Bird Populations 6:21-32

TRENDS IN MIDWINTER COUNTS OF BALD EAGLES IN THE CONTIGUOUS UNITED STATES, 1986-2000[1]

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Abstract. We estimated statewide, regional, and national trends in counts of Bald Eagles (*Haliaeetus leucocephalus*) along selected routes in the contiguous United States during midwinter, 1986-2000. Each January, several hundred observers collected data as part of a survey initiated by the National Wildlife Federation in 1979. To analyze these data, we used only those routes surveyed consistently in at least four years and on which at least four eagles were counted in a single year. We included surveys conducted during fog or precipitation after determining that changes in weather conditions probably did not affect trend estimates. Our final analysis, using a hierarchical mixed model, was based on 101,777 eagle sightings during 5,180 surveys of 563 routes in 42 states. In the model, fixed effects were year, region, and route-length category; the random effect was the route itself. Model-based estimates of Bald Eagle counts throughout the U.S. increased 1.9% yr^{-1}, but trend estimates varied by region. Estimated trends were statistically significant, and positive, in the northeastern U.S. (6.1% yr^{-1}), but were not significant in other regions. The proportion of increasing counts was higher north of 40° N and east of 100° W. Trends in numbers of adults and immatures showed similar geographic patterns, but counts of adults increased at a higher rate. Overall, trends were more similar to those identified by the Christmas Bird Count than the Breeding Bird Survey. In spite of limitations, the survey is a cost-effective way to monitor wintering eagles in the lower 48 states. We discuss estimated trends in the context of increased urbanization, changed weather, and recovery from pesticide pollution.
Key Words: Bald Eagle, *Haliaeetus leucocephalus*, regional trends, wintering populations

[1]Received: 15 July 2002. Accepted: 16 September 2002.

TENDENCIAS EN CONTEOS INVERNALES DE ÁGUILAS CALVAS EN LOS ESTADOS UNIDOS CONTIGUOS, 1986-2000.

Resumen. Estimamos tendencias en los conteos estatales, regionales y nacionales de águila calva (*Haliaeetus leucocephalus*) a lo largo de rutas selectas en los Estados Unidos contiguos durante el invierno, desde 1986 a 2000. Cada mes de enero, varios cientos de observadores colectaron datos como parte de un conteo iniciado por la National Wildlife Federation en 1979. Para analizar estos datos, utilizamos solamente las rutas muestreadas regularmente durante al menos cuatro años y en las que se contabilizaron al menos cuatro águilas en un solo año. Incluimos los conteos realizados en condiciones de niebla o lluvia tras determinar que los cambios meteorológicos no parecen afectar las estimas. Nuestro análisis final, utilizando un modelo jerárquico mixto, se basó en 101.777 avistamientos de águilas durante 5180 muestreos de 563 rutas en 42 estados. En el modelo, los efectos fijos fueron año, región, y categoría de longitud de ruta; el efecto aleatorio fue la ruta en sí. Las estimas de conteos de las águilas en todo EE.UU. aumentó 1.9% por año, pero las tendencias variaron por región. Las tendencias fueron estadísticamente significativas y positivas en el noreste de EE.UU. (6.1% yr^{-1}), pero no fueron significativos en otras regiones. La proporción de conteos en aumento fue más alta al norte de 40° N y al este de 100° N. Las tendencias en números de adultos e inmaduros mostraron patrones geográficos similares, pero los conteos de adultos mostraron una tasa de aumento más alta. En general, las tendencias fueron más similares a las detectadas por el Christmas Bird Count que las del Breeding Bird Survey. A pesar de las limitantes, el muestreo es un método de bajo costo para monitorear las águilas calvas invernantes en los 48 estados contiguos. Discutimos las tendencias estimadas en el contexto del aumento de la urbanización, cambios meteorológicos, y recuperación de contaminación por pesticidas.

Palabras clave: Aguila calva, *Haliaeetus leucocephalus*, tendencias regionales, poblaciones invernantes.

EVOLUTION DES EFFECTIFS DE PYGARGUES A TETE BLANCHE DENOMBRES EN MILIEU D'HIVER DANS LES ETATS-UNIS CONTIGUS, 1986-2000.

