WESTERN BIRDS

Volume 10, Number 1, 1979

FALL MIGRATION OF DIURNAL RAPTORS AT PT. DIABLO, CALIFORNIA

LAURENCE C. BINFORD, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118

For several years prior to the fall of 1972, I noted raptors migrating past my office window at the east end of Golden Gate Park, San Francisco, California. Concluding that I was by chance positioned along a raptor flyway, I set out to find a location where the birds would be more concentrated and easily observed. An examination of contour maps indicated that the hills at and near the base of Pt. Diablo, overlooking the mouth of San Francisco Bay, in the Marin (Co.) Headlands portion of the Golden Gate National Recreation Area, might offer the desired characteristics. On 21 September 1972, after seeing several hawks from my window, I visited Pt. Diablo and was rewarded with 162 individuals of 10 species of raptors in 3.17 hours of observation. That fall, on 29 partial days (102.33 hours), I recorded 4034 individuals of 14 species, thus establishing the importance of Pt. Diablo as the only known major hawk lookout in western North America.

Additional counts were made sporadically by myself and other observers during the falls of 1973-77. The primary purpose of this report is to present the data on relative abundance, timing and species diversity gathered during the six falls. A few comparisons are made with migration at Hawk Mountain, Pennsylvania. Thorough analysis of other aspects of the phenomenon must await data from continuous coverage.

DESCRIPTION OF AREA

The Pt. Diablo Hawk Lookout consists of two hills about 275 m high and 0.6 km apart and connected by a saddle-like ridge that runs southwest-northeast. The southwestern hill, which is honeycombed with old military bunkers, is called "Bunker Hill" by local birders and "Hill 129" by personnel of the Golden Gate National Recreation Area. Its top consists of cement bunkers and platforms on a short, narrow grassy ridge that peaks at the northeastern end. The northeastern hill, called "Cross Hill" by birders, is topped by an abandoned parking lot. The sides of

both hills are covered with grass and low chaparral, and Bunker Hill has small patches of pines that attract migrant passerines and, occasionally, hunting accipiters.

Bunker Hill is the better of the two hills for fall raptor observation, because it affords an unobstructed view to the west and northwest, whence come most of the birds. The flat top of Cross Hill makes observation more difficult; however, this seems to be the better observation point in spring. Binford (1977) gives highway directions to both hills.

OBSERVATIONS

Fall counts were conducted sporadically from 1972 through 1977. The earliest date was 15 August and the latest 6 December. Observations totaled 262.6 hours distributed over 72 partial days as follows: August, 22.2 hours, 5 days; September, 123.2, 33; October, 78.2, 21; November, 38.0, 12; and December, 1.0, 1. The vast majority of observations were made between 1000 and 1400 (PST), the prime period for raptor migration. Most of the counts were made by B. J. McCaffery or myself; the 20 other observers who generously provided data are listed under Acknowledgments.

The number of individual raptors observed at a lookout depends on, among other factors, the completeness of coverage on both a daily and seasonal basis. Continuous coverage of Pt. Diablo was impossible because of a military rifle range that, when active, necessitated closure of Bunker Hill. Because coverage was not continuous, neither the actual counts of individuals nor figures derived from them can be used to determine *true* abundance. They can, however, be used as approximate measures of *relative* abundance when combined for the six falls and converted into percentages of the total or into passing rates, i.e. the number of raptors per hour of observation. Percentages are shown in Table 1 and passing rates in Figures 1B-6. Even these calculations cannot completely eliminate errors resulting from interspecific variation in seasonal or daily timing of migration. For instance, a species that routinely migrates early or late in the day or season, when coverage was least extensive, would have relatively lower totals. However, I believe that this type of error is minimal.

RELATIVE ABUNDANCE

During the 262.6 hours of observation, 8696 individual raptors were recorded. Table 1 gives the 18 species that have been recorded and the relative abundance of each. The actual number of individuals seen over the six-fall span is presented for each species, but because these figures are difficult to visualize as measures of relative abundance, I have converted them into percentages of the total 8696 birds. I have also applied classical terminology to indicate relative abundance because

percentages are difficult to remember. These terms are based on the number of individuals that would be expected to pass in one typical flight day during the species' peak 10-day period, assuming twelve-hour days and 4 hours each at 100%, 50% and 10% of the maximum 10-day passing rate. The periods and approximate passing rates are shown in Figures 2-6. The scale is as follows: *abundant,* 625^{+}+ individuals per day; *very common,* 125^{+}-625; *common,* 25^{+}-125; *fairly common* 5^{+}-25; *uncommon,* 0-5 per day, averaging 5^{+}+ per fall season; *rare,* 0-5, 1-5; *occasional,* 0-1 per day, averaging once per 1^{+}-5 years; *casual,* 0-1, 5^{+}-25; *accidental,* 0-1, 25^{+}+. Species in the first six categories occur annually, whereas the others do not. Superscript "plus" signs indicate fractions.

