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NEW FULL-SEASON COUNT SITES FOR RAPTOR MIGRATION IN TALAMANCA, COSTA RICA

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Resumen. – Nuevos sitios para conteo de rapaces durante la temporada completa de migración en Talamanca, Costa Rica. – Con la ayuda de voluntarios y la comunidad local, se hicieron conteos estandarizados de aves rapaces en dos sitios en Talamanca, Costa Rica, durante los otoños boreales del 2000 y 2001. Los conteos demuestran una convergencia importante de la migración de rapaces en el área. Siguiente a Veracruz, Mexico, Talamanca es el segundo sitio en concentración de rapaces migratorias en el mundo. Cerca de tres millones de individuos, representando a 17 especies, se contaron durante el otoño del 2001. El Zopilote cabecirrojo (*Cathartes aura*), el Gavilán aludo (*Buteo platypterus*), el Gavilán de Swainson (*B. swainsoni*) y el Milano de Mississippi (*Ictinia mississippiensis*) representan más del 98% del total de las rapaces registradas en ambos años. El patrón diario de migración tiene un pico de actividad cercano al medio día, y no se ha observado "noon-lull" para ninguna especie. Sin embargo, a diferencia del vuelo en zonas templadas, la actividad diaria comienza muy temprano en la mañana y termina cerca del atardecer, y el vuelo continúa bajo lluvia ligera y moderada.

Abstract. – With the help of volunteers and the local community, standardized counts of migrating raptors were made at watchsites in Talamanca, Costa Rica, during the autumns of 2000 and 2001. The counts demonstrate a major autumn raptor migration convergence in the area. Talamanca is second only after Veracruz, Mexico, in recording the most concentrated flight of migratory raptors in the world. Close to three million individuals, representing 17 species, were counted during autumn 2001. Turkey Vultures (*Cathartes aura*), Broad-winged Hawks (*Buteo platypterus*), Swainson's Hawks (*Buteo swainsoni*), and Mississippi Kites (*Ictinia mississippiensis*) represent more than 98% of the total count in both years. Daily migration activity peaks around mid-day, and no noon-lull has been observed for any species. Even so, unlike flights in the temperate zone, passage begins early in the day and ends late in the afternoon, and the flight continues during light and moderate rain. *Accepted 13 February 2004.*

Key words: Raptors, migration, Talamanca, Costa Rica.

INTRODUCTION

In North America, raptor migration has been well studied since the early 1900s (Zalles & Bildstein 2000). The Hawk Mountain Sanctuary in eastern Pennsylvania, for example, has been monitoring raptor migration in North America since 1934 (Broun 1949, Bednarz *et al.* 1990). Counts of raptor migrants at watchsites have helped to better understand how climate and the geographic aspects of continental North America influence raptor migration (Kerlinger 1989; Allen *et al.* 1995).

The Mesoamerican Land Corridor consists of a series of inter-branching migration flyways used by 32 species of raptors that stretches for 4000 km south-southeast from the southern coast of Texas to northwestern Colombia (Bildstein & Zalles 2001). Recent counts at a hawk watchsite in Veracruz, Mex-

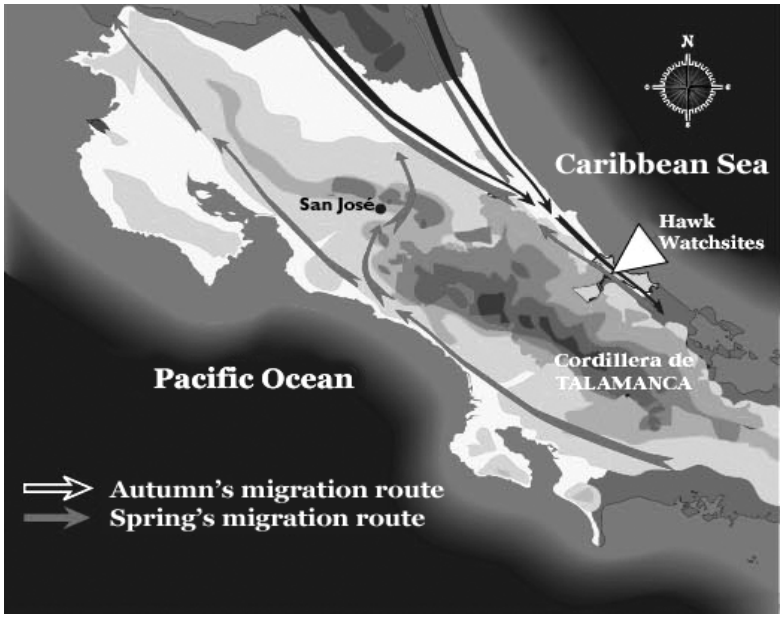

FIG. 1. Raptors' autumn migration routes through Costa Rica and location of the Kéköldi and BriBri watchsites.

ico, placed the southbound magnitude of autumn migration along this corridor at >1.5 million Turkey Vultures (*Cathartes aura*), >1.0 million Broad-winged Hawks (*Buteo platypterus*) and >0.5 million Swainson's Hawks (*B. swainsoni*) (Bildstein & Zalles 2001). These numbers represent about 90% of world populations of Broad-winged Hawks and 80% of world populations of Swainson's Hawks. As a result, the Mesoamerican land corridor ranks among the most important raptor flyways in the world (Bildstein & Zalles 2001).