Résumé. Nous avons estimé de 1986 à 2000 la tendance des effectifs de Pygargues à tête blanche (*Haliaeetus leucocephalus*) en milieu d'hiver, à l'échelle de la région, de l'état et du pays, le long de transects sélectionnés dans les Etats-Unis contigus. Lors de chaque mois de Janvier, plusieurs centaines d'observateurs ont récolté des données dans le cadre du recensement initié par la National Wildlife Federation en 1979. Pour analyser ces données, nous n'avons utilisé que les transects parcourus régulièrement au cours des quatre dernières années, et sur lesquels au moins quatre pygargues ont été comptés chaque année. Nous avons inclus les recensements ayant eu lieu par temps de brouillard ou durant des précipitations, après avoir déterminé que les conditions météorologiques n'affectaient probablement pas les estimations de tendances. Notre analyse finale, par un un modèle mixte hiérarchique, était basée sur 101,777 observations de pygargues, provenant de 5,180 recensements sur 563 transects, dans 42 états. Dans le modèle, les effets fixes étaient l'année, la région, et la catégorie de longueur du transect ; l'effet aléatoire était le transect lui-même. Les estimations du nombre de Pygargues à tête blanche aux Etats-Unis augmentaient de 1.9% par an, mais avec une variation entre régions. Les tendances estimées étaient statistiquement significatives, et positives, dans le nord-est des Etats-Unis (6.1% par an), mais non significatives dans les autres régions. La proportion d'effectifs en croissance était plus élevée au nord du 40° N et à l'est du 100° W. Les tendance des effectifs d'adultes et d'immatures montraient des patterns géographiques similaires, mais l'augmentation du nombres d'adultes comptés était plus rapide. Globalement, les tendances d'évolution étaient plus proches de celles identifiées par le Christmas Bird Count que par le Breeding Bird Survey. En dépit des limitations, le recensement est un moyen rentable de suivre les populations de pygargues hivernant dans les Etats-Unis contigus. Nous discutons ces tendances estimées dans le contexte de l'urbanisation croissante, des modifications des conditions météorologiques, et de la réduction de la pollution par les pesticides.

Mots-clés: Pygargue à tête blanche, *Haliaeetus leucocephalus*, tendances régionales, populations hivernantes

BESTANDSTRENDS BEI FLÄCHENHAFTEN MITTWINTERZÄHLUNGEN DES WEIßKOPFSEEADLERS IN DEN USA 1986-2000

Zusammenfassung. Die Arbeit fasst die Bestandsentwicklung des Weißkopfseeadlers *(Haliaeetus leucocephalus)* nach Zählungen auf ausgewählten Zählstrecken über die gesamte USA während der Mittwinter 1986-2000 für Einzelstaaten, Großregionen und die USA zusammen. In dem von der National Wildlife Federation 1979 initiierten Programm wurde in jedem Januar der Adlerbestand von mehreren hundert Mitarbeitern erfasst. Bei der Auswertung wurden aber nur Zählstrecken berücksichtigt, die in mindestens 4 aufeinanderfolgenden Wintern bearbeitet wurden und die eine Mindestzahl von 4 Seeadlern aufwiesen. Mit einbezogen wurden Zählungen bei Nebel oder Starkregen, wenn ersichtlich war, dass die Bestandsberechnungen von Wetteränderungen nicht beeinträchtigt wurden. Die Analyse mit Hilfe eines hierarchischen Misch-Modells basiert auf 101,777 Adlerbeobachtungen bei 5,180 Beobachtungsgängen auf 563 Zählstrecken in 42 Staaten. Im Berechnungsmodell waren Jahr Region und Streckenlänge die unabhängigen Variablen, die, Zählstrecke selbst die abhängige. Die Modellberechnungen der Adlerbestände ergaben für die gesamte USA eine Zunahme um 1.9% pro Jahr, wobei sich die Bestandentwicklung für die Regionen unterschied. Im NE waren die Bestandstrends statistisch signifikant positiv (Zunahme um 6.1%/Jahr), für die anderen Regionen nicht. Die Anzahl der Zählstrecken mit Bestandszunahmen nahm nördlich 40° N und östlich 100° W deutlich zu. Die Trends für Altvögel und Immature wiesen ähnliche geographische Muster auf, wobei die Zunahmen bei Altvögeln ausgeprägter waren. Generell stimmen die Ergebnisse besser mit denen des Christmas Bird Count überein als mit dem Brutvogel-Monitoringprogramm BBS. Trotz mancher Einschränkungen handelt es sich um ein sehr kosteneffektives Programm zur Erfassung überwinternder Weißkopfseeadler in 48 südlichen, kontinentalen Staaten der USA. Wir diskutieren die Trendangaben im Zusammenhang mit zunehmender Urbanisierung, Klimaveränderungen und der Erholung von Pestizidbelastungen.

Schlüsselworte: Weißkopfseeadler, *Haliaeetus leucocephalus*, regionale Trends, Winterbestände.

INTRODUCTION

Listing of the Bald Eagle *(Haliaeetus leucocephalus)* as "Threatened and Endangered" under the Endangered Species Act in 1978 prompted numerous efforts to monitor populations in both nesting and wintering areas. The National Wildlife Federation began sponsoring midwinter surveys of Bald Eagles in 1979. Initial objectives were to determine eagle distribution during winter, identify previously unrecognized areas of important winter habitat, and estimate the wintering Bald Eagle population in the lower 48 states. Total counts of eagles during midwinter surveys increased each year from 1979 through 1982 (Millsap 1986), but unequal survey effort among years prevented a meaningful analysis of population trends at that time.

