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MIGRATION AND RANGING OF PEREGRINE FALCONS WINTERING ON THE GULF OF MEXICO COAST, TAMAULIPAS, MEXICO

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Abstract. Movements of 11 female and 1 male adult Peregrine Falcons (*Falco peregrinus*) wintering in coastal Gulf of Mexico, Tamaulipas, Mexico, were monitored with satellite-received transmitters (PTTs), 1997–1998. Median areas for minimum convex polygon winter home ranges at 50% and 90% levels (both years) were 1173 and 8311 ha, respectively. Most birds left wintering grounds in the first week of May. Duration of northward migration averaged 30 days. Distances between capture location and summer settling place were between 4580 and 5844 km; birds traversed 40.4–46.4 degrees of latitude. Birds summered between far western Canada and coastal west Greenland. One was followed to the same summering ground in both years. Autumnal migration routes were through the middle of the continent, and initiated in August and September. Falcons arrived on wintering grounds in September and October, averaging 40 days to make the journey. PTT data and capture locations of birds trapped in more than 1 year suggest fidelity to wintering areas, although perhaps not particular winter home ranges.

Key words: bird migration, Falco peregrinus, *Mexico, nonbreeding grounds, Peregrine Falcon, winter ranging.*

Migración y Áreas de Ocurrencia de Halcones Peregrinos Invernantes en la Costa del Golfo de México, Tamaulipas, México

Resumen. Entre 1997 y 1998, se monitorearon con transmisores de satellite (PTTs) los movimientos de 12 halcones peregrinos adultos (*Falco peregrinus*; 11 hembras y 1 macho) invernando en la costa del Golfo de México, Tamaulipas, México. Se utilizaron niveles de precisión del 50% y 90% en los polígonos mínimos estimados para describir los hambitos hogareños de invernada (en ambos años); éstos fueron de 1173 y 8311 ha, respectivamente. La mayoría de las aves abandonaron las areas de invernada en la primera semana de mayo. La duración de la migración hacia el Norte promedió 30 días. Las distancias entre los lugares donde las aves fueron capturadas y donde se establecieron en el verano variaron entre 4580 y 5844 km; así que éstas recorrieron entre 40.4 y 46.4 grados de latitud. Los halcones pasaron el verano entre el lejano oeste de Canadá y la costa oeste de Groenlandia. Uno de ellos fue seguido en ambos años hasta la misma área de veraneo. Las rutas migratorias del otoño tuvieron lugar a través del centro del continente y se iniciaron en agosto y septiembre. Los halcones peregrinos llegaron a las áreas de inviernada en septiembre y octubre, promediando 40 días para hacer el recorrido. Los datos de los PTTs e información sobre las ubicaciones de los lugares de captura de las aves atrapadas en más de un año sugieren fidelidad a las áreas de invierno, pero tal vez no a hambitos hogareños particulares.

INTRODUCTION

Like other long-distance-migrant birds, Peregrine Falcons (*Falco peregrinus*) that breed in the far north spend more time on migration and wintering (nonbreeding) areas than on breeding areas. While migration patterns and wintering requirements of some taxa, such as passerines, are well studied (Rappole et al. 1979, Winker et al. 1990, Ramos and Rappole 1994), little is known about the winter ecology of peregrines (Palmer 1988, Ratcliffe 1993). This gap in information may undermine conservation efforts, which are based on data collected primarily on the breeding grounds.

Nearctic breeding grounds of Peregrine Falcons extend across the continent from arctic Alaska to Labrador including the southern arctic

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islands, and coastal Greenland as far north as 79°N latitude. Wintering grounds of these northern falcons extend from coastal areas of the mid-Atlantic United States (~39°N) and British Columbia (~50°N) south to Argentina (~39°S) (Palmer 1988, Fuller et al. 1998). Coastal Gulf of Mexico, especially Padre Island, Texas, has long been known as an important site of concentration of migrating peregrines, even during years when North American peregrine population levels were relatively low (Enderson 1969, Hunt et al. 1975).

