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COLD FRONTS AND RAPTOR MIGRATION IN BOLIVIA

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Relaciones entre frentes fríos y migración de rapaces en Bolivia.

Key words: Bolivia, Falconiformes, Black Vultures, Mississippi Kites, Plumbeous Kites, Swallow-tailed Kites, cold fronts, *Ictinia*, *Coragyps*, *Elanoides.*

INTRODUCTION

Cold fronts are formed when a cold-air mass advances and move under a warmer air mass (Elkins 1995). In North America and Europe, the passage of cold fronts has been linked to increases in the passage rates of migratory raptors at migration watchsites, with higher numbers of raptors being counted concurrently with several days after frontal passage (Lack 1963, Smith 1985, Kerlinger 1995, Allen *et al.* 1996). Cold fronts are thought to facilitate raptor movements by providing tail winds as well as updrafts for migrants along mountain chains (Kerlinger 1995). There are no studies dealing with the relationships between cold fronts and raptor migration in the Neotropics, and the aim of this study was to investigate the possibility of a similar phenomenon in the region.

METHODS

I observed migrating raptors at a watchsite near a reservoir on the outskirts of the town of Concepción in the Departamento de Santa Cruz (Provincia Ñuflo de Chávez) (16º08S, 62º02W), at 250–400 m a.s.l., 270 km northeast of Santa Cruz. Counts were made from 09:00 to 17:00 h on 70 days from 17 September to 26 November 2001, using 12 x 50 binoculars and a 20–60x Telescope. Records were kept on data sheets modeled after the Hawk Migration Association of North America (HMANA) daily report forms. Completed data sheets were sent to the HMANA archives at Hawk Mountain Sanctuary.

I used Kolmogorov-Smirnov tests to determine the normality of the data (Bednarz *et al.* 1990). Least significant difference tests (LSD), in conjunction with a one-way ANOVA, modified from the tests performed by Allen *et al.* (1996) and Bildstein (1998), were performed to determine if the passage rates (number of raptors/h) of the four most abundant species varied between the day of a cold front passage and only the following eight days, because there was only one record of a cold front within 11 days after frontal passage.

RESULTS

A total of 121,351 migrating raptors repre-

TABLE 1. Raptor species and number of individuals per species counted from September through November 2001 in Concepción, Bolivia.

	September (102.3 h)	October (205.0 h)	November (189.5 h)	Total (496.8 h)
	No. birds (birds/h)	No. birds (birds/h)	No. birds (birds/h)	No. birds (birds/h)
Cathartes aura	6 (0.06)	30 (0.15)	11 (0.06)	47 (0.09)
Coragyps atratus	104 (1.02)	534 (2.60)	225 (1.19)	863 (1.74)
Sarcoramphus papa		13 (0.06)	11 (0.06)	24 (0.05)
Pandion haliaetus	2 (0.02)	56 (0.27)	32 (0.17)	90 (0.18)
Chondrohierax uncinatus			1 (0.005)	1 (0.002)
Elanoides forficatus	16 (0.16)	116 (0.56)	103 (0.54)	235 (0.47)
Elanus leucurus		8 (0.04)	6 (0.03)	14 (0.03)
Rosthramus sociabilis	15 (0.15)	31 (0.15)	5 (0.03)	51 (0.10)
Ictinia plumbea	129 (1.26)	135 (0.66)	22 (0.12)	286 (0.57)
Ictinia mississippiensis	6,637 (64.88)	70,697 (344.86)	40,819 (215.40)	118 153 (237.83)
Circus buffoni		6 (0.03)	1 (0.005)	7 (0.01)
Accipiter striatus			1 (0.005)	1 (0.002)
Buteogallus urubitinga		7 (0.03)		7 (0.01)
Buteogallus meridionalis	1 (0.01)	4 (0.02)		5 (0.01)
Parabuteo unicinctus	1 (0.01)			1 (0.002)
Buteo plathypterus		8 (0.04)		8 (0.02)
Buteo swainsoni		1 (0.005)	3 (0.01)	4 (0.01)
Polyborus plancus	1 (0.01)			1 (0.002)
Falco sparverius	2 (0.02)	4 (0.02)	3 (0.01)	9 (0.02)
Falco peregrinus		1 (0.005)	1 (0.005)	2 (0.004)
No identified Vultures	2 (0.02)		9 (0.05)	11 (0.02)

TABLE 1. Continuation.