Beginning in 1984, National Wildlife Federation officials asked participants in each state to count eagles along standard, non-overlapping routes to provide data on winter trends in Bald Eagle populations. Federation guidelines stipulated that standard surveys be conducted by the same number of experienced observers using the same method (e.g., fixed-wing aircraft, helicopter, boat, vehicle) at approximately the same time of day each year in well-defined areas where eagles had been observed in prior winters. In this paper, we use data from counts conducted along standard routes from 1986 through 2000 to estimate national and regional count trends, overall and by age class.

METHODS

DATA COLLECTION

Each year, observers conducted surveys on standard routes during the first two weeks of January, usually on one of two target days. Coordinators in each state were responsible for organizing local surveys, enlisting participants, and verifying survey route consistency. Most survey participants were employees of state or federal conservation agencies, but private citizens also participated in the surveys as volunteers. Observers classified >97% of eagles seen as either adult (white head and tail) or immature (brown head and tail).

Due to weather and staffing limitations, not all standard routes were surveyed every year. Twenty-seven states identified and began surveying standard routes in 1986, but others did not begin standard surveys until the mid-1990s. Some states discontinued surveys in the 1990s.

More than 60% of surveys used in the analysis were conducted exclusively from the ground; 44% involved road vehicles. At least 10% involved boats, and almost 30% involved aircraft, both fixed wing and helicopter. Almost 20% of surveys used a combination of methods—mostly vehicle and foot. Most routes were surveyed in a single day, but a small proportion of surveys (< 4%) were conducted on more than one day when weather or logistical problems interfered with counts.

DATA SCREENING

We received more than 10,000 reports of surveys conducted between 1986 and 2000, but were able to use only about half of them for a variety of reasons. We did not use surveys if: (1) the count was conducted before 1 Jan or after 25 Jan; (2) the route covered was inconsistent from year to year or the route was not described clearly enough to determine if it was the same as in other years; (3) the survey method was not listed; or (4) we were unable to obtain information on length of the survey route. We used survey results only if the transportation type (air, ground, water) was consistent because the number of eagles visible from air, ground, or water usually differs significantly (Kaltenecker 1997, Anthony et al. 1999, Bowman and Schempf 1999). We tried to verify that route coverage was consistent from year to year, and we corrected or eliminated records when we became aware of cases where observers covered areas less than or greater than the defined standard route. Nevertheless, some erroneous records may have been included due to incomplete observer documentation.

We used data from only those routes surveyed consistently in at least four years and on which at least four eagles were counted in at least one year. Routes that never had >3 eagle observations in a single year were considered to be in marginal or unsuitable habitat; including them would have biased trend estimates towards zero. Analysis for both age classes combined was based on 5,180 surveys of 563 routes in 42 states (Fig. 1, Table 1). Our trend estimates for age classes were based on reduced data sets that included only those routes where at least four individuals of the age class (adult or immature) were counted in a single year. Adult count trends were based on 4,104 surveys of 464 routes, and immature count trends were based on 2,991 surveys of 370 routes.

DATA CLASSIFICATION

We assigned routes to one of four regions based on location relative to 100° W and 40° N (Northeast, Southeast, Northwest, Southwest). Lengths of survey routes varied considerably; we classified routes into categories, based on the length of river or shoreline surveyed: 0-17 km (n = 124 routes), 18-56 km (n = 181), 57-120 km (n = 159), and >120 km (n = 112). We then defined routes to be in eagle concentration areas if >15, 50, 80, or 100 eagles were ever counted on routes with the respective length categories (n = 111).

DATA EVALUATION

Differences in detectability rates among years on given routes could affect both the variability and the magnitude of trend estimates. We evaluated the data in two different ways to determine if any changes in detectability during fog or precipitation might have affected trend estimates. Approximately 17% of surveys were conducted during fog and/or precipitation. The percent of surveys conducted during fog/precipitation ranged from 0 - 80% per route; 189 of the 576 routes (33%) had fog and/or precipitation during ≥1 survey year. If fog or precipitation limited visibility of eagles, the variability of counts on a route should be related to the proportion of surveys conducted under such conditions. Therefore, to test whether fog or precipitation may have affected count variation, we compared the percent of years each route was surveyed during fog or precipitation to the route's coefficient of variation (CV) using correlation analysis. We evaluated only

