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MOVEMENTS OF JUVENILE GYRFALCONS FROM WESTERN AND INTERIOR ALASKA FOLLOWING DEPARTURE FROM THEIR NATAL AREAS

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ABSTRACT.—Juvenile raptors often travel thousands of kilometers from the time they leave their natal areas to the time they enter a breeding population. Documenting movements and identifying areas used by raptors before they enter a breeding population is important for understanding the factors that influence their survival. In North America, juvenile Gyrfalcons (*Falco rusticolus*) are routinely observed outside the species' breeding range during the nonbreeding season, but the natal origins of these birds are rarely known. We used satellite telemetry to track the movements of juvenile Gyrfalcons during their first months of independence. We instrumented nestlings with lightweight satellite transmitters within 10 d of estimated fledging dates on the Seward Peninsula in western Alaska and in Denali National Park (Denali) in interior Alaska. Gyrfalcons spent an average of 41.4 ± 6.1 d (range = 30–50 d) in their natal areas after fledging. The mean departure date from natal areas was 27 August ± 6.4 d. We tracked 15 individuals for an average of 70.5 ± 28.1 d post-departure; Gyrfalcons moved from 105 to 4299 km during this period and tended to move greater distances earlier in the tracking period than later in the tracking period. Gyrfalcons did not establish temporary winter ranges within the tracking period. We identified several movement patterns among Gyrfalcons, including unidirectional long-distance movements, multidirectional long- and short-distance movements, and shorter movements within a local region. Gyrfalcons from the Seward Peninsula remained in western Alaska or flew to eastern Russia with no movements into interior Alaska. In contrast, Gyrfalcons from Denali remained in interior Alaska, flew to northern and western Alaska, or flew to northern Alberta. Gyrfalcons from both study areas tended to move to coastal, riparian, and wetland areas during autumn and early winter. Because juvenile Gyrfalcons dispersed over a large geographic area and across three international boundaries, conservation efforts should focus on both regional and international scales.

KEY WORDS: *Gyrfalcon*; Falco rusticolus; *Alaska*; *dispersal*; *Russia*; *satellite telemetry*.

MOVIMIENTOS DE JUVENILES DE *FALCO RUSTICOLUS* LUEGO DE SU PARTIDA DESDE SUS ÁREAS NATALES EN EL OESTE Y EL INTERIOR DE ALASKA

RESUMEN.—Las rapaces juveniles comúnmente viajan miles de kilómetros desde el momento en que dejan sus áreas natales hasta el momento en que se incorporan a una población reproductiva. La documentación de los movimientos y la identificación de las áreas usadas por las rapaces antes de que se incorporen a una población reproductiva son importantes para entender los factores que influencian su supervivencia. En América del Norte, durante la estación no reproductiva se observan frecuentemente juveniles de *Falco rusticolus* fuera del rango de cría de la especie, pero en la mayoría de los casos se desconocen los orígenes de estas aves. Usamos telemetría satelital para seguir los movimientos de individuos juveniles durante sus primeros meses de independencia. Colocamos transmisores satelitales de peso liviano a pichones con

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fechas de emplumamiento en no más de 10 días (d) en la Península Seward en el oeste de Alaska y en el Parque Nacional Denali (Denali) en el interior de Alaska. Los juveniles pasaron un promedio de 41.4 ± 6.1 d (rango = 30–50 d) en sus áreas natales luego de emplumar. La fecha media de partida desde las áreas natales fue el 27 de agosto ± 6.4 d. Seguimos a 15 individuos por un promedio de 70.5 ± 28.1 d luego de la partida. Los juveniles se movieron entre 105 y 4299 km durante este período y tendieron a desplazarse más durante el comienzo que a fines del período de seguimiento. Los juveniles no establecieron áreas de distribución invernales temporarias durante el período de seguimiento. Identificamos varios patrones de movimiento entre los juveniles, incluyendo movimientos largos unidireccionales, movimientos largos y cortos multidireccionales y movimientos más cortos dentro de una región local. Los juveniles de la Península Seward permanecieron en el oeste de Alaska o volaron al este de Rusia sin dirigirse hacia el interior de Alaska. En contraste, los juveniles de Denali permanecieron en el interior de Alaska, volaron al norte y al oeste de Alaska, o volaron al norte de Alberta. Los juveniles de ambas áreas de estudio tendieron a moverse hacia las áreas costeras, ribereñas y de humedales durante el otoño y comienzos del invierno. Debido a que los juveniles se dispersaron sobre una gran área geográfica y cruzaron tres fronteras internacionales, los esfuerzos de conservación deberían enfocarse en escalas regionales e internacionales.

