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American White Pelicans Breeding in the Northern Plains—Productivity, Behavior, Movements, and Migration

Scientific Investigations Report 2013–5105

U.S. Department of the Interior
U.S. Geological Survey

Cover. Adult American white pelicans (*Pelecanus erythrorhynchos*) in breeding plumage at Medicine Lake National Wildlife Refuge, Montana, May 27, 2005 (Photograph by Ross D. Flagen, U.S. Geological Survey).

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Contents

Figures

Tables

Appendixes

Acknowledgments

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Animal Welfare Act Compliance

A research biologist from U.S. Department of Agriculture, who specializes in the study of American white pelicans, provided training and supervision for pelican trapping procedures (King and others, 1998) and transmitter attachment. Pelicans were captured at resting sites away from nests and after the majority of eggs were hatched. These precautions substantially lower the risk of nest abandonment. We followed the Ornithological Council's "Guidelines to the use of wild birds in research" (Gaunt and Oring, 1999) by ensuring that we (1) minimized disturbance to the nesting colony in all aspects of the study, (2) minimized handling time and stress to captured birds, (3) captured and attached transmitters to no more birds than necessary, (4) used only essential markers (for example, leg bands but no patagial tags, dyes, or paint), (5) used the lightest transmitters feasible to meet study objectives, (6) enlisted appropriate expertise in attaching transmitters and other markers, and (7) monitored newly released birds for any signs of adverse responses to transmitters or handling. No birds were injured during this study, although we were prepared to use approved methods of euthanasia on any seriously injured bird. The study plan and all methods were reviewed and approved by U.S. Geological Survey's Northern Prairie Wildlife Research Center Animal Care and Use Committee.

Conversion Factors and Datum

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	Acre
hectare (ha)	2.471	Acre
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (in^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	2.590	square mile (mi^2)
	Flow rate	
kilometer per hours (km/hr)	0.6214	mile per hour (mi/hr)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32)/1.8$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

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Abstract

Nearly half of American white pelicans (*Pelecanus erythrorhynchos*; hereafter pelicans) are believed to nest in several large colonies in the northern plains, yet few studies had been conducted on pelicans in this region until research began in 2004 to investigate the impact of West Nile virus (WNV) on their chicks. The work reported here focused on two of the largest colonies in the region, at Bitter Lake, South Dakota, and Chase Lake, North Dakota, during 2005–10.

Pelicans usually began arriving at these two breeding colonies in early April. Egg-laying began during mid-April and nest initiations continued through May. The number of nests documented at these colonies reached a high of about 15,400 at Bitter Lake and 17,300 at Chase Lake, both in 2006.

During 2006–8, annual variation in hatching success was high (40 to 100 percent) at video-monitored nests, averaging 61 percent for 82 nests at Bitter Lake and 57 percent for 88 nests at Chase Lake. Although most nests contained two eggs, of those where two chicks hatched, both chicks survived to the crèche stage (about 15 days old) at only two nests. Severe weather events, disturbance, and siblicide were documented causes of early season (before mid-July) mortalities. In the late season (mid-July to fledging), WNV was the most important factor contributing to chick mortality.

Nests were nearly always attended by one adult during incubation and brooding. Adults typically exchanged places at the nest around mid-day in all 3 years, apparently taking advantage of thermals to gain altitude for travel to and from foraging areas. The mean time of exchange differed by about an hour between Bitter Lake (1328 central standard time, CST) and Chase Lake (1434 CST) colonies. During incubation, nearly 3 days often passed between adult nest exchanges; after chicks hatched, exchanges usually occurred daily. Exchanges were more frequent and chicks were fed more often at successful nests than at failed nests.

Adult pelicans with satellite transmitters that incorporated a Global Positioning System (GPS) foraged primarily in shallow areas of lakes and semipermanent wetlands. These areas coincide with typical habitats of crayfish, salamanders, and rough fish, which were also the foods most commonly seen in pelican regurgitates at the colonies. Several satellite-tracked pelicans made frequent round trips between their breeding colony and foraging areas, most likely to provision their chicks. Typical distances travelled to foraging sites ranged from 30 kilometers to over 90 kilometers. Return times to the colonies (about 1300 and 1500 CST at Bitter Lake and Chase Lake, respectively) supported the colony difference documented at video-monitored nests.

Of 28 pelicans tagged with GPS satellite transmitters in 2005–6, 26 survived the first summer and migrated south during fall. Nineteen of these returned to the breeding region (defined as north of the latitude of South Dakota's southern border) in at least 1 year during 2006–9; collectively, they returned to the breeding region 33 times. Very few pelicans returned to the colony where they had been tagged; many did not breed and concentrated their activities at wetland complexes in South Dakota and North Dakota, but few tagged pelicans temporally overlapped at specific sites. During 2005–9, tagged pelicans collectively made 56 migratory trips south in the fall. Most wintered in Mexico, near the gulf coast and elsewhere; others wintered in Texas, Louisiana, Mississippi, and Florida. Individuals typically returned to the same general areas each winter. Individuals rarely followed the same migratory path on their way south and north, but they often roughly repeated southerly or northerly routes among years.

Ensuring a sustainable population of American white pelicans requires identification and mitigation of known threats. The work described herein has identified WNV and severe weather as important factors that potentially limit reproductive success and recruitment in the northern plains. Managers in this region could assess the influence of such factors on productivity at key colonies by annually obtaining aerial photographs during peak nesting, and estimating numbers of chicks fledged from aerial photographs or ground counts. Banding a subsample of chicks in late June or early July, followed by a sweep for bands at the end of the season, would allow estimation of mortality rates of older chicks (that normally would fledge) and help track the influence of WNV or other mortality factors over time and varying environmental conditions.

Background

Population Vulnerability

Nearly half of American white pelicans (*Pelecanus erythrorhynchos;* hereafter pelicans) are believed to nest in several large colonies in the northern plains (King and Anderson, 2005); therefore, sustained productivity from colonies in the northern plains is important to the health of the species. The colonial nesting of pelicans makes them especially vulnerable to factors that can influence productivity, such as weather events, disease, loss of nesting habitat, and disturbance by humans or predators. In addition, pelicans have relatively low reproductive rates, not breeding until at least 3 years of age and usually fledging less than one young per pair each year.

Near the end of the 2002 and 2003 breeding seasons, large die-offs (for example, more than 5,000 young at Chase Lake, North Dakota in 2003) were documented in the four largest pelican colonies in the northern plains (Sovada and others, 2008); West Nile virus (WNV) was the suspected cause. These significant losses prompted interest in monitoring of nesting colonies and learning more about biology and ecology of this species. In 2004, we began research at three major colonies—Bitter Lake in South Dakota, Chase Lake National Wildlife Refuge (NWR) in North Dakota, Medicine Lake NWR in Montana (fig. 1)—to evaluate the impact of WNV on pelican populations and to assess the importance of WNV relative to other mortality factors. During the first year of surveillance of the colonies, we observed the complete abandonment of the Chase Lake Colony, partial abandonment of the Medicine Lake Colony, and reduced productivity at the Bitter Lake Colony. The total abandonment at Chase Lake drew national and international attention and considerable speculation on the cause. The most reasonable suggestions proposed were (1) coyote depredation and disturbance, (2) anthropomorphic disturbance, (3) disease, (4) weather, (5) reduced or unavailable food resources, or (6) a combination of these factors.

The catastrophic abandonment of the Chase Lake Colony raised concerns about the stability of colonies in the northern plains and underscored the limits of our understanding of population dynamics and ecology in these colonial breeding birds. To address these shortcomings, we began a multifaceted effort to gather ecological information about the colonies in South Dakota, North Dakota, and Montana. Our goal was to advance understanding of pelican ecology and to provide sound science on which to base future management decisions.

We continued the work begun in 2004 to evaluate the impact of WNV on pelican populations in the northern plains and to assess its importance relative to other mortality factors. Results of the WNV studies have been reported in Sovada and others (2008). In 2005, our data collection effort was expanded to include the use of observers to monitor pelican breeding phenology and the deployment of satellite transmitters with Global Positioning System (GPS) equipment to document movements of adult pelicans. In 2006, we began monitoring nesting pelicans with surveillance cameras at the Bitter Lake and Chase Lake colonies. The objectives of the observations, telemetry, and video were to gather information on breeding behavior, sources of mortality and disturbance, patterns of nest attendance, foraging ranges and locations, and characteristics of foraging and resting sites. This report summarizes productivity, behavior, and movement data collected between 2005 and 2010 for pelicans breeding in the northern plains.

Status of Pelicans in the Dakotas

During their breeding season in the Dakotas, pelicans are concentrated at a few large nesting colonies. Breeding pelicans on foraging trips and nonbreeding pelicans also can be found throughout South and North Dakota where foraging habitats are present.

South Dakota

South Dakota Game, Fish, and Parks identified the pelican as a "species of greatest conservation need" for the purpose of developing the South Dakota Comprehensive Wildlife Conservation Plan (South Dakota Department of Game, Fish, and Parks, 2006). The South Dakota Natural Heritage Program identifies pelicans as a "S3B" species, that is "either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors" (South Dakota Department of Game, Fish, and Parks, 2012).

Two large colonies are located in South Dakota (fig. 1). The smaller of the two is located in the Lacreek NWR near Martin in Bennett County. This colony was initiated in 1949 and has had up to 2,733 nests (in 1985, from refuge records). The largest colony in South Dakota and the focus of this report is located in the Bitter Lake Game Production Area near Waubay in Day County. Records from Waubay NWR report nesting by pelicans on islands at Bitter Lake in 1964 and from 1987 to the present. Records also indicate that nesting pelicans used islands at nearby lakes (South Waubay 1963–91, North Drywood 1969–96, Piyas 1975–93, Grass 1987–88 and 1991–98). Through the years, it is likely that changing water levels influenced colony site selection in the area. Islands are the preferred nesting site, and many nesting islands previously used have been inundated. Certainly, smaller and perhaps more fleeting colonies have occurred in other locations in South Dakota. For example, in 2008, we observed the initiation of a pelican colony of approximately 50 nests on an island in Silver Lake, Hutchinson County (11 kilometers [km] north of Freeman). Pelicans nested on the island again in 2009, but the number of nests and their fates are unknown.

Figure 1. Known (as of 2008) breeding colony sites of American white pelicans in South Dakota and North Dakota and locations of the largest known colonies in Montana (Medicine Lake) and Minnesota (Marsh Lake).

North Dakota

In the North Dakota Game and Fish Department's "100 Species of Conservation Priority," pelicans are included as a "Level I Species in Greatest Need of Conservation" (North Dakota Game and Fish Department, 2012). Pelicans were assigned Level I status because the Chase Lake breeding colony in central North Dakota (fig. 1) is among the largest of all colonies in North America. Over a 10-year period (2000–9), the average number of nests counted annually at Chase Lake was 13,500. Because of the importance of this large colony, pelicans are considered a "responsibility" species by the State for management purposes (North Dakota Game and Fish Department, 2012). In addition to Chase Lake, there are small colonies (less than 500 nests) that have been documented in the State. Two colonies active in recent years were located in the Van Hook Arm area of Lake Sakakawea in Mountrail County and Willow Lake in Rolette County (fig.1).