Migrating falcons cover large distances (Kuyt 1967, Fuller et al. 1998), and banding data show that some falcons wintering along the coast of the Gulf of Mexico breed in arctic regions of North America (Yates et al. 1988). The Gulf Coast of Mexico and the U.S. is important to migrating (Yates et al. 1988), staging (Hunt and Ward 1988), and wintering Peregrine Falcons (Enderson et al. 1995). Apart from work by Enderson et al. (1995), little is known about Peregrine Falcon wintering ranges along the Gulf Coast of Mexico, although there are studies from other regions of hunting behavior during winter and migration (Dekker 1988, Cresswell and Whitfield 1994, Buchanan 1996).

Satellite-received telemetry has been useful in determining migration paths of large raptors (Meyburg et al. 1995, Ueta et al. 2000), including Peregrine Falcons (Fuller et al. 1998). Tracking via satellite is particularly appropriate when long-distance movements or movements to remote areas are of interest, but poor accuracy of location estimates may obscure results, particularly at smaller scales (Britten et al. 1999). The present paper reports satellite-received movement data from Peregrine Falcons wintering on the Gulf of Mexico coast, Tamaulipas, Mexico.

METHODS

Wintering peregrines were studied on the Gulf of Mexico coast between 22°17′N (Tampico) and 25°52′N latitudes (Matamoros), an area centered on the towns of La Pesca and Tepehuaje. Barrier islands (100–200 m wide) separate the Laguna Madre from the Gulf of Mexico, and sandy beaches, approximately 5–20 m wide at high tide, characterize the area. The western sides of the islands are covered in grasses such as seacoast bluestem (*Schizachyrium scoparium littoralis*), small shrubs such as partridge pea (*Cassia fasiculata*), and mangroves, (*Avicennia germinans*, *Rhizophora mangle*, *Languncularia racemosa*). Tide and weather conditions periodically flood the mud flats that line the Laguna Madre, particularly often during winter. Large numbers of shorebirds and waterfowl winter in the Laguna Madre (Morrison et al. 1993), and are preyed upon by wintering peregrines. The mainland west of the laguna has been largely converted to ranchland, and forest fragments are small. Prey abundance inland is most certainly less than on the coast during winter, but concentrations of Rock Doves (*Columba livia*) occur near cattle sheds.

During 11–24 January 1997 and 17 February–11 March 1998, wintering Peregrine Falcons were captured, banded, and released. Trapping efforts covered about 300 km of beach near La Pesca and Tepehuaje in 1997 and 1998, and about 100 km of beach near Matamoros in 1998. Capture locations were recorded using a handheld GPS receiver. Twelve adults were also fitted with backpack-mounted satellite-received transmitters (PTTs). PTTs (30 g for females, 20 g for males) were programmed to transmit 8 hr on, 24 hr off for 35 cycles, 8 hr on, 72 hr off for 25 cycles, then 8 hr on, 192 hr off for at least 18 cycles, running until battery failure. Total days in each cycle were 46.7, 83.3, and >150 respectively, arranged to transmit mostly on the wintering ground, but some power was reserved to track birds on their spring migration, on their summering grounds, and on autumn migration. Twenty-gram transmitters had a theoretical battery life of ~500 hr, 30-g transmitters ~800 hr. In the days immediately following capture, some falcons were resighted. Transmitters appeared to be well tolerated, and recaptured falcons (n = 3) showed no adverse physical effect due to transmitters.

Falcon location estimates were calculated by the ARGOS system (Service Argos 2001). The system estimates location using the Doppler shift in signal frequency, and calculates the distribution within which the estimate lies. The standard deviation of this distribution estimates the accuracy of the location, and assigns it to a location class (LC: Z, B, A, 0, 1, 2, 3, in ascending accuracy). LC 1, 2, and 3 have standard deviations of 350 m–1 km, 150–350 m and ≤150 m, respectively. We used only datapoints with location classes 1–3 for our analyses. Despite this restriction, outliers may have existed

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for which the location estimate was inaccurate by >1 SD.

