Migratory Pathways, Timing, and Home Ranges of Southern Greater Yellowstone Osprey

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Short Communications

MIGRATORY PATHWAYS, TIMING, AND HOME RANGES OF SOUTHERN GREATER YELLOWSTONE OSPREY

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Recent advances in satellite telemetry have facilitated multiple studies of migratory patterns and movements of raptors. Despite the many published studies outlining migratory routes and overwintering areas of North American raptors (e.g., Martell et al. 2001, McIntyre et al. 2008, Mojica et al. 2008, Mandernack et al. 2012), most existing knowledge is regional and species-specific. Although some raptor species have clearly defined and centralized wintering areas regardless of breeding location (e.g., Swainson's Hawk [*Buteo swainsonii*]; Kochert et al. 2011), it is more common for individuals from a species to have dispersed winter ranges (e.g., Brodeur et al. 1996).

Long-distance movements of Ospreys (*Pandion haliaetus*) have been studied extensively. Old World studies of migration include investigations of timing, routes, orientation, and fidelity (Kjellén et al. 1997, Hake et al. 2001, Alerstam et al. 2006). Several studies have led to a near-complete view of Osprey migration routes in the eastern, central, and northwestern United States (Martell et al. 2001) but data from Canada and the Rocky Mountains are still lacking. Satellite tracking data from Ospreys in British Columbia indicate wintering areas along the western coast of Mexico, the Gulf Coast, and in Central America, but migration routes were not reported (Elliott et al. 2007). Satellite tracking in the United States has largely corroborated banding records (Poole and Agler 1987, Martell et al. 2001). Based on banding records, Ospreys originating from Saskatchewan and British Columbia winter along the Gulf of Mexico (Ewins and Houston 1992), whereas those from northern Idaho and eastern Washington winter

along western Mexico and Central America (Johnson and Melquist 1991).

The long-term maintenance of biodiversity and conservation of migratory species is dependent on knowledge of annual movements and management of habitats and threats within breeding habitat, but also along migratory pathways and wintering areas. Adult Ospreys spend ca. 6–8 mo away from their breeding areas and dispersing juveniles do not return for ca. 18 mo (Poole et al. 2002), making knowledge of nonbreeding ecology important for the conservation of this species.

Here we report the migration movements of nine Ospreys from two nests in the southern Greater Yellowstone Ecosystem of northwestern Wyoming. Our objectives were to define migration timing, routes, and over-wintering areas for this population. We also report on family group dynamics of migration and home-range sizes of both breeding and wintering areas.

Methods

Ospreys included in this study either bred or were hatched in Grand Teton National Park (GTNP) in northwestern Wyoming (43°91′N, 110°40′W). Ospreys primarily nest on natural substrates within GTNP, but several pairs nest on power line poles and artificial platforms. GTNP contains a high-altitude intermountain valley situated at ca. 2300 m, with the Teton Mountain Range to the west, the Yellowstone plateau to the north and the Gros Ventre and Wyoming ranges to the east and south. Major habitat types within the valley include sagebrush (*Artemisia* spp.) steppe, cottonwood- (*Populus* spp.) dominated river corridors and conifer-dominated buttes and mountain foothills. Major waterways in GTNP include the Snake River and associated tributaries, Jackson Lake, and several glacial lakes, all with cutthroat trout (*Oncorhynchus clarkii*) as the primary resident prey species (Baril et al. 2013). The majority of

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precipitation falls as snow during the winter months and the average summer temperature is 27°C at the valley floor.

We outfitted Ospreys with satellite transmitters in 2010–2012 using solar-powered Argos/Doppler Platform Terminal Transmitters (PTTs) manufactured by Microwave Telemetry, Inc. (Columbia, Maryland, U.S.A.) weighing 28 g or 16 g. All transmitters constituted ≤2% of total body mass at time of banding for both adults and nestlings; the transmitters were affixed backpack-style with a Teflon ribbon cross-chest harness with a cotton breakaway stitch included in the breast patch. Nestlings were fitted with transmitters as close to fledging as possible without causing premature fledging. Adults were outfitted either prior to incubation or after young fledged and were captured using a floating noose-fish (Cain and Hodges 1989) or a noose-carpet on known perches. All birds were aged based on plumage and banded, and a blood sample was taken for concurrent studies. Sex was determined by DNA (Zoogen Services, Inc.; Davis, California, U.S.A.) for nestlings or by observations of position during incubation and copulation for adults.