Study Areas

Bitter Lake is located 5 km south of Waubay in Day County, S. Dak. The 4,600-hectare (ha) lake (estimated size in 2008) is bordered by a 1,360 ha State game production area on the east and west sides and by private land on the north and south sides. Bitter Lake is located in the Prairie Coteau physiographic region of northeastern South Dakota, characterized by a landscape of rolling tallgrass prairie hills interspersed with thousands of small wetlands and lakes. Land areas are used for pasture or croplands. Bitter Lake contains many islands created when rising water surrounded hilltops; pelicans have nested on four of these islands and a peninsula. As noted above, colonies occurred on four other lakes in the area in past years. In the years of this evaluation, Bitter Lake had the only known and consistently active colony in northeastern South Dakota (USFWS, Waubay NWR records; Drilling, 2007).

Chase Lake NWR is 19 km northwest of Medina in Stutsman County, N. Dak. The 1,775-ha refuge is within the previously glaciated Missouri Coteau physiographic region, characterized by morainic gently rolling plains interspersed with wetlands, prairie pastures, planted grasslands, hayfields, and cropland. An additional 2,474 ha of Federal- and State-owned grasslands and wetlands are adjacent to the refuge. Chase Lake is a shallow, 1,150-ha (2008 estimated size) alkaline lake that has no outlet and supports no aquatic vertebrates in most years. During the study, pelicans nested on one to three islands (see Sovada and others [2005] for additional description). Breeding by pelicans at Chase Lake was first documented in 1905, and the colony has been active since then. The area was designated as a NWR in 1908 to protect the colony.

Methods

Breeding Biology and Behavior

Direct Observations

Pelicans begin arriving at the breeding areas around the first week of April. This typically is before ice-out on the lake, thus it is difficult to closely observe the colony when courtship flights and the earliest nest initiations are occurring. In any case, during courtship and early incubation, we avoided activity close to the breeding sites because pelicans are sensitive to disturbance in the early stages of nesting (Knopf and Evans, 2004). Field personnel used spotting scopes and binoculars to remotely observe pelican arrivals and areas being settled. Field personnel were able to observe nests directly from blinds on nesting islands when eggs were near hatching or hatched. Phenology of development (hatching, crèching, first flights of young) was recorded, and disturbances or unusual behaviors were noted. To estimate the date nests were first initiated, we backdated 30 days (incubation period, Knopf and Evans 2004) from when the first eggs hatched.

Nest and Chick Counts

We used two methods to estimate the numbers of nests initiated on the islands in Bitter Lake and Chase Lake. Aerial photographs of the colonies were obtained and we used a semiautomated GIS-counting program to assess the number of visible nests (methods were developed at Northern Prairie Wildlife Research Center). For areas in aerial photographs that were obstructed by tree canopy, we used a ground count of nests and the count area was delineated with GPS mapping. The two counts then were combined for a final estimate of nests in the colony. Photographs were taken and ground counts conducted near the end of May or beginning of June to coincide with the time the maximum number of adults would be tending nests (that is, after most nests had been initiated and before chicks began to leave nests and form crèches). We estimated the number of chicks in mid-June, after most chicks had hatched and none had fledged. We used aerial photographs in 2006 and ground counts in 2007–8 to estimate numbers of chicks.

Camera Monitoring

Nesting pelicans are relatively sensitive to disturbance during early incubation (Knopf and Evans, 2004), therefore, cameras were not deployed in areas or at times that would disturb the birds. Thus, behavioral data were collected largely from the late incubation stage until chicks began to crèche, after which chicks spend most of their time away from the nest site.

We deployed digital video-camera systems to remotely monitor nesting pelicans and their chicks (fig. 2) at Bitter Lake and Chase Lake colonies during 2006–8. A camera system consisted of a high-quality digital video camera with a zoom lens in a waterproof housing, a digital video recorder in a weatherproof box, two sealed lead-acid AGM batteries (each with greater than [>] 100 amp-hr capacity), and a 120-watt solar panel. We set up camera systems to obtain time-lapse recordings of diurnal and crepuscular activities at groups of nests that were primarily in the brooding stage.

Figure 2. Video-camera system (solar panel in foreground, camera in upper left) deployed to monitor nesting birds at American white pelican colonies, Bitter Lake, South Dakota, and Chase Lake, North Dakota, 2006–8.

When transcribing data from the videos (fig. 3), we selected a sample of nests in close view of the camera to evaluate (1) hatching success of eggs, (2) rate at which chicks survive to crèche stage, (3) age chicks begin to disassociate from their nests, (4) chick health status, and (5) potential causes of chick deaths. Unusual events also were noted, including predation and intra- and interspecific interactions.

A nest was considered successful if one chick survived to crèche stage or near to crèche stage (>10 days old) if video recording ended prior to chicks moving away from the nest area. From video recordings, it is difficult to distinguish deaths caused by sibling aggression from deaths caused by exposure or starvation. Significant loss was expected from sibling aggression because pelicans are an obligate brood-reducing species (Evans, 1997). We assumed siblicide when all of the following conditions were met: (1) sibling aggression was documented, (2) one chick died within approximately 7 days of hatch, (3) one chick outlived the other, and (4) there was no other obvious cause of death. We monitored weather because unusually severe rain/wind events, prolonged cold and wet weather, and hail raised the potential for chick mortality. Cause of death was attributed to severe weather if (1) chicks appeared healthy and feeding behavior was normal just prior to severe weather, (2) death occurred during or just after inclement weather, and (3) no other obvious reason for death was detected. If chicks were continually brooded and reasonably fed during the event, weather was not considered a candidate for cause of death.

The arrival and departure times of adult pelicans from nests were recorded, and we computed the rate that adults exchanged attendance responsibilities at each nest. The exchange rate (exchanges per day) was computed for each nest as the number of days on which an exchange occurred divided by the number of days the nest was under observation. Only days with chicks at the nest were included. For nests with chicks, we compared exchange rates between study areas, years, and nest fates with a weighted analysis of variance model; the number of days a nest was observed was used as the weight in the models. Among monitored nests that were appropriate for analyses (hatched chicks), none failed at Bitter Lake in 2006 or at Chase Lake in 2008. Because of these missing cells, the model was run as a means model (that is, the model only included the three-way interaction term between study area, year, and fate). Contrasts then were computed to make comparisons among fates, year, and study areas. Only

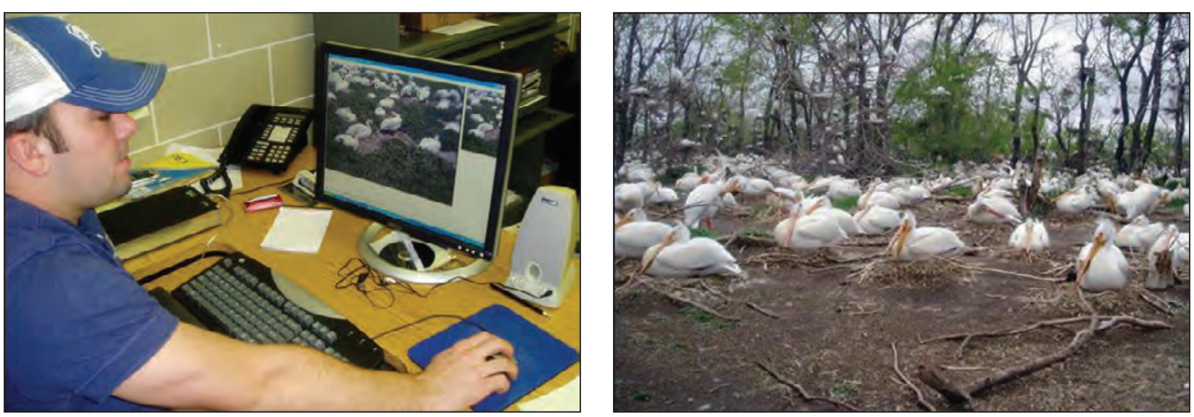


Figure 3. Technician (Mike Assenmacher) transcribing video data from views of American white pelicans nesting at Bitter Lake, South Dakota (left). View of pelicans nesting in Subcolony 1, Bitter Lake, S. Dak., monitored with remote video system (right).

nests of known fate were used in the analysis. The analysis was conducted with the mixed models procedure of SAS (SAS Institute, 2010).

We calculated frequency and length of feeding bouts for chicks at nests. Because adults provide food to chicks in series of short feedings and do not continuously maintain the feeding posture (Knopf and Evans, 2004), we chose to define a feeding bout as any period of time that adults fed chicks without a break of more than 5 minutes. We examined the relation of feeding rate (feedings per hour of observation) and feeding-bout length (to the nearest minute) to age of the chicks. The nests from each study area and year combination were subdivided into two groups: successful and failed nests. As noted above, all nests appropriate for these analyses were successful at Bitter Lake in 2006 and Chase Lake in 2008. Our data include several failed nests for Bitter Lake in 2007 and Chase Lake in 2006, however, only nests with chicks less than (<) 10 days old were represented, whereas, the range of ages for all other combinations of study area, year, and fate ranged from 1 to 19 days old. Therefore, analyses were conducted with data for chicks 1 to 10 days old. To account for the repeated measurements on nests and the variation among nests in the relation between age and the response variables, random coefficient models were fit to the data by using the mixed models procedure in SAS (Littell and others, 2006; SAS Institute, 2010). With random coefficient models, the intercept and slope parameters for the relation between feeding rate (or feeding-bout length) and chick age for each nest are considered to be a random sample from a population of possible model coefficients (Littell and others, 2006). Therefore, a model is fit, including an intercept and slope parameter, for each nest as random coefficients. Because there were some missing combinations of study area, year, and fate, only the study area by year by fate interaction term was included as a fixed factor in the model, along with age and the interaction between age and study area by year by fate. Least squares means were estimated for each combination of study area, year, and fate at several ages (2, 5, and 8 days old). Contrasts were conducted to compare these means among study area by year by fate combinations.

Movements and Wetland Use by Adult Pelicans

Capture and Satellite-Transmitter Tagging of Adult Pelicans

Modified and padded leg-hold traps were used to capture adult pelicans at loafing sites near nesting areas (King and others, 1998). Bill length was used to assess gender of captured adult pelicans (Dorr and others, 2005). Pelicans with culmen length less than or equal to (≤) 309 millimeters (mm) were classified as female and those greater than or equal to (≥) 310 mm were classified as male.