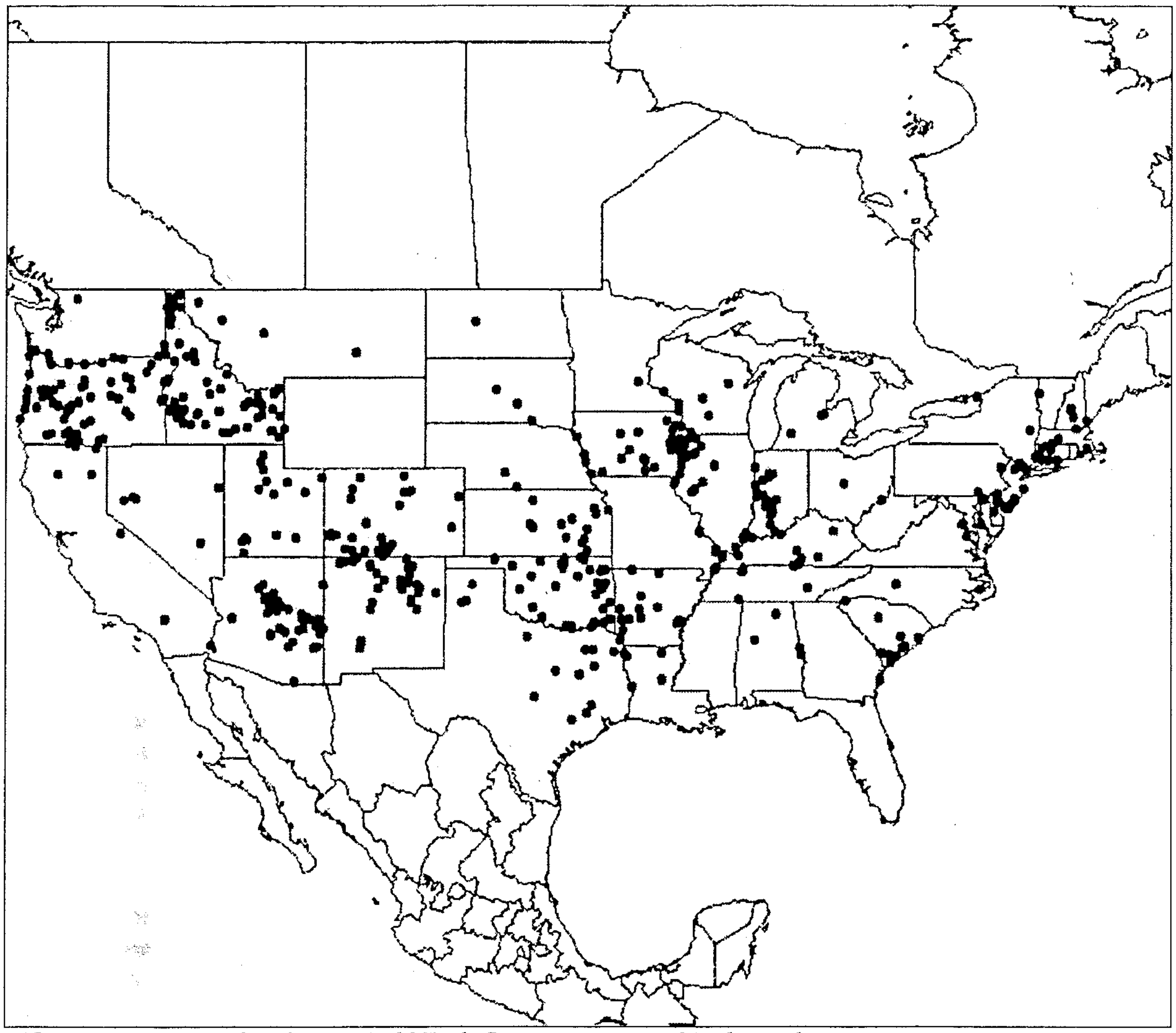

FIGURE 1. Location of Midwinter Bald Eagle Survey routes used in the analysis.

those routes in which ≥50% of surveys were conducted in fog/precipitation (i.e., a high degree of variability in weather) because routes usually surveyed in fog/precipitation might have low but consistent counts. Next, if fog/precipitation limited visibility of eagles consistently enough to systematically bias our analysis, then counts in successive years on the same route with different weather conditions should show a greater difference than counts in successive years when weather conditions were the same. We classified pairs of successive surveys into three groups: those that never had fog/precipitation, those that had fog/precipitation in both years, and those that had fog/precipitation in one survey but not the other. We calculated the absolute difference between logged counts of successive surveys, which is the equivalent of percent change between years. We used a linear mixed model fitting these differences as the dependent variable, group and time as the independent variables, and route as the random effect, to account for possible correlation within routes.

TREND ESTIMATION

To estimate trends, we fit a random coefficients (hierarchical mixed) model. This model estimates a national trend based on fixed effects from all routes and differences between each route's trend and the overall trend (Rutter and Elashoff 1994; McCulloch and Searle 2001). The general form of the model is:

$$Y = X\beta + Z\upsilon + \varepsilon$$

where Y is the logged count; X is the design matrix for fixed effects; β is the coefficient vector

TABLE 1. Number of survey routes and surveys used in the analysis, with estimated trends in the eagles counted, midwinter, by state.