In these classical terms, two species are considered very common, two common, three fairly common, four uncommon, three rare, three occasional, and one accidental. The three commonest species were Red-tailed, Sharp-shinned, and Cooper's hawks. Their respective percentages of the total raptors, based only on identified individuals, were 28.25, 28.22, and 19.96%. However, 517 (5.94%) unidentified accipiters were observed. If these are allocated according to the same ratio (1:1.41) noted for identified Cooper's and Sharp-shinned hawks (disregarding Goshawk and the five unidentified buteos), there were about 2758.5 (31.72%) Sharp-shinned and 1948.5 (22.41%) Cooper's. Thus the Sharp-shinned was the most common species, surpassing even the Red-tailed, and these three species accounted for approximately 82.38% (7164 birds) of the total.

Four other species accounted for an additional 15.72%: Turkey Vulture (9.81%), American Kestrel (3.17), Marsh Hawk (1.60), and Red-shouldered Hawk (1.14). Thus seven species, termed very common to fairly common in relative abundance and each occurring probably every suitable day during its peak period, accounted for about 98.10% of the total individuals. The remaining 11 species, considered uncommon to accidental, accounted for less than 1% each and only about 1.90% together.

TIMING OF MIGRATION

To demonstrate timing of fall migration at Pt. Diablo, I present histograms based on passing rates (Figures 1B-6). Despite the paucity of data, the rarer species (except Mississippi Kite) are included because in most cases their dates of occurrence fit patterns I have noted elsewhere in northern California. Periods of peak abundance for some species can be determined from gross inspection of the histograms, but for other species (e.g., Marsh Hawk, White-tailed Kite) histograms are not adequate. Therefore, I calculated "average dates" based on actual dates of occurrence weighted by abundance (in terms of passing rates, pr) according to the formula: $\leqslant(\text{pr} \cdot \text{date}) \div \leqslant\text{pr}$.

Table 1. Relative abundance, in terms of the number of individuals seen, percent of total and classical terminology (see text), of migrating diurnal raptors recorded at Pt. Diablo, California, during 262.6 hours of timed observations in six falls, 1972-77. Numbers in parentheses reflect allocation of the 517 unidentified accipiters between Cooper's and Sharp-shinned hawks according to the ratio 1:1.41 observed for identified birds. Figures in brackets represent additional records obtained outside timed periods (see Species Accounts).

	Number of individuals	Percent of total	Classical terminology
Turkey Vulture *(Cathartes aura)*	853	9.81	Common
White-tailed Kite *(Elanus leucurus)*	30	.34	Uncommon
Mississippi Kite *(Ictinia mississippiensis)*	0 [1]	.00 [+]	Accidental
Goshawk *(Accipiter gentilis)*	1 [+1]	.01	Occasional
Sharp-shinned Hawk *(A. striatus)*	2454 (2758.5)	28.22 (31.72)	Very Common
Cooper's Hawk *(A. cooperii)*	1736 (1948.5)	19.96 (22.41)	Common
Red-tailed Hawk *(Buteo jamaicensis)*	2457	28.25	Very Common
Red-shouldered Hawk *(B. lineatus)*	99	1.14	Fairly Common
Broad-winged Hawk *(B. platypterus)*	65 [+11]	.75	Uncommon
Swainson's Hawk *(B. swainsoni)*	3	.03	Rare
Rough-legged Hawk *(B. lagopus)*	3	.03	Rare
Ferruginous Hawk *(B. regalis)*	4	.05	Rare
Golden Eagle *(Aquila chrysaetos)*	9	.10	Uncommon
Marsh Hawk *(Circus cyaneus)*	139	1.60	Fairly Common
Osprey *(Pandion haliaetus)*	41	.47	Uncommon
Prairie Falcon *(Falco mexicanus)*	1	.01	Occasional
Peregrine Falcon *(F. peregrinus)*	1 [+1]	.01	Occasional
American Kestrel *(F. sparverius)*	276	3.17	Fairly Common
Accipiter sp.	517 (0)	5.94 (0.00)	
Buteo sp.	5	.06	
Falco sp.	2	.02	
Totals:	8696 (8696)	99.97 (99.98)	

Patterns of abundance. The raptors as a whole, as well as the individual species, exhibited distinct patterns of increase and decrease with time. For all species together (Figure 1B), migration progressed at a low intensity during the last two-thirds of August, increased rather abruptly in the first 10 days of September, reached a peak in the last 10 days of September, maintained a somewhat lower but fairly constant level through the end of October, and then decreased rather abruptly, reaching a low level in late November. Histograms for the three commonest species, the Red-tailed, Sharp-shinned and Cooper's hawks, demonstrate that the fairly constant level for the last third of September through October was primarily a result of coincident decreases in the two accipiters and an increase in the Red-tailed. The increase from the first to the second periods of November was a result of an influx of Red-tailed Hawks and may have reflected the arrival of adults, which averaged later than immatures (pers. obs.).