Unfortunately, little is known about raptor migration in the tropics, and details concerning the Central American part of the Mesoamerican Land Corridor are yet to be investigated (Smith 1985, Bildstein & Zalles 2000). Gathering this type of information is one of the main goals of our project, and will help to fill a gap in the knowledge of raptor migration in the Americas. After two years of standardized counts, the Kéköldi, watchsite has proved to be one of the most significant in the world, especially in terms of number of raptors counted. Here, we summarize the first two years of full-season autumn counts at the site. Specifically, we describe flight volume, species composition, seasonal timing, and daily activity patterns of migrants. We compare the two lookouts used in 2001 versus a single lookout used in 2000, and discuss the influence of the tropical environment on raptor migration. We also compare our data with those of Corpus Christi, Texas, another hawk watchsite at the northern entrance of the Mesoamerican Land Corridor.

STUDY AREAS AND METHODS

Location of watchsites. The watchsites are in the Caribbean lowlands of southeastern Talamanca, Costa Rica (Fig. 1). Elevation in this

region ranges from sea level to 300 m. Daily temperatures average 26ºC, and annual precipitation average 2370 mm. In autumn, large numbers of raptors migrate through this area that consists of mixed tropical lowland rainforests, agriculture, banana plantations and undeveloped coastline (Porras 2001). With the Talamanca mountains on one side and the Caribbean coastline on the other, raptors are funneled through the 5-km wide lowlands near the Kéköldi Indigenous Reserve neighboring Puerto Viejo, Costa Rica (Fig. 1).

The Kéköldi watchsite is located at the top of a mountain in the Indigenous Reserve (09º38'30"N). Vegetation is mostly second-growth rain forest and abandoned cacao plantations. It is 200 m a.s.l. and provides a good 112º view, from Carbon ridge southwest, to the Caribbean Sea northwest of the platform. Raptors usually approach from the northwest and fly along one of two major flight directions. They either follow the coast in a southeast direction, passing northeast of the platform, or take a more inland route west of the platform. Kéköldi was the only lookout used in autumn 2000.

In autumn 2001, a second watchsite was established in the town of BriBri (09º37'23"N) in the Sixaola Valley, 10 km southwest of the Kéköldi site (Fig. 1). The new watchsite is at a local community center, 90 m a.s.l. BriBri provides a 360º view of the sky that is partly obstructed to the northeast by a small 300 m northwest-southeast mountain ridge. Raptors travel from the northwest and usually follow that small mountain ridge to the southeast. This second watchsite was established because some raptors were suspected to use a more inland migratory route in the region (Bildstein & Saborio 2000, Porras pers. observ.). Our count in autumn 2001 served to evaluate the proportion of raptors using this route, and to investigate the necessity and importance of maintaining a monitoring site inland.

Count protocol. Count protocols followed those of the Hawk Migration Association of North America (HMANA) used at most North American migration watchsites. Hand-held tally devices (mechanical clickers) were used to help count migrants. Two to four observers were present at both sites during most counts. During peak migration, all counters divided tasks in order to identify and count individual birds and flocks, and maintain an idea of general movement. One person acted as a coordinator and scribe recording counts, keeping track of time to measure the climatic variables hourly, making certain that no birds were counted twice and that no birds were without being counted and identified.

In addition to counting raptors, we hourly recorded climatic and flight variables including visibility, temperature (ºC), cloud cover (0, 25, 50, 75 or 100%), wind speed, wind direction, precipitation, flight height and direction, number of observers and minutes of observation. Raptors flying in other directions and those exhibiting territorial behavior, hunting flights, hovering, and vocalizing were considered non-migrants and were not counted.

Observers at both sites used 8–10x binoculars and 20–60x telescopes to spot migrants. Wheeler & Clark (1995), Skutch & Stiles (1989) and Clark &Wheeler (1987) were used as field identification guides.

Most counters were biologists, biology students, or people with a strong interest in birding. Some counters arrived in Talamanca without any professional hawkwatching experience and were trained in their first two weeks. All counters were supervised and assisted by local project "lead" counters. At the beginning of each season, most flocks were counted twice and numbers were compared between observers to increase accuracy.

Counting period. In 2000, the count began on 7 September and ended on 15 December. In

TABLE 1. Raptor counts and passage rates by species at Kéköldi and BriBri watchsites in Talamanca, Costa Rica, 2000-2001.

