



## FEATURE ARTICLES

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### POPULATION TRENDS OF MIGRATORY RAPTORS IN WESTERN NORTH AMERICA, 1977–2001

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**Abstract.** Trained observers counted migrating raptors and vultures from ridgetops at six sites in the Intermountain and Rocky Mountain Flyways of western North America: Goshute Mountains, Nevada (autumn 1983–2001); Wellsville Mountains, Utah (autumn 1977–1979 and 1987–2001); Bridger Mountains, Montana (autumn 1992–2001); Manzano Mountains, New Mexico (autumn 1985–2001); Sandia Mountains, New Mexico (spring 1985–2001); and Lipan Point, Arizona (autumn 1991–2001). We analyzed site-specific trends in annual passage rates (raptors per 100 hr of observation), conducting species-level analyses for 13 species and age-specific analyses for Northern Goshawks (*Accipiter gentilis*) and Golden Eagles (*Aquila chrysaetos*). Our findings suggest that, until the late 1990s when possibly drought-related downturns began, Intermountain–Rocky Mountain populations of Turkey Vultures (*Cathartes aura*), Ospreys (*Pandion haliaetus*), Broad-winged Hawks (*Buteo platypterus*), Red-tailed Hawks (*B. jamaicensis*), Merlins (*Falco columbarius*), and Peregrine Falcons (*F. peregrinus*) were increasing for diverse reasons. In contrast, our migration data and other sources indicate concern over the status of western Golden Eagles and Ferruginous Hawks (*B. regalis*), and uncertainty about the status of western Northern Goshawks and American Kestrels (*F. sparverius*). Breeding Bird Survey and Christmas Bird Count trends generally corroborated our results. The migration data reveal regional variation in the status of some species, give new insight concerning Golden Eagle and Northern Goshawk migrations, and suggest effects of an ongoing, widespread drought. Our analyses demonstrate the value of standardized, long-term migration counts for monitoring the regional status and trends of migratory raptors in western North America.

**Key words:** migration counts, population trends, raptors, status review, western North America.

#### Tendencias Poblacionales de Aves Rapaces Migratorias en el Oeste de Norte América Entre 1977 y 2001

**Resumen.** Varios observadores entrenados contaron aves rapaces migratorias desde las cimas de montañas en seis sitios en los corredores de vuelo inter-montañas y de las Montañas Rocallosas en el oeste de Norte América: Goshute Mountains, Nevada (otoño 1983–2001); Wellsville Mountains, Utah (otoño 1977–1979 y 1987–2001); Bridger Mountains, Montana (otoño 1992–2001); Manzano Mountains, New Mexico (otoño 1985–2001); Sandia Mountains, New Mexico (primavera 1985–2001); Lipan Point, Arizona (otoño 1991–2001). Analizamos las tendencias específicas de cada sitio en las tasas anuales de paso (número de rapaces por 100 hr de observación), realizando análisis por especie para 13 especies y por edad para las especies *Accipiter gentilis* y *Aquila chrysaetos*. Nuestros hallazgos sugieren que hasta finales de los años 1990s (cuando comenzaron a verse tendencias negativas posiblemente relacionadas con sequías) las poblaciones de *Cathartes aura*, *Pandion haliaetus*, *Buteo platypterus*, *B. jamaicensis*, *Falco columbarius* y *F. peregrinus* estaban aumentando

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por diversos motivos. En contraste, nuestros datos de migración y otras fuentes causan preocupación en cuanto al estatus de *A. chrysaetos* y *B. regalis*, e incertidumbre sobre el estatus de *A. gentilis* y *F. sparverius*. Las tendencias evidentes en los censos de aves reproductivas y los conteos navideños generalmente corroboraron nuestros resultados. Los datos de migración mostraron la existencia de variación regional en el estatus de algunas especies, revelaron información nueva con respecto a las migraciones de *A. chrysaetos* y *A. gentilis* e indicaron los efectos de una sequía actual generalizada. Nuestros análisis demuestran el valor de conteos estandarizados de aves rapaces migratorias a largo plazo para monitorear el estatus regional y las tendencias poblacionales de estas aves en el oeste de Norte América.

## INTRODUCTION

As a group, raptors may be particularly sensitive indicators of environmental change because they inhabit most ecosystem types, occupy large home ranges, feed atop food webs, and are sensitive to chemical contamination and other forms of anthropogenic disturbance (Bildstein 2001). Long-term counts at sites where migrants concentrate can reveal broad-scale population trends for many raptor species; however, the usefulness and validity of migration counts depends on many factors (Fish 2001). Concerns include poor standardization of count procedures, locations, and observer numbers and proficiency; weather influences; and insufficient knowledge of sampling efficiency and species-specific migration behavior (Hussell 1985, Bednarz and Kerlinger 1989, Dunn and Hussell 1995, Lewis and Gould 2000).

Inconsistencies in data collection and subjective assessments of trends hampered early use of migration counts for raptor monitoring (Bednarz and Kerlinger 1989). More recently, some researchers standardized data collection procedures and analyzed data with statistics (Hussell 1985, Bednarz et al. 1990, Titus and Fuller 1990). In addition, evidence that migration counts reflect actual population trends has grown. Upon documenting concordance between the history of organochlorine pesticide use and dates of decline and recovery for raptor populations sampled at Hawk Mountain, Pennsylvania, Bednarz et al. (1990) concluded that standardized migration counts reflected qualitative trends of most raptor populations. Mueller et al. (1988) demonstrated similar concordance between patterns of pesticide use and Peregrine Falcon (*Falco peregrinus*) migration counts at Cedar Grove, Wisconsin. Titus and Fuller (1990) argued that consistency of trends across multiple count sites in eastern North America suggested that the results reflected actual regional population changes. Hussell and Brown (1992) docu-

mented significant positive correlations between spring migration counts in southern Ontario and Ontario Breeding Bird Survey (BBS) data for eight raptor species.

Because many raptor species occur at low densities and are difficult to detect, the BBS and Christmas Bird Counts (CBC) do not effectively monitor them (National Audubon Society 2002, Sauer et al. 2002). Adequate nesting studies are often logistically difficult and prohibitively expensive (Bednarz and Kerlinger 1989, Dunn and Hussell 1995). Therefore, counting migratory raptors at concentration points may be an efficient alternative for monitoring regional population trends of multiple species (Bildstein et al. 1995, Dunn and Hussell 1995, Dixon et al. 1998, Smith and Hoffman 2000, Zalles and Bildstein 2000). This may be particularly true for species with a substantial portion of their breeding range outside of BBS coverage zones in Canada and the northern U.S. (e.g., Peregrine Falcon and Merlin [*Falco columbarius*]). Thus, we agree with Dunn and Hussell (1995:78) who, after completing a thorough review of the status and usefulness of migration counts, concluded that "Overall, the benefits of migration counts for population monitoring appear substantial, while there are possible solutions for many of its drawbacks."

We analyze migration count trends for 15 species of raptors and vultures in western North America, using 10–19-year datasets from six sites in Montana, Utah, Nevada, Arizona, and New Mexico. Our data include trend information for several species of conservation concern: Peregrine Falcon, Northern Goshawk (*Accipiter gentilis*), Ferruginous Hawk (*Buteo regalis*), and Swainson's Hawk (*B. swainsoni*). Moreover, few current, multispecies summaries of the status of western raptor populations exist (White 1994, Kirk and Hyslop 1998). Herein, we review the status of each species analyzed and discuss possible environmental changes that may be responsible for current trends.

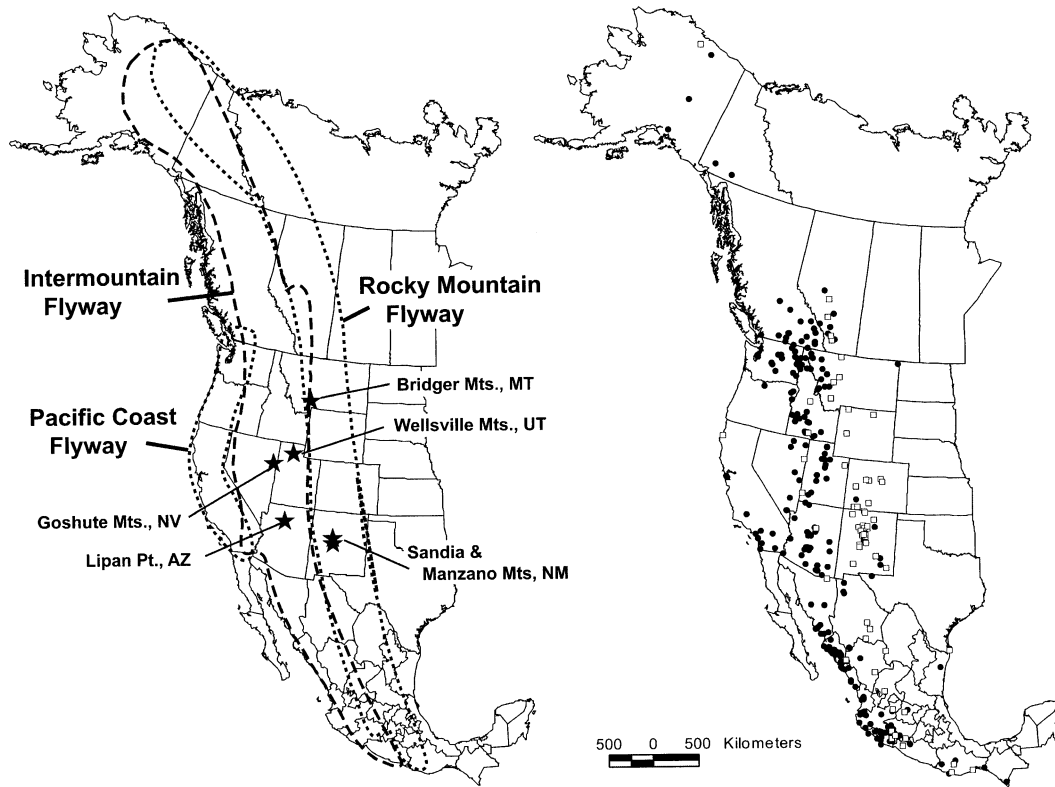


FIGURE 1. Locations of raptor counting sites in relation to major raptor migration flyways in western North America, and distributions of encounters with raptors (78% Sharp-shinned and Cooper’s Hawks) banded on migration in the Goshute Mountains, Nevada, from 1980–2001 (filled circles) and in the Sandia and Manzano Mountains, New Mexico, from 1985–2001 (unfilled squares; after Hoffman et al. 2002).