PTTs transmitted to the Argos satellite array every day (2–4 hr ''on'' period) during migration and every 2–3 d during the winter and summer months. Data were collated via CLS America, parsed using the manufacturer's software, and projected in Arc 10 (ESRI; Redlands, California, U.S.A.) for data analysis. Estimated errors associated with Argos/Doppler locations were calculated by Argos during the satellite pass and are classified, ranked highest to lowest, as location classes (LC) 3, 2, 1, 0, A, B, and Z. Estimated errors associated with each LC are <250 m, 250–500 m, 500–1500 m, >1500 m for LC 3-0, respectively (CLS America 2014). We filtered location data gathered during migration to location classes 0-3, visually inspected data subsets for outliers, and included all remaining locations for analysis. We included LC 0 in the datasets because those were often the best quality location in a given day and such quality has sufficient accuracy to define geographic ranges and interpretation of movement at a regional scale (Hake et al. 2001, Mandernack et al. 2012).

We defined start of migration as the first day the bird began movement north or south. In two cases, individuals moved to a staging area prior to initiation of long-term migration. In these instances, we defined onset of migration as the day continuous southerly movement occurred. Arrival at winter ranges was defined as the first day the Osprey's movements became localized. We investigated potential differences in migration speed of adults and juveniles using a measure of average km traveled/d while on migration with a Mann-Whitney U-test. We tested measures of speed both excluding and including days while the Osprey was at a stopover site and approximated total distance traveled from the actual path traveled to and from the estimated center of the summer and winter territories. Total distance was measured from the sum of the Euclidian distances between the best daily locations (highest LC) while on migration. We tested for differences between autumn and vernal migration speeds within individuals using a paired t-test on the autumn and subsequent vernal migration of each individual adult for which we had data. Stopovers were defined as areas where only local movement occurred for ≥5 d followed by a continuation of migration behavior. We used 5 d as a minimum to define stopovers to better differentiate between short stops (2–4 d) that could be caused by inhospitable migration weather and longer (≥5 d) stops for refueling purposes.

We used Argos LC 2 and 3 locations to estimate winter and summer ranges. We estimated winter ranges for both adult and juvenile Ospreys but used only adult Ospreys for summer range estimates, as juveniles were mostly near the nest site until their autumn migration. We estimated 50% and 95% minimum convex polygons (MCP) using the ade-habitatHR packing in the program R (R Core Development Team 2013). We tested for differences in summer and winter use area MCP estimates using a two-sample t-test. We included data gathered from the first year of each individual. Because juveniles tend to stay on or near their winter range for ca. 1.5 yr (Poole et al. 2002) and we hypothesized that juvenile winter MCPs would be greater than adults', we used a one-tailed t-test to determine whether juvenile home ranges were larger than adults'.

RESULTS

We fitted 11 Ospreys from two nests with satellite transmitters. The first nest was located on Colter Bay on the eastern shore of Jackson Lake in northern GTNP. On 2 August 2010, we fitted transmitters on the breeding female and an adult, non-nesting male captured near the nest. The breeding male was later captured on 16 September 2010. We fit the one nestling produced from this pair with a transmitter just before fledging on 20 August 2010. The breeding female was found dead from suspected eagle predation near the nest site on 1 October 2010 and was not included in the analyses. The breeding male was found dead from unknown causes prior to nesting in the spring of 2011 after completing his vernal migration back to GTNP. In 2011 and 2012, the previously marked adult, nonbreeding male began nesting at the Colter Bay nest with an unmarked female. The transmitter from this male failed on 13 October 2012. This individual was visually confirmed to be alive as late as September 2013 while on his annual autumn migration.

In September 2011, we outfitted two nestlings and the breeding male soon afterward from a nest on an artificial nesting platform in Poker Flats in southern GTNP. We ceased obtaining locations from both juveniles while on their wintering grounds in Mexico for unknown reasons. However, the last locations from both birds were in small towns, suggesting the possibility of human-caused mortality. After her return to GTNP in 2012, we captured and outfitted the breeding female from the Poker Flats nest. This female copulated and built on the existing nest with an unmarked male for ca. 1 wk before the previously marked male returned and resumed position as the breeding male.