[Traducción del equipo editorial]

Birds are highly mobile organisms and their spatial and temporal movement patterns are among the most diverse among vertebrates (Welty 1963, Alerstam 1990, Newton 2008). Some bird species remain within several kilometers of their natal nest throughout their entire lives, whereas others travel thousands of kilometers annually, starting with their initial movements away from their natal nests (Newton 2008). Juvenile raptors exhibit a wide range of movement patterns (Newton 1979), with individuals originating from high latitudes often traveling hundreds or thousands of kilometers across different habitats and often across international boundaries within their first year of life (e.g., McGrady et al. 1997, McIntyre et al. 2008).

Documenting the year-round movements and identifying the areas used by raptors before they enter a breeding population is important for understanding the factors that influence their survival (Steenhof et al. 2005). Further, because juvenile raptors often experience higher rates of mortality than older age classes (Newton 1979), identifying areas used by juveniles immediately after they leave their natal areas is important for understanding their survival.

Gyrfalcons (*Falco rusticolus*) are one of the least studied raptor species in North America, owing in part to their low nesting density in remote northern areas and their dispersed and often remote wintering areas (Clum and Cade 1994). In North America, Gyrfalcons are considered partial or irregular migrants (Kerlinger 1989), and birds remaining on their territories during winter are almost exclusively adults (Clum and Cade 1994). Little is known about the year-round movements of Gyrfalcons. Gyrfalcons are observed regularly south of their breeding range during winter, but most of these individuals are juveniles (Clum and Cade 1994). Encounters of seven Gyrfalcons banded as nestlings in Canada and Alaska showed that some juveniles moved long distances away from their natal areas (>2500 km; Schmutz et al. 1991), with one individual from Alaska completing a transcontinental flight between Alaska and eastern Russia (Kessel 1989).

We here describe the movements of juvenile Gyrfalcons from western and interior Alaska during the first few months of their independence.

STUDY AREAS

Our study areas were in the Highland region foothills (Kessel 1989) of the central Seward Peninsula (65.6°N, 165.0°W) in western Alaska and in the northern foothills of the Alaska Range (McIntyre and Adams 1999) in Denali National Park and Preserve (Denali) in central Alaska (63.5°N, 149.7°W). Both study areas contained relatively high densities of nesting Gyrfalcons (Swem et al. 1994). We used aerial surveys to locate Gyrfalcon nests on the Seward Peninsula and obtained Gyrfalcon nest locations in Denali from ongoing raptor studies.

METHODS

Radio-tagging Nestlings. We entered each nest using standard rock climbing techniques. Upon reaching the nest, we secured each nestling using an aba (Maechtle 1998) and a leather falconry hood. When possible, we conducted all marking at the nest; otherwise, we transported each nestling to a more suitable processing location nearby and returned them to the nest after marking. We weighed, measured and evaluated the physical condition of each nestling, but did not sex them. We banded all

nestlings with U.S. Geological Survey serially numbered aluminum leg bands and color-coded alphanumeric leg bands. The marking process, the time from entering to leaving the nest, required about 20 min per bird.

We used lightweight PTTs (Microwave Telemetry, Columbia, Maryland, U.S.A.) that weighed ≤3% of the mass of the nestling at deployment. PTTs were powered by lithium batteries and transmitted (duty cycle) for 6 hr every 72 to 120 hr. Transmitter life was estimated at approximately one year (P. Howey pers. comm.).

We attached PTTs to nestlings using breakaway backpack-style body harnesses (Buehler et al. 1991) constructed from 0.60-cm Teflon ribbon (Bally Ribbon, Bally, Pennsylvania, U.S.A.). Each harness contained a weak link sewn with cotton embroidery thread that ensured that the PTT would eventually fall free from the Gyrfalcon. The entire radio-package, including harness, was within the conventional guidelines for telemetric studies of birds (Caccamise and Hedin 1985).

We attached PTTs to nestling Gyrfalcons that were ≥40 d of age, with mass >1500 g in 1992 and mass >1100 g in 1993 and 1995, and in apparently good physical condition. All deployments occurred in early July ≤10 d from the estimated fledging date. We deployed five 48-g PTTs on the Seward Peninsula in 1992, seven 31-g PTTs on the Seward Peninsula in 1993, and eight 31-g PTTs in Denali in 1995.

We radio-tagged 20 Gyrfalcons, but four PTTs failed before Gyrfalcons left their natal areas and one Gyrfalcon tore off its harness before it left the natal area; hence, our final tracking sample size was 15 Gyrfalcons that successfully departed their natal areas with functioning PTTs. Our final tracking sample also included six groups of siblings (five nests with two radio-tagged siblings and one nest with three radio-tagged siblings).

Data Collection and Filtering. We obtained locations of radio-tagged Gyrfalcons using the Argos Data Collection and Location System (Argos 1996). Based on data from an internal PTT activity sensor, we categorized a PTT as a ''mortality/shed harness'' if it remained motionless for >2 consecutive duty cycles unless subsequent movement data indicated otherwise. We did not retrieve motionless PTTs; hence, we did not know whether motionless PTTs represented mortalities or harness detachments. We classified a PTT as a ''radio failure'' if we lost radio contact with it within its expected battery life span.