We attached 70-g solar-powered GPS satellite transmitters (platform transmitter terminals [PTT], Microwave Telemetry, Inc. PTT100) to captured adult pelicans. The transmitters weighed approximately 1 percent of this species' average body mass. Two-loop body harnesses made of Teflon ribbon were used to secure transmitters to the backs of the pelicans. The harness design followed Dunstan (1972) with modifications by D.T. King (U.S. Department of Agriculture, National Wildlife Research Center, 2005, oral commun.).

The transmitters deployed in May and June 2005 were programmed to acquire 24 GPS locations per day at 1-hour intervals year-round. The transmitters functioned relatively well; however, we discovered that not all 24 locations per day were successfully transmitted from the satellite, which resulted in unpredictable data gaps. Additionally, some of the transmitters began to exhibit low battery problems in late summer and fall 2005 as day length decreased. To address these issues, programming of transmitters deployed in 2006 was changed to acquire 19 GPS locations per day (5 fewer locations at night) from April through September and 3 GPS locations per day (at 6-hour intervals) from October through March.

Microwave Telemetry, Inc. listed the GPS accuracy for latitude/longitude coordinates from these transmitters as plus or minus (±)18 meters (m). Coordinates of pelican locations, direction and speed of movement, and altitude were collected through the Argos satellite system (Service Argos, 2008). We conducted spatial analyses of GPS locations and habitat layers with ArcGIS (ESRI, 2011).

On a few occasions, GPS locations could not be obtained but satellite locations were still available. In these cases, because satellite locations are not as accurate (for example, the most accurate class is defined as ± 150 m), we used the satellite locations to ascertain the general area in which the bird had been, but these locations were not included in the analyses.

Our goal was to tag with satellite transmitters approximately equal numbers of male and female pelicans. Location data were expected to help assess (1) colony attendance; (2) foraging site locations, characteristics of those sites, and distances from the colony; (3) area use; and (4) migration routes and wintering areas. Because there was little evidence that tagged pelicans attended nests in the years after they were tagged, most of our telemetry data addresses (1) wetland use by pelicans, (2) areas of activity in the breeding region, and (3) migration routes and wintering areas. However, we include descriptions of colony attendance and distance to foraging sites for the pelicans that appeared to make a breeding attempt.

Wetland Use by Satellite-Tracked Pelicans

Pelican locations acquired with satellite transmitters were summarized to examine the types and sizes of wetlands used within the area east of the Missouri River in both South Dakota and North Dakota. We focused our analyses on the area east of the river because, during the breeding season, the vast majority of pelican locations occurred there. Data were collected during 2005–8 with individual pelicans being satellite-tracked from 1 to 4 years. For analyzing types and sizes of wetlands used, each pelican in each year was treated as an independent experimental unit.

The National Wetland Inventory (NWI, U.S. Fish and Wildlife Service) inventoried and mapped wetlands in the region in the late 1970s and early 1980s. NWI classified the zones within a wetland basin by type (temporary, seasonal, semipermanent, lake, or riverine; see descriptions in Cowardin and others, 1979). We classified each wetland basin by the deepest part of the wetland; these data served as our base maps, but we recognized that water conditions during the years of our data collection were different from those during the years of the inventory. This study was conducted when some wetland basins contained more water than when the wetlands were inventoried, although the years of our study and years of the wetland inventory were both conducted during wet cycles. The higher water conditions sometimes resulted in shifting type to more permanent conditions (for example, seasonal to semipermanent) than the classification. If two or more wetlands merged because of high water conditions, we classified the entire wetland by the most permanent wetland classification among the wetlands that combined into one basin. Wetland use was estimated by basin type for each pelican-by-year combination by computing the percentage of telemetry locations within each of the five basin types. These percentages were then averaged across pelicans for the State to get an estimate of the average use of each basin type. The percentage of wetlands used in each basin type was compared to the percentage available within each type. Percentage available was computed from the total wetland area within each type in the part of the State east of the Missouri River. Chi-square analyses were used to test if all pelicans were using wetland types similarly and if use was proportional to availability (Manly and others, 2002). For further comparison, selection ratios for each type were computed for each pelican-by-year combination (Manly and others, 2002). These selection ratios were then averaged across pelicans, and Bonferroni confidence intervals were computed for the mean selection ratio for each wetland type. A selection ratio greater than one indicated selection for that wetland type and a selection ratio of less than one indicated selection against that wetland type. If the value of one is included within the confidence interval, then there is no support for saying that the pelicans, on average, selected for or against that wetland type.

Distribution of wetland sizes for used wetlands was estimated by computing the minimum, maximum, and 10, 25, 50, 75, and 90th percentiles for the subset of wetlands used by pelicans at least once during the 4 years. The distribution of wetland sizes for the full set of available wetlands also was computed.

For a subset of the location and wetland data, that is, the USFWS's Waubay Wetland Management District in northeastern South Dakota, areas within individual wetlands being used by monitored pelicans were examined to gain insight to how wetlands are being used by the pelicans. To facilitate this, we plotted pelican GPS locations on 2006 imagery from the National Agriculture Imagery Program (NAIP) to which we added the GIS layer of NWI wetland borders.

To help identify specific wetland areas of potential conservation value for pelicans, we examined GPS locations in North and South Dakota to find any wetland areas that were used repeatedly by more than one tagged pelican. We combined GPS locations of nonflying pelicans (that is, pelican speed <4 kilometers per hour [km/h]) across pelicans but separated by year and State before applying a k-means clustering method (Anderberg, 1973). Because the number of pelican locations varied greatly among years and States, the number of clusters requested in the clustering method varied with the sample size of each year and State combination. From the resulting clusters, we deleted any that did not include at least 20 locations each from at least two pelicans. The FASTCLUS procedure in SAS (SAS Institute, 2010) was used to create clusters and calculate their centroids. We then plotted clusters and centroids for each year and State combination on imagery from the Environmental Systems Research Institute (ESRI) to identify underlying wetland areas.

Results

Breeding Biology and Behavior

Spring Arrival and Subcolony Selection

Pelicans began to arrive at Bitter Lake and Chase Lake in late March 2006 and early April in 2007 and 2008. Each year, egg laying began during the second and third weeks of April. Nest initiations continued through May, with a few as late as mid-June, each year.

Bitter Lake

Five subcolonies (islands) were selected by the pelicans for nesting at Bitter Lake in 2006 (fig. 4; Subcolonies 1–5). Subcolonies 1–3 were also used in 2004 and 1–4 were used in 2005. Subcolony 5 was a newly initiated nesting site in 2006, with the first eggs laid around June 10. In 2007, four islands (fig. 4; Subcolonies 1, 2, 3, 5) were used for nesting. Additionally, around April 19, pelican initiated nests at a new subcolony (6) located on the mainland shoreline in a pasture, but the subcolony was abandoned by April 23 because of disturbance by cattle. In 2008, pelicans nested on Subcolonies 1, 2, 3, and 4. In 2009, although field personnel were no longer at Bitter Lake, we conducted aerial surveys to estimate the number of nests initiated at the colony. That year, Subcolony 1 was inundated and no habitat was available, but nesting occurred on Subcolonies 2, 3, 4, 5, and 6, and nests were initiated at new sites on three other islands (7, 8, 9). In 2010, no survey flight was conducted, but USFWS personnel (Waubay National Wildlife Refuge) noted that the only nesting at Bitter Lake was on a newly formed island along the southern shoreline of the lake.

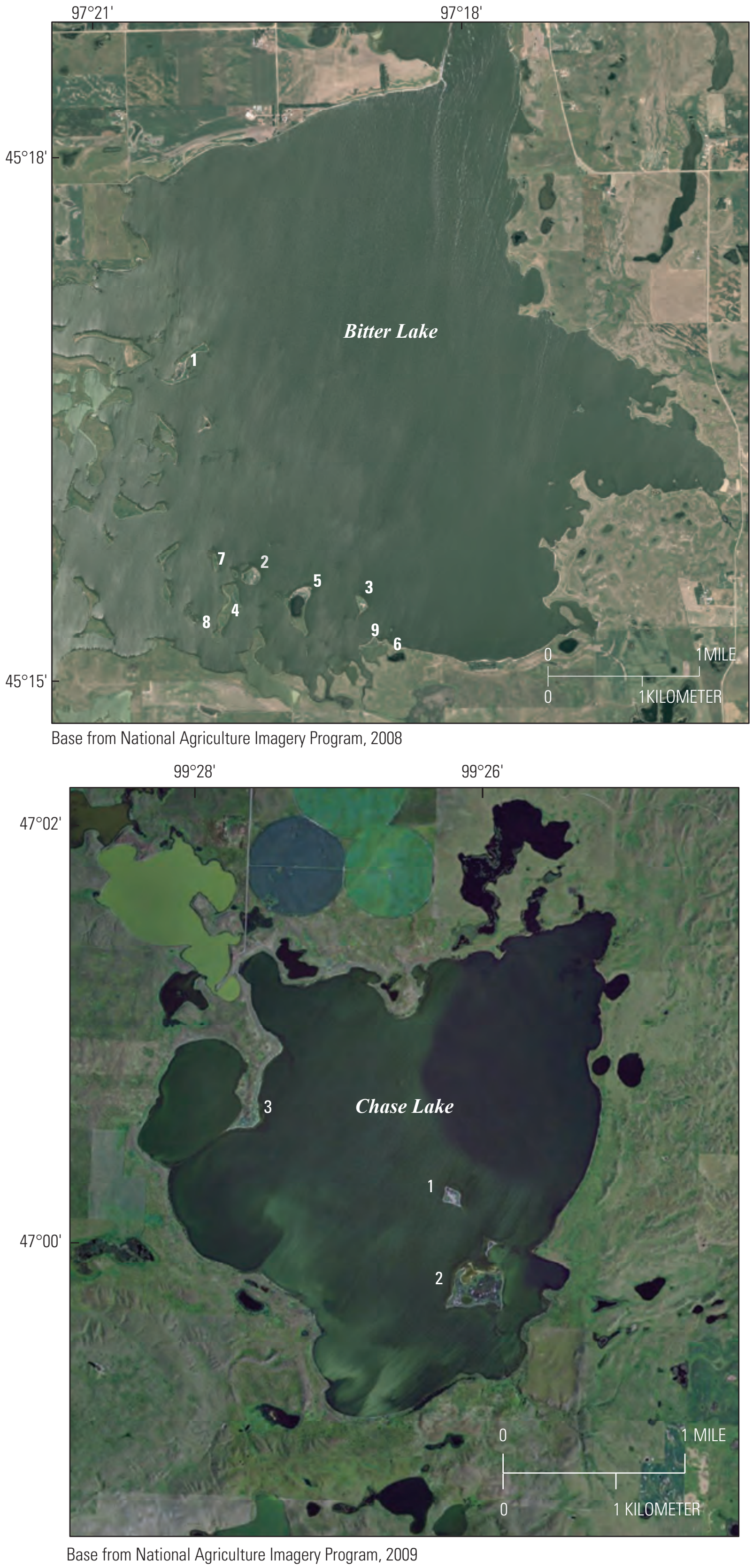


Figure 4. Nine subcolony sites used by American white pelicans at Bitter Lake, South Dakota, and three subcolony sites used at Chase Lake, North Dakota, 2006–9.

