

NEW FULL-SEASON COUNT SITES FOR RAPTOR MIGRATION IN
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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. Siguiendo a Veracruz, México, 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 abado (*Bubo platypterus*), el Gavilán de Swainson (*B. swainsoni*) y el Milano de Mississippi (*Lanius 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-hall" 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 watchtowers 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 (*Bubo platypterus*), Swainson's Hawks (*Bubo swainsoni*), and Mississippi Kites (*Lanius mississippiensis*) represent more than 98% of the total count in both years. Daily migration activity peaks around mid-day, and no noon-hall 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 (Brown 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 Kekoldi and Beñón 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

region ranges from sea level to 300 m. Daily temperatures average 26°C, 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 underdeveloped 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 Kekoldi Indigenous Reserve neighboring Puerto Viejo, Costa Rica (Fig. 1).

The Kekoldi watchsite is located at the top of a mountain in the Indigenous Reserve (09°38'30"N). Vegetation is mostly second-growth rain forest and abandoned cacao plantations. It is 200 m a.s.l. and provides a good 112° 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 south-east direction, passing northeast of the platform, or take a more inland route west of the platform. Kekoldi was the only lookout used in autumn 2000.

In autumn 2001, a second watchsite was established in the town of Beñón (09°37'23"N) in the Sixaola Valley, 10 km southwest of the Kekoldi site (Fig. 1). The new watchsite is at a local community center, 90 m a.s.l. Beñón provides a 360° 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 (HMNA) 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 (°C), 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

Species	Kékoldi		Bnbn		Total Talamanca 2001	
	Total count	Raptors/100 h	Total count	Raptors/100 h	Total count	Raptors/100 h
Turkey Vulture (<i>Cathartes aura</i>)	724,106	1,158,996	102,116.20	154,749.92	208,804	43,116.38
Osprey (<i>Pandion haliaetus</i>)	752	1,389	106.05	185.56	662	136.70
Swallow-tailed Kite (<i>Elanoides forficatus</i>)	122	407	17.20	34.37	188	38.82
Mississippi Kite (<i>Elanus leucurus</i>)	36,906	118,379	5,204.63	15,814.23	89,536	18,488.48
Plumbeous Kite (<i>L. plumbeus</i>)	0	22	0.00	2.94	0.00	0.00
Northern Harrier (<i>Circus hudsonius</i>)	4	10	0.56	1.34	0	0.00
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	22	17	3.10	2.27	1	0.21
Cooper's Hawk (<i>A. cooperii</i>)	24	13	3.38	1.74	3	0.62
Zone-tailed Hawk (<i>Buteo albicaudatus</i>)	14	19	1.97	2.54	1	0.21
Broad-winged Hawk (<i>B. platypterus</i>)	323,985	738,669	45,689.32	98,678.66	279,997	57,817.17
Swainson's Hawk (<i>B. swainsoni</i>)	227,168	172,139	32,036.16	22,996.02	202,049	41,721.52
Red-tailed Hawk (<i>B. jamaicensis</i>)	3	2	0.42	0.27	0	0.00
American Kestrel (<i>Falco sparverius</i>)	12	3	1.69	0.40	1	0.21
Merlin (<i>F. columbarius</i>)	61	41	8.60	5.48	2	0.41
Peregrine Falcon (<i>F. peregrinus</i>)	1,425	1,759	200.96	234.98	303	62.57
Undetermined <i>Accipiter</i>	11	8	1.55	1.07	5	1.03
Undetermined <i>Buteo</i>	6,589	2,560	929.21	341.99	996	205.67
Undetermined Falcon	79	6	11.14	0.80	1	0.21
Undetermined Raptor	10,986	388	1,549.29	51.83	2,309	476.79
Other migrant Raptor	0	17	0.00	2.27	0	0.00

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

2001 the count began on 3 September and ended on 30 November. At Kékoldi, observations usually started at 07:00 and ended at 16:00 h. At Bnbn, 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 hawk-watch was often limited to the hours of biggest recorded activity from previous data, and volunteers went to Bnbn 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 (*Elanus leucurus*), 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 (Kékoldi), we only considered the count of the Kékoldi 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 Kékoldi 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 Bnbn 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 Kékoldi (Table 1). The second full-season autumn count was from two different lookouts, Kékoldi and Bnbn. 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 (*Elanus plumbeus*), Snail (*Buteo swainsoni*), and Hook-billed (*Chondestes* s. *swainsoni*) kites.

