 km of shoreline.

EAGLE ABUNDANCE

The number of eagles on the northern Chesapeake increased during the three survey years ($P = 0.001$, Fig. 3). Eagle numbers increased from 1985–1986 surveys to 1987–1988 ($P = 0.004$), while 1985–1986 and 1986–1987 eagle abundance ($P = 0.204$) and 1986–1987 and 1987–1988 eagle abundance ($P = 0.056$) did not differ. Abundance varied in an annual cycle with winter peaks, spring lows, larger summer peaks, and fall lows.

EAGLE MOVEMENTS

Chesapeake breeding eagles. We relocated the radio-tagged breeding eagle 81 times from 19 April 1984–24 March 1985. More than 81% of the relocations were ≤ 3 km from its nest and the adult was never located > 7 km from the nest.

TABLE 3. Average within group distance (km) and area (km²) of harmonic means distribution contours of radio-telemetry locations of northern migrant, southern migrant, and Chesapeake nonbreeding Bald Eagles and nest sites, northern Chesapeake Bay, Maryland, 1985–1988.

Eagle group	<i>n</i>	Average within group distance (km) ^a	50% contour (km ²)	80% contour (km ²)	95% contour (km ²)
Nest sites	28	25.23AC	564.11	1,305.79	1,932.99
Nonbreeding bay					
Summer	427	23.53A	510.12	1,733.07	3,731.31
Fall	350	25.31B	395.43	1,244.20	2,304.65
Winter	204	20.06C	376.60	865.10	2,565.68
Spring	291	16.03D	185.56	679.35	2,558.84
Southern migrant	73	19.28E	98.07	331.63	2,265.61
Northern migrant	104	12.29F	88.08	340.21	1,335.82

^a Eagle groups with the same letter did not differ in distribution (MRPP tests, $P > 0.05$).

Chesapeake nonbreeding eagles. Radio-tagged Chesapeake nonbreeding eagles' use of the different regions of the Chesapeake varied by month of the year ($P < 0.001$, Fig. 4). Chesapeake nonbreeders were present most often on the northern Chesapeake in August, September, and July ($\bar{x} = 24.6, 24.2,$ and 22.9 days present/eagle, respectively) and present most often on the middle and southern Chesapeake in January, December, and February ($\bar{x} = 19.6, 19.5,$ and 14.4 days/eagle, respectively). Chesapeake nonbreeding eagles used the northern Chesapeake more from September 1987–August 1988 than from September 1986–August 1987 ($P < 0.001$).

We monitored 37 radio-tagged Chesapeake nonbreeding eagles for a total of 410 eagle-months. In 192 of 410 eagle-months (46.8%), eagles moved between northern Chesapeake areas (Aberdeen, Eastern Shore, and Susquehanna River). The frequency of movement on the northern Chesapeake (% eagles moving/month) did not differ among months or between years ($\chi^2 = 43.03, 34$ df, $P = 0.14$, Table 4). Eagles moved from the northern Chesapeake to the middle or southern Chesapeake during 61 of 410 eagle-months monitored (14.9% moved/month), whereas eagles on the middle or southern Chesapeake returned to the northern Chesapeake during 40 of 237 eagle-months monitored (14.4%). The frequency of movements to the southern Chesapeake and back did not differ among months or between years ($\chi^2 = 42.93, 34$ df, $P = 0.14$; $\chi^2 = 39.72, 34$ df, $P = 0.23$, southern and northern movements, respectively).

About 10% of Chesapeake nonbreeding eagle use was south of the bay in winter 1986–1987

but even less in winter 1987–1988. Eagle use was minimal north of the Chesapeake. We located three Chesapeake nonbreeding eagles on the Delaware Bay in April and September 1985, and March 1986, and two eagles in coastal Maine in August 1987 and August 1988.

Northern eagles. Arrival of radio-tagged northern eagles ranged from 25 November to 17 January ($\bar{x} = 21$ December, range = 61 days, $n = 7$). Of seven first locations after arrival on the northern Chesapeake, four occurred on Aberdeen (57%), two on the Eastern Shore (29%), and one on the Susquehanna (14%). Departure was more synchronous than arrival, ranging from 1 March to 13 April ($\bar{x} = 27$ March, range = 43 days, $n = 14$). Northern eagles were most often last observed on Aberdeen (12 of 14 last locations, 86%), whereas two of 14 (14%) last locations occurred on the Susquehanna.