We obtained 1664 relocations (Table 1) including 374 standard-class locations (LC = 3, 2, and 1) and 1290 auxiliary-class locations (LC = 0, A, B, and Z). Standard location classes, based on high-power PTTs tested under ideal ambient conditions, have an estimated 1-sigma error radius of 250, 500, and 1500 m, respectively (Argos 1996). Empirical tests of relatively low-power wildlife PTTs under a variety of environmental settings have reported slightly poorer accuracy for standard location classes (Harris et al. 1990, Vincent et al. 2002), but still acceptable for interpreting large-scale movement data. Because 78% of our data set was comprised of auxiliary locations, which have broad and unsatisfactory error variances (Vincent et al. 2002, Liaubet and Malardé 2003) and highly variable and undocumented location accuracy (Argos 1996), we used a hybrid filtering strategy developed by Douglas (2006) that evaluated the Argos auxiliary locations based on two independent methods. The first filtering method required that auxiliary locations, to be retained, have at least one other location that was both consecutive in time and redundant in space (<10 km). The second filtering method evaluated movement rates and turning angles. An auxiliary location was rejected if its vector length was >10 km and its rate was >100 km/hr or its internal turning angle was suspiciously acute (Douglas 2006). For hybridization, all locations that passed the first filter were retained and considered ''anchor points.'' Then, if the distance between two consecutive anchor points was >10 km, locations that passed the rate-angle filter during the intervening period were individually evaluated and retained if they passed a series of directionality tests (Douglas 2006).

The spatial redundancy filter retained 620 of 1290 auxiliary locations. An additional 25 different auxiliary locations were retained by the rate-angle filter because they passed the directionality tests. From these locations, we selected one location per duty cycle based on best LC-value. In cases of LC ties, we selected the location that was derived from the most messages received during the satellite overpass. The resulting filtered data set of ''best'' LC locations per duty cycle contained 347 records including 210 standard locations and 137 auxiliary locations (Table 1) and was used for all analyses and graphics presented in this paper.

Data Analyses. We estimated the age of nestlings on the day that we radio-tagged them based on their size and feather development. We backdated from the estimated age at radio-tagging to estimate hatch

Table 1. Argos satellite locations, by location quality-class before and after accuracy filtering, obtained from 15 radio-tagged Gyrfalcons from Alaska from July 1992 to December 1995.

Argos Location Class	All Argos Locations		All Filtered Locations		Best Filtered Location per Duty Cycle[a]	
	N	%	*N*	%	*N*	%
3	7	0.4	7	0.7	6	1.7
2	86	5.2	86	8.4	60	17.3
1	281	16.9	281	27.6	144	41.5
0	373	22.4	273	26.8	88	25.4
A	164	9.9	43	4.2	14	4.0
B	184	11.0	48	4.7	7	2.0
Z	569	34.2	281	27.6	28	8.1
Total	1664	100.0	1019	100.0	347	100.0

[a] Data used in analyses.

data, and added 50 d (fledging age; Poole and Bromley 1988) to the hatch date to predict fledging dates. We defined the natal area as the area within a 10-km radius of the natal nest site. Because of our ≥3-d duty cycle, we could not determine the actual dates of departure from the natal area; hence, we estimated departure date from the natal area as the midpoint date between the last date when the radio-tagged Gyrfalcon was in its natal area and the first date that it remained permanently out of its natal area. We calculated total distance moved during the tracking period as the cumulative tracking distance (km); however, we recognized that these were minimum estimates since our tracking was not continual and movements were certainly not strictly linear between locations acquired in consecutive duty cycles.

We generated summary statistics of the spatial and temporal parameters of Gyrfalcon movements during six successive 2-wk tracking periods after they permanently departed their natal areas (the post-departure period). We adopted this approach because we were most interested in examining patterns of movements among birds, our sample size of radio-tagged birds decreased during the study period, and our tracking period was relatively short. We report vector lengths as orthodromes (''great circle'' routes) and their azimuths as true bearing from the departure location. We used Watson's U^2 to test for differences in mean post-departure bearings and ANOVA to test for differences in mean distances moved by Gyrfalcons from the Seward Peninsula and Denali during six successive 2-wk periods post-departure. Means and medians are presented ±SD, unless otherwise noted, and we used an α level of 0.05 for all tests. We performed statistical analyses using Oriana software (Kovach 2003) and S-Plus Version 6.1 (Insightful 2001).