**METHODS**

**STUDY SITES**

We analyze data from one spring and five autumn count sites (Fig. 1). The autumn sites are in the Goshute Mountains of northeastern Nevada (40°25’N, 114°16’W, 2743 m elevation; Hoffman 1985), at Lipan Point on the south rim of the Grand Canyon in northern Arizona (36°02’N, 111°51’W, 2420 m), in the Bridger Mountains of southwestern Montana (45°49’N, 110°56’W, 2950 m; Omland and Hoffman 1996), in the Wellsville Mountains of northern Utah (41°41’N, 112°03’W, 2617 m; Hoffman 1985), and in the Manzano Mountains of central New Mexico (34°42’N, 106°25’W, 2805 m; DeLong and Hoffman 1999). The spring site is in the Sandia Mountains of north-central New Mexico (35°05’N, 106°26’W, 2196 m; Hoffman et al. 2002). For most species, counts at the two New

Mexico sites sample largely the same migratory populations.

**FIELD METHODS**

HawkWatch International and its organizational precursors coordinated all counts using the same methods. Systematic, season-long sampling occurred for 19 consecutive years in the Goshute Mountains (1983–2001), 18 years in the Wellsville Mountains (1977–1979, 1987–2001), 17 consecutive years in the Sandia and Manzano Mountains (1985–2001), 11 consecutive years at Lipan Point (1991–2001), and 10 consecutive years in the Bridger Mountains (1992–2001). The seasonal extent of sampling varied during the early years of each project because of initial financial uncertainty and attempts to identify the best site-specific sampling periods (Table 1). To reduce potential bias, we routinely truncated datasets to standardized sampling periods for each

TABLE 1. Sampling effort at six raptor migration count sites in the western United States.

Site	Years	Observation hours <sup>a</sup>				Start date				End date			
		Mean	Range	CV	Mean	Earliest	Latest	Used <sup>b</sup>	Mean	Earliest	Latest	Used <sup>b</sup>	
Goshute Mts., NV	1983–2001	651	485–772	11	15 Aug	15 Aug	20 Aug	15 Aug	3 Nov	22 Oct	17 Nov	3 Nov	
Lipan Point, AZ	1991–2001	496	400–553	8	29 Aug	27 Aug	8 Sep	29 Aug	5 Nov	5 Nov	5 Nov	5 Nov	
Bridger Mts., MT	1992–2001	305	239–337	16	2 Sep	27 Aug	13 Sep	9 Sep	29 Oct	28 Oct	2 Nov	29 Oct	
Wellsville Mts., UT	1977–1979	237	232–242	2	26 Aug	6 Aug	7 Sep	2 Sep	23 Oct	17 Oct	26 Nov	20 Oct	
Wellsville Mts., UT	1987–2001	316	242–381	11	26 Aug	6 Aug	7 Sep	2 Sep	23 Oct	17 Oct	26 Nov	20 Oct	
Manzano Mts., NM	1985–2001	495	343–559	11	27 Aug	23 Aug	6 Sep	27 Aug	3 Nov	31 Oct	8 Nov	3 Nov	
Sandia Mts., NM	1985–2001	501	411–605	10	17 Feb	7 Feb	1 Mar	24 Feb	5 May	29 Apr	12 May	5 May	

<sup>a</sup> Effort during standardized sampling periods, as defined in Table 2.

<sup>b</sup> Maximum sampling period used to truncate data for analysis of annual count trends; see Table 2 for final, species-specific sampling periods.

site (discussed below). After standardizing the seasonal sampling periods, total sampling time still varied among years (discussed below), but coefficients of variation always remained under 16% (Table 1).

Within the standardized sampling periods, observations occurred every day except during periods of heavy fog or precipitation, or when observer safety was compromised by heavy snow, lightning storms, or wildfires. Daily observation periods were similar across years and sites, with counts typically beginning between 08:00 and 09:00 Mountain Standard Time (MST) and continuing until at least 16:00; however, sampling often began earlier and continued later in the day on busy migration days. The primary exception to consistent daily sampling occurred in the Wellsvilles during the 1970s, when observers typically restricted their efforts to 6-hr peak-migration periods in the middle of the day. Comparative analyses with and without truncating the data to between 10:00 and 16:00 MST revealed no distinctly different trend results; therefore, the results presented below derive from the full dataset.

At each site, typically two trained observers worked together to conduct the counts, although a single observer was common before 1989. Observer teams varied across years, and visitors and other project crewmembers (e.g., educators and banders) frequently assisted with the counts.

Observers used 7–10× binoculars to detect and identify migrants, and occasionally 20–60× spotting scopes to aid in identifying but not detecting birds. They recorded all detected raptors and classified each to species, age, sex, and color morph whenever possible and applicable. Primary identification references included Clark and Wheeler (1987), Dunne et al. (1988), and Wheeler and Clark (1995).

Observers classified as residents and excluded from daily counts raptors that exhibited a distinct pattern of multidirectional flight, hunting, territorial display, or perching for an extended period (i.e., more than 10–15 min). Observers occasionally recorded as migrants birds that were not moving in “standard” northward or southward directions, if such birds otherwise displayed migrant characteristics (i.e., continuous flight without stopping or substantially changing directions for several kilometers). Such birds may be locally dispersing juveniles, adults moving relatively short distances from

nesting territories to nearby wintering grounds, or species that we know frequently migrate in a variety of directions.

At the Goshute and Manzano sites, one or more trapping stations were located in front of the count site relative to the travel direction of migrating raptors. Captures at these “north stations” averaged 11% of the raptors counted each season in both the Goshute and Manzano Mountains, excluding species that we were unable to trap, such as Ospreys (*Pandion haliaetus*) and Turkey Vultures (*Cathartes aura*). Observers did not record any raptors that they saw respond to the north trapping operations unless they confirmed that the bird was not captured and continued on its way. They minimized double counting by excluding birds released from the trapping stations based on behavioral observations (trapped birds often “rouse” and briefly shake their tails after release) and routine radio reports from capture stations about release times for each raptor. Observers then summed counts and trapping totals for the north stations to give daily passage totals for each site.

STATISTICAL ANALYSES

*Migration.* To minimize biases related to annual variation in sampling seasons, we defined species-specific sampling periods for each migration site (Table 2) following conventions proposed by Bednarz and Kerlinger (1989) and Bednarz et al. (1990). For each site, we converted counts to passage rates on a daily basis (raptors per 10 hr of observation), summed daily rates by Julian date across all years, and defined standardized passage periods for each species by eliminating approximately 2.5% from each extreme of the cumulative passage-rate distributions. Because the basis for this data trimming was entire count days, not individual bird sightings, the defined sample period for a given species and site included 95–100% of the detected number of migrants. In some cases, the sample periods defined in this way encompassed dates earlier or later than periods of continuous observations. In these cases, we further restricted the adjusted sampling periods to between mean starting and ending dates of continuous observations for the site or, especially for the Bridger and Wellsville sites where variation was more pronounced, to a compromise between mean dates and latest starting or earliest ending dates (Table 1).

TABLE 2. Species-specific, standardized sampling periods used to analyze trends in raptor migration counts at six sites in the western United States. Each period encompasses approximately 95% of the cumulative distribution of migration activity for a given species and site.

Species	Goshute Mountains, NV	Lujan Point, AZ	Bridger Mountains, MT	Wellsville Mountains, UT	Manzano Mountains, NM	Sandia Mountains, NM
Turkey Vulture	31 Aug–5 Oct	3 Sep–7 Oct	3 Sep–30 Sep	2 Sep–5 Oct	26 Aug–5 Oct	22 Mar–28 Apr
Osprey	25 Aug–8 Oct	5 Sep–3 Nov	1 Sep–2 Oct	2 Sep–3 Oct	30 Aug–9 Oct	28 Mar–1 May
Northern Harrier	18 Aug–29 Oct	3 Sep–17 Oct	1 Sep–24 Oct	2 Sep–20 Oct	29 Aug–30 Oct	4 Mar–30 Apr
Sharp-shinned Hawk	1 Sep–23 Oct	8 Sep–30 Oct	6 Sep–24 Oct	2 Sep–19 Oct	4 Sep–26 Oct	9 Mar–4 May
Cooper's Hawk	30 Aug–14 Oct	6 Sep–22 Oct	1 Sep–19 Oct	2 Sep–18 Oct	4 Sep–17 Oct	18 Mar–1 May
Northern Goshawk	23 Aug–3 Nov	7 Sep–3 Nov	5 Sep–28 Oct	2 Sep–20 Oct	2 Sep–1 Nov	24 Feb–29 Apr
Broad-winged Hawk	10 Sep–6 Oct	17 Sep–6 Oct	8 Sep–6 Oct	2 Sep–2 Oct	31 Aug–9 Oct	5 Mar–2 May
Swinson's Hawk	24 Aug–6 Oct	4 Sep–10 Oct	1 Sep–13 Oct	2 Sep–1 Oct	5 Sep–5 Oct	2 Apr–4 May
Red-tailed Hawk	21 Aug–31 Oct	8 Sep–2 Nov	1 Sep–20 Oct	2 Sep–19 Oct	2 Sep–1 Nov	2 Mar–29 Apr
Ferruginous Hawk	22 Aug–27 Oct	7 Sep–3 Nov	1 Sep–27 Oct	2 Sep–19 Oct	31 Aug–1 Nov	24 Feb–28 Apr
Golden Eagle	21 Aug–2 Nov	16 Sep–4 Nov	13 Sep–27 Oct	2 Sep–20 Oct	2 Sep–2 Nov	24 Feb–30 Apr
American Kestrel	21 Aug–11 Oct	2 Sep–16 Oct	1 Sep–12 Oct	2 Sep–12 Oct	31 Aug–13 Oct	16 Mar–1 May
Merlin	1 Sep–31 Oct	13 Sep–3 Nov	1 Sep–27 Oct	2 Sep–20 Oct	12 Sep–2 Nov	4 Mar–29 Apr
Prairie Falcon	17 Aug–25 Oct	2 Sep–30 Oct	1 Sep–25 Oct	2 Sep–20 Oct	29 Aug–27 Oct	24 Feb–30 Apr
Peregrine Falcon	20 Aug–20 Oct	29 Aug–29 Oct	8 Sep–18 Oct	2 Sep–18 Oct	30 Aug–20 Oct	24 Feb–2 May



Observers commonly identified distant or otherwise poorly observed migrants only to genus or other common groupings (e.g., unidentified eagle, which includes two genera, *Haliaeetus* and *Aquila*). Such identifications sometimes constituted a sizeable proportion of the birds seen, especially for accipiters, and varied with observer experience and weather conditions. Excluding these birds from trend analyses may render inaccurate assessments of true flight volume. Accordingly, before conducting trend analyses we adjusted the daily count data by distributing incompletely identified birds across relevant species in proportion to the relative abundance of birds identified to each species that day. After adjusting the daily counts as described, we calculated annual passage rates ([total raptors counted/total hours of observation for a given year] × 100 = raptors per 100 hr) for 15 species whose adjusted counts averaged at least five birds per year at four or more sites (Table 3) and for which we believe our monitoring provides useful trend assessments.