Southern eagles. Arrival of radio-tagged southern eagles on the northern Chesapeake ranged from 19 April to 22 July ($\bar{x} = 6$ June, range = 94 days, $n = 11$). Of 11 first-arrival locations, eight occurred on Aberdeen (73%), two occurred on the Susquehanna (18%), and only one occurred on the Eastern Shore (9%). Departure ranged from 19 June to 17 October ($\bar{x} = 3$ September, range = 119 days, $n = 22$). Southern eagles tended to be located last on Aberdeen (13 of 22, 59%) or the Susquehanna (7 of 22, 32%).

DISCUSSION

The distribution of Bald Eagles on the northern Chesapeake Bay differed by eagle class and season. Northern migrants were the most concentrated in distribution, using the Aberdeen area

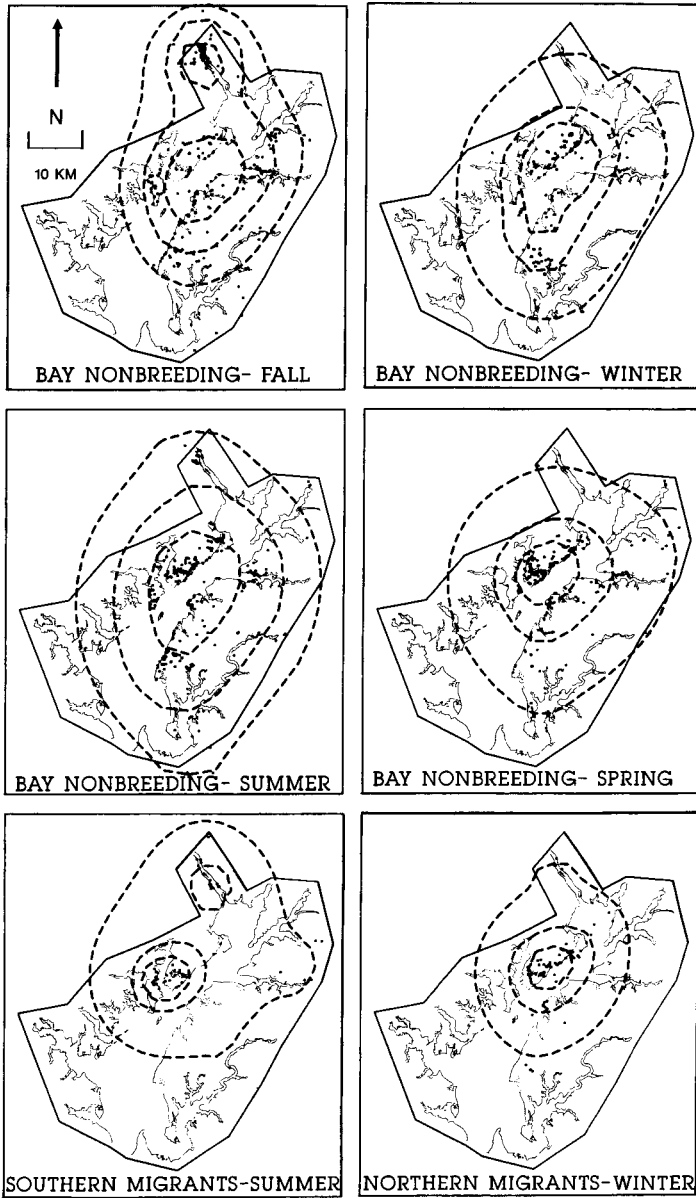


FIGURE 2. Radio-tagged Bald Eagle locations (dots) and harmonic-means activity-area model 50%, 80%, and 95% distribution contours (dashed lines) for Chesapeake nonbreeding Bald Eagles seasonally, and northern migrants in winter and southern migrants in summer, northern Chesapeake Bay, Maryland, 1985–1988.

almost exclusively. Southern migrants were more concentrated in distribution than resident breeding and nonbreeding eagles, but less concentrated than northern migrants. Breeding territories were dispersed throughout the northern Chesapeake, with the exception of the Baltimore area, apparently because of habitat alteration for homes and

other buildings (Buehler et al. 1991). Chesapeake nonbreeding eagles were found throughout the Chesapeake Bay in all seasons, although the most use was on the southern bay in winter and the northern bay in summer. Chesapeake nonbreeding eagles switched northern Chesapeake areas about once every two months, on average, with