Species	Kéköldi				Bribri		Total Talamanca 2001	
	Total count		Raptors/100 h		Total count	Raptors/100 h	Total count	Raptors/100 h
	2000	2001	2000	2001	2001	2001	2001	2001
Turkey Vulture (*Cathartes aura*)	724,106	1,158,396	102,116.20	154,749.92	208,804	43,116.38	1,367,200	110,898.41
Osprey (*Pandion haliaetus*)	752	1,389	106.05	185.56	662	136.70	2,051	166.36
Swallow-tailed Kite (*Elanoides forficatus*)	122	407	17.20	54.37	188	38.82	595	48.26
Mississippi Kite (*Ictinia mississippiensis*)	36,906	118,379	5,204.63	15,814.23	89,536	18,488.48	207,915	16,864.72
Plumbeus Kite (*I. plumbea*)	0	22	0.00	2.94	0	0.00	22	1.78
Northern Harrier (*Circus cyaneus*)	4	10	0.56	1.34	0	0.00	10	0.81
Sharp-shinned Hawk (*Accipiter striatus*)	22	17	3.10	2.27	1	0.21	18	1.46
Cooper's Hawk (*A. cooperi*)	24	13	3.38	1.74	3	0.62	16	1.30
Zone-tailed Hawk (*Buteo albonotatus*)	14	19	1.97	2.54	1	0.21	20	1.62
Broad-winged Hawk (*B. platypterus*)	323,983	738,669	45,689.32	98,678.66	279,997	57,817.17	1,018,666	82,627.59
Swainson's Hawk (*B. swainsoni*)	227,168	172,139	32,036.10	22,996.02	202,049	41,721.52	374,188	30,351.71
Red-tailed Hawk (*B. jamaicensis*)	3	2	0.42	0.27	0	0.00	2	0.16
American Kestrel (*Falco sparverius*)	12	3	1.69	0.40	1	0.21	4	0.32
Merlin (*F. columbarius*)	61	41	8.60	5.48	2	0.41	43	3.49
Peregrine Falcon (*F. peregrinus*)	1,425	1,759	200.96	234.98	303	62.57	2,062	167.26
Undetermined *Accipiter*	11	8	1.55	1.07	5	1.03	13	1.05
Undetermined *Buteo*	6,589	2,560	929.21	341.99	996	205.67	3,556	288.44
Undetermined Falcon	79	6	11.14	0.80	1	0.21	7	0.57
Undetermined Raptor	10,986	388	1,549.29	51.83	2,309	476.79	2,697	218.76
Other migrant Raptors	0	17	0.00	2.27	0	0.00	17	1.38

2001 the count began on 3 September and ended on 30 November. At Kéköldi, observations usually started at 07:00 and ended at 16:00 h. At Bribri, observations were made from 09:00 to 16:00 h. During peak migration, some days started earlier and ended later to deal with the increase in activity. Towards the end of the season, daily hours of hawkwatch was often limited to the hours of biggest recorded activity from previous data, and volunteers went to Bribri from 10:00 to 13:00 h from 12 November to 30 November 2001. The time at which the count began throughout the season also varied depending on early morning rains, with counts beginning after the rain had stopped and visibility improved.

Turkey Vultures, Mississippi Kites (*Ictinia mississippiensis*), Broad-winged and Swainson's hawks were the most common species seen, and the analyses below focus on these four species. To adjust for daily variation in sampling effort, we converted our data to annual passage rates (of individuals per 100 h of observation). According to the fact that the 2000 full-season fall count only included one lookout (Kéköldi), we only considered the count of the Kéköldi watch site in 2001 to evaluate differences in species counts between 2000 and 2001. We evaluated the percentage of variation in numbers of birds counted in Kéköldi between 2000 and 2001 by comparing the central 80% passage period rates (number of birds per 100 h of observation in the central 80% passage period). We used chi-square tests with a 5% alpha level ($P < 0.05$) to compare the species proportion between years and between sites.

As data in Bribri from 12 through 30 November 2001 were only recorded from 10:00 to 13:00 h, we only used the data until 12 November to compare the daily activity pattern of the migrants between the two sites in 2001. The daily activity pattern from 2000 could not be compared with 2001 since the count times were recorded differently in 2000 (hourly at the half hour) and 2001 (hourly at the top of the hour.)

RESULTS

Migration counts. A total of 1,332,267 migrants (187,881 raptors/100 h), representing 14 species, were counted during the first full-season autumn only at Kéköldi (Table 1). The second full-season autumn count was from two different lookouts, Kéköldi and Bribri. Numbers of migrants for these counts (combined) totaled 2,979,102 raptors (214,645 raptors/100 h) representing 17 species (Table 1). Three new species seen in 2001 were the Plumbeous (*Ictinia plumbea*), Snail (*Rostrhamus s. sociabilis*), and Hook-billed (*Chondrohierax u. uncinatus*) kites.