We assume that weather affects the magnitude of migration and the detectability of raptors at all count sites, but also that the effects of weather on our samples were random with respect to the population size in any given year (Burnham et al. 1980, Bednarz et al. 1990). Allen et al. (1996) confirmed that, although variation in the frequency of cold fronts is a primary cause of within-season activity patterns, it is not a significant cause of variation in annual count totals at Hawk Mountain, Pennsylvania. Although we agree with the premise behind Hussell's (1981, 1985) ANCOVA approach, we have not attempted to account for weather effects in our analyses. This may reduce statistical power for detecting underlying population trends, but should not result in erroneous conclusions when significant trends are indicated.

We analyzed trends in annual passage rates from most sites using simple linear and quadratic regressions with standard *t*-tests to assess the significance of the regression coefficients (Bednarz and Kerlinger 1989, Titus and Fuller 1990, Hatfield et al. 1996). We did not explore use of the multisite capabilities of route regression (Geissler and Sauer 1990), rank trend analysis (Titus et al. 1990), or ANCOVA (Hussell 1981). Instead, because of uncertainties about the monitored populations each site represents, we followed Dunn and Hussell's (1995) sugges-

TABLE 3. Mean (±SD) annual migration counts for 15 raptor species at six sites in the western United States, with counts adjusted for incompletely identified birds and standardized sampling periods (see Table 2). Counts occurred during autumn at five sites and during spring in the Sandia Mountains. See Table 1 for periods of record.

Species	Goshute Mountains, NV	Lipan Point, AZ	Bridger Mountains, MT	Wellsville Mountains, UT	Manzano Mountains, NM	Sandia Mountains, NM
Turkey Vulture	301 ± 154	156 ± 99	1 ± 2	14 ± 8	396 ± 270	1367 ± 626
Osprey	88 ± 46	80 ± 27	7 ± 5	23 ± 11	26 ± 12	62 ± 30
Northern Harrier	175 ± 74	90 ± 33	51 ± 55	243 ± 89	61 ± 26	57 ± 16
Sharp-shinned Hawk	4981 ± 2012	1620 ± 418	370 ± 124	853 ± 178	1473 ± 453	549 ± 276
Cooper's Hawk	3415 ± 1513	2576 ± 520	367 ± 177	545 ± 142	965 ± 323	838 ± 313
Northern Goshawk	117 ± 50	11 ± 12	39 ± 24	21 ± 11	15 ± 10	11 ± 6
Broad-winged Hawk	40 ± 36	10 ± 11	11 ± 11	4 ± 4	6 ± 3	6 ± 6
Swainson's Hawk	198 ± 137	29 ± 12	3 ± 4	136 ± 153	634 ± 1713	50 ± 19
Red-tailed Hawk	2962 ± 949	1760 ± 569	107 ± 50	502 ± 209	616 ± 170	339 ± 112
Ferruginous Hawk	16 ± 7	7 ± 4	3 ± 2	9 ± 5	13 ± 6	13 ± 5
Golden Eagle	260 ± 55	28 ± 16	1534 ± 213	171 ± 80	116 ± 30	336 ± 161
American Kestrel	1995 ± 930	2390 ± 350	168 ± 77	772 ± 205	553 ± 150	200 ± 95
Merlin	40 ± 29	23 ± 9	21 ± 13	10 ± 6	23 ± 14	9 ± 7
Prairie Falcon	30 ± 14	10 ± 6	24 ± 7	14 ± 6	21 ± 13	22 ± 10
Peregrine Falcon	11 ± 9	14 ± 7	17 ± 11	8 ± 6	37 ± 29	34 ± 26

tion to analyze results from each site separately and look for regional patterns.

Positive autocorrelation, which occurs in some annual count datasets and violates the assumption of independent residuals necessary for parametric analyses, tends to inflate the significance of apparent trends. For this reason, Hatfield et al. (1996) advocated assignment of significance only when  $P \leq 0.01$ . To determine the need for this conservative approach, we used two-tailed Durbin-Watson tests and plots of predicted values versus residuals to assess autocorrelation in our data (Myers 1990). In the absence of significant Durbin-Watson autocorrelation tests, we considered  $P \leq 0.10$  indicative of trends worthy of attention (Lewis and Gould 2000).

When diagnostic tests indicated possible quadratic terms (Myers 1990), we added a  $Year^2$  term to the regression model to assess its effect (Dunn and Hussell 1995) and retained it if the  $t$ -test  $P$ -value for that variable was  $\leq 0.10$ . When the diagnostics revealed problems with outliers and violations of the assumptions of normally distributed residuals or homogeneous variances, we recalculated the standard parametric regressions using log-transformed passage rates:  $\ln(\text{birds per } 100 \text{ hr} + 1)$  (Hussell 1985, Bednarz et al. 1990) and conducted two-tailed nonparametric rank trend analyses for comparison (method of Lehmann 1975 as modified by Titus et al. 1990; also see Hatfield et al. 1996).

For the Wellsville Mountains, we analyzed trends for the continuous observation period 1987–2001 using regressions; however, the gap in coverage between 1979 and 1987 precluded including the 1970s data in the regression analyses. Instead, we compared mean annual passage rates from 1977–1979 and 1987–2001 using two-tailed, independent  $t$ -tests (Hussell 1981, Bednarz and Kerlinger 1989). We used standard pooled-variance  $t$ -tests whenever a variance-ratio  $F$ -test indicated homogeneous variances ( $P > 0.05$ ) and separate-variance  $t$ -tests otherwise (Snedecor and Cochran 1989). For Peregrine Falcons, we used a nonparametric Mann-Whitney  $U$ -test because zero counts during 1977–1979 precluded using a  $t$ -test.

For most species, we conducted only species-level analyses; however, we conducted age-specific analyses for Northern Goshawks and Golden Eagles (*Aquila chrysaetos*). Age-specific analysis is particularly important for these spe-

cies because adults in many areas are only partial or irruptive migrants, whereas younger birds usually migrate on a regular basis (Squires and Reynolds 1997, Kochert et al. 2002). Species-level migration indices therefore cannot necessarily be interpreted as representing a particular subpopulation, as may be done for more migratory species (Bednarz et al. 1990, Dunn and Hussell 1995). Systematic measures of the movements of young birds, however, should represent an unbiased index of the size of the non-adult population in the relevant region. Moreover, age-specific sample sizes for these two species were generally large enough (average  $\leq 5$  birds per season for all but two site  $\times$  age-class combinations: second-year goshawks in the Sandias and adult goshawks in the Wellsvilles) to enable separate analyses, and percentages of unknown-age birds averaged less than 25% at all sites except Lipan Point (35–40%). The latter condition minimizes potential bias caused by considering age data when the proportion of unknown-age birds is large. Before calculating passage rates, we also allocated, on a daily basis, unknown-age birds to age-specific categories according to the relative proportions of known-age birds seen that day. We then analyzed trends in the adjusted age-specific passage rates, as well as annual immature:adult count ratios (with the ratios square-root transformed to normalize residuals; hereafter called “age ratios”), using the same methods as for species-level analyses.

In discussing age-specific data, we adopt the following terminology. For Northern Goshawks, when autumn data are being considered, “immature” refers to hatch-year or juvenile birds and “adult” refers to nonjuvenile birds, whereas for spring comparisons “immature” refers to second-year birds (still with predominantly juvenile plumage) and “adult” refers to after-second-year birds. For Golden Eagles, “immature” refers collectively to all juvenile and subadult (Basic I–III) plumage classes (i.e., birds with white in the wings or tail versus adults with no white plumage; Wheeler and Clark 1995).

We used SYSTAT® 10.0 (SPSS Inc. 2000) for all analyses. Detailed statistical results are available online (HawkWatch International 2003).

**BBS and CBC Data.** We calculated trends for the BBS Western Region for the period 1977–2000 using the data-selection, estimating-equation, and route-regression routines available on-

line (Sauer et al. 2002). We calculated trends in CBC counts for the period 1977–2001 using count per party hour data available online (National Audubon Society 2002). In this case, we extracted from the online database annual count per party hour estimates for an aggregated “western region” including four western Canadian provinces (British Columbia, Alberta, Yukon Territory, and Northwest Territory) and 12 western states (Alaska, Washington, Oregon, California, Idaho, Utah, Arizona, Montana, Wyoming, New Mexico, and Arizona). We then used linear and quadratic, parametric regressions to elucidate significant trends.

## RESULTS

Diagnostic residual plots from species-level regressions of the migration data indicated reasonable conformity to the assumption of homogeneous variances. Outliers and attendant moderately non-normal residuals occurred; however, aside from minor differences in significance levels, the regressions with and without log-transformed passage rates and nonparametric rank trend analyses usually resulted in the same basic conclusions. Therefore, we present the results of parametric regressions based on untransformed passage rates, but clearly highlight where log-transformations or rank-trend analyses suggested different conclusions.