PTTs did not perform equally. Causes for variation among PTTs in the percentage of LC 1–3 estimates include variation in signal quality. Variation in PTT longevity was probably due mostly to differences in battery quality. In general, as the study proceeded signal strength declined, resulting in a lower rate of acceptable location classes being received. The rate of deterioration of signal also varied.

STATISTICAL ANALYSES

Analyses of ranges were performed using RANGES V software (Kenward and Hodder 1996). Areas used by peregrines during winter were described by 90% and 50% minimum convex polygons (MCP, Mohr 1947, Kenward 1987). Overall winter home range extent was described by the 90% MCP. Describing ranges in this way probably excluded some accurate location estimates, but also lessened the effect of outliers described above. We defined 50% polygons as core area, although the duty cycle of the transmitters was not ideal for identifying centers of activity. Distances between wintering and summering areas were measured between the last LC 1–3 received on the wintering area to the first LC 1–3 received on the breeding area, and vice-versa. Migrations were measured as great circle distances (Fuller et al. 1998). Because PTTs did not transmit continuously, timing of migration could only be determined to within 4 days. Date of departure was defined as the last date the PTT was received from summering or wintering areas. Likewise, date of arrival was the first date the PTT was received from either area. Values reported are means ± SD unless otherwise stated. Independent, two tailed *t*-tests were performed using Statistix for Windows software (Analytical Software 1998).

In the course of capturing birds all sightings of peregrines were recorded. Because the focus was on capture rather than survey, some double-counting probably occurred. Also, observations of peregrines could not always be assigned to a particular sex or age category.

RESULTS

An estimated 84–110 individual falcons were sighted, ≥30 in 1997 and ≥54 in 1998. Few falcons were immature (∼4–9%) or male (∼2%). Thirty-three Peregrine Falcons were captured (23 adult females, 8 immature females, 2 adult males). Fourteen PTTs were fitted to 12 adult Peregrine Falcons, (6 females in 1997, 1 male and 7 females in 1998; 2 of the 1998 females had been tracked in 1997). One female (PTT 12846) was fitted with a 20-g transmitter in 1998 because no males were available for capture.

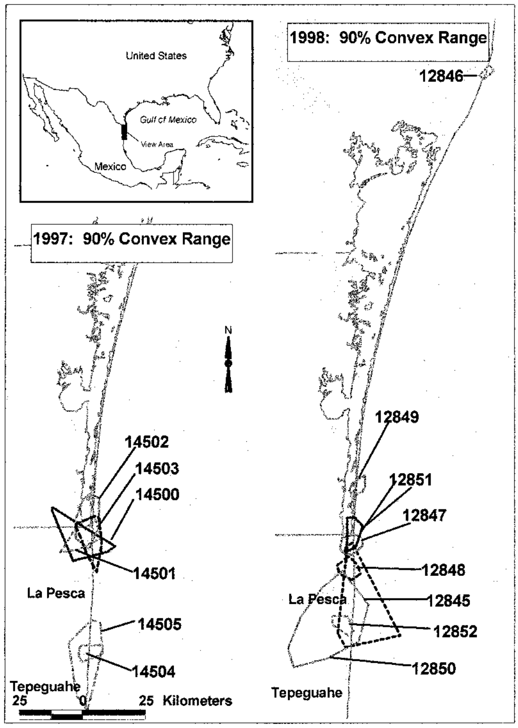

FIGURE 1. Location estimates and 90% minimum convex polygons of Peregrine Falcons wintering on the Gulf of Mexico coast, Tamaulipas, Mexico, in 1997 and 1998.

WINTERING AREAS

Mean area of 90% MCP for all birds was 169 ± 191 km^2 (Fig. 1, Table 1). MCP values were not significantly different between years at the 50% (t_{12} = −0.7, P = 0.45) or the 90% levels (t_{12} = −0.1, P = 0.80). The male falcon had the second largest range. There was extensive range overlap within years.