Raptors were counted at the Kéköldi lookout for 709 h on 98 days, by an average 3.0 observers/h in 2000, and for 748.6 h on 86 days, by an average of 2.3 observers/h in 2001. Raptors were counted at BriBri for 484.3 h on 79 days, by an average 2.1 observers/hour in 2001, giving a general number of 1232 h on 86 days, averaging 2.18 observers/h for Talamanca.

Passage rates at Kéköldi increased by 56% in 2001. Of the main species, the Broad-winged Hawk and the Mississippi Kite showed the greatest increases, of 122% and 94%, respectively. The proportion of Turkey Vultures, Broad-winged Hawks, Swainson's Hawks and Mississippi Kites combined was 98.6% in 2000, and 99.7% in 2001 ($\chi^2 = 0.16$, $P > 0.05$) (Table 2).

The 2001 autumn counts included 2,194,244 migrants representing 17 species at Kéköldi, and 784,858 individuals representing 12 species at BriBri (162,066.99 raptors/100 h; Table 1).

Seasonal activity patterns. Mississippi Kites and Swallow-tailed Kites (*Elanoides forficatus*) were the earliest migrants in Talamanca, with peak

TABLE 2. Species proportions between the Kéköldi and BriBri watchsites in Talamanca, Costa Rica, autumn 2001. For the scientific names of species, see Table 1.

Species	Talamanca 2001	Proportion	
	total count	% Kéköldi	% Bribri
Turkey Vulture	1,367,200	84.73	15.27
Osprey	2,051	67.72	32.28
Swallow-tailed Kite	595	68.40	31.60
Mississippi Kite	207,915	56.94	43.06
Plumbeus Kite	22	100.00	0.00
Northern Harrier	10	100.00	0.00
Sharp-shinned Hawk	18	94.44	5.56
Cooper's Hawk	16	81.25	18.75
Zone-tailed Hawk	20	95.00	5.00
Broad-winged Hawk	1,018,666	72.51	27.49
Swainson's Hawk	374,188	46.00	54.00
Red-tailed Hawk	2	100.00	0.00
American Kestrel	4	75.00	25.00
Merlin	43	95.35	4.65
Peregrine Falcon	2,062	85.31	14.69
Undetermined Accipiter	13	61.54	38.46
Undetermined Buteo	3,556	71.99	28.01
Undetermined Falcon	7	85.71	14.29
Undetermined Raptor	2,697	14.39	85.61
Other migrant raptors	17	100.00	0.00
Totals of raptors	2,979,102	73.65	26.35

passage in mid-September. Broad-winged Hawks, Osprey (*Pandion haliaetus*) and Peregrine Falcons (*Falco peregrinus*) passages were peaking between the end of September and mid-October. Turkey Vultures and Swainson's Hawks passages were peaking in late October to early November (Table 3, Figs. 2, 3 and 4). Overall, most passages occurred in October (Table 3). The central 80% passage period was 28 September–17 November (51 days) in 2000 and 27 September–1 November (36 days) in 2001 (Table 3). The central 80% of Broad-winged Hawk passage occurred over 19 days in 2000 and 15 days in 2001. The central 80% of Swainson's Hawk passage was 20 days in 2000 and 11 days in 2001. These two species had the most acute passage of any migrants. On the other hand, Ospreys exhibited the most protracted passage, with the central 80% over 43 days in 2000 and 38 days in 2001 (Table 3).

Daily activity patterns. The daily activity for all the migrants combined peaked at 10:00 h at Kéköldi and 12:00 h at Bribri (Fig. 5). Daily activity appeared to be more concentrated at Kéköldi, with one third of all the raptors counted between 10:00 and 10:59 h (Fig. 5).

Flight behavior. Migrants approached from the northwest and migrated to the south. All species used thermals. Most glided from one thermal to the next following each other in long streams without flapping.

TABLE 3. Central 80% passage periods and median passage dates at Kéköldi and BriBri watchsites in Talamanca, Costa Rica, autumn 2000 vs 2001.