Histograms for the eleven commonest species show three rather distinct patterns of abundance: (1) The Turkey Vulture and American Kestrel increased gradually to a rounded peak, then decreased gradually. (2) The Red-tailed Hawk, Marsh Hawk and perhaps White-tailed Kite also increased gradually but reached a sharp peak and then decreased rather abruptly. (3) The Sharp-shinned, Cooper's, Broad-winged and Red-shouldered hawks, Golden Eagle and Osprey increased rather abruptly to a sharp peak followed by a gradual decrease. More data are needed to test the validity of these patterns.

Even though passing rates based on less than continuous coverage are not measures of *true* abundance, I offer the following figures so that visitors will gain some idea of what to expect on days with good visibility and during the best times of day (ca. 1000-1400 PST) and year (ca. 21 Sep.-31 Oct.). The maximum daily passing rate recorded was 129.65 birds per hour (1 bird per 28 sec.) during a 4.25-hour period on 22 Sep. 1977; 458 (88.9%) of the total 515 birds were accipiters. Passing rates exceeded 60 birds per hour (1 per min.) on 10 (13.9%) of the 72 partial days of observation, all between 21 Sep. and 28 Oct. The average during the very best period, 21 Sep.-10 Oct., was 49.92 birds per hour (1 per 1 min., 12 sec.), while the average for all 72 partial days was 33.15 per hour (1 per 1 min., 49 sec.).

Sequence of occurrence. The sequence in which the 17 non-accidental species occurred may be determined by comparing peak periods and "average dates" shown in Figs. 2-6. The Swainson's Hawk, Osprey and perhaps Prairie Falcon were early migrants; the first two had peak periods and "average dates" in mid-September, and their migration was largely over before 1 October. The White-tailed Kite averaged slightly later but may also be termed an early migrant; its migration was over by late October. Seven species had "average dates" and peak periods close

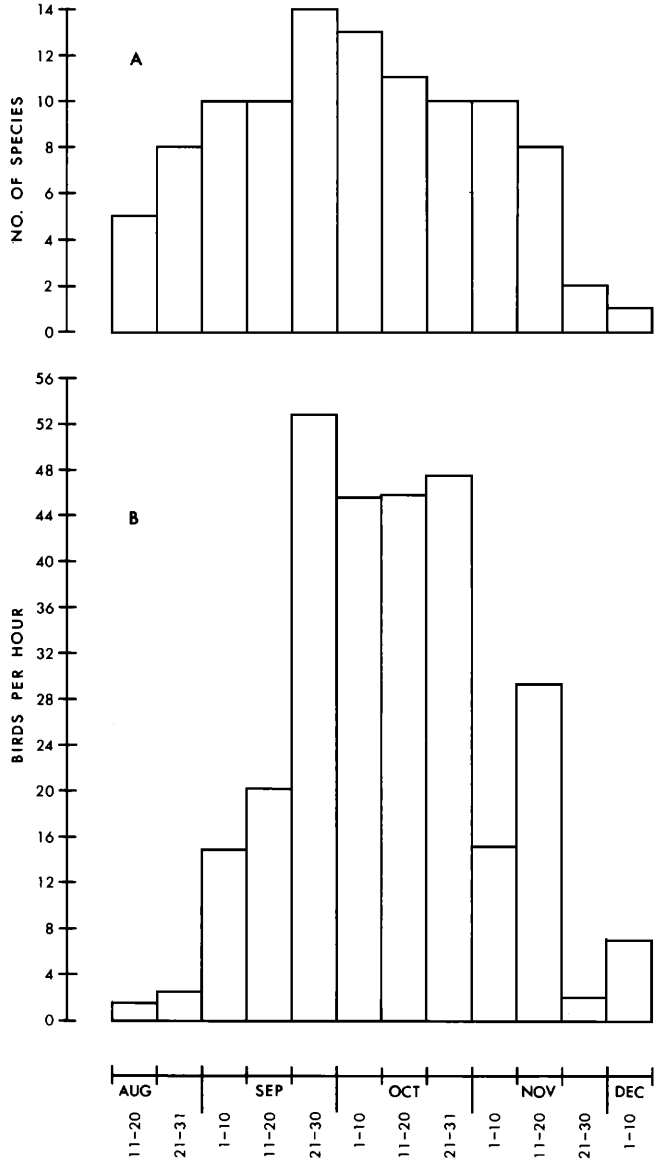

Figure 1. Temporal species diversity (A) and temporal distribution (B) of migrating diurnal raptors recorded at Pt. Diablo, California, during the six-fall period 1972-77. The histogram for species diversity includes all records for the 18 species (see Species Accounts), while that for distribution is based on the 8696 individuals seen during 262.6 hours of timed observations.

to 1 October and can be considered late-September through October, or mid-term migrants: American Kestrel, Sharp-shinned, Cooper's, Broad-winged and Red-shouldered hawks, and probably Peregrine Falcon and Ferruginous Hawk. The Turkey Vulture and Marsh Hawk were somewhat later, still with "average dates" in early October but with peak periods in mid- to late October. The Red-tailed Hawk and Golden Eagle were even later, averaging mid-October, and the Rough-legged Hawk and Goshawk were the latest, with "average dates" in November.