RESULTS

Gyrfalcons spent an average of 41.4 ± 6.1 d (range = 30–50 d) in their natal areas after fledging (Table 2). Gyrfalcons left their natal areas between 15 August and 6 September (median = 27 August ± 6.4 d; Table 2), but most left within a 2-wk period in late August and early September (Table 2). Siblings departed their natal areas an average of 4.2 ± 3.1 d apart (range = 0–9 d). Based on the time between their departures and the bearing of their movements away from the natal area, we assumed that siblings departed their natal areas independently.

We tracked 15 radio-tagged juvenile Gyrfalcons for an average of 70.5 ± 28.1 d post-departure (range = 3–102 d; Table 2). Of these, we tracked one Gyrfalcon for a single duty cycle or 3 d post-departure (Bird 53; Table 2). The mean post-departure bearings for Gyrfalcons from the Seward Peninsula and Denali were different (Watson's U^2 = 0.31, df = 26, 14, $P < 0.005$; Fig. 1); Seward Peninsula Gyrfalcons tended to move to the southwest; Denali Gyrfalcons tended to move north and northeast.

Gyrfalcons moved from 105 to 4299 km during the entire tracking period (Table 2) and tended to move greater distances earlier in the post-departure period (Table 3). Gyrfalcons from the Seward Peninsula and Denali moved similar distances during each successive two-week period ($F_{1,5}$ = 0.32, P = 0.57). The distance between Gyrfalcons and their natal nest at the last PTT transmission ranged from 105 to 3371 km (Table 2).

Table 2. Movements of juvenile Gyrfalcons from the Seward Peninsula (1992 and 1993) and Denali National Park (1995), Alaska, as determined by satellite radiotelemetry.

Bird ID	Year	Estimated Departure Date [a]	Estimated Post-fledging Dependence Period (d)[b]	Post-departure Tracking Period (d)	Cumulative Post-departure Tracking Distance (km)[c]	Straight-line Distance from Natal Area at End of Tracking Period (km)	Gyrfalcon or PTT Fate[c]
49	1992	9/4/1992	50	88	2660	1165	SH/Mort
52	1992	9/2/1992	48	86	1569	621	PTT failure
53	1992	9/4/1992	50	3	105	105	SH/Mort
44	1993	8/26/1993	39	68	4299	3371	SH/Mort
43	1993	8/22/1993	35	42	461	140	SH/Mort
42	1993	8/26/1993	39	102	1109	447	PTT failure
45	1993	8/26/1993	38	102	3175	664	SH/Mort
59	1993	8/27/1993	39	38	562	327	PTT failure
61	1993	8/28/1993	40	80	2027	454	SH/Mort
64	1993	9/6/1993	49	71	375	162	SH/Mort
71	1995	8/21/1995	36	98	1568	434	PTT failure
72	1995	8/15/1995	30	90	1841	302	SH/Mort
73	1995	8/28/1995	42	44	2577	1946	SH/Mort
77	1995	9/5/1995	47	81	2311	819	SH/Mort
78	1995	8/28/1995	39	64	2277	728	SH/Mort

[a] Midpoint between the last location within the natal area and the first location marking the permanent departure from the natal area.
[b] Number of days from fledging to permanent departure from the natal area.
[c] SH = shed harness; Mort = mortality. Note: we could not distinguish between these two outcomes.

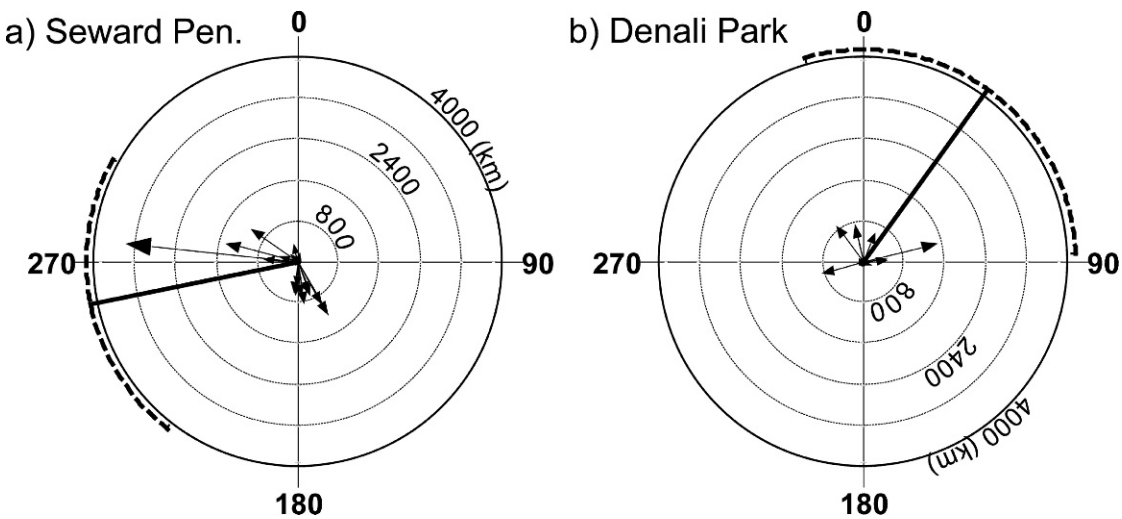

Figure 1. Distances and orthodrome compass bearings from the natal nest to the last recorded location each month after departure from natal areas for Gyrfalcon fledglings from the Seward Peninsula (a) and Denali National Park (b), Alaska. Radial line (solid) denotes mean bearing, with 95% confidence intervals (dashed line). Last monthly locations prior to the fifteenth day of the month were omitted to reduce temporal autocorrelations within individuals. The chart contains 26 vectors for Gyrfalcons from Seward Peninsula and 14 vectors for Gyrfalcons from Denali.