State	Routes	Surveys	Years	Trend
Alabama	3	42	1986-2000	-6.0%
Arizona	51	373	1992-2000	-1.6%
Arkansas	12	86	1986-2000	+0.3%
California	6	51	1986-2000	+3.2%
Colorado	32	312	1986-2000	-1.1%
Connecticut	8	76	1986-2000	+3.2%
Delaware	1	10	1989-1999	+4.5%
Georgia	3	22	1989-2000	-2.9%
Idaho	68	840	1986-2000	+1.9%
Illinois	14	62	1996-2000	+6.6%
Indiana	22	204	1986-2000	+3.3%
Iowa	42	282	1986-2000	+5.6%
Kansas	13	134	1986-2000	+1.5%
Kentucky	13	88	1986-2000	+2.0%
Louisiana	4	28	1986-2000	-2.4%
Maryland	3	40	1986-2000	+5.4%
Massachusetts	4	42	1986-2000	+3.7%
Michigan	3	31	1987-1998	+9.0%
Minnesota	4	49	1986-2000	+7.6%
Montana	4	40	1986-1997	-2.5%
Nebraska	2	29	1986-2000	+5.9%
Nevada	5	25	1992-2000	-2.4%
New Hampshire	4	29	1991-1999	+7.1%
New Jersey	17	165	1988-2000	+4.7%
New Mexico	41	284	1990-1996	-0.3%
New York	2	30	1986-2000	+8.3%
North Carolina	2	14	1987-2000	+0.9%
North Dakota	1	15	1986-2000	-4.4%
Ohio	1	5	1996-2000	+12.3%
Oklahoma	30	277	1986-2000	+0.9%
Oregon	78	801	1988-2000	+1.4%
Pennsylvania	4	35	1986-2000	+1.8%
South Carolina	10	70	1993-2000	+3.3%
South Dakota	4	49	1986-2000	-0.1%
Tennessee	6	86	1986-2000	+2.0%
Texas	19	189	1986-2000	+0.9%
Utah	16	187	1986-2000	+0.1%
Vermont	1	8	1993-2000	+7.3%
Virginia	2	8	1997-2000	+4.5%
Washington	2	27	1986-2000	+4.6%
West Virginia	1	5	1995-2000	+5.4%
Wisconsin	5	30	1991-2000	+0.2%
TOTAL	563	5180		

for fixed effects; Z is the design matrix for random effects; υ is the coefficient vector for random effects; and ε is the overall error. In this model, our fixed effects were year, region, route size category, and whether the route was in a concentration area. The random effect was the route itself.

In estimating the variance of random effects, this model can account for correlation among years within a route. Because migratory Bald Eagles vary in their degree of fidelity to wintering sites (Watson and Pierce 2001), and because this fidelity can be confounded by weather patterns and variations in prey availability, counts in one year are sometimes but not always related to counts in previous years. Preliminary examination of the data indicated that counts were correlated for four years or more in some regions; in others they correlated only with the preceding year. We, therefore, imposed no structure on the variance-covariance matrix. We initially evaluated a model with all effects and interactions included, and selected our final model by comparing significance levels, model diagnostics, and Akaike's Information Criterion. The model handles missing data, allows assessment of covariates, and produces trend estimates at several scales. Using the final model, we were able to estimate national and regional trends. By combining route-level data, we estimated trends for individual states and for ecoregions, defined by combining Bird Conservation Regions (U.S. NABCI Committee 2000, Table 2). We conducted all analyses using Proc Mixed in SAS version 8 (SAS Institute Inc. 1999).

All averages herein are expressed with plus or minus the standard error.

RESULTS

DATA CHARACTERISTICS

Of the 563 routes used in the analysis, 46 were surveyed in all 15 years, 34 in 13 years, 40 in 12 years, 41 in 11 years, 38 in 10 years, and 316 in <10 years. Surveys spanned the full 15-yr period (1986, 2000, and intervening years) on 114 routes. Counts on most routes showed a high degree of inter-year variability with CVs ranging 7 - 225%; CVs of 18% of routes were >100%. The total number of eagle sightings included in our analysis was 101,777. Number of eagles counted on individual surveys ranged from 0 (n = 441) to 965 (Lower Klamath Basin, 1988).

DATA EVALUATION

Route CVs were not related to the percent of surveys conducted during fog/precipitation ($r^2 = -0.051$, $P = 0.24$, $n = 549$ routes). Absolute percent differences in numbers of eagles seen between successive surveys differed significantly from 0 ($P < 0.001$), but absolute percent differences between successive surveys conducted under different weather conditions were similar to those when weather did not differ ($\chi^2_2 = 5.27$, $P = 0.072$). Absolute percent differences in counts between successive surveys averaged 0.71 ± 0.06 with fog/precipitation, 0.73 ± 0.02 with clear weather, and 0.80 ± 0.03 with different weather conditions. We therefore concluded that the variability

TABLE 2. Estimates of percent annual change in midwinter Bald Eagle counts by ecoregion, 1986-2000 (n = 563). Asterisks indicate trends significantly different from zero.