Duration. Migration was in progress at very low intensities when both the earliest (15 August) and latest (6 December) observations were made (Figure 1B). The extreme limits of the migration period probably are early August and late December.

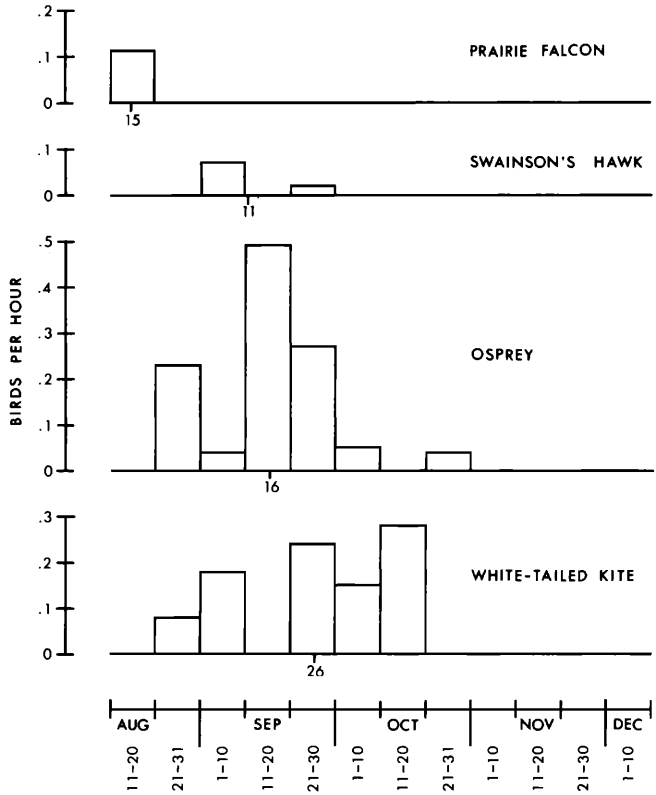

Figure 2. Temporal distribution of migrating diurnal raptors recorded at Pt. Diablo, California, during 262.6 hours of observation in the six-fall period 1972-77. Specific dates are "average dates" of occurrence weighted by passing rates (see text).

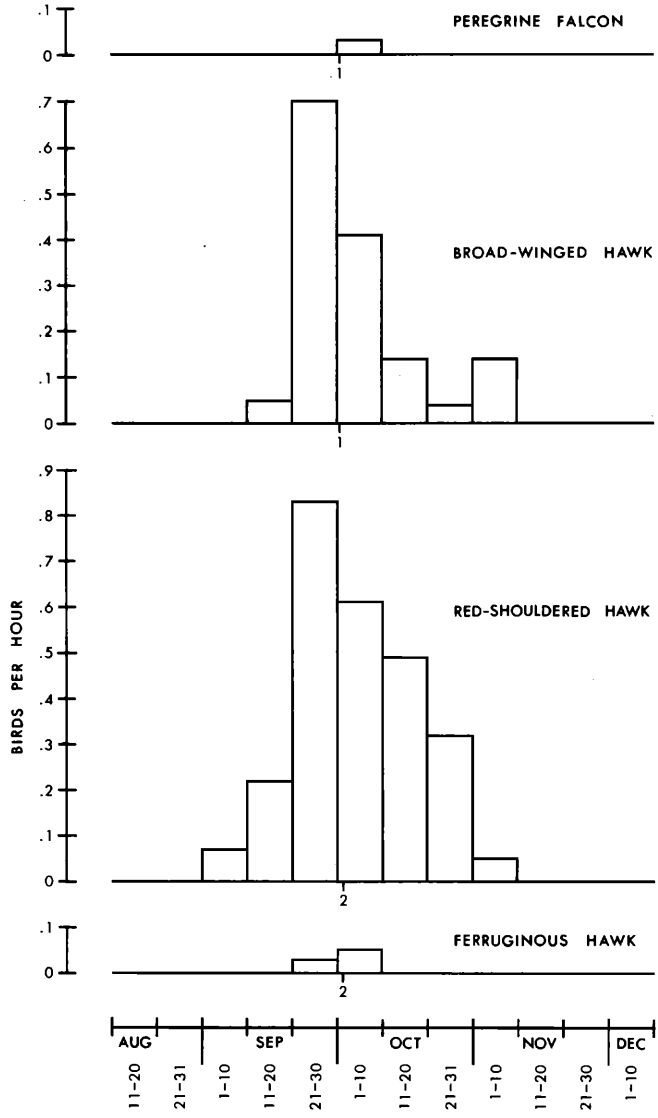

Figure 3. Temporal distribution of migrating diurnal raptors recorded at Pt. Diablo, California, during 262.6 hours of observation in the six-fall period 1972-77. Specific dates are "averages dates" of occurrence weighted by passing rates (see text).