Table 3. Average distance (with standard deviation) moved by radio-tagged juvenile Gyrfalcons from two study areas, Seward Peninsula and Denali National Park, Alaska, during six successive 2-wk tracking periods following departure from natal areas as determined by satellite telemetry.

	Seward Peninsula			Denali National Park		
Post-departure Interval (wk)	Mean (SD)	Range	*N*	Mean (SD)	Range	*N*
1–2	321 (258)	51–760	10	640 (388)	77–995	5
3–4	357 (356)	39–1031	9	431 (386)	39–895	5
5–6	548 (539)	36–1361	9	351 (225)	148–665	5
7–8	397 (515)	8–1456	7	430 (420)	1–960	5
9–10	179 (205)	29–588	7	144 (83)	55–232	4
11–12	108 (122)	8–292	6	160 (153)	70–337	3

Overall, Seward Peninsula Gyrfalcons tended to remain in western Alaska or eastern Russia with no movements into interior Alaska (Fig. 2a); however, their movements were diverse and included localized movements, round-trip ocean crossings, long-distance movements into eastern Russia, and localized movements on the Seward Peninsula after departing their natal areas. In contrast, Denali Gyrfalcons flew to northern Alaska, western Alaska, northern Alberta, or remained in interior Alaska (Fig. 2b).

All except one radio-tagged Gyrfalcon remained within the species' breeding range during the tracking period; one Gyrfalcon from the Seward Peninsula was located south of the documented breeding range for this species several weeks after leaving its natal area (Fig. 2a).

Four of the 10 Gyrfalcons from Seward Peninsula crossed the Bering and Chukchi seas 5–30 d after departing their natal areas. One Gyrfalcon from Seward Peninsula stopped on Little Diomede Island during its ocean crossing. Two Gyrfalcons from Seward Peninsula made round-trip flights between western Alaska and eastern Russia from 10–21 d after departing their natal areas; each bird spent 10–17 d in eastern Russia, then returned to western Alaska in early October and moved southward to the Yukon-Kuskokwim Delta region.

All Seward Peninsula Gyrfalcons and two Denali Gyrfalcons were located in or near coastal, wetland, or riparian habitats within one month of departing their natal areas (Fig. 2). One Gyrfalcon from Denali flew 902 km northwest to Cape Sabine on the Lisburne Peninsula on the northwestern Alaska coast within 10 d of leaving its natal area and its sibling flew 772 km north across the Brooks Range to a vast complex of wetlands about 20 km south of Teshekpuk Lake on the north slope of Alaska within 9 d of leaving its natal area. Two or more Gyrfalcons from different cohorts used several coastal areas in western Alaska (Fig. 3). Six Gyrfalcons from Seward Peninsula were located on the northwest coast of the Seward Peninsula from late August through late September ($N = 1$ bird in 1992, 5 birds in 1993).

Discussion

Juvenile Gyrfalcons from the Seward Peninsula and Denali exhibited a wide range of movement patterns. Our results documented areas used by juvenile Gyrfalcons during a critical life stage (post-natal area departure) and highlighted the importance of coastal areas of the Chukchi and Bering seas to this species. We also provided the first estimates of the duration of the post-fledging dependence period for Gyrfalcons in Alaska. Our study also demonstrated the efficiency of satellite tracking technology to identify movement patterns not previously documented, or postulated, for wide-ranging animals. For example, our most unexpected results included round-trip flights across the Bering Sea and northward flights of birds that eventually moved southward; such movements would have been difficult to document without satellite reconnaissance. Our results also underscore the applicability of satellite telemetry for studying dispersal (Walters 2000).

The length of the post-fledging period and timing of dispersal were similar among radio-tagged birds, regardless of the natal area, and were similar to estimates reported in the literature (28 to 56 d; Nielsen and Cade 1990, Clum and Cade 1994). Our results suggested that Gyrfalcons departed their natal areas from late August to early September; however, Kessel (1989) observed that some Gyrfalcon families on the Seward Peninsula remained together well into September and October.