Chase Lake

During the period of this study, pelicans selected two islands for nesting in Chase Lake (fig. 4). Pelicans began to nest on the north island (Subcolony 1) in 1995 when the original two nesting islands (nesting documented on original islands for over 100 years) were getting smaller as the lake level rose (Sovada and others, 2005). Subcolony 2 (south island) was first used for nesting in 2002, accommodating 5 percent of the colony's nests that year. By 2005, Subcolony 2 contained the majority (81percent) of the nests. Subcolony 3 (peninsula) was the main nesting site from 1999 until 2004, but the site was abandoned in 2004 following disturbance by coyotes. In 2010, pelicans once again used the site for a small number of nests (table 1). We first detected evidence of pelicans on nests on the north island each year (April 11, 2006, April 19, 2007, and April 22, 2008).

Nest Surveys

Bitter Lake

In 2006, aerial and ground counts resulted in an estimate of 15,385 nests at five subcolonies at Bitter Lake (table 1). In 2007, combined data from aerial photographs and ground counts indicated 14,863 nests initiated at four subcolonies (1, 2, 3, 5, 6). In 2008, we counted 12,946 nests at four subcolonies (1, 2, 3, 4). In 2009, Subcolony 1 was completely inundated and no nesting habitat was available; Subcolonies 2–6 had 9,508 nests and an additional 1,285 nests were initiated at three new subcolonies (7, 8, 9). In 2010, we did not count nests, but all islands previously used for nesting were inundated and a small group of pelicans nested on a newly formed island near the south shore of the lake.

Chase Lake

Nests at Chase Lake were counted each year from aerial photographs; additionally, small groups of nests located under shrubs were counted with ground surveys. The two islands held 17,302 nests in 2006, 11,262 nests in 2007, and 11,541 nests in 2008 (table 1). In the following two years, all nests were visible on aerial photographs; counts revealed 7,236 nests in 2009 and 10,235 nests in 2010 (table 1).

Table 1. Nest initiation dates and numbers of American white pelican nests and chicks for individual islands in Bitter Lake, South Dakota, and Chase Lake, North Dakota, 2006–8.

[Some data for 2009 and 2010 are included in the table, although the colonies were not intensively studied during these years]

	Bitter Lake subcolonies									Totals
	1	2	3	4	5	6	7	8	9	
2006										
Nest initiated	April 12	April 9	April 12	April 29	June11					
Number nests	9,691	1,661	3,336	647	50	0	0	0	0	15,385
Number chicks (July 17)	6,635	957	1,207	287	10					9,096
2007										
Nest initiated	April 12	April 16	April 16		May 7	April 19[1]				
Number nests	11,358	1,432	1,175	0	748	150	0	0	0	14,863
Number chicks (July 16–20)	4,240	315	275		140	0				4,970
2008										
Nest initiated	April 14	April 25	April 25	April 29						
Number nests	7,518	2,645	544	2,239	0	0	0	0	0	12,946
Number chicks (July 14)	2,119	427	41	592						3,179
[2]2009										
Number nests	[3]0	3,094	188	4,172	1,739	315	25	994	266	10,793
[2]2010										
In 2010, a systematic nest count was not conducted; however, National Agriculture Imagery Program (NAIP) for Bitter Lake showed all nesting islands were inundated. An unknown number of pelicans nested on a newly formed island along the southern shoreline; success of the colony in 2010 was unknown.										

	Chase Lake subcolonies			Totals
	1 North	2 South	3 Peninsula	
2006				
Nest initiated	April 11	April 13		
Number nests	3,202	14,100	0	17,302
Number chicks (July 14)	2,495	8,525		11,020
2007				
Nest initiated	April 19	April 23		
Number nests	10,105	1,157	0	11,262
Number chicks (July 17)	52	268		320
2008				
Nest initiated	April 22	April 25		
Number nests	2,716	8,825	0	11,541
Number chicks (July 17)	23	57		80
[2]2009				
Number nests	2,135	5,101	0	7,236
[2]2010				
Number nests	1,142	8,451	642	10,235

[1]In 2007, nests were initiated on mainland Subcolony 6 around April 19, but the colony was abandoned on April 23 after cattle disturbed adult pelicans.

[2]In 2009 and 2010, field personnel did not work at either colony, thus phenology data were not collected.

[3]In 2009, Subcolony 1 was inundated, thus no habitat was available for nesting.

Chick Surveys

Bitter Lake

Newly hatched chicks were first observed on May 9, 2006, May 17, 2007, and May 14, 2008. On July 17, 2006, we obtained air photographs of the subcolonies at Bitter Lake from which 9,096 chicks were estimated to be present (table 1). In 2007 and 2008, aerial photographs of the subcolonies were not available, but with ground surveys, we counted 4,970 chicks on July 16–20, 2007, and 3,179 chicks on July 14, 2008 (table 1).

In 2006, our last visit to the subcolonies was on September 5 and most chicks had departed; approximately 150 chicks remained on the islands and most of these young could fly. Seven chicks located together on Subcolony 5 were too young (approximately 8 weeks old) to fly; however, based on their condition, they were still being fed by adults. In 2007, our last visit to the subcolonies was on September 12; approximately 101 chicks remained and most of these chicks could fly. In 2008, our last visit to the site was on August 23; approximately 235 chicks remained on the islands. All remaining chicks seemed in good condition, and it is likely that many could fly.

Chase Lake

Newly hatched chicks were first observed at Chase Lake on May 9, 2006, May 18, 2007, and May 19, 2008. In 2006, we estimated the presence of 11,020 chicks from aerial photographs taken on July 14 (table 1). In 2007, we estimated the presence of 320 chicks from a ground count on July 17 (table 1). On July 17, 2008, ground counts yielded 80 surviving chicks at Chase Lake (table 1).

In 2006, our last assessment of chick status at the colony was on August 21; on that date, deaths caused by WNV had diminished and were almost undetectable. The majority of chicks had dispersed away from the nesting areas and approximately 1,000 to 1,500 chicks remained at the colony. These chicks seemed in good condition. In 2007, our last visit to the island was on August 22; 177 healthy chicks and 2 moribund chicks were present in the nesting area. The majority of these chicks could fly. In 2008, our last assessment of chick status was on August 12; 78 apparently healthy chicks were present and all could fly.

Monitored Nests

Bitter Lake

Video data were examined from 82 pelican nests at Bitter Lake during the 2006–8 nesting seasons (table 2). The 82 nests collectively were monitored for 14,085 hours (appendix A). Success rate was 89 percent for 9 monitored nests in 2006, 40 percent for 25 nests in 2007, and 67 percent for 48 nests in 2008. Overall, we monitored 58 nests in which two eggs were detected; both chicks reached crèche stage at only two of these nests. Fifty-seven percent of the two-egg nests had at least one chick reach crèche stage. We monitored 23 nests in which only one egg was detected during the period the nests were monitored; 74 percent of these nests were successful. Note that most nests were not monitored early in the incubation stage at either colony, and some eggs likely were lost before monitoring began.

Chase Lake

Video data were examined from 88 nests at Chase Lake during the 2006–8 nesting seasons (table 2). The 88 nests collectively were monitored for 11,392 hours (appendix A). Success rate was 69 percent for 26 nests monitored in 2006, 43 percent for 53 nests monitored in 2007, and 100 percent for 9 nests monitored in 2008. Overall, we monitored 44 nests in which two eggs were detected; both chicks reached crèche stage at only one of these nests. Fifty-two percent of the two-egg nests had at least one chick reach crèche stage. We monitored 54 nests in which only one egg was detected; 48 percent of these resulted in a crèche-aged chick. The number of eggs in one nest was uncertain because of poor visibility; that nest was successful.

Causes of Egg and Chick Loss

We documented siblicide, severe weather events, predation, and disturbance as contributing factors to early season (before mid-July) egg losses and chick deaths. In the late season (mid-July to fledging), WNV was the most important cause of chick deaths.

West Nile Virus

Detailed results for the assessment of the impact of WNV on pelican productivity are reported in Sovada and others (2008). In brief summary, during 2004–7 three major colonies in the northern plains—Bitter Lake, Chase Lake, and Medicine Lake—were intensely monitored to assess mortality of chicks during the late breeding season. WNV was first detected in the region in 2002 (Ginsberg 2003). Before that, documented chick mortality rates in the late breeding season were less than 5 percent, including reports from Medicine Lake and Chase Lake in 1999–2002 (Sovada and others, 2008), Chase Lake in the 1970s (Strait, 1973), and Marsh Lake before 2002 (J. DiMatteo, North Dakota State University, oral commun., 2008). In the years since WNV arrived in the region, it has contributed significantly to chick deaths in the late breeding season, with mortality rates as high as 25 percent at Bitter Lake, 40 percent at Chase Lake, and 44 percent at Medicine Lake (fig. 5; Sovada and others, 2008).

Table 2. Number of American white pelican nests by clutch size and fate, number of unhatched eggs, number of chicks, and likely causes of chick mortalities for nests monitored with video recordings at Bitter Lake, South Dakota, and Chase Lake, North Dakota, 2006–8.

Year	Number of nests (successful[1], failed, unknown)			Number of unhatched eggs	Number of chicks			Likely causes of chick mortalities			
	2-Egg nest	1-Egg nest	Unknown eggs[2]		Total hatched	Crèched	Unknown fate[3]	Siblicide[4]	Predation[5]	Weather[6]	Unknown cause
Bitter Lake											
2006	8,1,0	0,0,0	0,0,0	5	13	8	1	3	1	0	1
2007	5,11,0,	5,3,0	0,1,0	[7]22	19	12	5	0	2	0	0
2008	20,13,0	12,3,0	0,0,0	36	59	32	16	4	0	5	2
Chase Lake											
2006	8,6,0	10,2,0	0,0,0	4	36	17	6	6	0	0	6
[8]2007	6,14,1	16,14,1	1,0,0	23	62	23	5	5	0	32	0
2008	9,0,0	0,0,0	0,0,0	3	15	9	0	[8]6	0	0	0

[1]Nests that had at least one chick leave to crèche were categorized as successful.

[2]Unknown number of eggs in these nests because camera view was obstructed.

[3]For this subset of nests, chicks were 7 to 10 days old when camera surveillance was discontinued, thus fate could not be determined.

[4]If a chick with a surviving sibling was observed dead in the nest bowl at less than 7 days old, and sibling aggression had been observed, cause of death was assumed to be siblicide.

[5]In all three cases, one chick was taken from under a brooding adult pelican by a black-crowned night-heron (*Nycticorax nycticorax*).

[6]Chicks were young and sibling aggression could have factored into the weather-related mortalities.