Centers of activity for most peregrines throughout winter were near their capture site. For some individuals (PTTs 14505, 12845, 12850, and 12851), geographically distinct clusters of location estimates suggested more than one activity center. MCPs can overestimate

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TABLE 1. Size of winter ranges of adult Peregrine Falcons on the Gulf of Mexico coast, Tamaulipas, Mexico, in 1997 and 1998. PTT number 12845 (1998) was the only male tracked.

Year	PTT number	Number of location estimates (n)	Area of 50% convex polygon (ha)	Area of 90% convex polygon (ha)
1997	14500	31	1220	19 770
	14501	35	1239	10 938
	14502	48	2357	14 986
	14503	34	1833	12 510
	14504	36	648	4785
	14505	27	4927	28 408
1997 mean			2037 ± 1531	15 232 ± 8115
median			1536	13 748
1998	12845	22	9278	53 346
	12846	20	251	1683
	12847	42	728	4917
	12848	35	516	4972
	12849	28	840	2694
	12850	33	29 481	68 965
	12851	23	1127	5684
	12852	18	417	3691
1998 mean			5329 ± 10 218	18 244 ± 26 843
median			784	4944
Overall mean			3918 ± 7243	16 953 ± 19 104
median			1173	8311

range size by including areas between clusters that are unused by falcons. When ranges that had more than one activity center were excluded, range sizes in 1997 were larger than in 1998 at both the 50% ($t_8 = 2.9$, $P < 0.02$) and 90% level ($t_8 = -3.5$, $P < 0.01$). Two falcons were marked in both years (Fig. 2). Both had larger winter home ranges in 1997 than 1998, and between-year overlap of ranges was high. At the 50% MCP level polygons included primarily areas of barrier island and laguna.

NON-WINTER MOVEMENTS

Spring departures were between ~27 April and ~21 May ($n = 14$; Table 2). There was no between-year difference in dates on which northward migration began. Of the two females tracked in both years, one began migration seven days later in 1998 than it had in 1997; the other began migration four days earlier in 1998 than 1997.

Birds traveled north through the center of the continent, dispersing to sites across the Canadian north coast and Greenland from 123.0°W to 51.8°W longitude ($n = 13$; Fig. 3). Both birds tracked on their northward migration in consecutive years appeared to use the same general migration paths, although data were incomplete in 1998.

The migratory period for 12 of 13 birds lasted into the first half of June. Over the two northward migrations, the mean rate of travel was 171.6 ± 33.2 km day^{-1} ($n = 13$). In 1997, the mean rate was 153.2 ± 21.8 km day^{-1} ($n = 6$); in 1998 it was 187.3 ± 34.4 km day^{-1} ($n = 7$). All birds monitored to summering grounds where more than 10 location estimates were received ($n = 13$) settled into relatively restricted areas (Fig. 3). Mean degrees of latitude traversed between winter and summer areas was 43.8 ± 1.7.

Dates of initiation of autumn migration could not be identified precisely because PTTs were transmitting every 7.3 days. Falcons monitored on autumn migration ($n = 9$) left their summering sites in August and September, and migrated along a non-coastal route to Mexico (Fig. 4). On average, Peregrine Falcons took 39.7 ± 11.7 days to complete autumn migration at a mean rate of 141.5 ± 45.9 km day^{-1} ($n = 6$).

Falcons arrived on their wintering grounds in September and October. Falcons showed fidelity to wintering areas, but we could not determine if they settled on the same wintering territories.