Ecoregion	% Annual Change	95% C.I.
East Coast[a]	+3.6%	1.3 - 5.9*
Eastern Woodland[b]	+2.5%	0.6 - 4.3*
Great Basin[c]	+1.3%	-0.4 - 3.0
Great Lakes[d]	+7.0%	3.5 - 10.6*
Gulf[e]	+1.4%	-0.8 - 3.6
Pacific Coast[f]	+1.6%	-0.4 - 3.5
Prairie[g]	+3.2%	1.5 - 4.8*
Rockies[h]	-0.3%	-1.8 - 1.3
Southwest Desert[i]	-1.2%	-3.9 - 1.5

[a] Southeastern Coastal Plan (27) and New England/Mid-Atlantic Coast (30)
[b] Atlantic Northern Forest (14), Central Hardwoods (24), Appalachian Mountains (28), and Piedmont (29)
[c] Great Basin (9) and Sierra Nevada (15)
[d] Boreal Hardwood Transition (12), Lower Great Lakes (13), and Prairie Hardwood Transition (23)
[e] Oaks and Prairies (21), West Gulf Coastal Plain (25), Mississippi Alluvial Valley (26), and Gulf Coastal Prairie (37)
[f] Northern Pacific Rainforest (5) and Coastal California (32)
[g] Prairie Potholes (11), Badlands and Prairie (17), Shortgrass Prairie (18)
[h] Northern Rockies (10) and Southern Rockies (16)
[i] Sonora and Mohave Deserts (33), Sierra Madre Occidental (34), and Chihuahua Desert (35)

introduced by fog/precipitation was not a systematic or important component of the variability already inherent in the eagle counts and that it was not necessary to exclude surveys conducted during fog/precipitation.

TREND ESTIMATION

Our final model retained all fixed effects and several interactions (Table 3). As expected, numbers of eagles seen increased with route length and were higher in concentration areas. However, these fixed effects did not interact with year, so we concluded that trends were similar across route lengths and concentration areas.

Counts of Bald Eagles increased 1.9% yr^{-1} across all regions from 1986 to 2000 (95% CI = 0.9-3.0%; $P < 0.001$; Table 4). Estimated counts were 33% higher in 2000 than in 1986. Of the 563 routes, 366 (65%) exhibited positive trends, and 197 (35%) exhibited negative trends.

Trends varied by region (Table 4). Model-based estimates of total counts in the Northeast increased 6.1% yr^{-1} (95% CI = 3.4 –8.8%, $P < 0.001$), whereas those in the Northwest, Southwest, and Southeast showed no change (Table 4). Increasing trends were statistically significant in the northern and eastern portion of the country, but not in the West and South. Counts in the Northeast — almost 2.5 times higher in 2000 than in 1986 — indicated much steeper trends than in other regions. Trends were positive on 90% of routes in the Northeast. The proportions of routes with increasing trends in the Northwest and the Southeast were lower than in the Northeast but higher than in the Southwest. The proportion of routes with increasing trends was much higher north of 40° N compared to the south ($G_1 = 13.91$, $P < 0.001$), and much higher east of 100° W compared to the west ($G_1 = 32.54$, $P < 0.001$; Table 4).

Trends for ecoregions also showed a general Northeast-Southwest gradient, with significant ($P < 0.05$) increases for the East Coast, Eastern Woodlands, Great Lakes, and Prairie regions. The Great Lakes region showed the greatest estimated annual increase (7%); counts in the Rockies and Southwest Desert showed non-significant decreases (Table 2).

Trends were positive in 32 states and negative in 10 states. None of the decreases was significant, but 11 of the increases were significantly different from zero (Table 1). Most of the

TABLE 3. Significance of covariates and random effects in the hierarchical mixed model used to estimate trends in midwinter counts of Bald Eagles, 1986-2000.[a]

Fixed Effects	Numerator DF	Denominator DF	F^b	$P > F$
Year	1	547	13.23	0.0003
Route size category	3	4054	24.05	<0.0001
Route size by year	3	4054	0.80	0.4913
Region	3	4054	3.88	0.0087
Region by year	3	4054	5.14	0.0015
Region by route size	9	4054	0.71	0.6989
Region by route size by year	9	4054	0.62	0.7779
Concentration area	1	4054	364.98	<0.0001
Random Effects	**Estimate**	**Standard Error**	Z^c	$P > Z$
Slope increments	0.996	0.096	10.66	<0.0001
Intercept increments	0.005	0.001	7.65	<0.0001
Covariance	-0.044	0.007	-6.26	<0.0001
Model residual	0.545	0.012	45.53	<0.0001

[a] Based on 563 routes and 5,180 surveys.

[b] Model estimated by restricted maximum likelihood estimation; the defining contrast for the effect is tested with an approximate *F*-test (Littell et al. 1996, McCulloch and Searle 2001).

[c] Random effects have expected value of 0; this section shows variance estimate for these effects, using maximum likelihood theory and assumption of asymptotic normality. Tests whether the variance of these random effects is 0.

TABLE 4. Estimates of trends in the midwinter Bald Eagle count and proportion of survey routes with increasing trends by region, 1986-2000.

