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Abstract.—Satellite telemetry was used to investigate summer and winter home ranges for resident and migrant American White Pelicans (*Pelecanus erythrorhynchos*) captured in the southeastern United States between 2002 and 2007. Home range utilization distributions were calculated using 50% and 95% kernel density estimators with the plug-in bandwidth selector. Mean summer home ranges (95%) varied from 177 to 4,710 km^2 and mean winter home ranges (95%) ranged from 185 to 916 km^2. Mean 50% and 95% home ranges of adult American White Pelicans during summer tended to be larger than those during winter, whereas mean 50% and 95% home ranges of immature pelicans during summer tended to be smaller than those during winter. Home ranges for all American White Pelicans encompassed the latitude range of 24°-55° N, including wintering, stop over, and nesting habitat. These data provide baseline movement and home range data for future studies of American White Pelican ecology.
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Key words.—American White Pelican, aquaculture, home range, kernel density estimation, movements, *Pelecanus erythrorhynchos*, plug-in bandwidth, satellite telemetry.

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The American White Pelican (*Pelecanus erythrorhynchos*; hereafter pelican) is a charismatic and well known species in North America (Anderson and King 2005; Keith 2005), but little is actually known about its general movements, home ranges, and core use areas (Knopf and Evans 2004). Using VHF (Very High Frequency) telemetry, King and Werner (2001) documented daily activity budgets of pelicans captured near aquaculture facilities in the southeastern United States. Logistical constraints involved with the utilization of VHF telemetry, however, precluded its use to effectively address many local, regional, and continental questions concerning pelican ranges and movements (King and Werner 2001). Breeding bird surveys and band recoveries of pelicans have partially identified dispersal patterns (Houston 1972; Strait and Sloan 1975; King and Grewe 2001; Anderson and Anderson 2005) and the location of North American colonies (King and Anderson 2005), but seasonal and regional movements of these wide-ranging birds are of considerable added interest. Recent advances in satellite telemetry have allowed monitoring of animal movements over expansive areas (Lindberg and Walker 2007; Robinson *et al.* 2009; Hebblewhite and Haydon 2010). Shannon *et al.* (2002) used satellite telemetry to document American White Pelican soaring flight times, and Izhaki *et al.* (2002) used satellite telemetry to describe the migratory and ranging behavior of immature Great White Pelicans (*P. onocrotalus*). Further advances have led to the incorporation of a Global Positioning System (GPS) into satellite transmitters, allowing for very precise location data and intensive monitoring of animal movements. For example, Avery *et al.* (2011) used GPS-technology to document home ranges of

Black Vultures (*Coragyps atratus*) and Turkey Vultures (*Cathartes aura*) in South Carolina, USA, and their migration to central Florida, USA.

To our knowledge, the home range of American White Pelicans has not been previously estimated. The objectives of this study were to: 1) estimate seasonal home ranges and core use areas for pelicans captured in the southeastern United States; and 2) determine effects of season, age, and sex on home range sizes of pelicans. Data from this study provide novel information on local, regional, and continental movements of American White Pelicans and can also be interpreted on a behavioral basis.

METHODS

Study Area

We captured pelicans at loafing sites near aquaculture-intensive areas in Alabama, Arkansas, Louisiana, and Mississippi, USA (Fig. 1) using rocket nets and modified foot-hold traps (King *et al.* 1998). We fitted pelicans with backpack 70-g solar-powered GPS satellite transmitters (PTT-100, Microwave Telemetry; Dunstan 1972); transmitters were programmed to record one location per hour for the duration of the study and were < 3% of the individual's body weight. We estimated age (≥ 3 years old = adult; < 3 years old = immature) using plumage and eye and skin color characteristics (D. T. King, unpubl. data) and determined sex by using culmen length (Dorr *et al.* 2005) for each captured pelican. We released all captured birds at the trap site.

The summer season included locations from 1 June-31 August, and the winter season included locations from 1 November-15 April. A pelican's home range for a given season/year was computed only if there were > 50 locations and if those locations were logged during > 50% of the time period. We identified 1 June the year following capture as the date when a bird tagged as a 2-year-old immature would be considered an adult. We defined migration as seasonal movements from wintering areas in the southern United States to breeding and summering areas in the north central United States and southern Canada. Because a few individuals exhibited nomadic behavior when flying north in the spring, but never reached breeding colonies, we identified 36°