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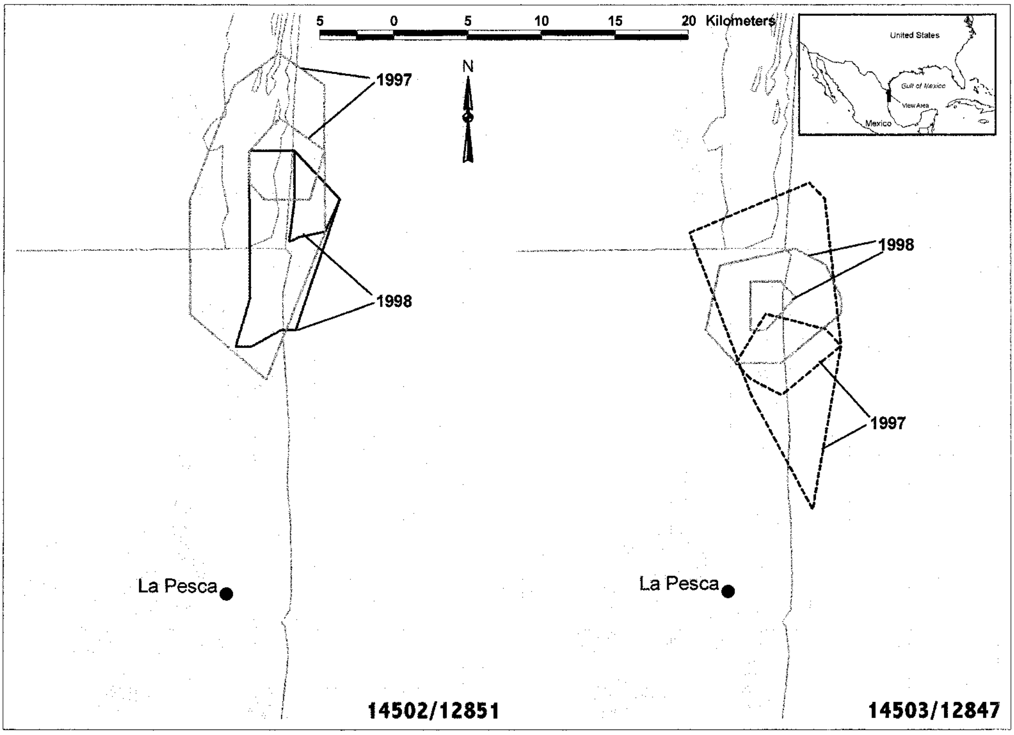

FIGURE 2. Winter ranges (90% and 50% MCP) of two female Peregrine Falcons tracked in both 1997 and 1998 on the Gulf of Mexico coast, Tamaulipas, Mexico. Numbers in the lower right of each panel indicate the transmitter numbers worn by each individual in each year.

Falcons followed to their wintering grounds in the year subsequent to capture ($n = 6$) were located close to capture places, although few location estimates were made in the second winter. The distances between capture locations for the two birds that were trapped in both years were 2080 and 5598 m, and the 1997 and 1998 winter home ranges of each of these birds overlapped extensively (Fig. 2). One falcon was caught in 1996 by other researchers and recaptured 500 m away in 1997 by us.

DISCUSSION

The Tamaulipas coast is an important wintering area for female peregrines. Neither males nor immatures winter there in proportion to their abundance, although they do migrate through in spring and autumn (Hunt et al. 1975, Hernández and Zook 1993). Coastal wintering areas in Ecuador and Peru appear also to be populated mostly by female falcons (White et al. 1989), although observations and trapping of peregrines in a coastal area near Lima, Peru (1989–1992), suggest males predominate there (O. Beingolea, pers. comm.). Male peregrines banded as nestlings in Greenland wintered in South America, whereas females wintered in Central America and the Caribbean (Restani and Mattox 2000). The causes of this apparent separation of sexes and age classes on wintering grounds are not known.

Arrival of falcons in our study area coincided with the peak of peregrine migration (25 September to 25 October) at Padre Island (TLM, unpubl. data), and was similar to arrival dates of peregrines wintering in Peru (Bertochi et al. 1984).