Autocorrelation was only a minor problem. A significant Durbin-Watson test ( $\alpha = 0.05$ ) arose only once out of 90 site-species cases and inconclusive results arose only seven times (8%). Moreover, for three of the eight problem cases the trend results were far from statistically significant, so inflated significance was not an issue. Residual plots also gave no definitive indications of positive or negative autocorrelation. We recognize, however, that statistical power to detect autocorrelation was probably low because of the limited number of annual samples. Accordingly, we distinguished results as highly significant ( $P \leq 0.01$ ), significant ( $P \leq 0.05$ ), marginally significant ( $P \leq 0.10$ ), or nonsignificant ( $P > 0.10$ ).

### SPECIES-LEVEL MIGRATION TRENDS

Regressions of Goshute Mountains passage rates indicated a marginally significant increase for Swainson’s Hawks (significant using log-transformed passage rates); significant quadratic trends (former increasing trends now stabilized

or decreasing) for Ferruginous Hawks and Merlins; no trend for Northern Goshawks or Golden Eagles (though rank-trend analysis indicated a marginally significant increase for eagles); and significant to highly significant increases for the remaining 10 species (Fig. 2–6).

Regressions of Lipan Point passage rates indicated significant (highly significant using log-transformed passage rates) quadratic trends for Ospreys and Swainson’s Hawks (strong increases through 1996 or 1997, followed by declines); a significant (highly significant using log-transformed passage rates) quadratic trend for Golden Eagles (large increase from 1991 to 1992 but a pronounced decline thereafter); a significant increase for Broad-winged Hawks (*B. platypterus*; highly significant using log-transformed passage rates); a significant decline for Ferruginous Hawks; and no trends for 10 species (Fig. 2–6). Absent an outlier high count in 1992, Peregrine Falcon passage rates also increased strongly through 1998, then dropped and stabilized during the following years (Fig. 6).

Wellsville Mountains *t*-tests of mean annual passage rates for 1977–1979 and 1987–2001 indicated significant or highly significant increases for Turkey Vultures, Ospreys, Swainson’s Hawks, Red-tailed Hawks (*Buteo jamaicensis*), Ferruginous Hawks, Merlins, and Peregrine Falcons; a marginally significant increase for Broad-winged Hawks (significant using log-transformed passage rates); significant or highly significant declines for Northern Goshawks ( $P < 0.01$ ), Golden Eagles, and American Kestrels (*Falco sparverius*); and no difference for four other species (Fig. 2–6). Regressions of 1987–2001 passage rates indicated marginally to highly significant quadratic trends (increases through the mid-1990s followed by recent declines) for Ospreys, Cooper’s Hawks (*Accipiter cooperii*), Swainson’s Hawks, Red-tailed Hawks, Ferruginous Hawks, and American Kestrels; a highly significant quadratic trend for Peregrine Falcons (accelerating increase); and no trends for eight species (Fig. 2–6).

Regressions of Bridger Mountains passage rates indicated a marginally significant increase for Broad-winged Hawks, marginally significant declines for Swainson’s Hawks and Golden Eagles, and no trends for 12 species (Fig. 2–6). Despite a lack of statistical significance (partly a result of the shorter period), Peregrine Falcon passage rates in the Bridger Mountains followed



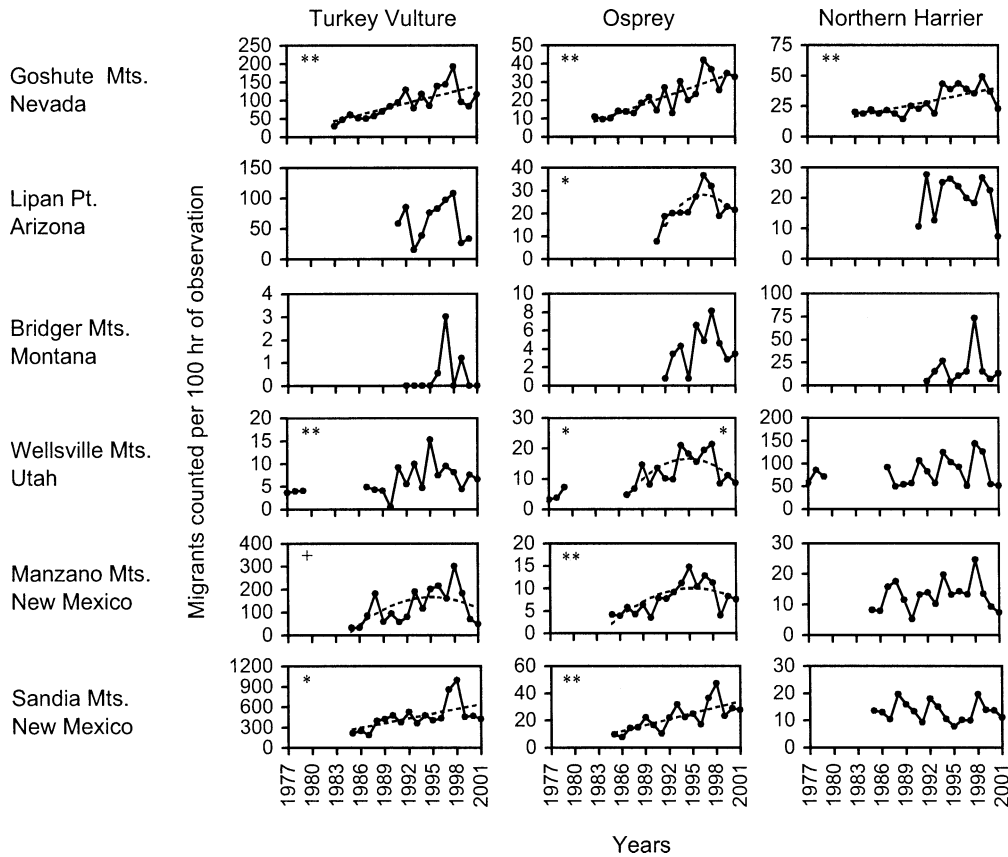


FIGURE 2. Annual passage rates of Turkey Vultures, Ospreys, and Northern Harriers at six migration count sites in the western United States, adjusted for incompletely identified birds and standardized sampling periods. Dashed lines indicate significant linear or quadratic regressions of trends in passage rates. Regression significance: + $P \leq 0.10$ , \*  $P \leq 0.05$ , \*\*  $P \leq 0.01$ . For the Wellsville Mountains, symbols in the upper left corners indicate significant  $t$ -tests comparing average passage rates for 1977–1979 and 1987–2001, whereas symbols in the upper right corners indicate significant regressions of passage rates for 1987–2001.

a pattern similar to other migration sites, increasing through 1998, decreasing thereafter (Fig. 6).

Regressions of Manzano Mountains passage rates indicated significant to highly significant increases for Swainson’s Hawks (only when based on log-transformed passage rates), Merlins, Prairie Falcons (*Falco mexicanus*), and Peregrine Falcons; marginally significant increases for Cooper’s Hawks and Red-tailed Hawks; a highly significant decline for Ferruginous Hawks; marginally significant or significant quadratic trends (increasing patterns through 1997 or 1998 followed by recent declines) for Ospreys and Turkey Vultures; and no trends for six species (Fig. 2–6).

Regressions of Sandia Mountains passage rates indicated highly significant increases for Turkey Vultures, Ospreys, Broad-winged Hawks, Merlins, and Peregrine Falcons; marginally significant increases for Swainson’s Hawks (significant using rank trend analysis) and Red-tailed Hawks; and no trends for eight species (Fig. 2–6).

A common pattern of stable or increasing trends through the mid-1990s followed by declines after 1998 emerged for most species at all sites. Significant quadratic trends frequently confirmed the pattern. In several other cases, however, quadratic regressions did not provide a significant fit, but linear regressions of data through 1998 revealed significant increases that did not extend beyond that time due to a decline

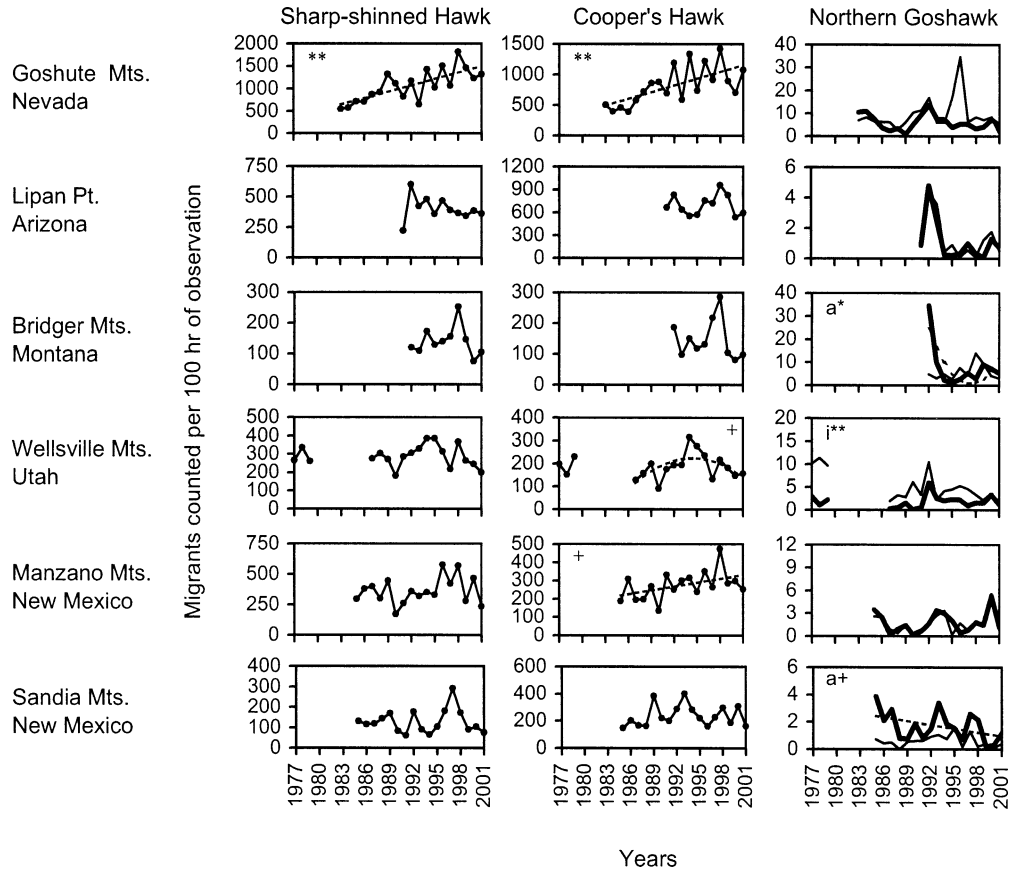


FIGURE 3. Annual passage rates of Sharp-shinned Hawks, Cooper's Hawks, and Northern Goshawks (thick lines for adults; thin lines for immatures) at six migration count sites in the western U.S., adjusted for incompletely identified birds and standardized sampling periods. Dashed lines indicate significant linear or quadratic regressions of trends in passage rates. Regression significance: + $P \leq 0.10$ , \* $P \leq 0.05$ , \*\* $P \leq 0.01$ . For the Wellsville Mountains, symbols in the upper left corners indicate significant  $t$ -tests comparing average passage rates for 1977–1979 and 1987–2001, whereas symbols in the upper right corners indicate significant regressions of passage rates for 1987–2001. For Northern Goshawks, symbols signifying statistical significance are preceded by “a” for adults or “i” for immatures.