[7]At one nest, an adult male tending a single-egg nest threw the egg out of the nest prior to its hatch date. The nest was then abandoned.

[8]Severe weather cannot be ruled out as a factor for some of these mortalities, but typically very young chicks are brooded by adults, affording them protection from severe weather. Therefore, despite the occurrence of severe weather, in these cases siblicide was believed to be the cause of death.

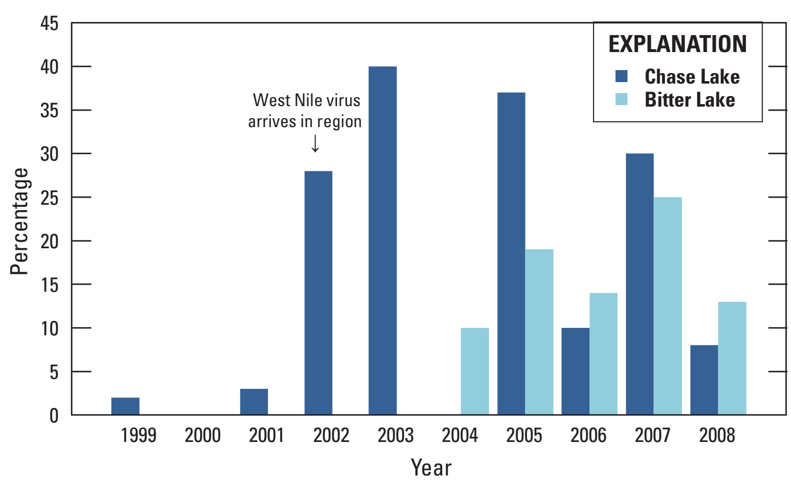


Figure 5. Percentage of banded American white pelican chicks that were recovered mid-July to early September at Bitter Lake, South Dakota, and Chase Lake, North Dakota. West Nile virus (WNV) arrived in the region in 2002. Diagnostic results from samples of dead chicks in 2002–8 indicate WNV likely caused the majority of late-breeding-season chick mortality (Sovada and others, 2008).

Siblicide

Returning to early season sources of chick mortality, sibling aggression occurred frequently in the pelican colonies we monitored and is commonly observed in colonies throughout the species' range (Knopf and Evans 2004; fig. 6). At Bitter Lake, sibling aggression led to 7 chick deaths among the 29 video-monitored nests known to have 2 chicks hatch. At Chase Lake, among 34 monitored 2-chick nests, 17 chicks died with circumstances that fit criteria for assigning cause of death to siblicide. Ultimately, only 1 chick survived per nest at 65 of the 68 monitored 2-chick nests.

Figure 6. American white pelican siblings illustrating aggression (top) and size dimorphism (bottom) with the smaller chick showing signs (dorsal contusions) of aggression by its nest mate.

Severe Weather

Two major storm events occurred at Bitter Lake in 2008; one caused significant chick mortality. On June 11, a severe thunderstorm with hail occurred, which was followed by 3 days of cold, wet, windy conditions. Approximately 1,000 pelican chicks died during this event. It is difficult to positively assign cause of death to the weather event, but chicks that died were especially vulnerable because they had reached the age (12–19 days old) at which their parents stop brooding them and they begin to form crèches to help retain warmth. The second severe storm occurred on July 31, 2008; unrelenting strong winds (up to 185 km/hr) were recorded for about 45 minutes. On one island, trees and branches were downed and the heron/egret colony suffered some damage, but no significant loss of pelican chicks was detected.

Weather was more problematic at Chase Lake. In 2005 (not a year that nests were monitored with cameras) on June 16, one-half of approximately 1,600 chicks on the north island were found dead. Carcasses were not fresh enough to determine cause of death. Nonetheless, it is likely that cool (lows around 10 °Celsius [C]), wet, windy weather during the previous week contributed to these deaths (and also prevented access to the islands by researchers). As at Bitter Lake, these chicks were at a vulnerable age between being brooded and forming crèches. Another catastrophic weather event during the night of July 2–3, 2005 (sustained winds of 80–97 km/hr), likely caused deaths of approximately 1,500 chicks, which were discovered on all islands at Chase Lake on July 5, 2005. Dead chicks were found, often in piles, already too decomposed for necropsy. In 2006, severe weather on June 8–10 caused deaths of approximately 400 chicks at Chase Lake. Again, chicks that died were approximately 2–4 weeks old, the vulnerable transition period between brooding and crèching.

In 2007, the Chase Lake colony once again suffered nearly complete failure in productivity (table 1), at least partly because of weather. From May 1 to June 18, Chase Lake received 260 mm (10.18 in.) of rain; 149 mm (7.85 in.) of that rain came in a 3-week period (May 29–June 18). Average rainfall for this period is less than 76 mm. Moreover, daily low temperatures were -1 to 4 °C (30–39 °Fahrenheit [F]). The earliest nests initiated would have hatched around May 19. During late May and particularly early June, many chicks would have been vulnerable to severe weather. On June 5, we began to see the effects of cold, wet, windy weather. Dead chicks in nests were observed on the east side of the north island (nests that hatched around May 20). Among nine nests located nearby that were being video monitored during this period, six failed probably because of infrequent parental exchanges and chick feedings, and poor attendance by adults when chicks needed thermal protection. We continued to observe chick losses through the month of June. On June 28, a conservative ground count of chicks indicated a minimum of 531 on the south island and fewer than 50 chicks on the north island (we assumed that some chicks were not detected because of high vegetation.). There were two small groups of adults that appeared to be sitting on nests with young chicks (we did not disturb these birds to verify).

In 2008, cold rainy weather, largely during the first 2 weeks of June, again impacted chick survival at Chase Lake. Nearly 130 mm (5 in.) of rain fell during that period; it rained during 11 of the first 14 days of June. The daily low temperatures were 7–10 °C (44–50 °F), and were as much as 11 °C (19 °F) colder than in the same period in 2006. We visited the islands on June 10, 2008, and observed that a large portion of the chicks between 2 and 3 weeks old were dead; many surviving chicks were observed shivering in 10 °C (50 °F) weather. We estimated that chicks from 1,700 nests could have been at vulnerable ages. In areas on the islands that appeared most affected, we counted 50 dead chicks for every 10 chicks alive and healthy. The dead chicks seemed to be in excellent body condition just prior to death based on their ample weight, no evidence of excessive lice or tick infestations, and healthy looking internal organs. Some of the dead chicks were found in small groups of 3–4 chicks; but most of the dead chicks were associated with nest bowls. The nests with eggs or with chicks younger than 2 weeks old and tended by an adult appeared normal. Because evidence so strongly suggested weather-related deaths, carcasses were not tested for disease. We believed the prolonged poor weather resulted in the loss of at least 1,400 chicks. The weather continued to be relatively poor through June, with another 40 mm (1.5 in.) of rain, and daily low temperatures of 8–13 °C (46–56 °F). There continued to be a gradual loss of chicks during the month of June.

Documented Predation

We documented incidents of predation of both eggs and chicks. A gull was recorded (likely a California gull *Larus californicus*) taking eggs from three unattended nests. Gulls also were recorded pecking at abandoned eggs in view of the camera at both Bitter Lake and Chase Lake. Black-crowned night-herons (*Nycticorax nycticorax*) were recorded stealing chicks from under sleeping adults (fig. 7) at Bitter Lake on three occasions, once in 2006 and twice in 2007. Chicks were 1, 6, and 9 days old. A night-heron was recorded making repeated attempts to steal chicks from under brooding adults at other nests. The night-heron showed no interest in nearby abandoned eggs that were readily available but did consume a dead pelican chick that had been tossed away from its nest. A striped skunk (*Mephitus mephitus*) also was recorded walking through an area with nests on the largest island (Subcolony 1, fig. 4) at Bitter Lake. Adult pelicans jabbed at the skunk; the skunk appeared to spray but did not threaten eggs or chicks.

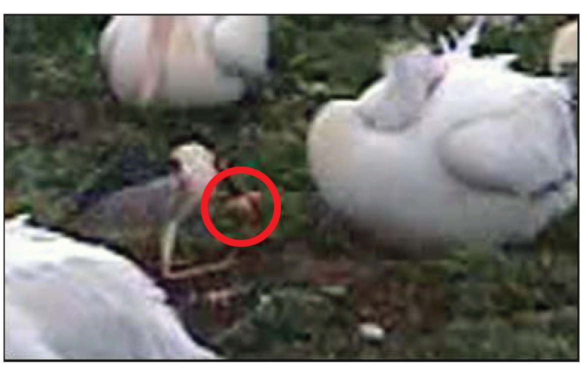


Figure 7. Black-crowned night-heron (*Nycticorax nycticorax*) taking a pelican chick (approximately 1 or 2 days old) from under an adult American white pelican that was asleep on its nest at Bitter Lake, South Dakota.

Other Disturbances

On April 19, 2007, we counted approximately 150 nests located in a pasture on the mainland along the south shore of Bitter Lake (Subcolony 6). About 5 days after these nests were initiated, the adults abandoned the subcolony, likely as a result of disturbance by cattle. On one occasion in 2008, anglers disembarked on a Bitter Lake island with a pelican subcolony that included active nests and chicks at the crèche stage. The anglers were intercepted by our field biologist who was present on a nearby island, and the anglers left without disturbing the pelicans.

At Bitter Lake during May 15–25, 2007, 10 nests in one camera view failed during the incubation stage. Compared to other pelicans being monitored by cameras, the adults tending these nests displayed unusual behavior, appearing agitated and repeatedly reacted to something off camera. Because the adults' attention was diverted and they temporarily moved off their nests, gulls were able to depredate eggs from three nests in this group (reported above). An adult pelican from one nest tossed both eggs out of its neighbor's nest and then returned to an incubation posture; the explanation for this behavior is unknown. Among all nests monitored with cameras, this group of nests was located closest to the water. It is possible that boating activity influenced the attending adults, although other possible explanations cannot be ruled out.

Nest Attendance

Male and female adult pelicans share the incubation of eggs and the brooding and feeding of chicks. Nests were nearly always attended by one adult during incubation and the period between hatch and crèche stage (fig. 8). After hatch, some adults gradually left chicks unattended for longer periods, but rarely left them alone for more than an hour (cumulatively) of the day (fig. 8). During the few occasions that chicks were observed at crèche stage, adults only visited these chicks long enough to feed them; however, a few adults were always at the colony with the chicks.