Distribution of prey likely affects location of peregrine wintering areas (Fuller et al. 1998), diet, and individual ranging behavior (Buchanan 1996). The distribution of small and medium-sized shorebirds, probably the most abundant potential prey for peregrines in our study area, was likely related to the extent of mudflats and beach where they fed, which was determined by wind conditions and tide. Winter home range

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TABLE 2. Summary of Peregrine Falcon migration from wintering grounds on the Gulf of Mexico coast, Tamaulipas, Mexico, to summer settling areas in 1997 and 1998. Two individuals were tracked in both years: 14502 and 14503 in 1997 refer to 12851 and 12847, respectively, in 1998. 12845 (1998) was the only male tracked.

PTT number	Depart winter	Arrive summer	Depart summer	Arrive winter	Last location	Harmonic mean of wintering area		Summer location[a]	Harmonic mean of summering area		Distance (km)	Diff in lat (°)
						lat (°N)	long (°W)		lat (°N)	long (°W)		
1997												
14500	10 May	14 Jun			20 Sep	23.93	97.72	Repulse Bay, Nun	66.18	84.66	4793	42.25
14501	7 May	4 Jun	16 Sep		30 Sep	23.96	97.74	Thelon River, Nun	65.03	101.74	4580	41.07
14502	3 May	31 May	17 Aug	27 Sep	28 Dec	24.04	97.74	Coronation Gulf, Nun	67.68	110.69	4939	43.64
14503	21 May	25 Jun	25 Sep	24 Oct	3 Jan	23.94	97.70	Baffin Island, Nun	64.39	71.06	4900	40.45
14504	27 Apr	6 Jun	20 Aug	6 Oct	20 Dec	23.57	97.75	Pelly Bay, Nun	68.57	91.38	5027	44.00
14505	13 May	11 Jun			10 July	23.66	97.73	Victoria Island, Nun	68.62	113.47	5116	44.96
1998												
12845	10 May	10 Jun	3 Sep		3 Sep	23.64	97.75	Melville Peninsula, Nun	68.31	81.80	5089	44.67
12846	30 Apr	7 Jun			20 Jul	25.66	97.18	Franklin Strait, Nun	72.11	96.55	5170	46.45
12847	17 May				27 May	23.94	97.74					
12848	1 May	2 Jun	30 Aug	25 Oct	10 Nov	23.86	97.74	Victoria Island, Nun	69.81	110.39	5181	45.94
12849	27 Apr	19 May			4 Nov	24.18	97.73	Coronation Gulf, Nun	67.51	113.97	4951	43.33
12850	6 May	31 May	23 Aug	16 Sep	11 Nov	23.87	97.77	Franklin River, NWT	68.13	123.01	5217	44.26
12851	10 May	5 Jun	22 Aug		17 Oct	23.93	97.76	Coronation Gulf, Nun	67.73	110.54	4954	43.80
12852	1 May	27 May	5 Sep	16 Oct	18 Nov	23.68	97.80	W. Greenland	68.28	51.84	5844	44.60

[a]NWT = Northwest Territories, Canada; Nun = Nunavut, Canada.