in activity. This applied to Turkey Vultures ( $r^2 = 0.32$ ,  $P = 0.06$ ) in the Wellsville Mountains; Ospreys ( $r^2 = 0.58$ ,  $P = 0.05$ ), Sharp-shinned Hawks (*Accipiter striatus*;  $r^2 = 0.54$ ,  $P = 0.06$ ), and American Kestrels ( $r^2 = 0.52$ ,  $P = 0.07$ ) in the Bridger Mountains; and Northern Harriers (*Circus cyaneus*;  $r^2 = 0.27$ ,  $P = 0.06$ ) and Sharp-shinned Hawks ( $r^2 = 0.24$ ,  $P = 0.07$ ) in the Manzano Mountains.

AGE-SPECIFIC MIGRATION TRENDS

For Northern Goshawks, Bridger Mountains regressions indicated a significant quadratic trend for adults (decline from 1992–1995, probably an

artifact of the count beginning during an irruption year [Mueller et al. 1977], followed by a gradual increase) and no trends for immatures or age ratios (Fig. 3). Wellsville Mountains  $t$ -tests indicated a highly significant decline for immatures, no significant difference for adults, and a marginally significant decline in age ratios. Wellsville Mountains regressions indicated no significant trends for adults or immatures, but a significant decline in age ratios. Sandia Mountains regressions indicated no trend for immatures, a marginally significant decline for adults, and a marginally significant quadratic trend in age ratios (increase through 1991 followed by

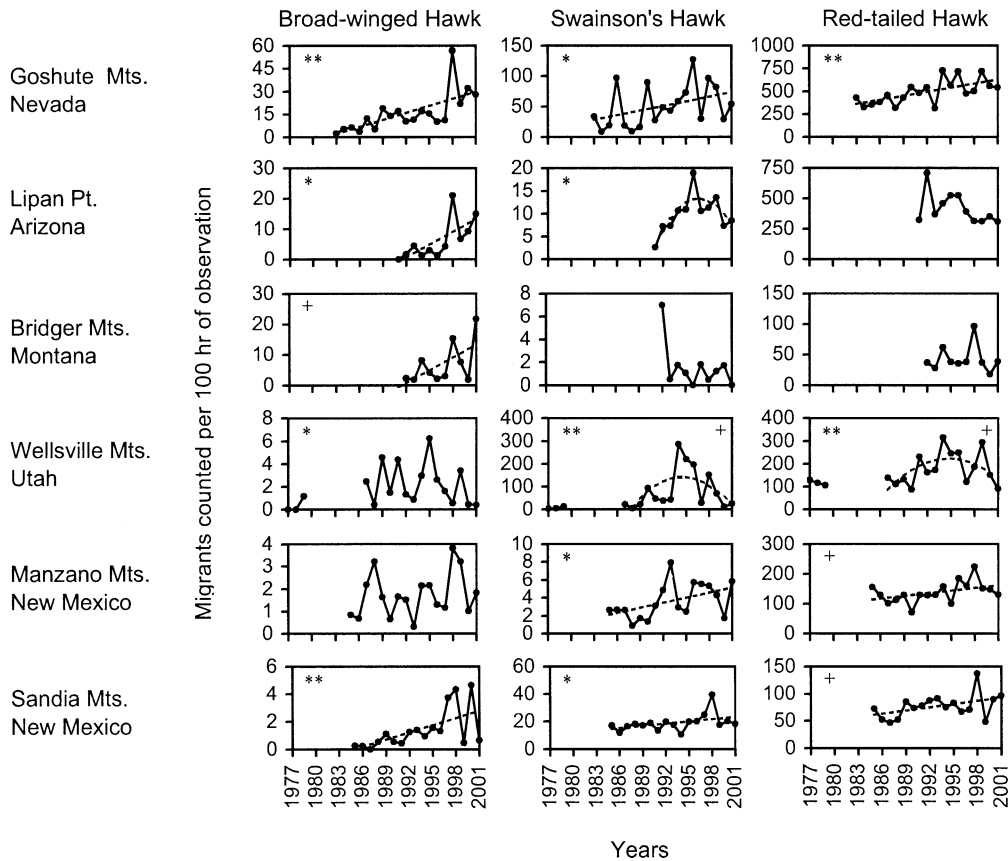


FIGURE 4. Annual passage rates of Broad-winged Hawks, Swainson's Hawks (y-axis for Manzano Mountains =  $\ln[\text{migrants per } 100 \text{ hr} + 1]$ ), and Red-tailed Hawks at six migration count sites in the western U.S., adjusted for incompletely identified birds and standardized sampling periods. Dashed lines indicate significant linear or quadratic regressions of trends in passage rates. Regression significance: +  $P \leq 0.10$ , \*  $P \leq 0.05$ , \*\*  $P \leq 0.01$ . For the Wellsville Mountains, symbols in the upper left corners indicate significant *t*-tests comparing average passage rates for 1977–1979 and 1987–2001, whereas symbols in the upper right corners indicate significant regressions of passage rates for 1987–2001.

stabilization and a possible recent decline). Goshute Mountains, Lipan Point, and Manzano Mountains regressions indicated no trends.

For Golden Eagles, Goshute Mountains regressions indicated a significant increase for immatures but no trends for adults or age ratios (Fig. 5). Lipan Point regressions indicated a significant quadratic trend for adults (increase through 1996 but a steep decline thereafter) and significant declines for immatures and age ratios. Wellsville Mountains *t*-tests indicated no difference for adults, a highly significant decline for immatures, and a significant decline in age ratios. Wellsville Mountains regressions indicated a significant quadratic trend for adults (increase through 1993 but stabilization and a possible re-

cent decline since), but no trends for immatures or age ratios. Bridger, Manzano, and Sandia Mountains regressions indicated no trends.

BBS AND CBC TRENDS

Western BBS data indicated highly significant increases for Turkey Vultures, Ospreys, Sharpshinned Hawks, Red-tailed Hawks, and Peregrine Falcons; marginally significant increases for Ferruginous Hawks and Prairie Falcons; significant to highly significant declines for Northern Harriers and American Kestrels; and no trends for six species (Table 4).

CBCs do not provide useful data for Broad-winged or Swainson's Hawks because these species generally vacate North America for the win-

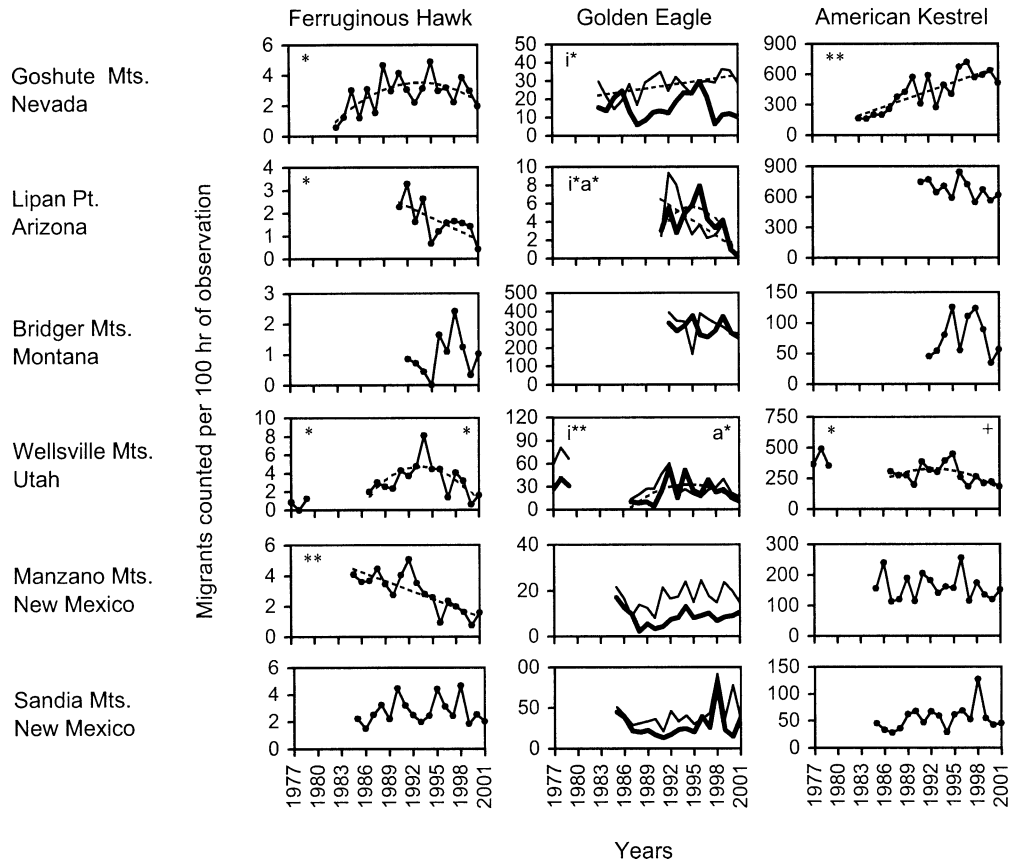


FIGURE 5. Annual passage rates of Ferruginous Hawks, Golden Eagles (thick lines for adults, thin lines for immatures), and American Kestrels at six migration count sites in the western U.S., adjusted for incompletely identified birds and standardized sampling periods. Dashed lines indicate significant linear or quadratic regressions of trends in passage rates. Regression significance: + $P \leq 0.10$ , \* $P \leq 0.05$ , \*\* $P \leq 0.01$ . For the Wellsville Mountains, symbols in the upper left corners indicate significant  $t$ -tests comparing average passage rates for 1977–1979 and 1987–2001, whereas symbols in the upper right corners indicate significant regressions of passage rates for 1987–2001. For Golden Eagles, symbols signifying statistical significance are preceded by “a” for adults or “i” for immatures.