Periods	Species	Kéköldi				Bribri	
		Central 80% passage date: number of days		Median passage date		Central 80% passage date: number of days	Median passage date
		2000	2001	2000	2001	2001	
2 first weeks of September migrants	Swallow-tailed Kite	7 Sept/25 Sept: 19 days	4 Sept/24 Sept: 21 days	13 Sept	05 Sept	4 Sept/18 Sept: 15 days	04 Sept
	Plumbeous kite	—	6 Sept/4 Oct: 29 days	—	12 Sept	—	—
	Mississippi Kite	7 Sept/28 Sept: 22 days	4 Sept/25 Sept: 22 days	16 Sept	15 Sept	5 Sept/22 Sept: 18 days	15 Sept
						21 Sept/24 Oct: 34 days	06 Oct
2 first weeks of October migrants	Osprey	20 Sept/30 Oct: 41 days	20 Sept/27 Oct: 38 days	06 Oct	04 Oct		
	Broad-winged Hawk	27 Sept/15 Oct: 19 days	29 Sept/13 Oct: 15 days	01 Oct	09 Oct	26 Sept/13 Oct: 18 days	08 Oct
	Zone-tailed Hawk	25 Sept/17 Oct: 23 days	24 Sept/27 Oct: 34 days	10 Oct	09 Oct	1 individual: 5 Sept	05 Sept
	Peregrine Falcon	4 Oct/25 Oct: 22 days	1 Oct/24 Oct: 24 days	14 Oct	09 Oct	1 Oct/23 Oct: 23 days	08 Oct
	Red-tailed Hawk	12 Oct/6 Nov: 26 days	12 Oct/18 Oct: 7 days	17 Oct	12 Oct	—	—
2 last weeks of October migrants	Sharp-shinned Hawk	21 Sept/26 Oct: 36 days	8 Sept/27 Oct: 50 days	12 Oct	18 Oct	30 Oct	30 Oct
	American Kestrel	12 Sept/9 Oct: 28 days	21 Sept/31 Oct: 41 days	26 Sept	21 Oct	1 individual: 8 Sept	08 Sept
	Swainson's Hawk	21 Oct/9 Nov: 20 days	17 Oct/27 Oct: 11 days	25 Oct	22 Oct	18 Oct/25 Oct: 8 days	21 Oct
	Merlin	16 Oct/25 Oct: 10 days	11 Oct/27 Oct: 17 days	21 Oct	23 Oct	3 Oct/17 Oct: 15 days	03 Oct
	Cooper's Hawk	19 Sept/5 Nov: 48 days	24 Sept/30 Oct: 37 days	27 Oct	23 Oct	24 Oct/29 Oct: 6 days	29 Oct
	Turkey Vulture	22 Oct/22 Nov: 32 days	11 Oct/13 Nov: 34 days	03 Nov	26 Oct	16 Oct/28 Oct: 13 days	22 Oct
	Northern Harrier	6 Oct/15 Oct: 10 days	18 Oct/28 Nov: 42 days	13 Oct	27 Oct	—	—
							17 Oct
	Total of raptors	28 Sept/17 Nov: 51 days	30 Sept/4 Nov: 36 days	25 Oct	19 Oct	21 Sept/27 Oct: 37 days	

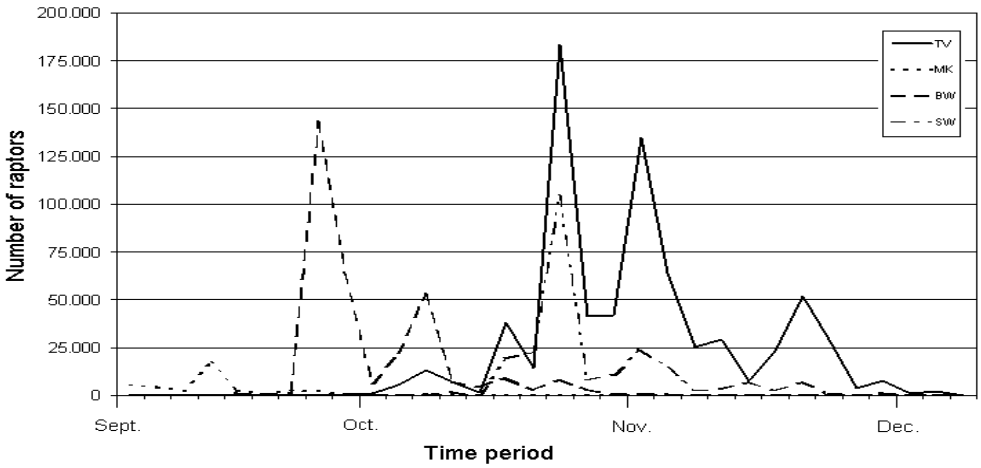

FIG. 2. Number of migrating individuals of the four most abundant raptor species counted at the Kéköldi lookout during autumn 2000. BW = Broad-winged Hawk, MK = Mississippi Kite, SW = Swainson' Hawk, and TV = Turkey Vulture.