	September (102.3 h)	October (205.0 h)	November (189.5 h)	Total (496.8 h)
	No. birds (birds/h)	No. birds (birds/h)	No. birds (birds/h)	No. birds (birds/h)
No identified Kites	372 (3.64)	624 (3.04)	505 (2.66)	1,501 (3.02)
No identified Accipiters	1 (0.01)			1 (0.002)
No identified Buteos		1 (0.005)		1 (0.002)
No identified Falcos			2 (0.01)	2 (0.004)
No identified Raptors	14 (0.14)	2 (0.01)	10 (0.05)	26 (0.05)
TOTAL	7,303 (71.39)	72,278 (352.57)	41,770 (203.76)	121,351 (244.26)

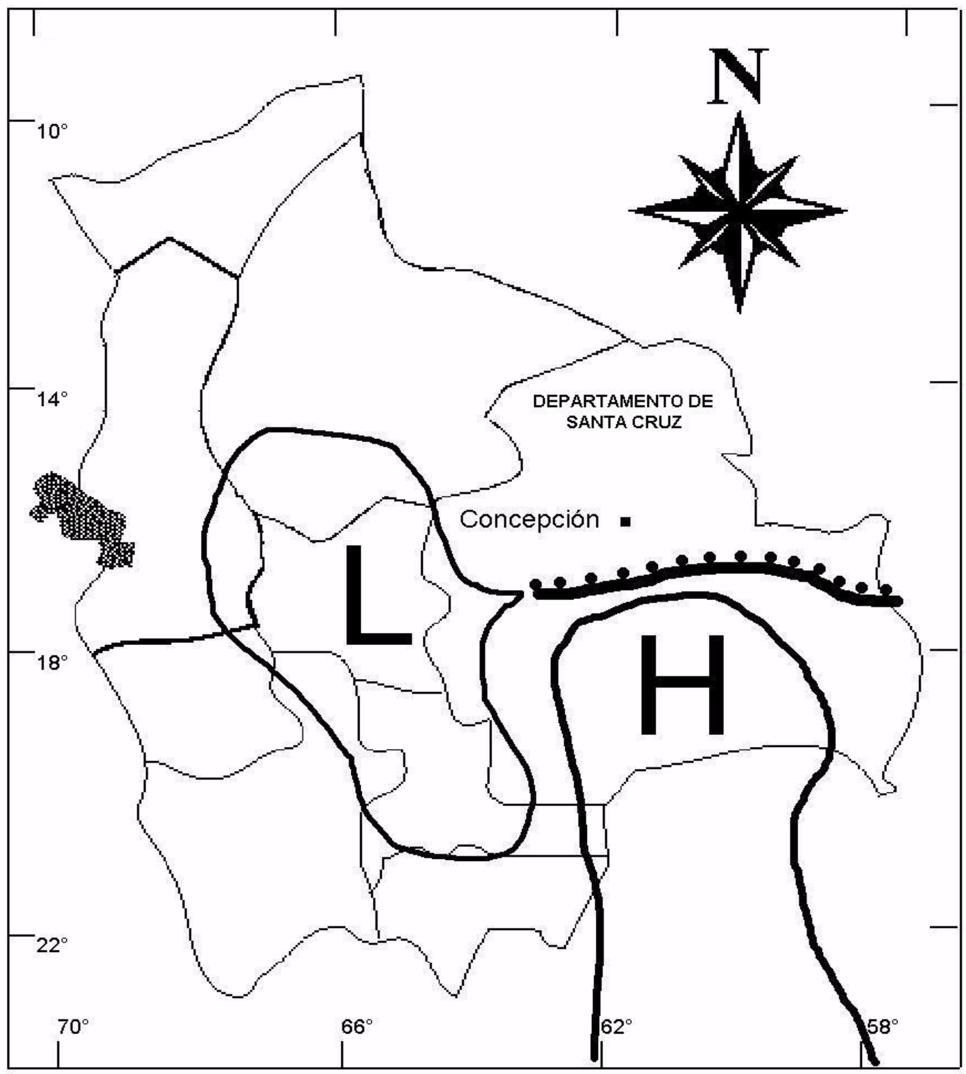

FIG. 1. Synoptic weather map of a representative cold front, from the Administración de Aeropuertos y Servicios Auxiliares a la Navegación Aérea (AASANA) for 18:00 h on 12 October 2001. The line with the northward-facing points represents a cold front. The "B" indicates an area with low barometric pressure, the "A" an area of high barometric pressure.