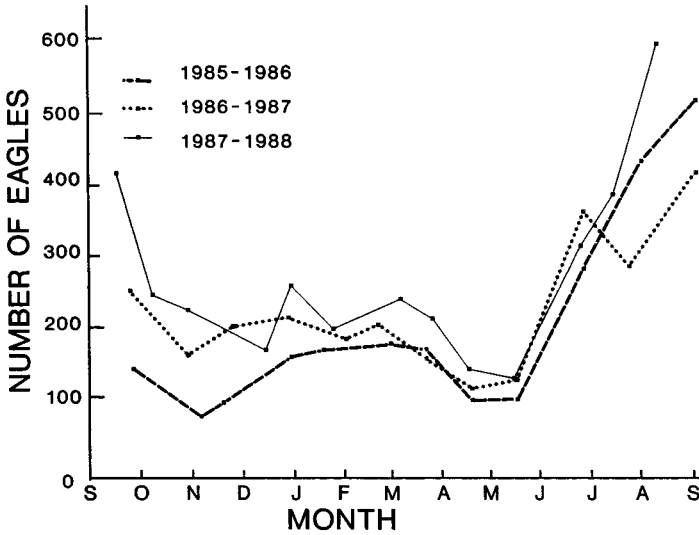


FIGURE 3. Total estimated Bald Eagle abundance on the northern Chesapeake Bay, Maryland based on September–August surveys for three years beginning September 1985.

no differences in movement by month and year. Chesapeake nonbreeding eagles moved between northern and southern Chesapeake regions less frequently than their movements among northern Chesapeake areas, probably because of the greater distances involved in the bay-wide movements. The frequency of the bay-wide movements did not change seasonally, suggesting that these birds do not have a strong tendency to migrate synchronously. When present on the northern bay, Chesapeake nonbreeding eagles were equally dispersed as the breeding birds in summer and winter, more concentrated on Aberdeen in spring, and dispersed but shifted toward the Susquehanna River in the fall.

The differences in distribution and movements among the eagle subpopulations are undoubtedly explained by different selective pressures on the subgroups. Breeding birds probably select nest sites that have abundant food available over the relatively long nesting season from January to August (e.g., Lack 1954, Newton 1979). Moreover, these birds may increase the probability of territory retention if they remain on the territory and defend it throughout the year. Nest maintenance also takes place throughout the year (Fraser 1981). Thus the benefits to adults of remaining on territory apparently outweigh the advantage to be gained by moving to other areas during the nonbreeding period.

Chesapeake nonbreeding eagles, in contrast, are free to move to areas of short-term food abundance, such as the Susquehanna River in fall (Mersmann 1989), and then move on to other areas as food distribution changes. Their need to eventually find mates and vacant breeding territories may further increase the tendency to move among areas. Furthermore, local experience may allow these birds to risk investigating a previously-used area to determine the level of food abundance. This may explain why Chesapeake nonbreeding eagles moved between the northern and southern bay throughout the year, although they spent the majority of their time on the northern bay in summer and on the southern bay in winter.

Migrants, in contrast, may be more likely to seek out one suitable area for surviving the winter or summer and remaining there until it is time to migrate, unless local conditions change. They also may be more likely to use the largest, most easily recognized patches of habitat, such as the Aberdeen area.

Social factors also may play a significant role in determining the observed distributional differences. Distributional differences may be attributable to the competitive advantage of the larger northern migrants over the smaller Chesapeake nonbreeding eagles at communal foraging areas. In winter, live fish are relatively scarce or

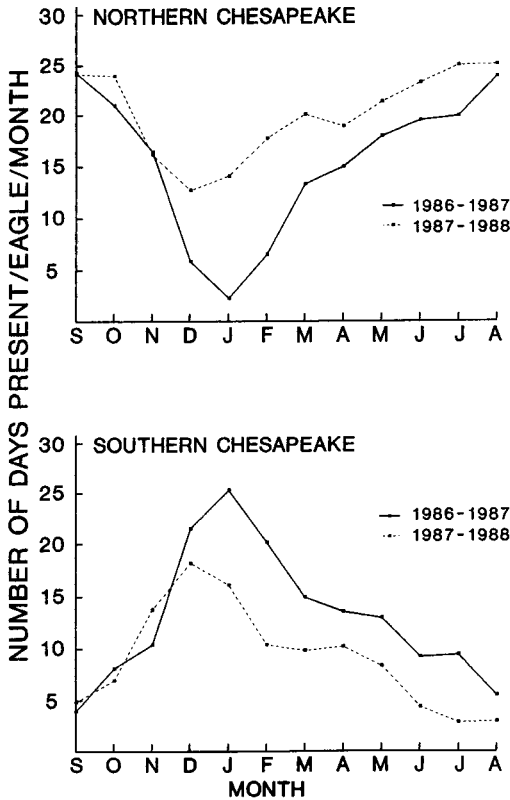


FIGURE 4. Average number of days spent per radio-tagged Chesapeake nonbreeding Bald Eagle per month on the northern Chesapeake, and on the middle-southern Chesapeake from September 1986–August 1988.