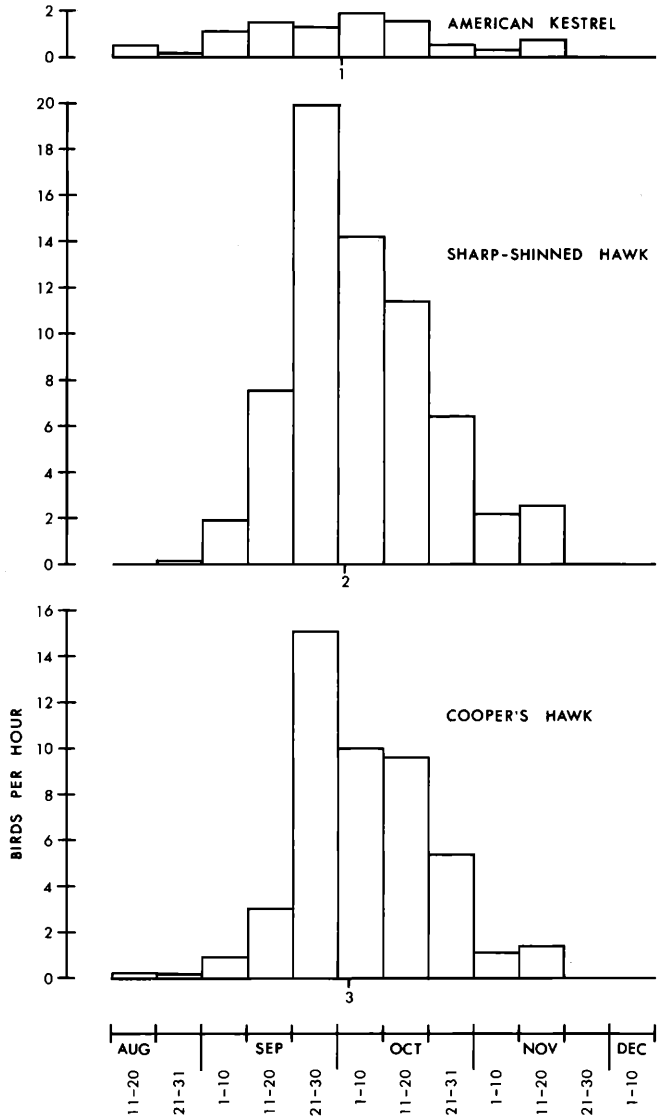

Figure 4. Temporal distribution of migrating diurnal raptors recorded at Pt. Diablo, California, during 262.6 hours of observation in the six-fall period 1972-77. Specific dates are "average dates" of occurrence weighted by passing rates (see text).

Analysis of the duration of the migratory period for individual species must await data from continuous coverage. It is interesting to note, however, that five of the six commonest species (Turkey Vulture, Red-tailed, Cooper's and Marsh hawks and American Kestrel) were recorded during periods lasting over 3 months (range 96 to 111 days), while the four next commonest species, the White-tailed Kite, Red-shouldered and Broad-winged hawks and Osprey, were seen during periods lasting