We outfitted the three young produced from that pairing in 2012 with PTTs, resulting in the entire family group being outfitted with transmitters. Of the 2012 juvenile cohort, we confirmed one died while on migration (not included in migration analyses) and we stopped receiving transmissions from the other two juveniles as well as the adult male while on their wintering grounds. The female's transmitter was still active during data analysis. The fate of the adult male was unknown but he was not the breeding male at the Poker Flats nest in 2013.

We recorded 13 full autumn migrations from the nine Ospreys (four adults, five juveniles; Table 1, Fig. 1). Ospreys had total autumn migrations lasting 7–66 d, (range ca. 2348–4619 km). Two adults and one juvenile had stopovers (range 5–45 d) and birds with multiple migrations recorded ($n = 3$) were consistent between years regarding whether they had a stopover, and the location and duration of the stopover. Mean departure dates were 19 September (range = 29 Aug–11 Oct) and 23 September (range = 12 Sept–8 Oct) for adults and juveniles, respectively. The three breeding males did not initiate autumn migration until their young had initiated migration. The breeding female with young initiated autumn migration after her first young had dispersed, but prior to the remaining two fledglings. Mean arrival date on wintering areas for adults and juveniles was 1 October and 23 October, respectively. We found no difference ($P = 1.0$, $w = 56.0$) in average speed (excluding days on a stopover) for adults (mean = 225 km/d, SE = 20.0) and juveniles (mean = 227 km/d, SE = 29.5). Average speed including stopovers was 169 and 181 km/d for adults and juveniles, respectively ($P = 0.81$, $w = 43.5$). There was no consistency of wintering areas among family groups. The nearest distance between any family members was 462 km.

We recorded a total of five vernal migrations from four adult Ospreys. We were unable to track juveniles long enough to record any northbound migrations and the fates of most were unknown (i.e., mortality or transmitter failure). The average speed for vernal migrants was 269 km/d (range = 161–355) and 229 km/d (range = 105–355) excluding and including stopovers, respectively. Mean departure date was 2 April (range = 19 Mar–15 April) and mean arrival date on breeding territories was 23 April (range = 20 April–26 April), across years. In contrast to the timing of autumn migration, all adults arrived on their summer ranges within one week, regardless of the time spent on migration, including stopovers. This suggests that individuals have some awareness of the overall time needed to return to breeding sites and adjust their winter range departure dates accordingly. We found no difference in migration speed among individuals between autumn and vernal migrations for either speed, excluding stopovers ($P = 0.31$, $w = 48.5$), or including stopovers ($P = 0.42$, $w = 40.0$). Further, paired t-tests indicated that there was no difference in speed within individuals when comparing autumn speed to the following spring ($P = 0.283$, $t = -1.24$).

Table 1. Migration timing, distance, and speed for Ospreys breeding or fledged in Grand Teton National Park, Wyoming, 2010–2012.

| ID | AGE | SEX | YEAR | AUTUMN MIGRATION | | | | | | VERNAL MIGRATION | | | | | |
				DEPARTURE	ARRIVAL	DURATION (d)	DISTANCE (km)	STOPOVER (d)	SPEED (km/d)	YEAR	DEPARTURE	ARRIVAL	DURATION (d)	STOPOVER (d)	SPEED (km/d)
11521	Adult	M	2010	1 Sep	8 Oct	38	4025	10	144*	2011	21 Mar	23 Apr	33	8	161*
			2011	29 Aug	18 Sep	21	4025	5	252*	2012	19 Mar	26 Apr	38	23	268*
			2012	10 Sep	3 Oct	23	4025	5	224*						
11523	Juv	F	2012	26 Sep	17 Nov	53	2300	34	121*						
11525	Adult	M	2010	11 Oct	2 Nov	23	3192	-	139	2011	15 Apr	24 Apr	9	-	355
11526	Juv	F	2011	8 Oct	20 Oct	12	3221	-	268						
11527	Juv	F	2011	17 Sep	29 Sep	12	2793	-	233						
11528	Adult	M	2011	8 Oct	21 Oct	13	3629	-	279	2012	6 Apr	22 Apr	16	-	227
			2012	29 Sep	15 Oct	16	3629	-	227						
11529	Adult	F	2012	17 Sep	25 Sep	8	2017	-	252	2013	14 Apr	20 Apr	6	-	336
			2013	18 Sep	25 Sep	7	2017	-	288						
11531	Juv	M	2012	12 Sep	17 Nov	66	4619	45	220*						
11532	Juv	F	2012	25 Sep	3 Oct	8	2348	-	294						