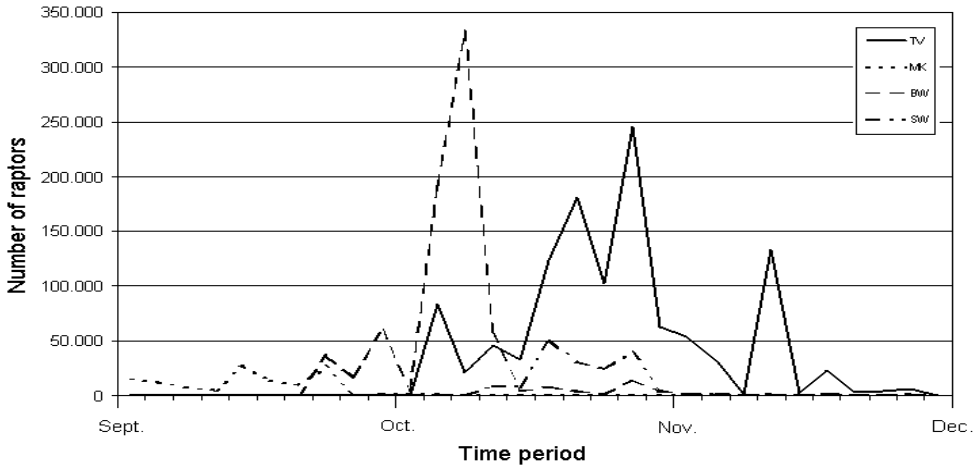

FIG. 3. Number of migrating individuals of the four most abundant raptor species counted at the Kéköldi lookout during autumn 2001. BW = Broad-winged Hawk, MK = Mississippi Kite, SW = Swainson' Hawk, and TV = Turkey Vulture.

A small amount of flapping flight occurred on days with heavy overcast. Raptors also used winds that were deflected up and over the region's mountains, especially from the NW/SE oriented ridge at the north of the Bribri watch site.

Flocking migrants (i.e., Broad-winged and Swainson's hawks and Turkey Vultures) usually came in groups of from 10 to more than 1000. Groups usually followed each other, and often used the same thermals. In the peak of migration, especially on days with the big-

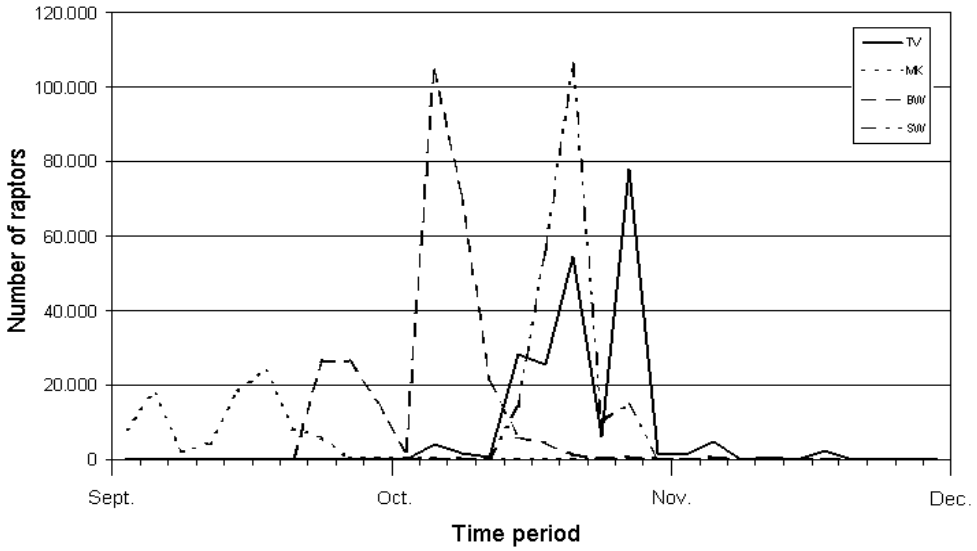

FIG. 4. Number of migrating individuals of the four most abundant raptor species counted at the Bribri lookout during autumn 2001. BW = Broad-winged Hawk, MK = Mississippi Kite, SW = Swainson' Hawk, and TV = Turkey Vulture.

gest flights, it was often impossible to distinguish individual groups of migrants. Thermals were used constantly, with raptors entering them at the base and others leaving at the top. On such days, a long "river of raptors" linked the thermals and seemed to cover the sky when the birds were passing overhead.

The four most abundant species (Turkey Vulture, Mississippi Kite, Broad-winged and Swainson's hawks) traveled in large flocks between thermals, whereas Ospreys, Peregrine Falcons, and most others species, were more solitary and did not rely as much on thermals.

When Turkey Vultures flew together in flocks with Swainson's and Broad-winged hawks, almost invariably the former flew lower than the other two species. Turkey Vultures also ascended thermals slower than did the two buteos, and sometimes collided with the latter when traveling in dense flocks.

Ospreys often migrated in flocks of several birds; thus if one was spotted, a second and sometimes third one could be seen flying not too far away.

Two Peregrine Falcons were seen carrying prey, another was seen chasing swallows; two Ospreys were seen carrying fish, another was seen perched and eating a fish; one Plumbeous Kite was seen chasing swallows, one Swainson's Hawk was seen perched and eating; and one Broad-winged Hawk was seen carrying prey.

Weather effects. Soaring raptors sometimes gained altitude and disappeared into the bases of clouds. They then glided out of the clouds apparently unaffected. Birds did not seem to avoid such events. However, they did avoid very thick storm clouds, either by flying below or around them. Raptors also were seen migrating in light rain.