ter (Bechard and Schmutz 1995, Goodrich et al. 1996). Otherwise, CBC data indicated marginally to highly significant quadratic trends for Turkey Vultures (stable pattern through 1990, accelerating increase since then), Ospreys (long-term, accelerating increase), Cooper’s Hawks (mild trough pattern with low years in 1987 and from 1990–1992, but mostly higher counts since), Red-tailed Hawks (strong increasing trend through 1995, mostly stable counts since), and Ferruginous Hawks (strong increasing trend through 1992, steady decline since); significant to highly significant increases for Sharp-shinned Hawks, Golden Eagles, Merlins, and Peregrine Falcons; a marginally significant decline for

American Kestrels; a significant decline for Prairie Falcons; and no significant trends for Northern Harriers and Northern Goshawks (Table 4).

DISCUSSION

GEOGRAPHIC SOURCES OF MIGRATING RAPTORS

Accurate interpretation of migration count trends requires knowledge of source populations, which is incomplete for our migration sites. Nevertheless, band-return and satellite-telemetry studies provide insight. Encounters with birds banded on migration in the western U.S. delineate three major regional flyways: from west to east, Pacific Coast, Intermountain, and Rocky

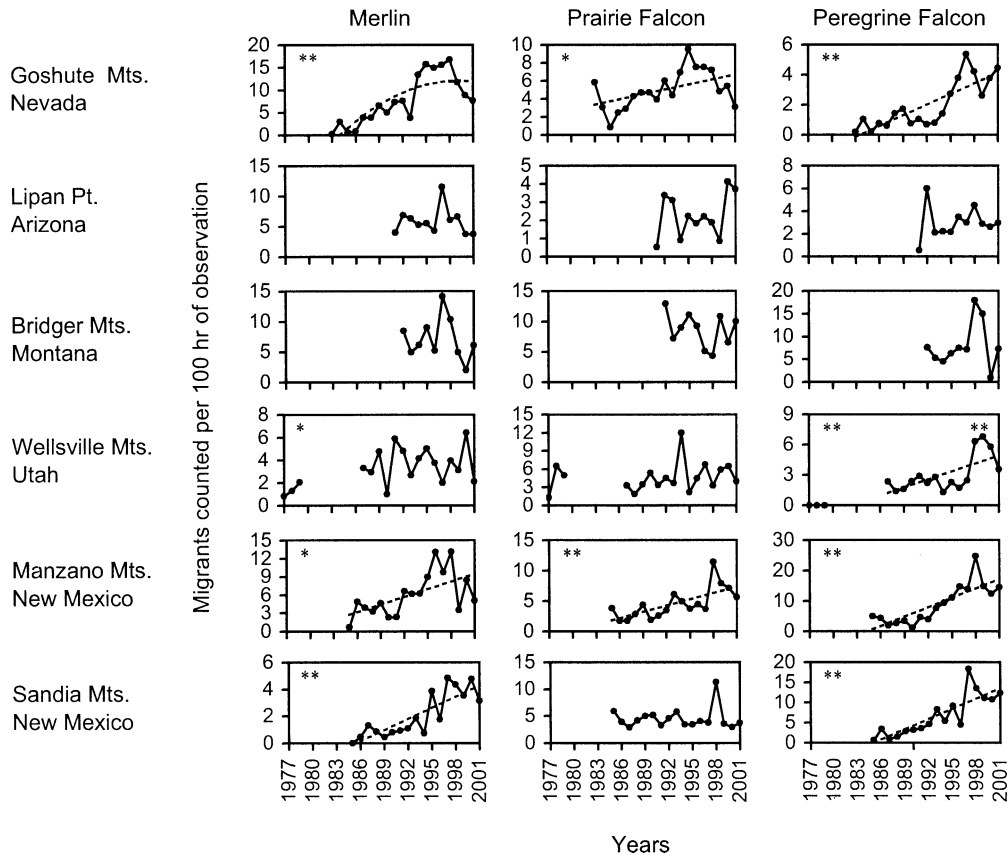


FIGURE 6. Annual passage rates for Merlins, Prairie Falcons, and Peregrine Falcons at six migration count sites in the western U.S., adjusted for incompletely identified birds and standardized sampling periods. Dashed lines indicate significant linear or quadratic regressions of trends in passage rates. Regression significance: + $P \leq 0.10$ , \*  $P \leq 0.05$ , \*\*  $P \leq 0.01$ . For the Wellsville Mountains, symbols in the upper left corners indicate significant  $t$ -tests (Mann-Whitney  $U$ -test for Peregrine Falcons) comparing average passage rates for 1977–1979 and 1987–2001, whereas symbols in the upper right corners indicate significant regressions of passage rates for 1987–2001.

Mountain (Fig. 1; Hoffman et al. 2002). The Nevada and Arizona sites lie within the Intermountain Flyway. The Montana and New Mexico sites lie within the Rocky Mountain Flyway. The Wellsville Mountains also are considered part of the Rocky Mountains complex, but may lie along a transition zone between the Intermountain and Rocky Mountain Flyways.

Extensive band-return data paint a relatively complete picture of the overall source and destination areas for Sharp-shinned Hawks and Cooper's Hawks associated with the Goshute and New Mexico project sites (Fig. 1). Goshute migrants originate as far north as Alaska (or the northern extent of the Cooper's Hawk range in British Columbia). The Intermountain Flyway in

which they travel runs between the Rocky Mountains and Cascade-Sierra Nevada ranges, south through British Columbia, the Intermountain West, and the Great Basin, and into southwestern Mexico west of the Sierra Madre Occidental. New Mexico migrants also may originate as far north as Alaska and the Yukon Territory. The Rocky Mountain Flyway in which they travel runs along the Rocky Mountains, or its eastern flanks, through Alberta and south into Mexico along either the eastern flanks of the Sierra Madre Occidental and into far southwestern Mexico, or south along the Sierra Madre Oriental and into southeastern Mexico. Available band-return data are limited for most other species, but data for American Kestrels and Red-



TABLE 4. Raptor count trends in western North America as documented by Breeding Bird Surveys (1977–2000) and Christmas Bird Counts (1977–2001). BBS trend estimates derive from online procedures (route regression using estimating equations) and the standard “western region” geographic context (Sauer et al. 2002). CBC trend estimates derive from linear or quadratic regressions of annual count per party hour estimates (National Audubon Society 2002) for western states and provinces specified in Methods. I = linear increase; D = linear decrease; Q<sub>AI</sub> = quadratic trend, accelerating increase; Q<sub>H</sub> = quadratic trend, convex hill pattern; Q<sub>SI</sub> = quadratic trend, stabilizing increase pattern; Q<sub>T</sub> = trough pattern; +  $P \leq 0.10$ , \*  $P \leq 0.05$ , \*\*  $P \leq 0.01$ ; — = insufficient data for analysis.

Species	Breeding Bird Survey	Christmas Bird Count
Turkey Vulture	I**	Q <sub>AI</sub> **
Osprey	I**	Q <sub>AI</sub> **
Northern Harrier	D**	
Sharp-shinned Hawk	I**	I**
Cooper's Hawk		Q <sub>T</sub> +
Northern Goshawk		
Broad-winged Hawk		—
Swainson's Hawk		—
Red-tailed Hawk	I**	Q <sub>SI</sub> **
Ferruginous Hawk	I+	Q <sub>H</sub> **
Golden Eagle		I*
American Kestrel	D**	D+
Merlin		I**
Prairie Falcon	I+	D*
Peregrine Falcon	I**	I**

tailed Hawks banded in the two project areas conform well to the distribution of accipiter encounter locations, and it seems reasonable to presume that most other moderate to long-distance migrants would show similar tendencies (Hoffman et al. 2002). Recent Red-tailed Hawk satellite-telemetry data also demonstrate good conformity with the regional flyway model, and confirm a flyway connection between the Goshute and Lipan Point sites (JPS and HawkWatch International, unpubl. data).

Satellite-telemetry data from juvenile Golden Eagles outfitted in central Alaska has shown that most of these birds migrate south along the Rocky Mountains and remain within or east of the Rockies, usually in the northern tier of states but occasionally as far south as New Mexico (Kochert et al. 2002). Substantial reductions in numbers of migrating eagles as one moves south within the Rocky Mountain Flyway from central Alberta (3500–5000 per fall season; Sherrington 1999) to the Bridger Mountains (1300–2000) to

the Manzano Mountains (75–150) also suggests that most northern migrants do not travel much farther south than Montana and Wyoming. This suggests that, other than in the Bridger Mountains, most of the eagles counted at the migration sites considered herein are probably relatively short-distance migrants. In fact, band-return, resighting, and telemetry data from eagles outfitted as migrants in the Goshute and Manzano Mountains or on nesting grounds in the Snake River area of Idaho indicate primarily regional residency, with birds moving in many directions and generally remaining in a 2–3 state area (Steenhof et al. 1984; JPS and HawkWatch International, unpubl. data). A similar pattern has emerged for Northern Goshawks banded or outfitted with telemetry at the two migration locales, with movements generally constrained to within 400 km of the banding sites (Hoffman et al. 2002; JPS and HawkWatch International, unpubl. data).