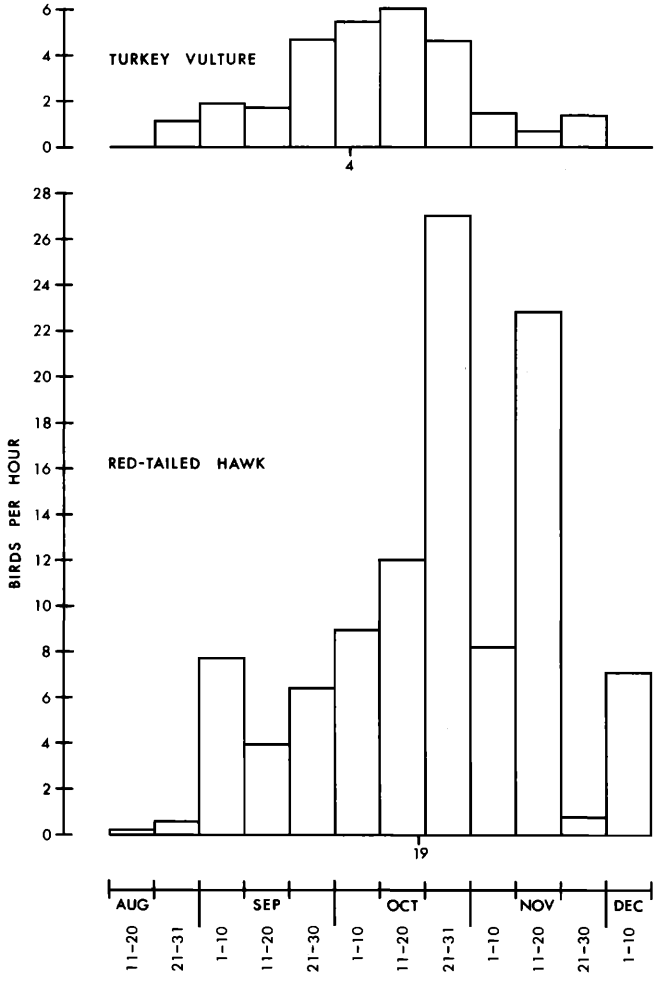

Figure 5. Temporal distribution of migrating diurnal raptors recorded at Pt. Diablo, California, during 262.6 hours of observation in the six-fall period 1972-77. Specific dates are "average dates" of occurrence weighted by passing rates (see text).

only about 2 months (52-62 days). The Sharp-shinned Hawk occupied an intermediate position of about 2.75 months (82 days).

SPECIES DIVERSITY

The number of species per 10-day period (Fig. 1A) varied from 1 to 14 and generally followed the curve for abundance (Fig. 1B), although the increase of species before and decrease after the late-September peak were somewhat more gradual. Species and individuals both dropped off rather sharply in the last third of November, although this was at least

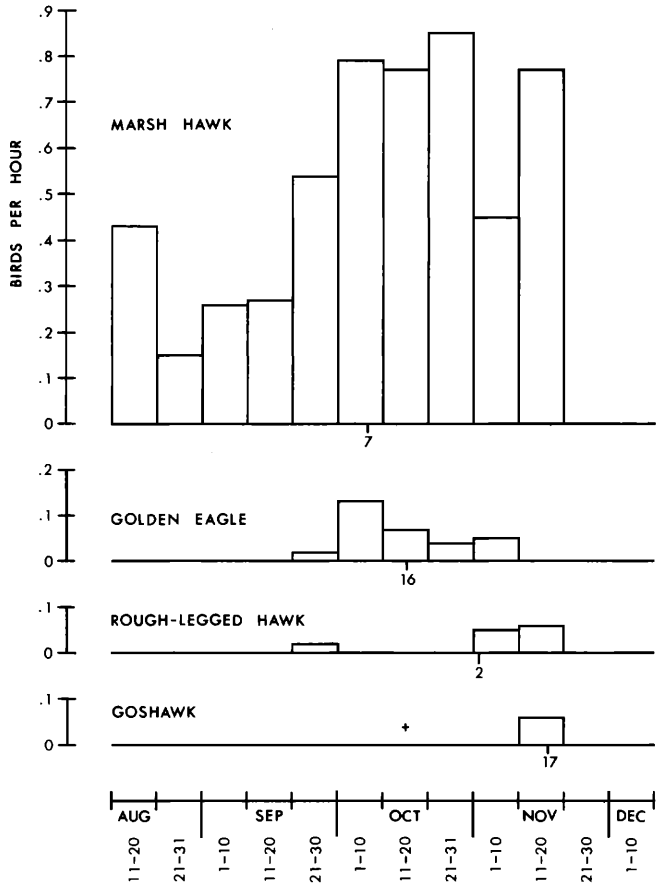

Figure 6. Temporal distribution of migrating diurnal raptors recorded at Pt. Diablo, California, during 262.6 hours of observation in the six-fall period 1972-77. Specific dates are "average dates" of occurrence weighted by passing rates (see text).

partly an artifact of incomplete coverage. Daily species totals varied from 0 to 11, with an overall average of 6.49. For the very best period, 21 Sep.-10 Oct., totals ranged from 5 to 11 and averaged 8.15. Continuous coverage would, of course, affect these figures.

SPECIES ACCOUNTS

Prior to this study, neither the White-tailed Kite nor Red-shouldered Hawk was known to be migratory in California (Small 1974). Their abundance, annual regularity and southward movement at Pt. Diablo suggest true migration rather than random post-breeding dispersal, but corresponding spring data are needed for confirmation.

The regular occurrence of the Broad-winged Hawk was most unexpected, as there were only about 15 previous records for the entire state. Details for this and the seven rare to accidental species are presented below; data for the commoner species are contained in Table 1 and Figures 2-6.

Mississippi Kite. Accidental fall visitant. A single adult was seen well by W. M. Pursell and A. Mericourt on 13 Sep. 1976 (Winter and Erickson 1977). This was only the second record for northern California; the first was an immature seen by B. Clow 3 miles east of Cape Mendocino, Humboldt Co., on 6 Sep. 1975 (Stallcup and Winter 1976); the closeness of the two dates is perhaps significant.

Goshawk. Occasional fall transient here and elsewhere on the coast of northern California. Two records: one immature seen by L. C. Binford on 17 Nov. 1972 during an invasion year for numerous northern or montane species, and one adult observed by W. M. Pursell on 20 Oct. 1974 (Stallcup et al. 1975).