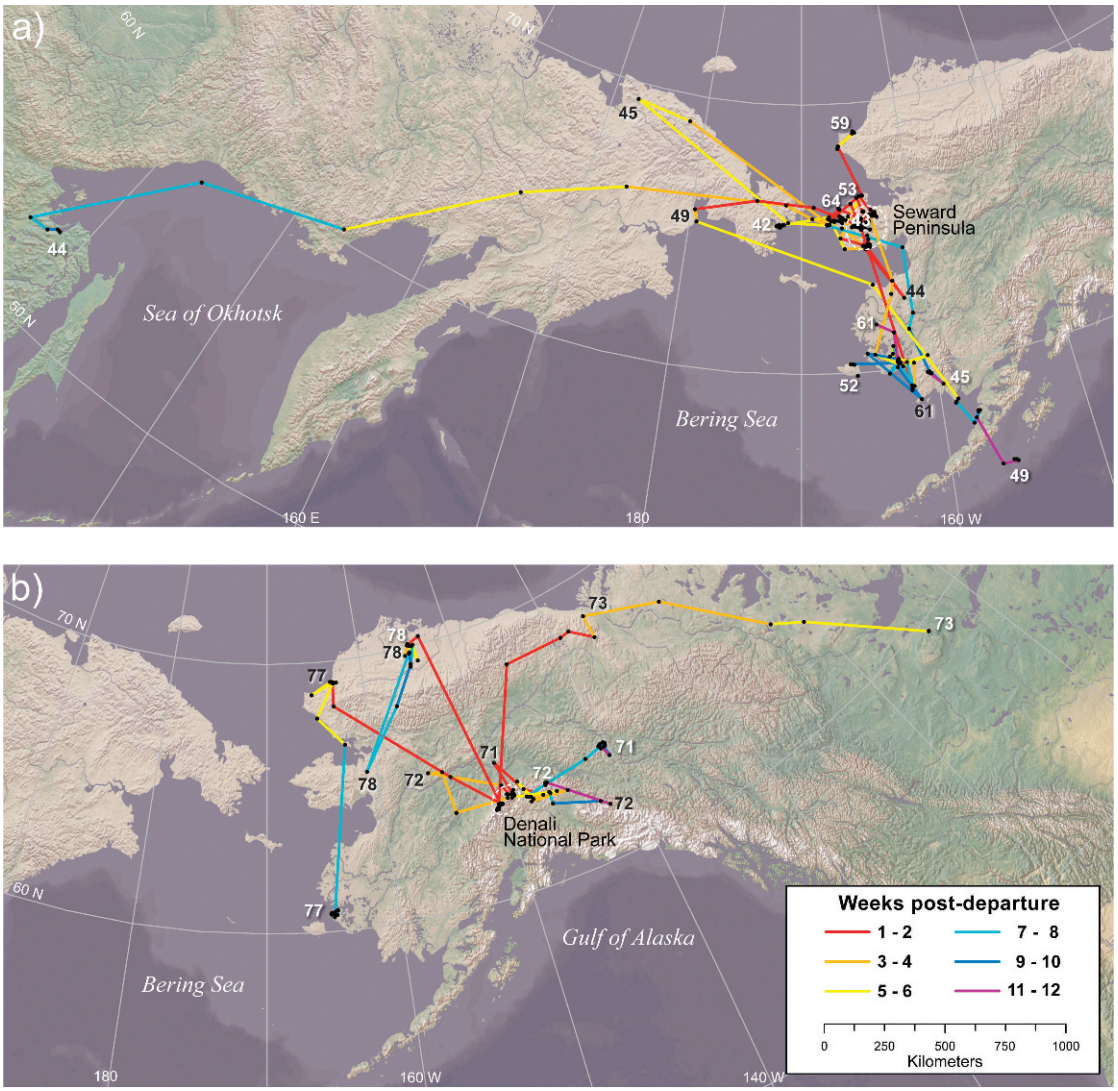

Figure 2. Movements of juvenile Gyrfalcons after leaving their natal areas on the Seward Peninsula (a) and Denali National Park (b), Alaska. Satellite tracking vectors are chronologically color-coded within 2-wk intervals after departing natal areas for up to 12 wk. White numbers denote bird-IDs (Table 2) at the terminus of their tracking, or at the end of 12 wk; additional black numbers denote bird-IDs where substantive departures occurred in the general direction of dispersal. White broken lines encompass study areas where Gyrfalcons were instrumented.