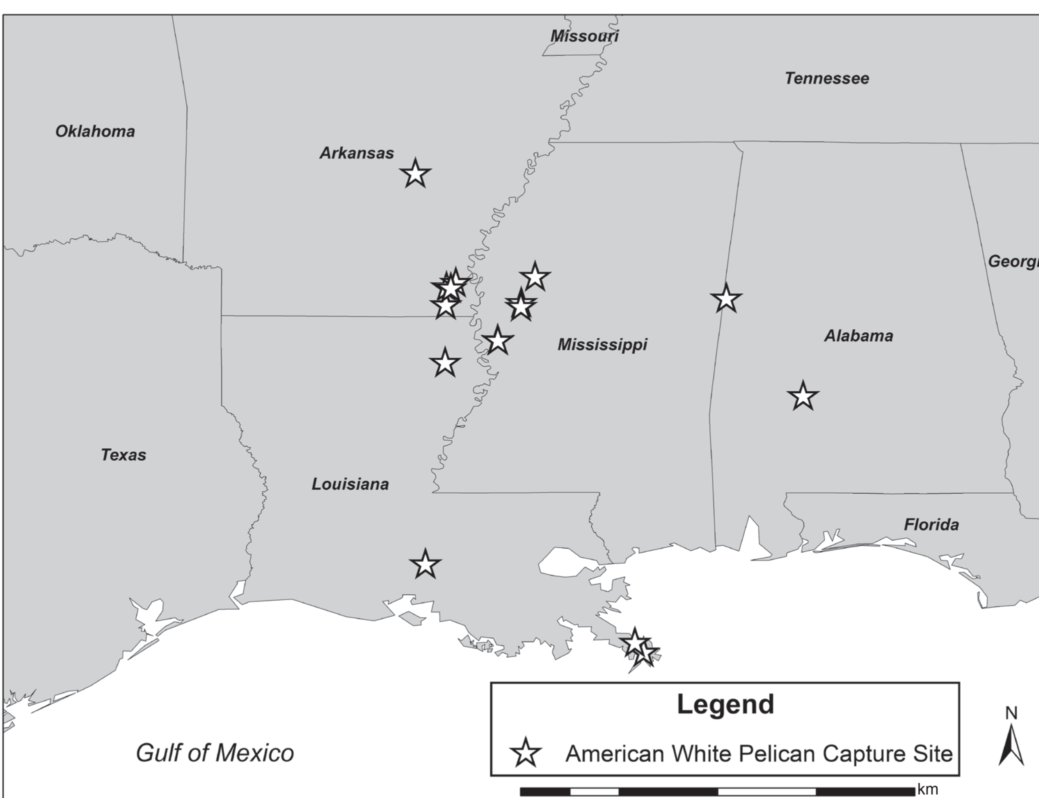

Figure 1. American White Pelican capture locations in Alabama, Arkansas, Louisiana, and Mississippi, 19 April 2002-4 April 2007.

30′ N latitude as the dividing line and 15 June as the cutoff date for individuals to either be classified as residents or migrants.

Statistical Analysis

We used kernel density estimation (KDE) to estimate summer and winter 50% (i.e., core area) and 95% (i.e., overall use area) utilization distributions for pelicans. We used the second generation plug-in bandwidth selection method because our GPS data set had numerous locations (i.e., 50-24,000 per season) that often caused first generation methods to fail (Gitzen *et al.* 2006; Walter *et al.* 2011). First generation methods such as least squares cross-validation failed to converge with a large number of identical or very tight clustered points (Hemson *et al.* 2005; Gitzen *et al.* 2006; Pellerin *et al.* 2008) or had a tendency to grossly over-smooth the data (default or reference bandwidth; Worton 1995; Seaman and Powell 1996; Hemson *et al.* 2005). The plug-in bandwidth selection method is data-based, uses an equation to directly estimate the 'ideal' bandwidth, and estimates pilot bandwidths to tune the performance of the covariance estimator (Jones *et al.* 1996; Duong and Hazelton 2003; Duong 2007). We calculated KDE plug-in home ranges in the R language for statistical computing (R Development Core Team 2012) using the ks package (Duong 2007).

We used mixed-effect models to detect effects of season, age, and sex on home range sizes of pelicans with animal ID as a random effect variable to account for temporal autocorrelation because of repeated observations of the same individual (R Development Core Team 2012). If the estimate of variance for animal ID was 0.00, we used analysis of variance to compare home range sizes by age, sex, season, and their interactions at the significance level of 0.05. In preliminary analyses, effects of year were not significant ($P > 0.10$). Therefore, we pooled our data over years in subsequent analyses.

We tested for effects of fixed-effect variables (age, sex, and season) and their interactions with: 1) all possible combinations of two-factor interactions; and 2) three-factor interaction. We conducted backward model selection at the significance level of 0.05. We conducted multiple comparisons of least square means (lsmeans) or sliced lsmeans of home ranges with the Tukey adjustment using the SAS procedure MIXED with the slice option (Littell *et al.* 2006). We conducted linear model or mixed-model analysis for 50% and 95% KDE home range sizes, with home range sizes log transformed for the normality assumption.