Broad-winged Hawk. Uncommon fall transient. At least 76 individuals were observed at Pt. Diablo in the falls of 1972-77. Extreme dates were 15 Sep. (1975) and 5 Nov. (1975). The true average date for all records was 4 Oct., and the "average date" weighted by passing rate, based on the 65 birds recorded during timed periods, was 1 Oct. The maximum daily count was 14 on 30 Sep. 1974 (L. C. B.), of which eight were in sight at one time. Three immatures of the very rare dark phase were seen: 4 Oct. 1974 (L. C. B.), 6 Oct. 1974 (S. F. Bailey) and 28 Oct. 1972 (L. C. B.). This suggests that Pt. Diablo Broad-winged Hawks originate in the northwestern part of the species' range, where the melanistic morph seems to occur most often.

Swainson's Hawk. Rare fall transient here and elsewhere along the coast of northern California. Three records, all for single immatures: 4 and 23 Sep. 1975 (L. C. B.) and 7 Sep. 1976 (B. J. McCaffery). The last bird was wing-tagged as a juvenile near Richland, Benton Co., southeastern Washington in 1975 or 1976 (McCaffery pers. comm.; Winter and Erickson 1977).

Rough-legged Hawk. Rare fall transient; possibly increases to uncommon status during some invasion years. Probably has been seen at Pt. Diablo more often than the three times for which I have data: single birds on 30 Sep. 1977 (B. D. Parmeter, W. M. Pursell et al.) and on 5 and 17 Nov. 1972 (L. C. B.).

Ferruginous Hawk. Rare fall transient here and elsewhere on the coast of northern California. Four records: 21 Sep. 1977 (J. W. Shipman and L. Compagno), 30 Sep. 1977 (B. D. Parmeter, W. M. Pursell et al.), 1 Oct. 1977 (S. F. Bailey) and 7 Oct. 1972 (L. C. B.).

Prairie Falcon. Occasional fall transient here and elsewhere on the coast of northern California. One record: a single bird seen by B. A. Sorrie on 15 Aug. 1977.

Peregrine Falcon. Occasional fall transient. Two records: one seen by S. F. Bailey et al. on 1 Oct. 1977 and one photographed by J. W. Shipman and L. Compagno on 6 Oct. 1977. The scarcity of the Peregrine Falcon and apparent absence of the Merlin *(Falco columbarius)*, despite their regularity elsewhere on the northern California coast, may reflect behavioral responses to local geography. Both species are direct flyers that show little avoidance of water barriers or dependence on updrafts, and in fact seem to favor outer beaches where available (pers. obs.); possibly Marin Co. birds cut directly across the extreme mouth of San Francisco Bay rather than detouring eastward to Bunker and Cross hills. As support for this theory, Peregrine Falcons are seen with more regularity to the west of Bunker Hill over Rodeo Lagoon, and even the bird seen from Bunker Hill on 1 Oct. 1977 was described by Bailey (pers. comm.) as "far to the west-northwest and northwest."

COMPARISONS WITH THE EASTERN UNITED STATES

I have compared certain aspects of migration at Pt. Diablo with data given by Haugh (1972) for Hawk Mountain, which is near Allentown, Pennsylvania, and is on a latitude about 320 km north of San Francisco. Although detailed comparisons of abundance must await data from continuous coverage of Pt. Diablo, some statements are warranted. Certainly, the Broad-winged Hawk is much less numerous and the Cooper's Hawk much more so at Pt. Diablo. Aside from the western species (Swainson's Hawk, Ferruginous Hawk and Prairie Falcon), only one other species, the Turkey Vulture, is clearly more common at Pt. Diablo. On the other hand, seven species occur in larger numbers at Hawk Mountain: Goshawk, Red-shouldered Hawk, Bald Eagle, Osprey, Peregrine Falcon and Merlin; the eagle and Merlin have not been recorded at Pt. Diablo, but should occur in small numbers.

The patterns of abundance for individual species at Hawk Mountain are similar to the three noted at Pt. Diablo, except that the two accipiters decrease abruptly and the Golden Eagle increases gradually to a rounded peak.

The duration of the fall migratory period is similar at the two lookouts, both having low intensities of movement in the last half of August and first part of December. The relative durations for individual species are also fairly similar, with the Red-tailed Hawk, Cooper's Hawk, Marsh Hawk and American Kestrel spending about 3 months on migration, the Sharp-shinned Hawk, Red-shouldered Hawk and Osprey about 2.5 months, and the Broad-winged Hawk about 1.5 months. The Golden Eagle, however, has an extended period of about 3.5 months, rather than 1 month, at Hawk Mountain.