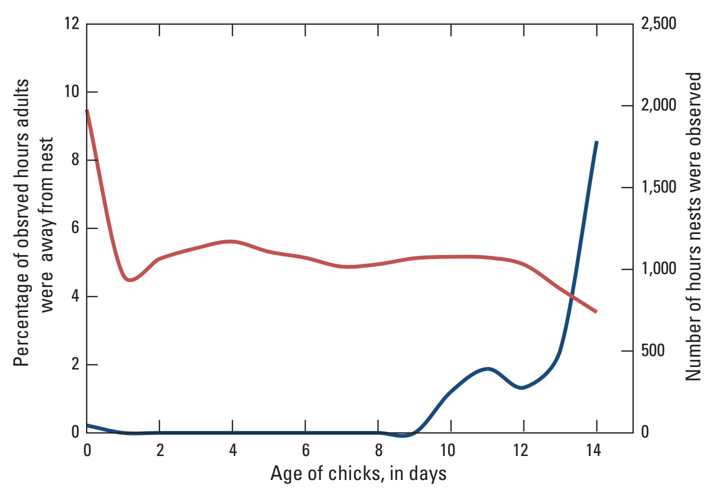


Figure 8. Percentage of time that American white pelican adults were away from their nests containing egg(s) or chick(s) that were less than 15 days old (blue line) compared to the number of hours recorded at those nests (red line) at Bitter Lake, South Dakota, and Chase Lake, North Dakota, 2006–8.

Most often, adults exchanged places at the nest in early afternoon (table 3, fig. 9a, b). Overall, the mean time of day for exchanges at Bitter Lake was 1328 central standard time (CST) (n = 25 pairs, SD = 69 minutes, 2006–8). There was no difference in time of exchange at different stages of nesting ($F_{4,123} = 0.10$, P = 0.98). We found no variation in the average time of exchange among the 3 years of the study at Bitter Lake (fig. 9a; $F_{2,72} = 0.11$, P = 0.90). This lack of annual variability also was true for Chase Lake exchanges ($F_{2,69}$ = 2.16, P = 0.12); however, there was a difference between the study areas (fig. 9b, $F_{1,2} = 29.09$, P < 0.0001), with Chase Lake exchanges occurring later in the afternoons (mean time = 1434 CST, SD = 79 min, n = 72 pairs, 2006–8).

Table 3. Mean time of day that adult American white pelicans exchanged egg- or chick-tending responsibilities, weighted by samples size for individual pairs.

[CST, central standard time; n, number of pairs sampled; SD, standard deviation in minutes]

Year	Bitter Lake			Chase Lake		
	n	Mean time (CST)	SD (min)	n	Mean time (CST)	SD (min)
2006	9	1334	115	20	1406	178
2007	21	1326	208	43	1438	132
2008	45	1325	171	9	1426	162
Overall	75	1328	174	72	1423	152

The period of time between parental exchanges depended on the stage of the nest. During incubation, often nearly 3 days passed between exchanges (fig. 10). Once chicks were hatched and needed to be fed, exchanges typically occurred daily.

Chicks began to stand and walk at approximately 10–12 days, at first remaining close to the nest and gradually moving out of camera view for longer periods. We observed chicks start disassociation from 35 nests at an average age of 16 days (range 10–24 days). At another 22 nests with chicks that survived beyond 16 days (range 16–19), we did not see any movement away from nests (mean chick age when monitoring ended was 17 days old). Cameras were not left at a site long enough to adequately assess the oldest age or an overall average age that chicks remain associated with their nests.

For 132 nests with chicks, adequate data were collected to compare the parental exchange rates of successful and unsuccessful nests (table 4). Most failed nests were observed for less than 11 days after hatch; however, a few were observed for more days. Successful nests were observed up to 23 days after hatch. The exchange rate varied among study area by year by fate combinations ($F_{9,122} = 8.72$, P < 0.001). Adult exchanges were more frequent at successful nests than failed nests in all testable combinations of study area and year (Bitter Lake 2007: P = 0.030; Bitter Lake 2008: P = 0.009; Chase Lake 2006: P = 0.063; Chase Lake 2007: P < 0.001). Significant study area differences were observed only for successful nests in 2008 with exchanges between adults more frequent at Bitter Lake than Chase Lake (P = 0.004). Year differences were detected between 2006 and 2008 for successful

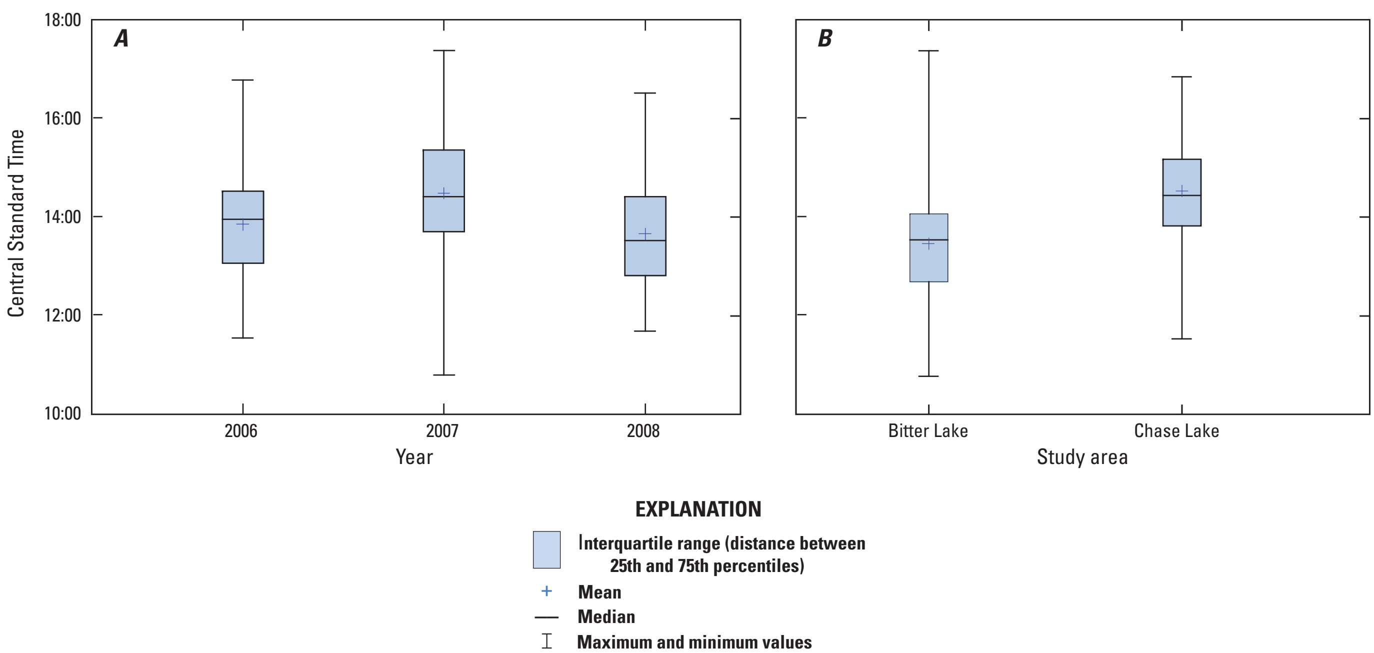


Figure 9. Times of day that American white pelican adults exchanged nest attendance duties. *A*, by year (2006–8) at Bitter Lake and Chase Lake colonies combined and *B*, by colony (Bitter Lake, South Dakota, and Chase Lake, North Dakota) for all years combined.

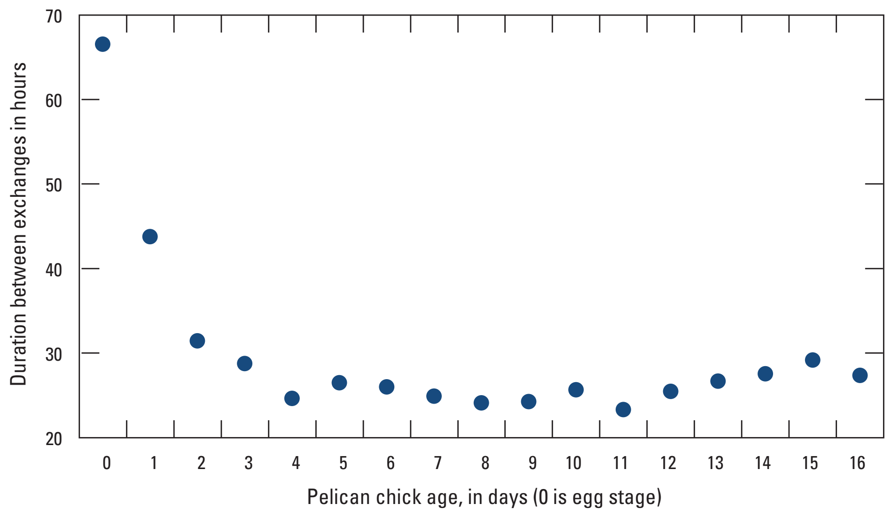


Figure 10. Average number of hours separating exchanges in attendance between male and female American white pelicans tending nests at egg stage and by age of oldest chick in individual nests at Bitter Lake, South Dakota, and Chase Lake, North Dakota, 2006–8.

nests at Bitter Lake ($P = 0.052$) and Chase Lake ($P < 0.001$), and between 2006 and 2007 at Chase Lake for successful nests ($P = 0.007$) and failed nests ($P = 0.003$). In all cases, exchange rates were greater in 2006.

Chick Feeding Rate

Chicks (≤10-days old) were fed less frequently as they aged (slope = -0.022, SE = 0.011, $t_{45} = -1.98$, $P = 0.05$; fig. 11), and this relation significantly differed among study area by year by fate combinations ($F_{9, 69} = 3.34$, $P < 0.01$). Significant differences were detected between successful and failed nests with chicks at 2 and 5 days old for Bitter Lake in 2008 ($P \leq 0.02$) and Chase Lake in 2006 ($P \leq 0.03$), also at age 8 days for Chase Lake in 2006 and 2007 ($P \leq 0.01$). In all cases, chicks at failed nests were fed less frequently than chicks at successful nests. Year differences were detected for successful nests for Chase Lake; chicks were fed more frequently in 2006 than in both 2007 and 2008 at ages 2 and 5 days (all $P \leq 0.03$). For successful nests at Bitter Lake, the feeding rate was higher in 2006 than in 2007 at age 2 days and was higher in 2008 than in 2007 at ages 5 and 8 days (all $P < 0.01$).

Chick Feeding-Bout Length

Average feeding-bout length increased with chick age (slope = 0.287, SE = 0.122, $t_{37} = 2.35$, $P = 0.02$; fig. 12); however, bout length did not significantly differ among study area by year by fate combinations ($F_{9,61} = 1.96$, $P = 0.06$). Nevertheless, prior comparisons of study areas, years, and fates had been conducted, and a few significant differences were found. For example, bout length was lower for failed nests than for successful nests at Bitter Lake in 2008 for chick ages 5 and 8 days ($P < 0.04$).