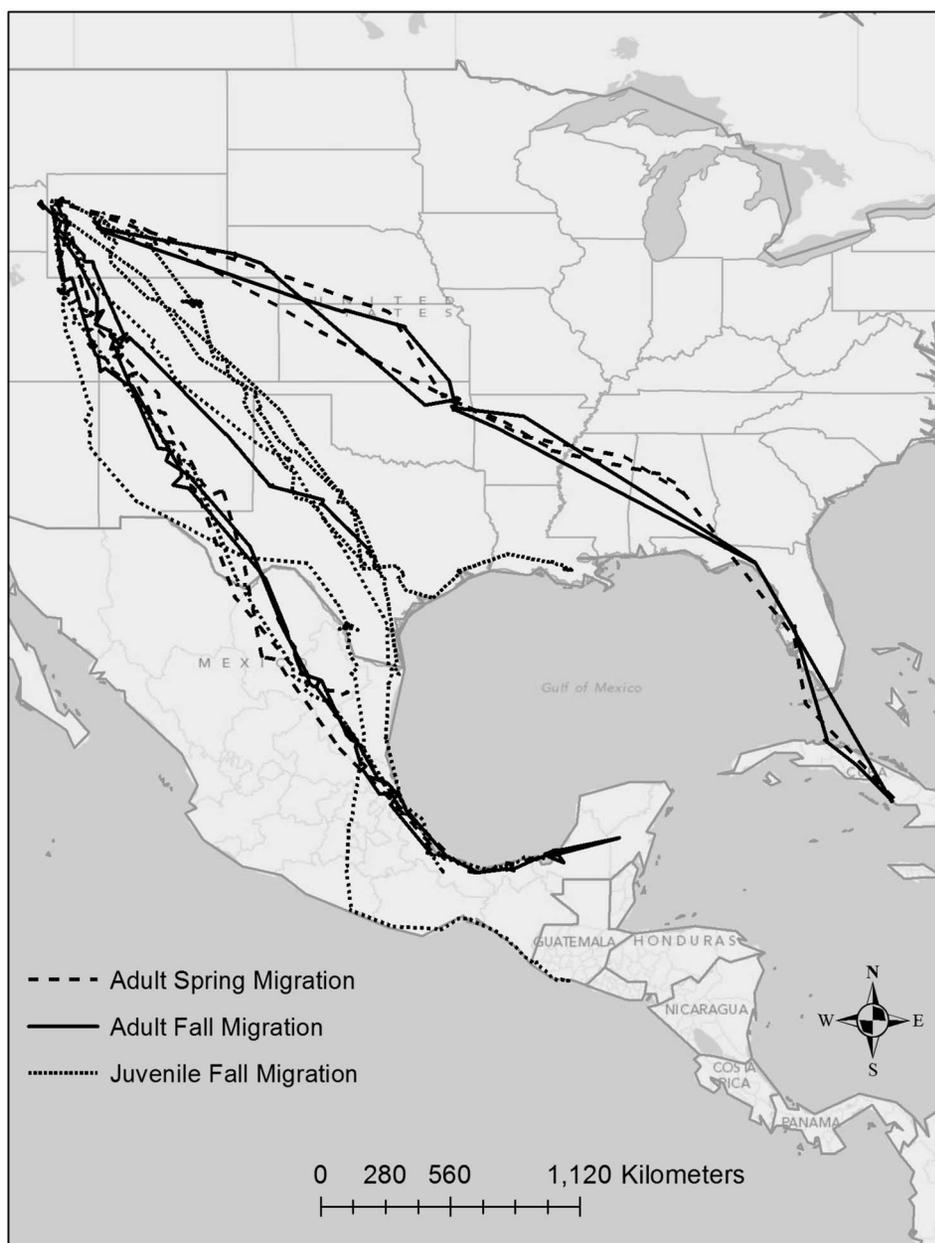* Speed calculated excluding days at a stopover site.

Figure 1. Migratory pathways of adult ($n = 4$) and juvenile ($n = 5$) Ospreys breeding or fledged in Grand Teton National Park, Wyoming, 2010–2012.

We calculated both 50% and 95% MCP use area estimates for adult Ospreys during the breeding seasons and for all Ospreys during the winter seasons (Table 2). We found no differences ($P > 0.1$) between average summer and winter MCP estimates for adults. The mean 50% summer and winter MCP estimates for adults were 5.39 ha (SD = 6.86) and 13.9 ha (SD = 17.59), respectively.