On cloudy days, fewer birds were counted; groups were smaller and more scattered in the sky. On such days, the rate of movement was slower as well, sometimes with groups of rap-

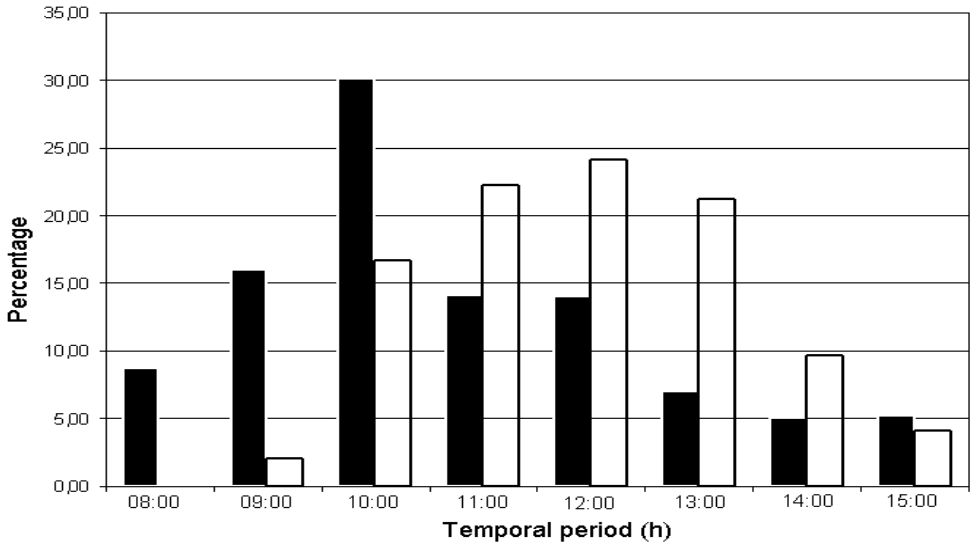

FIG. 5. Daily flight patterns, as percent of the total number of counted birds, of migrating raptors at the Kekoldi and Bribri lookouts in autumn 2001. Black columns = Kéköldi, white columns = Bribri.

tors going from one weak thermal to another and back again, staying in sight for longer periods of time. Birds gained altitude in thermals much faster on hot sunny days than on days when the sky was covered. For example, relatively few birds (< 25,000) were counted between 1 and 6 October 2001 when it was raining in Talamanca, and there was a hurricane over Nicaragua. Once the hurricane passed (on 6 October), local weather improved and we recorded our biggest flight day on 10 October, with the passage of 279,092 birds, 96% of which were Broad-winged Hawks. The same pattern also was observed when we counted 122,246 raptors (99% of which were Turkey Vultures) on 13 November (during the central 80% passage period of Turkey Vultures), immediately after a week of rainy weather.

DISCUSSION

Our observation place, Talamanca, Costa Rica, together with Veracruz, Mexico, and Elat, Israel, is one of only three hawk watch-sites worldwide to count more than one million raptors in a single season. Of these three sites, Talamanca, with almost 3 million migrants in autumn 2001, has the second highest counts, after Veracruz (Ruelas Inzunza *et al.* 2000, Zalles & Bildstein 2000). Presumably, raptors counted in Talamanca are the same as those counted in Veracruz. Indeed, the seasonal progression by which the four most abundant species migrated south along the Mesoamerican Land Corridor seemed to be the same throughout the corridor as they passed in the same order at Corpus Christi, Texas, as in Talamanca (Smith *et al.* 2001). The 2001 counts in Talamanca demonstrate the importance of the Mesoamerican Land Corridor as the largest migration flyway in the world (Bildstein & Saborio 2000). Raptors in the tropics seem to migrate in what, in the temperate zone, would be considered "sub-optimal" conditions. Flight conditions are quite different in the tropics than in the temperate zones (Smith 1985). We know that

raptors can remain grounded for many days when tropical storms bring heavy rain in the morning while hawks and vultures are still on the ground (Loftin 1967; pers. observ.). The "migration-pulses" observed in Talamanca in 2001 confirm Loftin's observations. During cyclonic storms, raptors apparently roost and wait for better flight conditions to migrate. Most of our big count days were recorded on sunny days when strong thermals form. However, many raptors also could be seen using weak thermals on generally overcast days.

The spatial segregation of Turkey Vultures from buteos in mixed streams, also reported by Purdue *et al.* (1972), is probably due to differences in wing loading.

For the four most abundant species, flocking behavior also appears to be profitable in tropical environments. Searching for thermals is easier in groups, as distant thermals are easier to find when other groups can be seen ketting in them (Smith 1985).

Bildstein & Zalles (2001) proposed two possible explanations for the more rapid transit of raptors over the tropics reported by Fuller *et al* (1998). Raptors might be less likely to feed while migrating in the tropics (Smith *et al* 1986), or tropical soaring conditions might permit faster travel there. The fact that we observed very few migrating raptors feeding in 2001 supports the first explanation. On the other hand, our observations of thermal soaring in the tropics support the second explanation.