Region[a]	No. Routes	Trend estimate[b]	Standard error[b]	P-value	Change per year[c]	Routes with increasing counts
Overall	563	0.0192	0.005	0.000	1.9%	65%
North	267	0.0348	0.008	<0.001	3.5%	73%
South	296	0.0037	0.007	0.619	0.4%	58%
East	253	0.0367	0.008	<0.001	3.7%	78%
West	310	0.0017	0.007	0.808	0.2%	55%
Northeast	98	0.0590	0.013	<0.001	6.1%	90%
Southeast	155	0.0145	0.009	0.104	1.5%	70%
Northwest	169	0.0106	0.008	0.183	1.1%	63%
Southwest	141	-0.0072	0.012	0.540	-0.7%	45%

[a] Regions defined in relation to 40° N and 100° W.
[b] Calculated from logged counts.
[c] Estimated from actual counts (back-transformed).

significant increases were in northeastern or midwestern states; the highest significant increases occurred in Michigan (9.0% yr^{-1}) and New York (8.3% yr^{-1}).

Among eagles observed and aged, 67% were adults. The mean proportion of immatures varied from 29% in the Northwest, 34% in the Southwest, 33% in the Northeast, to 37% in the Southeast. The number of immature Bald Eagles increased approximately 1.5% yr^{-1} in all regions over the 15-yr period; counts of adults increased 2.7% yr^{-1} over the same period. Increases in counts of immatures were significant in the Northeast ($P < 0.001$), but not in the other regions (P's > 0.30). Counts of immatures in the Northwest showed a declining although nonsignificant trend ($P = 0.35$). In all regions, counts of adults increased at a higher rate than immatures. The increase in numbers of adults was significant ($P < 0.04$) in all regions except the Southwest ($P = 0.81$; Fig. 2).

DISCUSSION

SURVEY LIMITATIONS

As a large-scale volunteer effort that developed over several years, the Midwinter Bald Eagle survey has a number of problems that a well-designed monitoring effort would not have. Many reports could not be used because of incomplete documentation or inconsistent survey methods. Because survey routes were not randomly selected, we do not know if the standard routes used in this analysis are representative of the contiguous 48 states. Our findings are likely biased towards states and portions of states where agencies and individuals were committed to long-term, consistent data collection. Within those areas, sampling has emphasized river stretches and water bodies where Bald Eagles are known to occur. The survey, therefore, represents a type of "convenience sampling" and is subject to the inferential

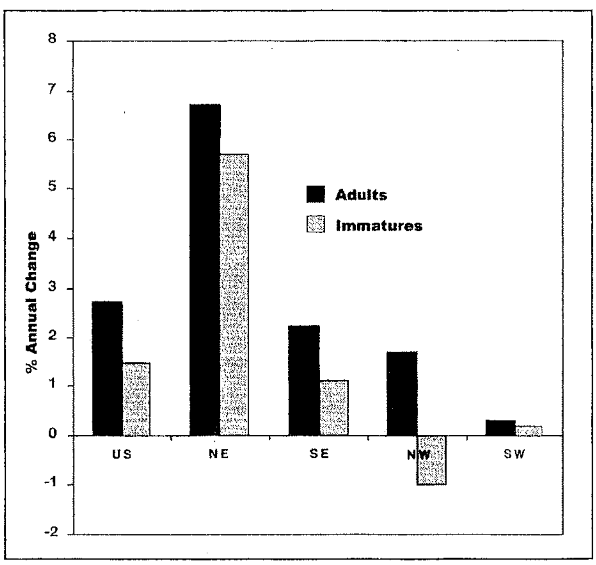

FIGURE 2. Estimated percent annual change in midwinter Bald Eagle counts by age class and region, 1986-2000. Regions are defined in relation to 40° N and 100° W.

constraints outlined by Anderson (2001). The midwinter counts cannot be used to estimate actual population size, and inferences about trends must be gauged carefully and restricted to the areas sampled by survey routes.

We have assumed that winter counts are a reasonable index to eagle abundance in the areas surveyed during the January sampling period. Trend analyses based on counts as indexes are valid only if the proportion of the population sampled is constant from year to year (Lancia et al. 1996). The ability to detect eagles may vary with many factors, including weather, topography, and vegetation. Because we treat each survey route equally and independently, our trend analysis only assumes that errors in detectability are consistent from year to year on a given survey route. Our analyses indicated that fog and precipitation did not influence counts significantly. We have controlled for variation in detectability by including only those surveys that covered the same area, using the same transportation method each year. Observer bias is likely not as much of a problem in our surveys compared to Breeding Bird Surveys (Sauer et al. 1994) and other singing-bird surveys (Bart and Schoultz 1984) because eagles are large, conspicuous, and relatively easy to identify by species and age class.