The mean 95% MCP estimate for adults was 176.0 (SD = 301) and 118.6 ha (SD = 173.1) for summer and winter ranges, respectively. Juveniles exhibited larger 50% MCP estimates for winter ranges compared to adults ($P = 0.034$, $t = -2.78$), with a mean size of 662 ha (SD = 465) and had a mean 95% MCP estimate of 9716.0 ha (SD = 15 386).

Table 2. Minimum convex polygon home-range size estimates (ha) for Ospreys breeding or fledged in Grand Teton National Park, Wyoming, 2010–2012.

OSPREY ID	NEST	AGE	SEX	YEAR	SUMMER		WINTER	
					50% MCP	95% MCP	50% MCP	95% MCP
11521	Colter Bay	Adult	Male	2010[a]	0.8	417.0	39.4	376.4
				2011	2.1	9.8	28.7	212.1
				2012	3.0	14.6	-	-
11522	Colter Bay	Adult	Female	2010	3.4	92.6	-	-
11523	Colter Bay	Juvenile	Female	2010	-	-	735.2	32 685.4
11525	Colter Bay	Adult	Male	2010	3.2	42.8	3.6	25.5
11526	Poker Flats	Juvenile	Female	2011	-	-	2.9	26.7
11527	Poker Flats	Juvenile	Female	2011	-	-	816.6	3563.0
11528	Poker Flats	Adult	Male	2011	4.5	29.8	1.0	11.5
				2012	3.4	33.9	1.2	13.4
11529	Poker Flats	Adult	Female	2012	23.4	902.0	11.5	61.0
				2013	4.7	44.0	4.8	20.4
11532	Poker Flats	Juvenile	Female	2012	-	-	1093.7	2586.9

[a] Nonbreeding year.

DISCUSSION

Migration data from North American Ospreys exist from the East Coast, the Midwest, and West Coast (Martell et al. 2001), but tracking data are lacking from the Rocky Mountain region. We found that nine Ospreys from our northwest Wyoming study area followed three distinct migration routes, two of which have not been previously described (Fig. 2). As in previous studies (Kjellén et al. 1997, Martell et al. 2001), we found the Osprey's winter ranges stretched across an expansive area although the birds originated from the same breeding region (Fig. 1, 2). Ospreys from GTNP mainly wintered around the Gulf of Mexico and Texas, with one juvenile traveling as far as Guatemala. Birds from GTNP tended to winter further north than others described in Martell et al. (2001) even though our study site is located further south than those included in the aforementioned study, which is typical of a leapfrog migratory pattern (Newton 2008). Although our sample size was very small, the three breeding males wintered further south than the breeding female, contrary to previous studies (Kjellén et al. 1997, Martell et al. 2001). The males in our study were the last to leave the nesting territories, always departing after the fledglings. The median nest initiation and fall departure dates from our study were later than in other studies (Martell et al. 2001, Elliott et al. 2007), likely due to the relatively high altitude of our study area. The high altitude leads to later spring river runoff and melting of ice on lakes, thereby delaying prey availability, which leads to later nesting and later fall migration. Most of the Ospreys in our study did not exhibit stopover behavior, and it did not appear that the presence of a stopover was related to distance traveled.

One notable adult male made a major east–west migration before resuming the more normal north–south pattern. This Osprey flew from the Rocky Mountain flyway, across the Central and Mississippi flyways, entered the East Coast flyway and continued down through Florida and across the Gulf of Mexico into Cuba, where it wintered. It returned along the same path and repeated this migratory pathway the following year (Fig. 1). Martell et al. (2001) documented Ospreys entering the East Coast flyway from the Midwest (Fig. 2) but this magnitude of east–west movement has not been previously documented. We did not obtain any data to suggest that family groups of Ospreys winter in the same geographic region. Similarly, members of one tagged family group from Minnesota did not winter in similar areas (M. Martell pers. comm.), suggesting there may not be a strong genetic component to determining wintering areas.

Although Osprey populations across North America have been stable or increasing (Hoffman and Smith 2003, Poole et al. 2002), there have been declines in density and productivity in Osprey from the Greater Yellowstone Ecosystem due to declining native prey populations (Baril et al. 2013). That case is likely limited to local perturbations in Yellowstone Lake, as Osprey nest occupancy and productivity have remained stable in GTNP from 1990–2013 (S. Cain unpubl. data).