Improvements to the counts should include increased weather data gathering. The narrowness of the Mesoamerican Land Corridor in the region also suggests that detection of the migration using Doppler weather surveillance radar might be a useful strategy at the site (Gauthreaux *et al* 2001).

Considering the magnitude of the Peregrine Falcon's migration activity at the site, Talamanca appears to be a very good location for long term monitoring of this species which is recovering from pesticide-era lows (Bildstein 2001).

Finally, coordinating count efforts at Talamanca with those conducted elsewhere along the Mesoamerican Land Corridor also would be of value (Smith 1980).

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REFERENCES

Allen, P. E., L. J. Goodrich, & K. L. Bildstein. 1995. Within- and among-year effects of cold fronts on migrating raptors at Hawk Mountain, Pennsylvania, 1934–1991. Auk 113: 329–338.

Bildstein, K. L. 2001. Why migratory birds of prey make great biological indicators. Pp. 169–179 *in* Bildstein, K. L., & D. Klem, Jr. (eds.). Hawkwatching in the Americas. Hawk Migration Association of North America, North Wales, Pennsylvania.

Bildstein, K. L., & M. Saborio. 2000. Spring migration counts of raptors and New World vultures in Costa Rica. Ornitol. Neotrop. 11: 197–205.

Bildstein, K. L., & J. Zalles. 2001. Raptors migration along the Mesoamerican Land Corridor. Pp. 119–136 *in* Bildstein, K. L., & D. Klem, Jr. (eds.). Hawkwatching in the Americas. Hawk Migration Association of North America, North Wales, Pennsylvania.

Broun, M. 1949. Hawks aloft: the story of Hawk Mountain Sanctuary. Cornwall Press, Cornwall, New York.

Clark, W. S., & B. K. Wheeler. 1987. A field guide to the hawks of North America. Hough Mifflin

Company, Boston, Massachusetts.

Fuller, M. R., W. S. Seegar, & L. S. Schueck. 1998. Routes and travel rates of migrating Peregrine Falcons *Falco peregrinus* and Swainson's Hawks *Buteo Swainsoni* in the Western Hemisphere. J. Avian Biol. 29: 433–440.

Gauthreaux, Jr., S. A., Belser C. G., & A. Farnsworth. 2001. How to use Doppler weather surveillance radar to study hawk migration. Pp. 149–160 *in* Bildstein, K. L., & D. Klem, Jr. (eds.). Hawkwatching in the Americas. Hawk Migration Association of North America, North Wales, Pennsylvania.

Kerlinger, P. 1989. Dynamics of raptor migration. Univ. Chicago Press, Chicago, Illinois.

Loftin, H. 1967. Hawks delayed by weather soaring on spring migration through Panama. Florida Nat. 40: 29.

Porras, P. 2001. Migratory Raptor Conservation Project: Volunteer manual. Asociacion ANAI, San Jose, Costa Rica.

Purdue, J. R., C. C. Carpenta, D. L. Marcellini, & R. F. Clarke. 1972. Spring migration of Swainson's Hawk and Turkey Vulture trough Veracruz. Wilson Bull. 84: 92–92.

Ruelas Inzunza, E., S. W. Hoffman, L. J. Goodrich, & R. Tingay. 2000. Conservation strategies for the world's largest known raptors migration flyway: Veracruz the river of raptors. Pp. 591–596 *in* Chancellor, R. D., & B.-U. Meyburg (eds.). Raptors at risk. Proceeding of the Vth World Working Group on Birds of Prey and Owls, Midrand, South Africa, 1998. World Working Group on Birds of Prey and Owls, Berlin, Germany.

Skutch, A. F., & F. G. Stiles. 1989. A guide to the birds of Costa Rica. Cornell Univ. Press, Ithaca, New York.

Smith, N.G. 1980. Hawk and Vulture migration in the Neotropics. Pp. 51–65 *in* Keast A. & Morton E.S. (eds.). Migrant birds in the Neotropics. Smithsonian Institute Press, Washington, D.C.

Smith, N. G. 1985. Thermals, clouds streets, trade winds, and tropical storms: how migrating raptors make the most of atmospheric energy in Central America. Pp. 51–65 *in* Hardwood, M. (ed.). Proceedings of hawk migration conference IV. Hawk Migration Association of North America. Lynchburg, Virginia.

Smith, J. P., J. Simon, S. W. Hoffman, & C. Riley. 2001. New full-season autumn hawkwatches in coastal Texas. Pp. 67–91 *in* Bildstein, K. L., & D. Klem, Jr. (eds.). Hawkwatching in the Americas. Hawk Migration Association of North America, North Wales, Pennsylvania.

Wheeler, B. K., & W. S. Clark. 1995. A photographic guide to North American raptors. Academic Press, San Diego, California.

Zalles, J., & K. L. Bildstein. 2000. Raptors watch: a global directory of raptor migration sites. BirdLife International, Cambridge, UK.