Raptors were counted at the Kékoldi 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 Bnbn 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 Kékoldi 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 Kékoldi, and 784,858 individuals representing 12 species at Bnbn (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 Kékoldi and Brñri watchsites in Talamanca, Costa Rica, autumn 2001. For the scientific names of species, see Table 1.

Species	Talamancas 2001		Proportion	
	total count	% Kékoldi	% Kékoldi	% Brñri
Turkey Vulture	1,367,200	84.73	84.73	15.27
Osprey	2,051	67.72	67.72	32.28
Swallow-tailed Kite	595	68.40	68.40	31.60
Mississippi Kite	207,915	56.94	56.94	43.06
Plumbeous Kite	22	100.00	100.00	0.00
Northern Harrier	10	100.00	100.00	0.00
Sharp-shinned Hawk	18	94.44	94.44	5.56
Cooper's Hawk	16	81.25	81.25	18.75
Zone-tailed Hawk	20	95.00	95.00	5.00
Broad-winged Hawk	1,018,666	72.51	72.51	27.49
Swainson's Hawk	374,188	46.00	46.00	54.00
Red-tailed Hawk	2	100.00	100.00	0.00
American Kestrel	4	75.00	75.00	25.00
Merlin	43	95.35	95.35	4.65
Peregrine Falcon	2,062	85.31	85.31	14.69
Undetermined Accipiter	13	61.54	61.54	38.46
Undetermined Buteo	3,556	71.99	71.99	28.01
Undetermined Falcon	7	85.71	85.71	14.29
Undetermined Raptor	2,697	14.39	14.39	85.61
Other migrant raptors	17	100.00	100.00	0.00
Totals of raptors	2,979,102	73.65	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 Kékoldi and 12:00 h at Brñri (Fig. 5). Daily activity appeared to be more concentrated at Kékoldi, 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 Kékoldi and Brñri watchsites in Talamanca, Costa Rica, autumn 2000 vs 2001.

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

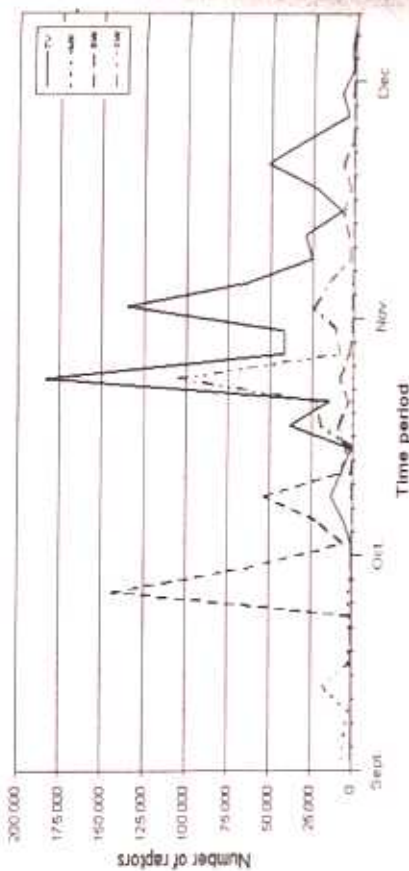


FIG. 2. Number of migrating individuals of the four most abundant raptor species counted at the Kéroulé lookout during autumn 2000. BW = Broad-winged Hawk, MK = Mississippi Kite, SW = Swainson's Hawk, and TV = Turkey Vulture.