Evidence of Food Resources

Our study did not include a component to exhaustively identify or quantify the foods fed to chicks by adult pelicans. However, based on regurgitates (fig. 13) at the colonies, we have some information on what adults were feeding their chicks. Crayfish (*Cambaridae*), tiger salamanders (*Ambystoma tigrinum*), and minnows (*Cyprinidae*) were the most frequently identified contents in chick regurgitates. On occasion, we observed adult pelicans regurgitate fish (primarily

Table 4. Average (least squares means) number of exchanges per day (rate) between pair members of American white pelicans that were attending their chicks in nests monitored by video cameras at Bitter Lake, South Dakota, and Chase Lake, North Dakota, 2006–8.

[Includes data from nests with known status of chicks to age 14 days; n, number of pairs in the sample; SD, standard deviation, in minutes]

Study area	Year	Failed nests			Successful nests		
		n	Rate	SD (min)	n	Rate	SD (min)
Bitter Lake	2006	0	--	--	8	0.936	0.059
	2007	4	0.536	0.125	10	0.832	0.052
	2008	8	0.595	0.072	32	0.805	0.031
Chase Lake	2006	7	0.729	0.095	18	0.929	0.047
	2007	22	0.392	0.060	14	0.718	0.061
	2008	0	--	--	9	0.630	0.050

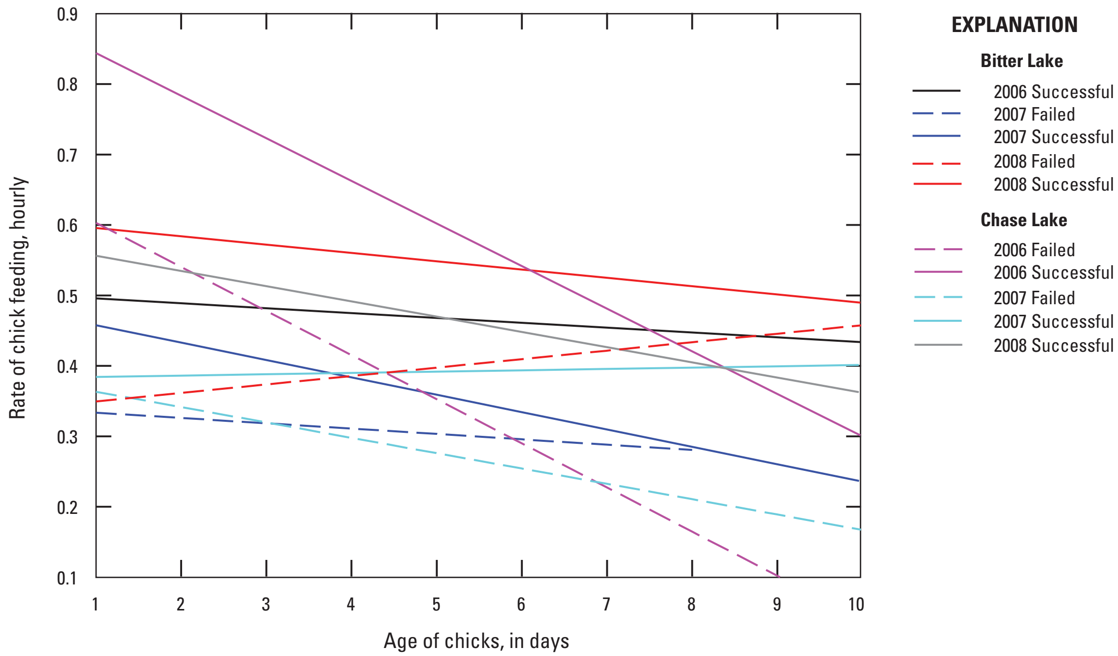


Figure 11. Relation between feeding rate and age of American white pelican chicks for each study area (Bitter Lake, South Dakota, and Chase Lake, North Dakota) by year (2006–8) by fate (successful or failed) combination.

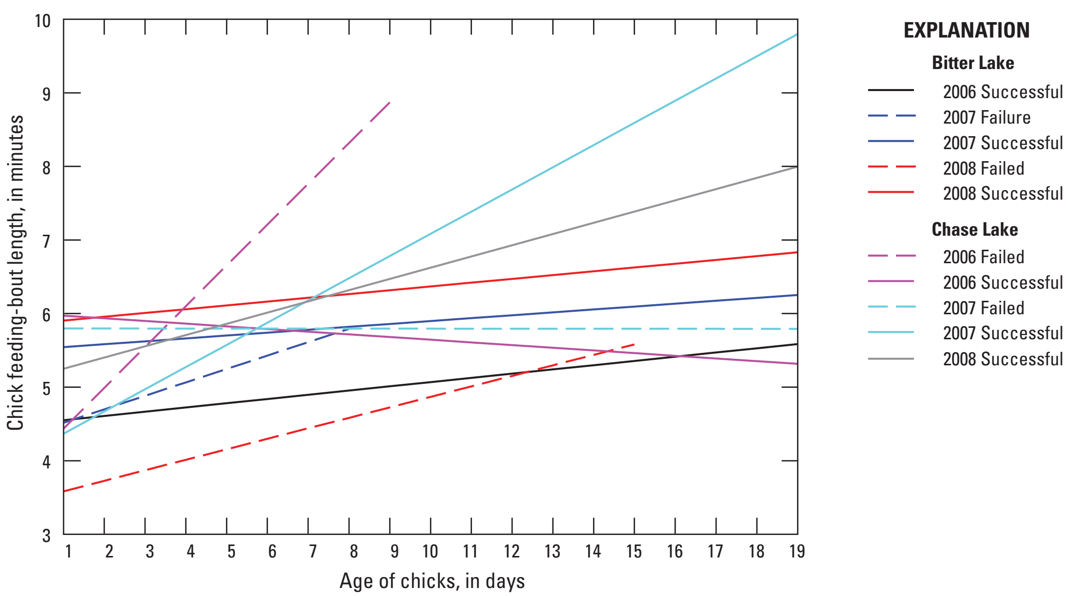


Figure 12. Relation between feeding-bout length and age of American white pelican chicks for each study area (Bitter Lake, South Dakota, and Chase Lake, North Dakota) by year (2006–8) by fate (successful or failed) combination.

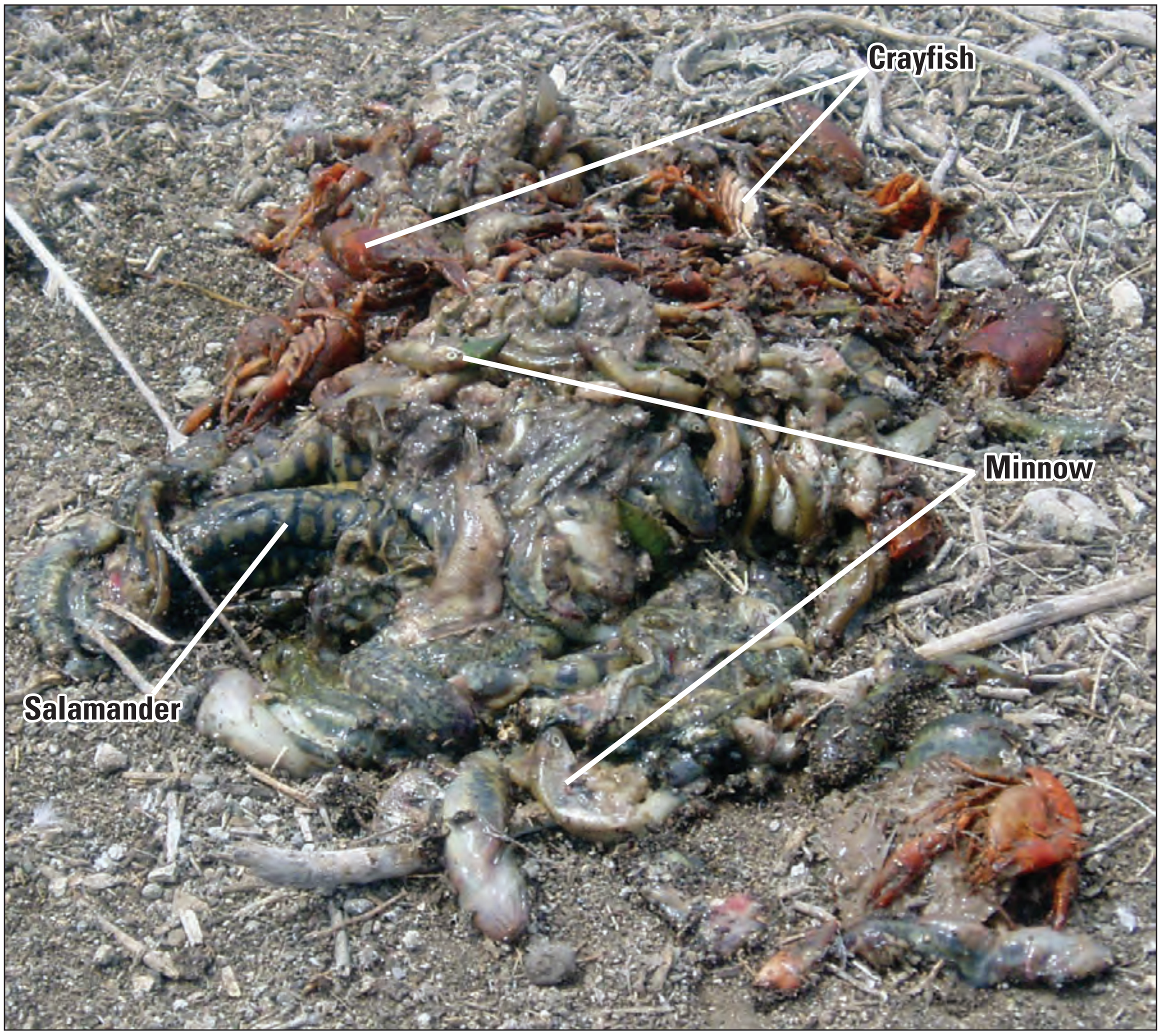


Figure 13. Regurgitate from an American white pelican chick at Bitter Lake, South Dakota. The most commonly observed food items in chick regurgitate were crayfish, salamanders, and minnows.

common carp, *Cyprinus carpio*) that were too large for chicks to swallow. One captured adult pelican regurgitated three fish, one 25-centimeter (cm) goldeye (*Hiodon alosoides*) and two 10 to 13 cm bullheads (*Ameiurus* sp.). These large items were reingested by an adult or left on the ground. Partially digested fish were not and perhaps could not be identified in regurgitates; yet, despite lack of regurgitate evidence from chicks, it is likely that some larger fish were occasionally fed to chicks.

Movements and Wetland Use by Satellite-Tracked Pelicans

Captured Pelicans

In 2005–6, we captured and attached GPS satellite transmitters to 28 adult pelicans, including 14 females and 14 males (table 5). Satellite-tracked pelicans included in analyses for this report were captured at Bitter Lake, Chase Lake, and Medicine Lake. Although the Medicine Lake colony was not a subject for this report, the pelicans captured there spent significant time in South Dakota and North Dakota; therefore, their locations were included in the analyses. All captured pelicans seemed to be in good health, and none were injured during capture.