We recognized several movement patterns of the radio-tagged Gyrfalcons from both study areas including unidirectional long-distance movements out of the breeding range, long-distance movements within the breeding range, and shorter distance movements within a local region. There was a strong tendency for Gyrfalcons to move to coastal or wetland areas soon after leaving their natal areas. Coastal and wetland habitats in western and northwestern Alaska and eastern Russia, including the Seward Peninsula, Yukon-Kuskokwim Delta, Teshekpuk Lake and the Chukotka Peninsula appeared to be important to juvenile Gyrfalcons during the first few months of their independence. Cade (1960) also described regular autumn movements of Gyrfalcons in coastal Alaska including Kotzebue Sound, Cold Bay, and Kodiak Island. Juvenile Gyrfalcons in Iceland, where the dispersal distances were relative-

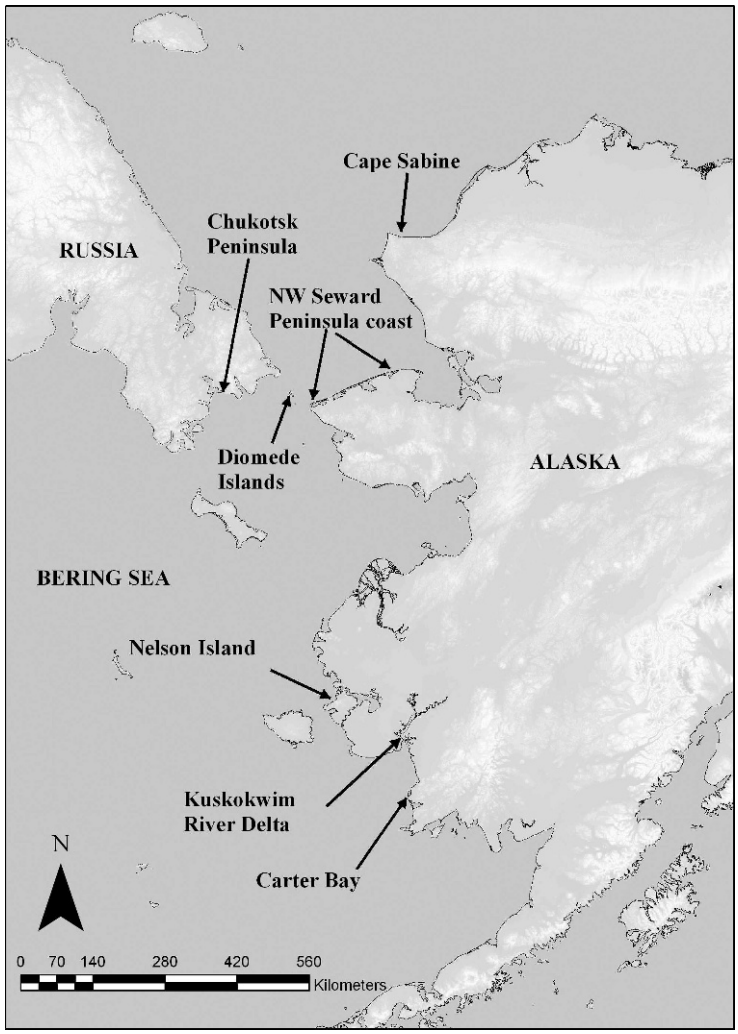

Figure 3. Areas where ≥2 radio-tagged juvenile Gyrfalcons were located between late August and early December 1992–1993, and 1995.

ly short, and in Fennoscandia also moved to coastal areas in autumn and winter (see references in Nielsen and Cade 1990). Kessel (1989) also noted the movement of multiple Gyrfalcons across the northwestern coast of the Seward Peninsula in autumn (from late August through mid-September).

The northward movements of three Denali Gyrfalcons immediately after leaving their natal areas were unexpected and previously undocumented. We hypothesize that these Gyrfalcons were following northward-moving ptarmigan (*Lagopus* spp.; Irving et al. 1967, Kessel 1989) and moving to areas that support high densities of potential prey species. For example, Cape Lisburne supports an estimated 100 000 nesting Common Murres (*Uria aalge*) and other seabirds (Hatch et al. 2000), and the wetlands complex south of Teshekpuk Lake supports substantial numbers of staging waterfowl in autumn (Derksen et al. 1981).

Two Gyrfalcons from Seward Peninsula made round-trip flights between North America and eastern Russia during the tracking period, a behavior not previously documented in Gyrfalcons from Alaska or eastern Russia. Two other Gyrfalcons from Seward Peninsula made one-way trips across the Bering Sea to Russia; this behavior was also document-

ed by Kessel (1989) who reported that a Gyrfalcon banded as a nestling on the Seward Peninsula was found a year later on the Kamchatka Peninsula, Russia.

We could not measure the distance of the ocean crossings because we did not continuously track Gyrfalcons; however, one Gyrfalcon must have flown ≥37 km between mainland Alaska to the Diomede Islands and ≥36 km between the Diomede Islands to mainland Russia at a time when the Bering Sea was not frozen. This distance covers the Bering Straits and was well within the reported water crossing distance for this species (Kerlinger 1989). Also, there are reports of Gyrfalcons using icebergs as ''stepping stones'' during oceanic crossings (T. Cade pers. comm.) or sitting on pack ice during winter (Everett et al. 1989), but we could not document this behavior using our data.