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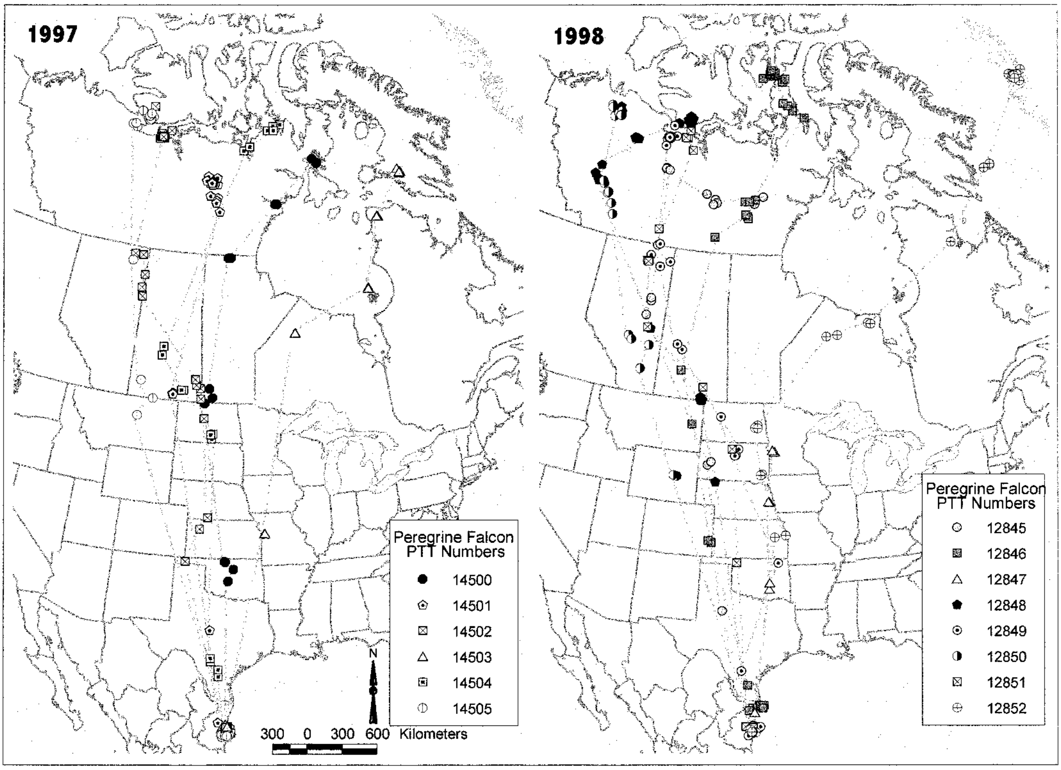

FIGURE 3. Northward (spring) migration and summering areas of Peregrine Falcons that wintered on the Gulf of Mexico coast, Tamaulipas, Mexico, in 1997 and 1998.

sizes were within the bounds of published values (Dobler and Spencer 1989, Enderson et al. 1995). Between-year differences in size of ranges with only one cluster of activity might have been due to differences in prey distribution and availability, but could have been influenced by the shorter study period in 1998.

The islands and laguna appeared to be most important to peregrines, but falcons were also located relatively far offshore and at inland sites. Peregrines hunt over the ocean (Enderson et al. 1995, Buchanan 1996), and from boats at sea (Grayson 1872, Byers 1957, Craddock and Carlson 1970), and use offshore oil platforms in the Gulf of Mexico (Enderson et al. 1995, Russell 2001). Locations inland may be related to food (e.g., pigeons at cattle barns) or inland roosting. Enderson et al. (1995) recorded inland locations of radio-tagged peregrines wintering on the Texas coast.

Information on peregrine migration comes from sightings (Dekker 1984, Kerlinger 1989), banding (Ambrose and Riddle 1988, Yates et al. 1988), and VHF and satellite telemetry (Chavez-Ramirez et al. 1994, Fuller et al. 1998); autumn migration routes are better documented. All birds in this study migrated through the central part of the continent (in spring and autumn), but band recoveries show that some peregrines that pass through or winter on the Gulf coast migrate along East Coast and West Coast flyways (Shor 1970, Yates et al. 1988). Further, some migrating Peregrine Falcons tagged with PTTs on the Virginia coast in autumn migrated along an inland route in spring to Greenland (WSS, unpubl. data). Our data agree with Fuller et al. (1998) in suggesting that features such as mountain ranges produce local effects on migration and that the shape of peregrine migration in North America can be better viewed as the result of a sieving rather than a funnel or fanning effect.