RESULTS

From 19 April 2002-4 April 2007, we captured 39 pelicans (3-17 per year) and fitted them with transmitters. We captured 34 males (5 adults, 29 immatures) and 5 immature females. These birds were tracked from 19 April 2002-29 October 2007. Transmitters ($n = 39$) operated an average of 17.3 months (± 1.5 SE; Range = 1-52), excluding birds that were known to be killed (shot under depredation permits at aquaculture facilities) within 3 weeks of release. We obtained an average of 2,299 (± 271.8 SE) locations per bird, some of which were represented by captured immatures reaching adulthood (male: $n = 17$; female: $n = 4$).

Mean 50% and 95% home ranges of adult pelicans during summer tended to be larger than those during winter, whereas mean 50% and 95% home ranges of immature pelicans during summer tended to be smaller than those during winter (Table 1). Estimated mean 95% home ranges for all pelicans covered the latitude range of 24°-55° N, including wintering, stop over, and nesting habitat. Mean 50% summer home ranges for migrating pelicans were located in the northern part of the species' range (i.e., summer nesting habitat; Fig. 2). The

Table 1. Mean summer and winter home ranges of American White Pelicans using kernel density estimation and the plug-in bandwidth selector for 50% and 95% utilization distributions (km² (± SE)). Pelicans were captured in the southeastern United States from April 2002-October 2007. Each season-year was considered a separate range (*n* = 178).

Sex	Age	Season	50%	95%
Male	Adult	Summer	2,818 ± 1,418	28,487 ± 10,147
		Winter	916 ± 228	12,632 ± 3,140
	Immature	Summer	326 ± 124	5,275 ± 2,175
		Winter	681 ± 162	11,410 ± 2,994
Female	Adult	Summer	4,711 ± 2,794	65,880 ± 28,866
		Winter	186 ± 29	1,329 ± 248
	Immature	Summer	177 ± 66	2,089 ± 557
		Winter	342 ± 79	4,960 ± 814

Figure 2. Extent of 50% and 95% fixed-kernel density estimates (KDE) with the plug-in bandwidth selector of summer home ranges for migrating American White Pelicans captured in the southeastern United States during 2002-2007.

extents of mean 50% and 95% home ranges of summer residents (i.e., non-migrants) were similar to those of winter home ranges (Figs. 3 and 4).

50% Kernel Home Range

The estimate of variance for animal ID was 0.00 when including animal ID as a random effect. Therefore, we compared 50% kernel home ranges using analysis of variance. No comparisons of 50% kernel home range sizes by age, sex, and season were significant ($P > 0.10$).

95% Kernel Home Range

In the mixed model, the age-sex-season interaction was significant ($F_{4, 75} = 4.82$, $P = 0.002$). Female adults had larger home ranges in summer than in winter ($t_{75} = 3.28$, Tukey adjusted $P = 0.03$), with the least square mean of log transformed 95% kernel home range sizes being 10.4 and 7.06, respectively. Moreover, female adults had larger home range sizes than did male immatures during summer ($t_{75} = 3.6$, adjusted $P = 0.01$), with the least square mean of log transformed 95% kernel home range sizes being 10.4 and 7.21, respectively. Female home range sizes did not differ from those of adult males.

DISCUSSION

Migratory birds make seasonal movements between wintering and summer nesting habitats to take advantage of available resources in different locations to meet habitat and nutritional requirements (Pulido 2007; Ramenofsky and Wingfield 2007). Mean 50% kernel home ranges (i.e., core home

Figure 3. Extent of 50% and 95% fixed-kernel density estimates (KDE) with the plug-in bandwidth selector of summer home ranges for resident American White Pelicans captured in the southeastern United States during 2002-2007.

ranges) of pelicans were spatially unconnected (Figs. 2 and 4). The northern boundary of winter 95% kernel home ranges probably represents the northern boundary of pelican wintering habitat (Fig. 4). For migrating pelicans, the lower latitude limit of the range of summer core or 50% kernel home ranges was approximately the same as that of known breeding colonies (Fig. 2; King and Anderson 2005). Therefore, our estimated summer and winter core home ranges probably delineate the lower latitude limit of nesting habitat and upper latitude limit of wintering habitat respectively, providing insight for future studies of habitat selection and requirements by nesting and wintering American White Pelicans.