We also know from banding and telemetry studies that Prairie Falcons and Ferruginous Hawks often migrate in a variety of directions to take advantage of favored postbreeding and wintering habitats, frequently following lengthy migration loops (Steenhof et al. 1984, Schueck et al. 1998, Watson and Pierce 2000). Thus, counts for these species at each site undoubtedly reflect some local flavor, but delineating overall site-specific source populations may be very difficult; hence, regionwide summaries are probably the only appropriate objective (in this case representing the Columbia Basin, Great Basin, western plains, and other areas of suitable shrubsteppe and prairie in the Rocky Mountains). This is likely true for Peregrine Falcons, as well, because they may derive from a broad range of far-northern territory, often migrate very long distances into South America, rely primarily on powered flight during migration, and therefore can and frequently do follow a variety of migratory routes from a given area (Fuller et al. 1998).

#### TURKEY VULTURE

Four of six migration counts and western BBS and CBC data indicated strong increasing trends through the mid-1990s (Table 4, Fig. 2; also see Kirk and Hyslop 1998). After 1998, however, the increasing migration trends consistently reversed and a previously strong CBC increase turned to an unstable pattern. Thus, aside from

probable downturns after 1998, our long-term migration data appear to confirm a broad-scale expansion of Turkey Vultures in western North America, similar to the situation in northeastern North America (Wilbur 1983, Kirk and Mossman 1998). Kiff (2000) suggested that this northward range expansion might reflect the positive response of a tropical species to global warming. Vultures may also have benefited from expansion of open habitat by logging and rural development, reduced human persecution since the mid-twentieth century, and increases in carrion availability associated with higher road densities, greater dispersion or intensity of livestock operations, and other elements of an expanding human population (Wilbur 1983, Kirk and Mossman 1998).

#### OSPREY

Passage rates increased at all six migration sites through the mid-1990s, but declined after 1998 (Fig. 2). Western BBS and CBC data also indicated long-term increases, with the rate of increase accelerating after the 1980s (Table 4). This pattern is consistent with increases documented by eastern and midwestern migration counts and Canadian BBS data (Bednarz et al. 1990, Titus and Fuller 1990, Kirk and Hyslop 1998, Mueller et al. 2001). This suggests that Ospreys continue to rebound from the deleterious effects of the DDT era (Speitzer et al. 1978). Increasing availability of reservoirs and artificial nesting platforms also has contributed to higher nesting densities and breeding-range expansion (Swenson 1981, Henny 1983, Henny and Kaiser 1995).

#### NORTHERN HARRIER

Only the Goshute Mountains migration count indicated a significant long-term increase for harriers; however, despite a lack of significance due to high variability and pronounced drops after 1998, at least the peaks in harrier abundance increased through the late 1990s in the Wellsville and Bridger Mountains (Fig. 2).

Harrier breeding populations declined during the past century from reforestation of farmlands in the eastern U.S. and widespread loss of wetland and native prairie habitats (MacWhirter and Bildstein 1996, Kirk and Hyslop 1998). Western BBS data also indicated a significant decline since 1977 (Table 4), whereas both our migration data (Fig. 2) and western CBC data indi-

cated stable or increasing patterns (Table 4). The difference between the BBS and CBC results (the latter representing northern breeding populations that occur in the BBS–CBC coverage area only in winter) and the greater prevalence of increasing patterns in the northern migration datasets, suggest that harrier productivity has been increasing north of Nevada and Wyoming but decreasing farther south.

#### SHARP-SHINNED AND COOPER'S HAWKS

The migration data indicated stable or increasing trends for Sharp-shinned and Cooper's Hawks through the mid-1990s, with increases within both the Intermountain and Rocky Mountain flyways (Fig. 3). No significant quadratic regressions emerged; nonetheless, counts dropped noticeably for both species at most sites after 1998. Kirk and Hyslop (1998) also documented mostly stable or increasing trends for Sharp-shinned Hawks and increasing trends for Cooper's Hawks based on Canadian BBS (1985–1994) and CBC (1959–1988) data. BBS data are generally inadequate to assess accipiter trends (Sauer et al. 2002); nevertheless, western BBS and CBC analyses also indicated significant increases for Sharp-shinned Hawks, but essentially no long-term trends for Cooper's Hawks (Table 4). Rosenfield and Bielefeldt (1993) also concluded that western Cooper's Hawk populations were mostly stable through the early 1990s. Thus, the available data suggest that both species at least held their own throughout most of the Intermountain–Rocky Mountain region from the late 1970s through the mid-1990s, and were probably increasing in many areas through 1998.

#### NORTHERN GOSHAWK

Age-specific migration data revealed a correspondence between increases in adult detections during 1983–1984 and 1992–1993 (Fig. 3) and occurrence of known boreal irruptions (Palmer 1988, Doyle and Smith 1994, Squires and Reynolds 1997). The western CBC data indicated the same pattern. These cyclical southward irruptions of boreal birds, which are driven by cycles of snowshoe hare and Ruffed Grouse (*Bonasa umbellus*) abundance (Squires and Reynolds 1997), have been reported as involving primarily adults (Mueller et al. 1977); however, our migration data indicated matched increases of adults and immatures at most sites.

A huge peak in detections of immatures but low adult activity (Fig. 3) suggests that productivity was high in 1995 and especially 1996 for goshawks that migrate through the Goshutes (i.e., from the northern Great Basin and mountains of west-central Idaho). The three-year period of high immature abundance but average adult counts in the Wellsville Mountains during the late 1970s also may reflect a spike in productivity. However, such abundances have not occurred again in the Wellsvilles since 1987, except during the known 1992 irruption when counts of both adults and immatures rose considerably, and age ratios continued to decline there through the 1990s. This suggests that productivity dropped substantially in significant portions of northern Utah, eastern Idaho, and western Montana during the early 1980s, has not recovered, and may still be declining.

Several researchers who reported declines in goshawk abundance and productivity in the western U.S. suggested that widespread logging of old-growth conifer forest degraded goshawk nesting habitat (e.g., Reynolds 1989, Crocker-Bedford 1990). Since then, additional study has revealed birds nesting in a variety of habitats, including second-growth forest; however, the weight of evidence indicates that breeding goshawks in western North America do best in association with large tracts of mature coniferous or aspen (*Populus tremuloides*) forest (Reynolds et al. 1992, Block et al. 1994, Squires and Reynolds 1997). Therefore, logging or land-management activities that fragment or remove such forest stands will undoubtedly result in diminished goshawk productivity. Kennedy (1997) failed to find evidence for widespread declines in the West; nevertheless, in many areas the ecology and status of goshawks remains poorly known (Squires and Reynolds 1997).

#### BROAD-WINGED HAWK

Migration data from Hawk Mountain, Pennsylvania, indicated a stable pattern from 1936–1986, but a possible decline in the early 1990s (Bednarz et al. 1990, Goodrich et al. 1996). A multisite analysis of eastern migration data indicated a probable regional decline from 1972–1987 (Titus and Fuller 1990). Data from Hawk Ridge, Minnesota, also indicated a declining pattern from 1975–1987, but a pronounced increase after that through 1995 (Goodrich et al. 1996). Eastern BBS data from the late 1960s through

late 1980s indicated potential regional shifts in abundance related to human development, but otherwise mostly stable trends overall (Titus et al. 1989, Goodrich et al. 1996).

Thus, long-term trend indicators for eastern and central North America are mixed, but it appears likely that the disparate indicators may reflect shifts in distribution within a mostly stable regional population. Moreover, evidence of shifts in breeding density away from developing areas and the strong increase in migration counts since 1987 at Hawk Ridge suggest that the species' core population density may be shifting to the west. In fact, increased sightings in several western states during the 1980s and documentation of the first nesting records west of the Rocky Mountains in 1999 suggest that the species is expanding its breeding range in western Canada, and our migration counts corroborate this trend (Fig. 4; Smith et al. 2001).

#### SWAINSON'S HAWK

Reasons for concern over the status of Swainson's Hawks include extirpation from several areas in California and local declines in Oregon (England et al. 1997), extensive mortality from pesticide exposure on Argentina wintering grounds (Woodbridge, Finley, and Seager 1995), and productivity declines in Saskatchewan and Alberta (Houston and Schmutz 1995, Kirk and Hyslop 1998); however, Swainson's Hawks have adjusted successfully to irrigated agricultural habitats in many areas of the West (Woodbridge, Finley, and Bloom 1995). White (1994) listed the species as declining in the West, but with status in question, whereas others considered the species common and stable in most western states (Harlow and Bloom 1989, England et al. 1997). Western BBS data, which for this species are reasonably robust (Sauer et al. 2002), indicated no overall trend for 1977–2000 (Table 4).

Our longest-term migration datasets also indicated primarily stable patterns from the late 1970s to the late 1980s, but then all but the Lipan Point data indicated significant increases through the late 1990s (Fig. 4). Thus, despite extensive pesticide-related mortality in Argentina through the early 1990s and long-term declines in California and the northern Great Plains, our analyses suggest that the overall abundance of Swainson's Hawks probably increased in the Intermountain–Rocky Mountain region during the early to mid-1990s.

## RED-TAILED HAWK

Similar to White (1994) and Kirk and Hyslop (1998), our migration-count analyses, as well as western BBS and CBC data, consistently indicated significant increases through the mid-1990s (Table 4, Fig. 4). The increases likely reflect benefits of logging and rural development, which have increased availability of the open woodlands that Red-tailed Hawks prefer (Preston and Beane 1993). Expansion of telephone and electric distribution lines also may have allowed Red-tailed Hawks to expand their foraging and nesting ranges into many areas that previously were devoid of hunting perches and nest substrates.

## FERRUGINOUS HAWK

In the Goshute and Wellsville Mountains, passage rates increased through the early to mid-1990s but declined thereafter, whereas long-term declines occurred in the Manzano Mountains and at Lipan Point (Fig. 5). Numerous authors have reported apparent declines among Ferruginous Hawks during the past 30 years, and the species is listed as sensitive by the BLM and in several western states and provinces (Olendorff 1993, Bechard and Schmutz 1995). Primary threats include conversion of native grassland to agriculture, degradation of native grassland and shrubsteppe habitats from cheatgrass (*Bromus tectorum*) invasion, control of prairie dogs (*Cynomys* spp.) and ground squirrels (*Spermophilus* spp.), and human disturbance of nesting activities. However, Olendorff's (1993) review indicated stable populations in 10 states and Saskatchewan; strong increases in Oregon, Wyoming, Alberta, and Manitoba between 1976 and 1992 (also see White 1994); and confirmed declines during the previous decade only in northern Utah and eastern Nevada. Western BBS data also indicated a marginally significant increasing trend for 1977–2000 (Table 4).