In timing of peak periods, the most striking differences are that at Pt. Diablo the Broad-winged Hawk peaks about 2 weeks *later* and the Red-

shouldered Hawk somewhat over 3 weeks *earlier* than at Hawk Mountain. The Red-tailed Hawk, Golden Eagle, Sharp-shinned Hawk and Cooper's Hawk also peak earlier at Pt. Diablo, by about 2 weeks for the first two species and 1 week for the accipiters. The Marsh Hawk, Osprey and American Kestrel peak at about the same time at the two lookouts, but the first two species seem to average a few days earlier and the American Kestrel a few days later at Pt. Diablo. Three additional species, for which data are few, the Rough-legged Hawk, Peregrine Falcon and Goshawk, also appear to occur a few days earlier. Thus with the notable exception of the Broad-winged Hawk and possibly the American Kestrel, migration is earlier at Pt. Diablo than at Hawk Mountain, in spite of the 320-km difference in latitude. Distance to the nearest breeding grounds, which are in central Alberta about 1750 km from Pt. Diablo, may account for the lateness of the Broad-winged Hawk.

SOURCE OF RAPTORS

Several factors probably contribute to the concentration of raptors at Pt. Diablo. Perhaps most important is the juxtaposition of the ocean and bay. The ocean shore of Marin Co. runs northwest-southeast, while the northwestern shore of the northern arm of San Francisco Bay runs approximately north-south. The land between thus forms a funnel culminating at Pt. Diablo. Both shorelines probably form leading lines, especially for those species such as buteos that hesitate to cross large bodies of water. In addition, the mountain ranges in this area form long northwest-southeast ridges, the most important of which is Bolinas Ridge, extending for some 55 km from Tomales to the Marin Headlands. Other long ridges form a series of lines parallel to the coast and extend nearly from the Oregon border. The importance of Bolinas Ridge is suggested by the fact that many raptors approach Bunker Hill from the northwest and especially west, with the latter birds originating in the northwest but being forced to follow the eastward curve of the Marin Peninsula. Very likely many of the raptors observed at Pt. Diablo in fall originate in the northwestern coast belt of North America. However, evidence demonstrates that some come from the Great Basin and Great Plains; these birds could take a westward or southwestward course to the coast much in the manner of certain water birds, such as the California Gull *(Larus californicus)* and Western Grebe *(Aechmophorus occidentalis)*, and then turn to follow the coast southward. A Swainson's Hawk wing-tagged near Richland, Washington, east of the Cascade Range, was seen at Pt. Diablo. The Broad-winged Hawk is not known to breed west of central Alberta, whence probably came at least the three dark phase birds observed at Pt. Diablo. Finally, the Ferruginous Hawks could have come only from their breeding grounds to the northeast.

SUMMARY

Pt. Diablo, located just north of San Francisco, California, is the only known major hawk lookout in western North America. Since its discovery in the fall of 1972, 18 species of diurnal raptors have been recorded. Sporadic observations totaling 262.6 hours over 72 days in the falls of 1972 through 1977 produced 8696 individual birds. The relative abundance of each species is given. Seven species, termed very common to fairly common, accounted for about 98.10% of the total. The most numerous three, the Sharp-shinned (~31.72%), Red-tailed (28.25), and Cooper's (~22.41) hawks, produced about 82.38% of the total.

Raptor migration begins in earnest about the first of September, reaches a peak in number of individuals in the end of September, and tapers off to a low level in late November. Limited migration takes place at least as early as mid-August and as late as early December. Peak periods and "average dates," which together provide a sequence of occurrence, are presented for each species, and three patterns of abundance are postulated.

The temporal pattern for species diversity is similar to that for abundance. Separate accounts are presented for the rarer species. The White-tailed Kite and Red-shouldered Hawk, previously thought to be sedentary in California, are shown to be migratory in fall. The Broad-winged Hawk, believed to be a casual vagrant in the state, is an uncommon fall transient at Pt. Diablo.

Most individuals at Pt. Diablo probably originate in the northwestern coastal areas of North America and use northwest-southeast ridges, the Pacific coast, and locally the shore of San Francisco Bay as leading lines and sources of updrafts, but some birds come from northeast of the Cascades.

Only two species (Turkey Vulture and Cooper's Hawk) are more common at Pt. Diablo than at Hawk Mountain, Pennsylvania, while seven are more common at the latter. Most species peak earlier at Pt. Diablo. In most other aspects studied, migration is rather similar at the two lookouts.

ACKNOWLEDGMENTS

I thank the following people who generously provided their migration notes from Pt. Diablo: Stephen F. Bailey, Gordon Beebe, Leonard Compagno, Richard DeCoster, William Dillon, Bruce G. Elliott, Bud Fry, Ronald LeValley, Brian J. McCaffery, Alice Mericourt, John and Benjamin D. Parmeter, William M. Pursell, J. Van Remsen, Don Roberson, Mary Louise Rosegay, John W. Shipman, Bruce A. Sorrie, Richard W. Stallcup, and Robert Sutherland. Nancy M. Poh typed the manuscript.

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Accepted 15 December 1978

Sketch by F. J. Watson