Habitat, food abundance, and bird reproductive condition may affect bird movement distance and home range sizes (McNab 1963; Weimerskirch *et al.* 1994). More abundant food resources may result in smaller home ranges of animals (McNab 1963). Home ranges of adult pelicans during winter tended to be smaller than those during summer (Table 1). Additionally, home range size of female adults in summer was greater than that in winter. Wintering pelicans feed on fish at commercial aquaculture facilities, such as catfish (*Ictalurus punctatus*) ponds, in the southeastern United States (King *et al.* 2010). Catfish aquaculture in the southeastern United States was estimated to produce a total of 1,626,401,709 kg of fish during our study period (National Agricultural Statistics Service 2013). Abundant fish at commercial aquaculture facilities improves the body condition of pelicans (King *et al.* 2010) and may reduce winter home range sizes of pelicans. During the breeding season, egg incubation and provision feeding by adults are energetically demanding with nesting birds often

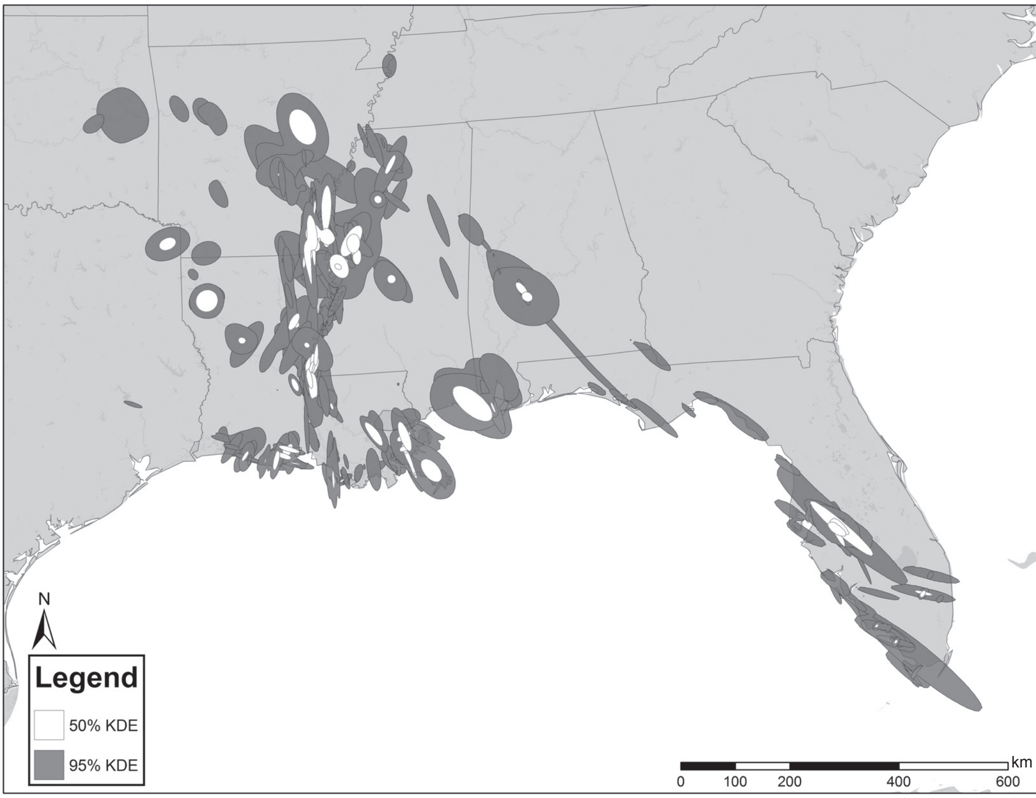

Figure 4. Extent of 50% and 95% fixed-kernel density estimates (KDE) with the plug-in bandwidth selector of winter home ranges for American White Pelicans captured in the southeastern United States during 2002-2007.

making long foraging trips to meet these energetic demands (Behle 1958; Johnson and Sloan 1978; Weimerskirch *et al.* 1994; Findholt and Anderson 1995).

When compared to peak years, the aquaculture industry in the USA has undergone a 54.6% reduction in total catfish water surface acres and a 55.6% reduction in the number of commercial catfish farms due to foreign imports and rising feed costs (Hanson and Sites 2014). It has been speculated that the remaining commercial catfish farms will suffer increased predation losses and disease risk as pelicans concentrate their foraging efforts on fewer facilities, which could also restrict pelican winter home ranges to smaller areas. This information will be important to catfish farmers to help them better understand the threat that changes in American White Pelican distribution represents, allowing farmers to concentrate control and harassment efforts during the appropriate months to increase efficiency and reduce predation losses. These data can be used as baseline movement and home range data for future studies of American White Pelican ecology.

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