Differences in the New Mexico spring and fall migration trends may be another indication of significant local variation in the status of Ferruginous Hawks in western North America. Ferruginous Hawks often follow circuitous migration routes (Schueck et al. 1998, Watson and Pierce 2000); therefore, we cannot assume that physically close spring and fall monitoring sites track the same populations. It is also possible that the disparate trend indicators reflect a nomadic lifestyle, with local populations naturally

coming and going over time as habitat and prey availability change (Bechard and Schmutz 1995). Since the mid-1990s, however, four of our six migration counts as well as western CBC data (Table 4) have indicated decreases, and passage rates have been average to below-average at the other two migration sites since 1998.

## GOLDEN EAGLE

At all migration sites except the Bridger Mountains, adult passage rates followed similar patterns through at least the mid-1990s: high abundance in the mid-1980s (the Wellsville surveys may have missed this period), generally sharp declines the next 2–3 years, then mostly steady increases through the mid-1990s (Fig. 5). In the Intermountain Flyway, as illustrated by the Goshute Mountains, Lipan Point, and to a lesser degree Wellsville Mountains transition-zone counts, it appeared that the cycle began repeating after a mid-1990s peak. In comparison, except for an unusually high 1998 spike in the Sandia Mountains, adult passage rates remained relatively stable after the mid-1990s at the three other Rocky Mountain sites. This suggests that the migratory abundance of eagles within the Intermountain Flyway cycles with a periodicity of ~10 years. This tendency is less pronounced in the Rocky Mountain Flyway but may increase with decreasing latitude.

The Goshute and Lipan Point migration counts also suggest that multiyear drops in the abundance of immature eagles generally precede peaks in adult activity (Fig. 5). Migration data from the eastern Rocky Mountains in Alberta also indicate a negative correlation between immature and adult abundance (Sherrington 2003). The autumn abundance of immature migrants in Alberta correlates positively with fledgling production in Alaska, with Alaska productivity trends strongly correlated with cycles of snowshoe hare (*Lepus americanus*) abundance. Similarly, long-term nesting studies in the Intermountain West confirm that the reproductive success of lowland-nesting eagles is coupled tightly with black-tailed jackrabbit (*L. californicus*) abundance (e.g., Steenhof et al. 1997). Snowshoe hares and black-tailed jackrabbits naturally undergo 10–11-year population cycles.

South of ~55°N latitude, breeding adult Golden Eagles are largely sedentary, generally moving only altitudinally in winter. Steenhof et al. (1984) also indicated that breeding adults in the

Snake River area of Idaho did not irrupt in response to low prey availability during their 1966–1982 study. However, tracking of three cycles of jackrabbit abundance in the Snake River area revealed that the mid-1990s low-abundance period was more severe and prolonged than normal and that peaks in jackrabbit abundance have declined since the 1970s (U.S. Department of Interior 1996, Steenhof et al. 1997). Thus, record-high adult migration counts in the Intermountain Flyway in the mid-1990s were preceded by multiyear drops in the migratory abundance of immature birds and corresponded to a particularly low-abundance period for jackrabbits in the surrounding region. This suggests that, as for northern breeders tied to snowshoe hare cycles (Kochert et al. 2002), high adult migration in the Intermountain region likely reflects greater wandering of largely sedentary adults in response to cyclical declines in jackrabbit abundance.

Patterns in the Goshute migration data suggested that the abundance of immature birds declined in advance of major peaks in adult abundance corresponding to periods of low jackrabbit abundance and hence low eagle productivity in the Intermountain region. The long-term increase in passage rates of immature eagles in the Goshute Mountains does not, however, match evidence of long-term (1971–1994) declines in occupied nesting territories in the Snake River area of Idaho, which were associated with loss of native shrubs and jackrabbit habitat due to widespread fires (Steenhof et al. 1997, Kochert et al. 1999). Thus, counts of immature eagles in the Goshute Mountains appear to accurately reflect major cyclical productivity declines in the northern Great Basin, but overall most likely represent a broad source population that includes birds from the northern Great Basin, which may not be doing particularly well, and birds from more northerly latitudes (i.e., Canada and Alaska) where populations are relatively stable and productive (Kochert et al. 2002). No western-region BBS trend but an increasing CBC trend (Table 4) also may reflect primarily winter influxes from healthier northern populations.

#### AMERICAN KESTREL

Goshute Mountains migration data indicated a strong increase through 1997; however, other migration data indicated either no trends or declines (Fig. 5) and the western BBS and CBC

analyses both indicated long-term declines (Table 4; also see Smallwood and Bird 2002). White (1994) and Kirk and Hyslop (1998) also documented mixed trends but concluded that overall kestrel populations were probably stable or increasing in the West and Canada, respectively. Thus, at present the status of western kestrels appears uncertain, with more evidence of declines since the early 1990s. Kestrels benefit from expansion of mosaic woodland habitat from logging and other land-clearing activities, and widespread installation of artificial nest boxes has aided other populations (Platt and Endereson 1989, Smallwood and Bird 2002). Declines have been attributed to regrowth of logged forests and loss of old fields and pastures preferred for foraging (Kirk and Hyslop 1998, Smallwood and Bird 2002).

#### MERLIN

Data on the status of Merlins are scarce, especially in western North America (Sodhi et al. 1993); therefore, our migration data may be especially useful for this species. All migration datasets indicated at least stable patterns and usually strong increases through 1998 (Fig. 6). Western CBC data (Table 4), White (1994), Kirk and Hyslop (1998), and Mueller et al. (2001) also all indicated increases in western and mid-western North America. Western BBS data indicated no long-term trend (Table 4), but are not a robust indicator (Sauer et al. 2002).

Whether the increases reflect continued recovery from DDT-era lows or other factors is unknown. Richardson's Merlin (*F. c. richardsonii*) rebounded in Saskatchewan grasslands in the late 1970s following near extirpation in the 1960s due to extensive use of dieldrin for grasshopper control (Houston and Hodson 1997). Artificial propagation contributed to increased nesting densities in southern Alberta and Saskatchewan during the early 1980s (Platt and Endereson 1989). Merlins have also adapted well to many semiurban and rural areas in response to increased availability of flocking species such as European Starlings (*Sturnus vulgaris*) and House Sparrows (*Passer domesticus*; Sodhi et al. 1992, 1993, White 1994, Kirk and Hyslop 1998).

#### PRAIRIE FALCON

Migration data indicated increasing trends in Nevada (although possibly a recovery from an apparent 1984–1985 downturn rather than a



long-term increase) and New Mexico, but generally stable trends otherwise (Fig. 6). Western BBS data indicated a marginally significant increase, whereas western CBC data indicated a significant decline (Table 4). Platt and Enderson (1989) and White (1994) concluded that western populations were stable through the 1980s. Kirk and Hyslop (1998) concluded similarly concerning Canadian populations, but also cited several studies suggesting that loss of native grasslands and attendant reductions in ground squirrel populations may have caused localized declines in some areas. In the Snake River area of Idaho, Prairie Falcon nesting density declined significantly from 1976–1997, at least partly due to habitat changes that altered the availability of Townsend's ground squirrels (*Spermophilus townsendii*; U.S. Department of the Interior 1996, Steenhof et al. 1999); however, a new 2002 survey revealed the highest nesting density ever recorded for that study (K. Steenhof, pers. comm.). Thus, the available evidence suggests that Prairie Falcon populations in the Intermountain–Rocky Mountain region are probably stable to increasing overall, but regional variation in the status of local breeding populations may be pronounced.

#### PEREGRINE FALCON

Peregrine Falcons declined during the DDT era and were classified as endangered (Cade et al. 1988), but have now recovered and were recently removed from the U.S. Endangered Species List (USDI Fish and Wildlife Service 1999). Similar to those from several eastern and mid-western migration sites (Dunne and Sutton 1986, Bednarz et al. 1990, Kirk and Hyslop 1998, Mueller et al. 2001), most, if not all, of our migration datasets confirmed strong increases, especially during the early to mid-1990s (Fig. 6).

#### CONCLUSIONS

Our findings suggest that, until the late 1990s and for diverse reasons, populations of Turkey Vultures, Ospreys, Broad-winged Hawks, Red-tailed Hawks, Merlins, and Peregrine Falcons were increasing throughout much of the Intermountain–Rocky Mountain region. Swainson's Hawks also may have experienced a regional population surge in the early to mid-1990s. In contrast, our migration data and other sources indicate that we should be concerned about the status of Golden Eagles and Ferruginous Hawks

in the western U.S., and that we need to learn more about the regional status and trends of Northern Goshawks and American Kestrels.

For this paper, we did not attempt a detailed analysis of relationships between migration counts and long-term weather patterns. Nevertheless, a common pattern of distinct downturns since 1998 corresponds to the onset of an ongoing, severe drought that has affected much of the interior West (National Drought Mitigation Center 2003). A record number of mortality band returns from Goshute Mountains migrants in 2002 (142% above average), high mortality among telemetered Red-tailed Hawks returning to affected areas, and high migration trapping success in 2001 and 2002 at most western banding sites (JPS and HawkWatch International, unpubl. data) suggest that the drought has indeed increased raptor hunger levels and mortality in the interior West. We acknowledge, however, that declines in our migration counts may also reflect alteration of migration routes to avoid drought-stricken areas (e.g., diverting toward the Pacific Coast where drought has generally been less pronounced).

Other relevant status and trend indicators generally corroborated our results. The migration data revealed additional intra- and interflyway variation in the status of some species, as well as new insight concerning the migration ecology of Golden Eagles and Northern Goshawks, and the likely effects of certain climatic changes on raptor populations in the region. Agreement among surveys and the comparative efficiency of migration counts suggest that our efforts are useful for identifying regional population changes for migratory diurnal raptors. Our results also indicate diverse, variable, and complex factors associated with raptor population dynamics in the Intermountain and Rocky Mountain regions of interior western North America.

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