unavailable in deep water and scavenging on White-tailed Deer (*Odocoileus virginianus*) and waterfowl is common (Mersmann 1989). Because the northern migrants are larger (Buehler et al., unpubl. data) and because size imparts a competitive advantage in communal scavenging situations (Hansen 1986, Wallace and Temple 1987, Knight and Skagen 1988), migrants may exclude Chesapeake nonbreeders from the best foraging opportunities in winter. This exclusion may necessitate Chesapeake nonbreeding eagles spending the majority of their time on the southern bay, where live fish are more available or northern birds are less common. Chesapeake breeding eagles, in contrast, may be more competitive with the northern migrants because they are older and have more experience.

Weather also may influence eagle distribution indirectly by affecting food availability. Mersmann (1989) noted that severe weather during winter 1987–1988 caused fish kills on the northern Chesapeake, thus making dead fish available at a time when most live fish are in deep water and unavailable to eagles. Chesapeake nonbreeders spent more time on the northern Chesapeake during this winter than in previous winters, probably in response to the increased fish abundance.

Cold weather effects on food supply on the breeding grounds of the northern migrants also may affect the movement of these birds to the Chesapeake. Almost all (92%) of the eagles that

TABLE 4. Movements (% moved/month) by radio-tagged Chesapeake-hatched Bald Eagles between northern Chesapeake Bay sub-areas, to the southern Chesapeake, and returning to the northern Chesapeake by month and year.

Month	1986–1987					1987–1988				
	Eagles on N. Ches.	% moved on N. Ches. ^a	% moved to S. Ches. ^b	Eagles on S. Ches.	% moved to N. Ches.	Eagles on N. Ches.	% moved on N. Ches. ^a	% moved to S. Ches. ^b	Eagles on S. Ches.	% moved to N. Ches. ^c
Sep	15	53.3	33.3	3	0.0	26	50.0	19.2	10	20.0
Oct	13	38.5	7.7	6	16.7	27	48.1	33.3	15	6.7
Nov	11	27.3	9.1	9	11.1	19	42.1	26.3	16	37.5
Dec	7	0.0	0.0	15	13.3	16	43.8	6.3	20	5.0
Jan	4	25.0	0.0	16	6.3	17	41.2	17.6	21	14.3
Feb	8	50.0	37.5	17	29.4	21	47.6	14.3	20	5.0
Mar	12	41.7	0.0	12	8.3	23	43.5	8.7	13	15.4
Apr	11	90.9	36.4	13	30.8	27	37.0	3.7	16	12.5
May	13	84.6	7.7	10	10.0	23	34.8	8.7	11	0.0
Jun	14	50.0	14.3	8	12.5	23	69.6	21.7	5	60.0
Jul	14	50.0	0.0	7	0.0	24	41.7	12.5	4	25.0
Aug	16	50.0	6.3	5	20.0	26	42.3	15.4	5	0.0

^a Movements among northern Chesapeake areas did not differ among months or between years, based on log-linear analysis ($P = 0.14$).

^b Movements to the southern Chesapeake did not differ among months or between years ($P = 0.14$).

^c Movements returning to the northern Chesapeake did not differ among months or between years ($P = 0.23$).

located experimental feeding stations in fall in Maine did not migrate (McCullough 1986). This suggests that anything affecting food supply, such as severe winter weather, may affect the tendency to migrate. This in turn may affect the abundance of northern migrants on the northern Chesapeake and possibly the distribution of the Chesapeake nonbreeders if competitive interactions are important.

Weather may also influence the movement of the southern migrants. Fish availability in the Southeast may decline in late spring-early summer as increasing water temperatures cause fish to abandon shallow-water areas. Edwards (1988) reported declining fish abundance near the surface of inland lakes in north-central Florida during the late spring-early summer period, coincident with the movement of eagles northward. An alternative or additional explanation is that southern eagles migrate northward in late spring to avoid the physiologic consequences of extreme summer heat. Summer temperatures in the Southeast undoubtedly exceed the levels reportedly inducing thermal stress in raptors (34°C, Hayes and Gessaman 1980). Variation in the summer weather from year to year may affect the extent of the migration northward, thus affecting the number of southern migrants on the northern Chesapeake.

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