Spring migration by peregrines in Mexico appears to have occurred about 2 weeks later than in Peru (Bertochi et al. 1984), but at a time similar to that observed in Costa Rica (Hernández and Zook 1993) and North Dakota (Murphy and

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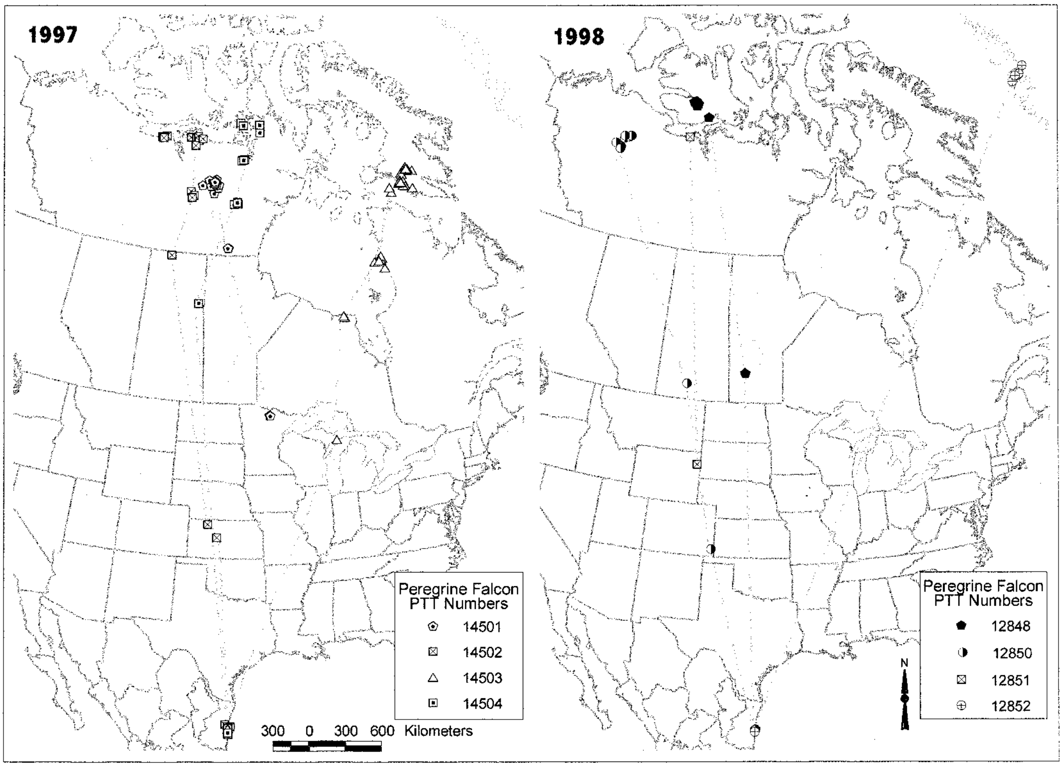

FIGURE 4. Summering areas and southward (autumn) migration of Peregrine Falcons in 1997 and 1998 that wintered on the Gulf of Mexico coast, Tamaulipas, Mexico.

Green 1992). Differences from Peru may be related to latitude of wintering ground, location of breeding place, age of peregrines, observation bias, or annual variation.

A peregrine migration peak occurs on Padre Island from 10 April to 3 May (TLM, unpubl. data), somewhat earlier than the departure date of tagged peregrines in this study. Together, date of departure from our study area, the earlier migration date in Peru, and the peak observed on Padre Island agree with Enderson (1965), White (1968), and Schmutz et al. (1991) in suggesting a leapfrog migration.

PTT transmission rate was low during migration, probably resulting in a smoothing of the path and an underestimation of migration rate. In general, rates of migration by falcons in this study agree with those from other peregrines fitted with PTTs (Fuller et al. 1998), but were slower than that of a single bird followed by Chavez-Ramirez et al. (1994).

Peregrines spend a large proportion of their year on migration and wintering grounds. Large gaps exist in our understanding of peregrine ecology at these times, which potentially undermine conservation efforts. Our data add detail to what is known about timing and route of migration, provide new information on winter range size, and the geographical spread of summering ranges of birds wintering in the same location, and suggest that peregrines are faithful to their wintering areas. It is important that more peregrine research is focused away from breeding grounds, where threats to Peregrine Falcons may be greatest (Iñigo and Dominguez 1989).

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Beingolea. Reviews by E. Iñigo Elias, J. Enderson and C. White improved earlier drafts.

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