Although sample size was limited, all five tagged juveniles died or stopped transmitting before completing their first migration cycle. We were unable to determine the fates of most nestlings (one confirmed death from unknown causes). However, last locations in the vicinity of towns in Mexico and Central America were suggestive of anthropogenic sources of mortality. Alternatively, we also could not dismiss the potential of transmitter effects on young Ospreys. Other researchers have noted similar
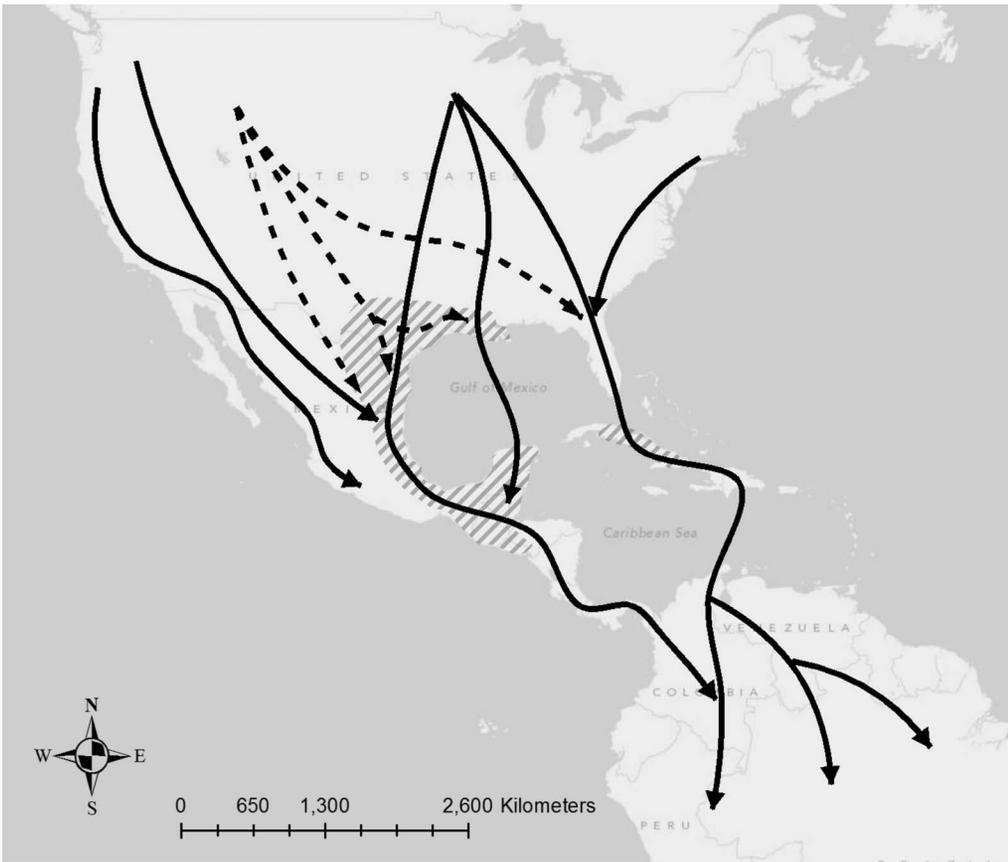
Figure 2.   Known autumn Osprey migration routes (black; adapted from Martell et al. 2001) and autumn migration routes recorded in this study (dashed). Shaded areas indicate areas of winter use by Ospreys during this study.

potential issues with Ospreys (R. Bierregaard pers. comm.). It is possible that the transmitters affected hunting capabilities or otherwise compromised fitness (e.g., Steenhof et al. 2006). More research is warranted to investigate causes and rates of mortality and anthropogenic influences (i.e., direct mortality and transmitter effects) on Ospreys prior to first breeding.

   Band recoveries from the study area nearest to ours (northern Idaho and eastern Washington) indicated that Ospreys from that region winter mainly on the Pacific coast of Central America (Melquist et al. 1978). All but one of the Osprey in this study wintered along or near the Gulf of Mexico. Wintering areas were all around the Gulf in the southern U.S., Mexico, and Cuba. Juveniles tended to have larger wintering home ranges than adults (Table 2). This is likely due to the fact that young Ospreys do not return to natal territories until they are almost 2 yr old (Henny and Van Velzen 1972), and young Ospreys may be searching for optimum wintering habitat or can energetically afford to wander because they are not migrat-

ing the following spring. Once established, adults exhibit fidelity to those wintering areas and exhibit tight home ranges (Alerstam et al. 2006), which was corroborated in this study. Unlike European Ospreys, the few Ospreys for which we gathered multiple years of migratory movement data use similar routes between years and even between autumn and vernal routes. One Osprey used a stopover site in northwest Oklahoma and stopped at the same location on all four recorded migrations (two autumn, two vernal). The three other adults with recorded multiple migrations also exhibited fidelity to migration routes.