COUNT IMPLICATIONS

Our analysis confirms other findings that Bald Eagle populations in the U.S. are increasing. However, the magnitude of increase in our winter counts is not as dramatic as what has been observed for U.S. nesting populations. The number of nesting pairs reported by the Fish and Wildlife Service in the lower 48 states increased an average of 8% yr^{-1} from 1986 to 2000 (U.S. Fish and Wildlife Service unpubl. data); Breeding Bird Surveys showed Bald Eagle populations to be increasing 8% yr^{-1} from 1966 to 2000 (Sauer et al. 2001). The difference may be due to the fact that winter counts likely include individuals that nest in Canada and Alaska, where populations may not be increasing at the same rates as populations in the conterminous U.S. Spring counts of adult Bald Eagles in southeast Alaska increased from 1987 to 1992 but decreased from 1992 to 1997, suggesting that the population had stabilized (Jacobson and Hodges 1999). Our estimated trends are more similar to Christmas Bird Counts (CBC), which showed a 4.25% annual increase from 1955 to 1999 throughout North America (Sauer and Link 2000). The CBC trend may be slightly higher than our overall estimate because of the higher proportion of CBC routes in the northeastern U.S., where eagle counts appear to be increasing at a higher rate than elsewhere.

Increases in winter counts were higher in the northern and eastern part of the U.S. than in the West and South. This geographic variation could be due several factors. First, increasingly warmer winters during the sampling period (National Oceanic and Atmospheric Administration, unpubl. data) may have resulted in more eagles spending the winter farther north and fewer migrating south. New dams, spillways, and wastewater facilities that keep water from freezing in northern regions also may be enticing an increasing number of eagles to winter farther north and in greater densities at higher latitudes than in the past (Kerlinger 1989). Second, increases in winter counts may be inversely proportional to the declines suffered in the DDT-era. Population declines were most serious in the Great Lakes, Mississippi Valley, and East Coast, where both DDT and dieldrin were used heavily during the 1950s (Nisbet 1989). Just before surveys began (1980-84), residues of DDE were much higher in Bald Eagle eggs from Maine than in those from Arizona (Wiemeyer et al. 1993). Third, regional trends in Bald Eagle counts are inversely related to regional trends in human population growth. More rapid rates of human population expansion in the West and South (U.S. Census Bureau 2001) could be preventing eagles from colonizing previously suitable habitat. Bald eagle counts did not increase in the southwestern U.S during the sampling period.

Finally, the fact that counts of adults increased at almost twice the rate as counts of immatures suggests that the overall trend may reflect past increases in recruitment. In fact, the most substantial population recovery may have occurred before and at the beginning of the 15-yr sampling period. Thus, population recruitment may already be stabilizing.

RECOMMENDATIONS FOR FUTURE MONITORING

Despite its shortcomings, the Midwinter Bald

Eagle Survey represents a unique source of long-term data. Unlike nesting surveys, it provides information on both breeding and nonbreeding segments of the population at a potentially limiting time of year. It also provides an opportunity to monitor modifications or threats to habitat at important wintering areas.

Meaningful data on the population status of a mobile species like the Bald Eagle must be gathered over many years and on a large geographic scale. Previous studies have shown that when data variability is high, adding years to the survey effort will increase the power to detect population changes (Lewis and Gould 2000). Most midwinter survey routes showed a high degree of inter-year variability. The number of Bald Eagles and the timing of peak aggregations at particular wintering areas may change from year to year depending on food availability (Stalmaster 1987). Weather conditions influence the distribution of wintering Bald Eagles, with individuals moving farther south to find food in colder winters (Steenhof 1978). Eagles that usually occur on one survey route in a cold winter may be on another survey route several kilometers away in a warmer winter. Short-term counts at a limited number of survey sites can yield misleading information about population trends, when viewed alone. Long-term monitoring at sites throughout the continent provides more reliable data. The Midwinter Bald Eagle Survey provides a framework for such an effort.

The Midwinter Eagle Survey has become a national institution (Stalmaster 1987) and a tradition that will likely continue in many states. In addition to providing information on the trends, distribution, and habitat use of eagle populations, the count has helped to create public interest in Bald Eagles and their conservation. The survey is relatively economical, as the count infrastructure is in place and the analysis is relatively inexpensive. Future counts could help track how eagle populations respond to delisting and are no longer protected by the Endangered Species Act.

ACKNOWLEDGMENTS

This paper is a contribution from the USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station. Analyses would not have been possible without the cooperation of agencies and individuals in the 42 states that participated in the annual survey. We are indebted to the National Wildlife Federation for initiating the count and for providing 1986-1991 data. The Bureau of Land Management's Raptor Research and Technical Assistance Center (RRTAC) assumed responsibility for overseeing the count in 1992. Coordination and analysis continued when RRTAC staff became a part of the National Biological Survey and later the U.S. Geological Survey. The University of Minnesota's Raptor Center assisted with automating records from 1992 through 1994. We thank our many office assistants for entering and proofing data in all other years. Our paper was improved by the critical comments of D. Plumpton.

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