senting 20 different species was recorded during 497 observation hours on 70 days of observation, with an average passage rate of 243 raptors/h. The species included known austral, intratropical and Nearctic migrants (Table 1). The four most abundant species were the Mississippi Kite (*Ictinia mississippiensis*) (97.4%), the Black Vulture (*Coragyps atratus*) (0.7%), the Plumbeous Kite (*I. plumbea*) (0.23%), and the Swallow-tailed Kite

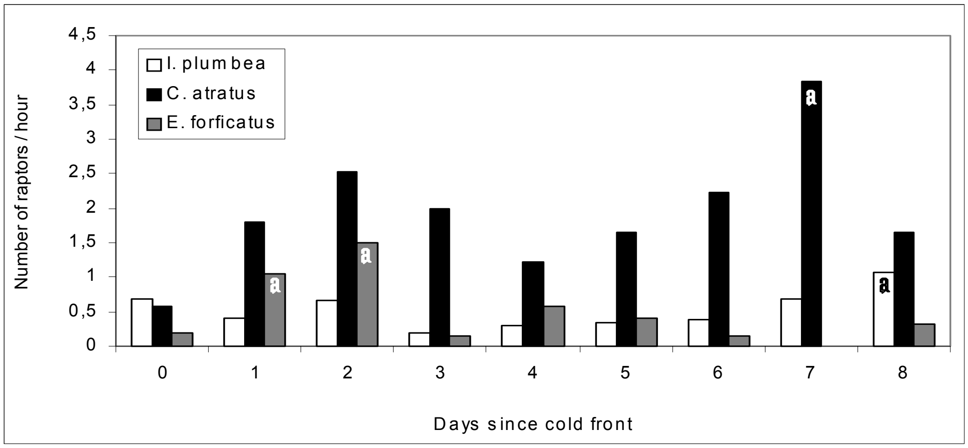

FIG. 2. Passage rates of Black Vultures, Plumbeous Kites and Swallow-tailed Kites at Concepción, Bolivia, between September and November 2001. Passage rates are expressed as a function of the number of days since the most recent cold front passed through the watch site. A LSD test in association with 1-way ANOVA determined significant differences in the number of raptors/h as a function of the number of days between the day of a frontal passage and the following days ($P = 0.01$). Bars with the letter "a" are significantly different from the others.

(*Elanoides forficatus*) (0.2%).

Intervals among 11 successive cold fronts ranged from 1 to 11 days, with 28% of all fronts passing within 1 and 2 days, 36% within 6 days, 27% within 8 days, and 9% within 11 days of the previous front (Fig. 1). The four most abundant species showed significant shifts in the magnitude of their passages as a function of the passage of cold fronts (LSD test in association with one-way ANOVA: $P < 0.05$). Significant changes in the passage rates of the four species occurred on the days following a frontal passage. The four species fell into two response groups (Figs 2 and 3). Black Vultures and Plumbeous Kites had their highest passage rates 7 to 8 days after a frontal passage. Passage rates of Black Vultures increased on the day following a frontal passage, decreased on the 4th day, and increased again on the 7th day. Passage rates for Plumbeous Kites were low on the 1st and 2nd days after a frontal passage, and subsequently increased from the 7th to the 9th days after a frontal passage. Peak passage rates for Swallow-tailed and Mississippi kites took place 1 to 3 days after a frontal passage, and then decreased.