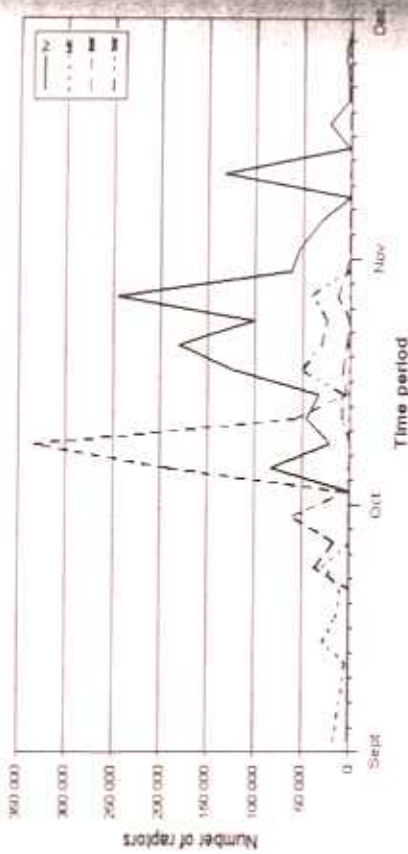


FIG. 3. Number of migrating individuals of the four most abundant raptor species counted at the Bribrí lookout during autumn 2001. BW = Broad-winged Hawk, MK = Mississippi Kite, SW = Swainson's Hawk, and TV = Turkey Vulture.

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 Bribrí watch site.

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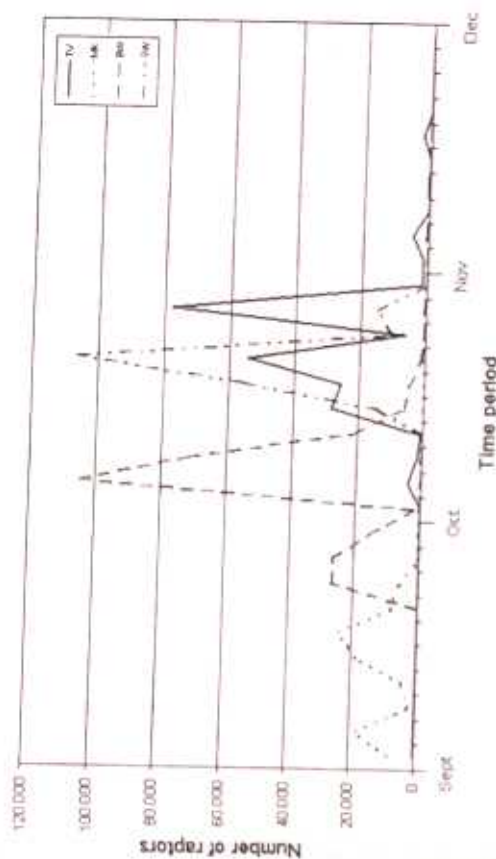


FIG. 4. Number of migrating individuals of the four most abundant raptor species counted at the Bribrí lookout during autumn 2001. BW = Broad-winged Hawk, MK = Mississippi Kite, SW = Swainson's Hawk, and TV = Turkey Vulture.

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 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.

Feather 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-

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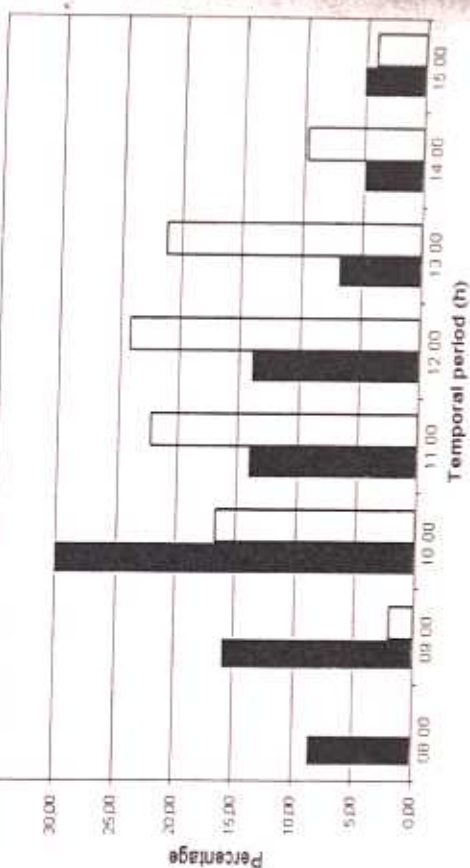


FIG. 5. Daily flight patterns, as percent of the total number of counted birds, of migrating raptors at the Kekoldi and Bribri lookouts in autumn 2001. Black columns = Kekoldi, white columns = Bribri.

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

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 (Lofin 1967; pers. observ.). The "migration-pulses" observed in Talamanca in 2001 confirm Lofin'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 leading 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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