   Adult Ospreys used similarly sized wintering and summering ranges. Interestingly, the adult female's summer breeding range from the Poker Flats nest did not include the nearby Snake River, which was the closest and primary fishing habitat used by her mate. During our limited observation periods at this nest (ca. 26 hr), the female was never observed fishing or away from the nest and there was only one small, temporary irrigation ditch within her use area, suggesting that this female may have relied on the male for

providing food for both her and the young, which is typical for nesting Ospreys (Poole 1989). Martell et al. (2001) surmised that female Osprey leave the breeding territory prior to the young dispersing to reduce competition for food resources with the offspring. The fact that the female extended her home range >15 km into Idaho prior to her autumn migration supports that theory. Breeding male use areas from both pairs were similar.

We documented one novel and two likely, but previously undescribed, migratory paths of Ospreys originating from northwest Wyoming, including migration corridors along both the western and eastern sides of the Rocky Mountains and across the Great Plains (Fig. 1, 2). We recorded Ospreys wintering in Texas, Louisiana, and northern Mexico, whereas most Ospreys from the Midwest and East Coast traveled much further into Central and South America. Elliott et al. (2007) documented British Columbia Ospreys wintering along the western coast of Mexico and the Gulf Coast, including one in Texas, but did not report their migration routes.

The Ospreys we tracked differed in their migratory timing, distance, and winter locations even though they bred or were fledged in the same geographical region. This finding is consistent with other Osprey studies in North America and Europe and suggests that, like other raptors with widespread wintering areas (Brodeur et al. 1996), breeding populations may be resistant to local perturbations on specific wintering grounds (Webster et al. 2002). In species such as Osprey, which have weak migratory connectivity (i.e., dispersed migratory routes and wintering grounds), changes observed in breeding populations are more likely a result of local conditions (e.g., Baril et al. 2013), with the notable exceptions of regional perturbations to winter range, such as climate change influences on weather patterns. In the absence of issues across large sections of Osprey winter range, management of breeding Osprey populations should generally be directed locally within the breeding habitat. However, our data suggest that Ospreys from the Rocky Mountain region show fidelity to migration routes and we believe that degradation of habitat along those routes and in stopover areas can result in a loss of Ospreys.

RUTAS MIGRATORIAS, TIEMPOS Y ÁREA DE CAMPEO DE *PANDION HALIAETUS* EN EL SUR DE YELLOWSTONE

Resumen.—Durante el periodo 2010–2012 documentamos los movimientos migratorios y estacionales de 11 individuos de *Pandion haliaetus* que se reproducen o que nacieron en el Parque Nacional Grand Teton, Wyoming. Seguimos los movimientos de los individuos de *P. haliaetus* con emisores de telemetría satelital a través de Argos, documentando un total de 13 migraciones otoñales y cinco migraciones primaverales. Las fechas de partida promedio durante el otoño fueron el 19 de septiembre y el 23 de septiembre para los adultos y juveniles, respectivamente, y los individuos viajaron un promedio de 225 km/d. Los individuos de *P. haliaetus* presentaron áreas de invernada dispersas, generalmente en los alrededores del Golfo de México. La fecha de partida promedio en la primavera fue el 2 de abril y los individuos adultos viajaron un promedio de 269 km/d. Los adultos presentaron un área de campeo en promedio de 176 y 199 ha, considerando el mínimo polígono convexo del 95%, para sus distribuciones de verano e invierno, respectivamente. Documentamos una nueva ruta migratoria, desde las Montañas Rocosas hacia Cuba a través de las Grandes Planicies y de Florida. Nuestros datos sugieren que el hábitat de invernada de los individuos de *P. haliaetus* que se reproducen en el norte de las Montañas Rocosas es disperso y que cualquier perturbación en las poblaciones reproductoras puede ser el resultado de cambios en las rutas migratorias o en la distribución de verano.

[Traducción del equipo editorial]

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