Kessel (1989) summarized observations of Gyrfalcons moving into and through the Seward Peninsula from mid-August at least through September, and at Little Diomede Island from late August to early September. Kessel (1989) also reported the eastward movement of Gyrfalcons at Little Diomede Island, where the birds stopped to rest before flying eastward toward Wales on the western coast of the Seward Peninsula. Aside from these movements being generally southward, Kessel (1989) reported that these movements lacked consistent directional orientation and that most observations suggested a generally eastward movement of Gyrfalcons on the Seward Peninsula during autumn. Kessel (1989) also reported that some Gyrfalcons on the Seward Peninsula were apparently winter visitants from other regions. Although our results corroborated that juvenile Gyrfalcons ranged across the western Seward Peninsula during late August and early September, most movements we observed in our study were westward to coastal areas and to Russia. Two Denali Gyrfalcons remained in interior Alaska throughout the tracking period. These two birds were located in riparian areas in interior Alaska and western Yukon during the tracking period. We hypothesize that these Gyrfalcons were following flocks of ptarmigan that use riparian areas during autumn and early winter (Weeden 1965).

Wintering Gyrfalcons often concentrate in areas with high prey densities (Clum and Cade 1994), and we hypothesize that the radio-tagged Gyrfalcons moved out of their natal areas at a time when diversity and abundance of prey was decreasing and moved to areas where the diversity and abundance of prey was increasing. For example, coastal and near-coastal areas in western Alaska (i.e., Seward Peninsula, Yukon-Kuskokwim Delta) and eastern Russia along the Chukchi and Bering seas support a large, diverse avifauna with globally significant breeding and wintering populations of seabirds (Sowls et al. 1978, Konyukhov et al. 1998), substantial numbers of migrating waterfowl and shorebirds (Gill and Handel 1990, Schmutz and Kondratyev 1995, Petersen et al. 2003), and substantial numbers of wintering waterfowl (Phillips et al. 2006). Some coastal and riparian areas in Alaska also support large concentrations of ptarmigan (Cade 1960, Weeden 1965).

Satellite telemetry has greatly enhanced the study of bird migration, allowing biologists to follow individual migratory birds and investigate their behavior, movement patterns, and seasonal distribution. This information is necessary for improving our understanding of the ecological requirements of wide-ranging birds; however, researchers must use caution to prevent detrimental impacts of the transmitter or attachment devices (Steenhof et al. 2006). We could not determine the fate of radio-tagged Gyrfalcons or assess effects of the harness or PTTs on their health, energetics, or survival. Hence, we could not rule out the possibility that the PTTs had a negative effect on Gyrfalcons, particularly during the later periods of the tracking period when we assume that the radio-tagged birds experienced additional stresses associated with decreasing prey abundance and increasing weather severity (freezing temperatures, freezing rain, and snow). Although contemporary PTTs and Global Positioning System (GPS) telemetry units are much lighter and smaller than the PTTs we deployed, we agree with the recommendations of Steenhof et al. (2006) that researchers thoroughly investigate the possible impacts of radio-marking free-flying raptors by conducting treatment and control experiments before deploying PTTs on wild birds.

Our results demonstrated that juvenile Gyrfalcons from western and interior Alaska are wide-ranging animals; the radio-tagged juveniles ranged over large geographic areas, including movements across two continents and three countries. Conserving the habitat of wide-ranging animals is difficult and complex, particularly when animals range across international boundaries and live in areas that are undergoing rapid change resulting from the cascading effects of climate change and increasing human activities. Identifying movements of birds between

North America and Asia is important for assessing population structure, identifying important habitats on both continents, and evaluating potential vectors for avian-borne pathogens (Olsen et al. 2006, Hupp et al. 2007). Our results also underscored the importance of coastal areas in western Alaska and eastern Russia to juvenile Gyrfalcons. Small-scale wind power projects are currently generating electricity in remote coastal areas of western Alaska (e.g., Tooksook Bay, Wales, Pribilofs, and Kotzebue; Dabo 2008) and similar projects are being proposed for other coastal areas in western Alaska, including several areas used by the radio-tagged Gyrfalcons. Although these wind-powered energy projects are currently much smaller in size and scale than others in the United States (R. Ritchie pers. comm.), it is important to identify the spatial and temporal movements of Gyrfalcons and other birds through these areas to avoid wind turbine strikes. Further, because the radio-tagged Gyrfalcons used coastal areas and because environmental contaminants may be higher in coastal and wetland birds (Ólafsdóttir et al. 2001) and in migratory species such as shorebirds (Walker 1977), we suggest that future studies of this species include assessment of prey for exposure to environmental contaminants. Finally, because juvenile Gyrfalcons dispersed over a large geographic area that included movements across three international boundaries, conservation efforts for Gyrfalcons originating in Alaska should occur at regional and international scales.

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