DISCUSSION

It is possible that the high passage rates of Swallow-tailed and Mississippi kites between 1 and 3 days after a cold front passage and the high passage rates of Black Vultures and Plumbeous Kites between 7 and 8 days after frontal passage resulted from rapidly changing local weather conditions that typify the passage of cold fronts, combined with the different aerodynamic flight capacities of the four species and their migratory geography (short- versus long-distance migrants). Long-distance migrants (Swallow-tailed and Mississippi kites) differed in their responses from short distance migrants (Black Vultures and Plumbeous Kites). Unfortunately, it is not possible to determine if all observed Swallow-

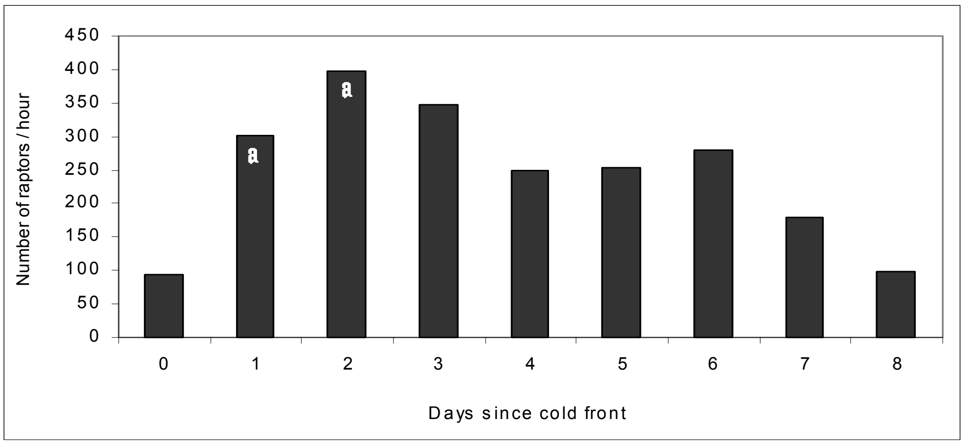

FIG. 3. Passage rates of Mississippi Kites at Concepción, Bolivia, between September and November 2001. Passage rates are expressed as a function of the number of days since the most recent cold front passed through the watch site. A LSD test in association with 1-way ANOVA determined significant differences in the number of raptors/h as a function of the number of days between the day of a frontal passage and the following days ($P = 0.01$). Bars with the letter "a" are significantly different from the others.

tailed Kites were Nearctic rather than intratropical migrants.

Another possible explanation for the high passage rates of Mississippi Kites between 1 and 3 days after cold front is that the fronts are normally accompanied by strong rains, which coincide with abundances of flying ants (*Atta* spp.). Kites may track frontal passages to take advantage of these abundant prey species (Davis 1993). The migration of Black Vultures appears to depend on thermal activity. Black Vultures are well suited for migrating in the fine weather that takes place between 2 and 6 days after a cold front passage (Allen *et al.* 1996), and thus can have high passage rates on the 7th day after a frontal passage. Overall, the results of my study support the general hypothesis (Mueller & Berger 1961, Allen *et al.* 1996) that frontal passages increase the likelihood of raptor migration.

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REFERENCES

Allen, P. E., L. J. Goodrich, & K. L. Bildstein. 1996. Within- and among-year effects of cold fronts on migrating raptors at Hawk Mountain, Pennsylvania, 19341991. Auk 113: 329–338.

Bednarz, J. C., D. Klem, L. J. Goodrich, & S. E. Senner. 1990. Migration counts of raptors at Hawk Mountain Sanctuary, as indicators of population trends, 1934–1986. Auk 107: 96–109.

Bildstein, K. L. 1998. Long-term counts of migrating raptors a role for volunteers in wildlife research. J. Wildl. Manage. 62: 435–445.

Davis, S.E. 1993. Seasonal status, relative abundance, and behaviour of the birds of Concepción, Departamento Santa Cruz, Bolivia. Fieldiana Zool. 71:1–33.

Elkins, N. 1995. Weather and bird behaviour. T & A D Poyser, London, UK.

Kerlinger, P. 1995. How birds migrate. Stackpole Books, Mechanicsburg, Pennsylvania.

Lack, D. 1963. Weather factors initiating migration. Proc. Int. Ornithol. Congr. 13: 412–414.

Mueller, H. C., & D. D. Berger. 1961. Weather and fall migration of hawks at Cedar Grove, Wisconsin. Wilson Bull. 73: 171–192.

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

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