Adult Mortalities and Transmitter Life

Definitive causes of death were not determined for any of the satellite-tracked pelicans, but circumstantial evidence suggested that at least one pelican was shot (21893 [PTT number], July 2005, North Dakota) and one collided with a high-tension power line (21925, November 2005, Kansas). Intact transmitters from two other pelicans were retrieved; however, with no carcass for one (21722, March 2006, Mexico) and only bones and feathers for the other (21311, September 2007, South Dakota), no attempt was made to speculate on cause of death for these two birds.

Table 5. Adult American white pelicans captured at Bitter Lake (South Dakota), Chase Lake (North Dakota), and Medicine Lake (Montana) that were tagged with 70-gram solar-powered satellite-received Global Positioning System (GPS) platform transmitter terminals, 2005–6.

[PTT, platform transimtter terminal; mm, millimeter; kg, kilogram]

Date	PTT number[1]	Band number	Sex	Culmen (mm)	Tarsus (mm)	Wing chord (mm)	Weight (kg)
Bitter Lake							
July 27, 2005	21945	509-85795	F	293	115	541	4.5
July 27, 2005	21878	509-85796	F	268	108	550	4.4
July 28, 2005	21893r	509-85797	F	304	112	557	5.0
June 6, 2006	64535	669-18684	F	275	108	550	3.9
June 6, 2006	21925r	669-18685	M	335	127	630	5.8
June 6, 2006	64537	669-18686	M	355	122	610	6.4
June 6, 2006	64532	669-18687	F	270	110	555	3.8
June 6, 2006	64539	669-18688	M	350	128	615	6.8
June 6, 2006	64534	669-18689	F	295	120	555	4.9
June 6, 2006	64536	669-18690	M	360	125	615	6.4
June 6, 2006	64538	669-18691	F	280	104	555	4.5
Chase Lake							
May 26, 2005	21922	509-85764	M	365	127	604	7.0
May 26, 2005	21893	509-85785	F	280	118	568	5.7
May 31, 2005	21917	509-85786	M	340	123	596	6.7
June 1, 2005	21932	509-85787	M	360	126	595	6.0
June 3, 2005	21913	509-85788	F	280	112	536	4.7
June 4, 2005	21925	509-85789	M	344	120	570	6.0
June 4, 2005	21959	509-85790	M	342	127	607	6.6
June 16, 2005	21944	[2]669-02752	F	284	110	562	3.4
June 1, 2006	64533	669-18682	F	275	109	550	5.2
June 1, 2006	64537	669-18683	F	284	124	545	4.1
June 1, 2006	64530	509-85798	F	303	111	570	4.3
June 10, 2006	21722r	669-18692	M	370	124	605	6.4
Medicine Lake							
June 7, 2005	21428	509-85791	M	335	123	575	5.4
June 7, 2005	21545	509-85792	M	365	130	608	7.8
June 8, 2005	21311	509-85793	M	334	121	627	5.5
June 9, 2005	21546	[3]649-03030	F	287	113	560	4.4
June 10, 2005	21722	509-85794	M	345	126	608	7.2

[1]A satellite-tag number ending in the letter “r” represents a transmitter that was redeployed on a second pelican after being recoved from a deceased pelican on which it was originally deployed.

[2]Banded as a chick at Chase Lake in 2000; 5-years old at time of capture.

[3]Banded as a chick at Chase Lake in 1998; 7-years old at time of capture.

Satellite tags of 17 pelicans stopped transmitting about 3 months to 3.5 years after deployment, with an average transmitting period of about 22 months. These tags may have stopped transmitting because the bird died in a position that prevented sufficient light from reaching the tag's solar panel (allowing the battery to drain), or because of failure of the transmitter.

An additional seven satellite tags were turned off in January and February 2009 after transmitting an average of more than 3 years (25 to 45 months). The pelicans wearing these tags seemed to be moving normally at the time their transmitters were turned off.

Wetland Use by Satellite-Tracked Pelicans

During the 4 years that satellite transmitters were monitored, 27 adult pelicans were located in wetlands in South Dakota east of the Missouri River. One pelican was found in this part of South Dakota in all 4 years, 7 in 3 years, 11 in 2 years, and 8 in just 1 year, resulting in 55 pelican-by-year combinations. Locations of 20 tagged pelicans occurred in North Dakota east of the Missouri River during the 4 years. One pelican was found in this part of North Dakota in all 4 years, 1 in 3 years, 7 in 2 years, and 11 in 1 year, resulting in 32 pelican-by-year combinations.

East of the Missouri River, in South Dakota there were 289,912 available wetland basins and in North Dakota there were 382,791 wetland basins. Within each wetland type, the average percentage of telemetry locations among pelicans (percentage used) and the percentage of total wetland area (percentage available) are listed in table 6. The average percentage of locations in lakes and semipermanent wetlands was greater than the percentage of those wetland types available in both South Dakota and North Dakota (table 6). Also in both States, the average percentage of locations in temporary and seasonal wetlands was less than the percentage of those wetland types available (table 6).

All chi-square tests were significant ($P < 0.001$) for comparisons of use and availability of wetlands for both South Dakota and North Dakota, indicating that pelicans did not use wetland types indiscriminately. The average selection ratio for each type and the Bonferroni 95-percent confidence intervals for these means are given in table 7. In both South Dakota and North Dakota, there was evidence of selection against temporary and seasonal wetlands and selection for lakes; semipermanent wetlands were used in proportion to availability. There was evidence of selection against rivers in North Dakota; however, rivers appeared to be used in proportion to their availability in South Dakota. The distribution of sizes (in hectares) for wetlands used at least once by pelicans is described by summary statistics in table 8. For comparison, summary statistics also are given for the full set of available wetlands. Within each wetland type in both States, the average size of the wetlands used by pelicans was larger than the average for that type. The minimum and maximum wetland sizes used within each type were often the same as what was available; however, the means, medians, and quartiles were invariably higher for the subset of used wetlands compared to the available wetlands.

Foraging Habitats

For pelicans with locations in USFWS Waubay Wetland Management District (Clark, Codington, Day, Grant, Marshall, and Roberts Counties), we calculated the proportion of locations that were within wetland boundaries delineated during the 1980 National Wetland Inventory (NWI) classification of wetland basins. Only 11 percent (161/1515), 6 percent (122/1929), and 28 percent (510/1823) of the pelican locations recorded in 2006, 2007, and 2008, respectively, were within a wetland as classified by NWI. These low percentages reflect the selection of shallow water for foraging. An example of foraging locations around Lynn Lake is illustrated in figure 14; the locations outside the blue shading were in areas flooded since NWI delineated wetland borders. These data also illustrate how water levels, and thus foraging habitats, in this area have changed over time.

Table 6. For each wetland type, the average percentage of telemetry locations among satellite-tracked American white pelicans (percentage used) and the percentage of the total wetland area (percentage available) east of the Missouri River in South Dakota and North Dakota, 2005–8.

Wetland type	South Dakota		North Dakota	
	Used, percent	Available, percent	Used, percent	Available, percent
Temporary	6.04	13.66	1.14	8.08
Seasonal	6.82	24.00	12.78	28.04
Semipermanent	40.64	34.33	33.22	29.67
Lake	42.71	24.80	52.29	32.11
Riverine	3.78	3.21	0.58	2.10

Table 7. Average selection ratios and the associated Bonferroni 95-percent confidence intervals (CI) for each wetland type, calculated from telemetry locations of American white pelicans east of the Missouri River in South Dakota and North Dakota, 2005–8.

[A selection ratio greater than one indicates selection for that type and a selection ratio of less than one indicates selection against that type. If the value of one is included within the confidence interval, then there is no support for saying that the pelicans, on average, selected for or against that type]

Wetland type	South Dakota			North Dakota		
	Selection ratio	Lower CI	Upper CI	Selection ratio	Lower CI	Upper CI
Temporary	0.44	0.20	0.68	0.14	0.04	0.24
Seasonal	0.28	0.08	0.48	0.46	0.13	0.78
Semipermanent	1.18	0.86	1.51	1.12	0.67	1.57
Lake	1.72	1.22	2.23	1.63	1.13	2.13
Riverine	1.18	0.00	2.36	0.27	0.00	0.58

Table 8. Summary statistics for the distribution of sizes, in hectares, of all wetlands east of the Missouri River in South Dakota and North Dakota and of wetlands that were used at least once by American white pelicans monitored with satellite transmitters, 2005–8.

[Min, minimum; P10, 10th percentile; Q1, first quartile; Med, median; Q3, third quartile; P90, 90th percentile; Max, maximum]

Wetland type		Mean	Min	P10	Q1	Med	Q3	P90	Max
South Dakota									
Temporary	Wetlands used	6.0	0.4	0.5	0.8	1.7	4.4	16.0	83.7
	All wetlands	1.2	0.4	0.4	0.5	0.7	1.2	2.1	164.5
Seasonal	Wetlands used	4.8	0.4	0.5	0.7	1.6	4.3	9.3	131.4
	All wetlands	1.5	0.4	0.5	0.6	0.9	1.6	3.0	136.8
Semi-permanent	Wetlands used	27.9	0.4	1.3	3.6	10.1	24.7	55.9	1,374.2
	All wetlands	4.0	0.4	0.5	0.8	1.5	3.4	7.8	1,374.2
Lake	Wetlands used	297.4	0.4	1.0	3.2	18.8	67.8	343.2	19,694.7
	All wetlands	26.2	0.4	0.5	0.9	2.0	7.0	24.7	19,694.7
Riverine	Wetlands used	206.7	0.8	3.0	15.2	59.9	156.7	737.2	1,303.0
	All wetlands	9.9	0.4	0.6	1.1	2.5	6.5	15.2	1,303.0
North Dakota									
Temporary	Wetlands used	7.2	0.4	0.5	0.6	1.4	4.0	12.1	177.6
	All wetlands	1.4	0.4	0.4	0.5	0.7	1.2	2.5	177.6
Seasonal	Wetlands used	5.8	0.4	0.6	1.0	2.2	5.3	14.3	191.1
	All wetlands	1.5	0.4	0.5	0.5	0.8	1.4	2.7	543.7
Semi-permanent	Wetlands used	16.2	0.4	1.0	1.9	5.1	14.8	38.3	428.9
	All wetlands	3.4	0.4	0.5	0.8	1.4	3.0	6.7	1,435.3
Lake	Wetlands used	251.5	0.4	1.1	3.3	15.8	50.0	132.4	40,136.4
	All wetlands	24.1	0.4	0.6	1.0	2.8	12.0	32.3	40,136.4
Riverine	Wetlands used	74.7	1.3	2.0	6.3	24.6	36.2	214.1	6,37.9
	All wetlands	13.3	0.4	0.6	1.2	3.3	9.1	26.1	1,362.3

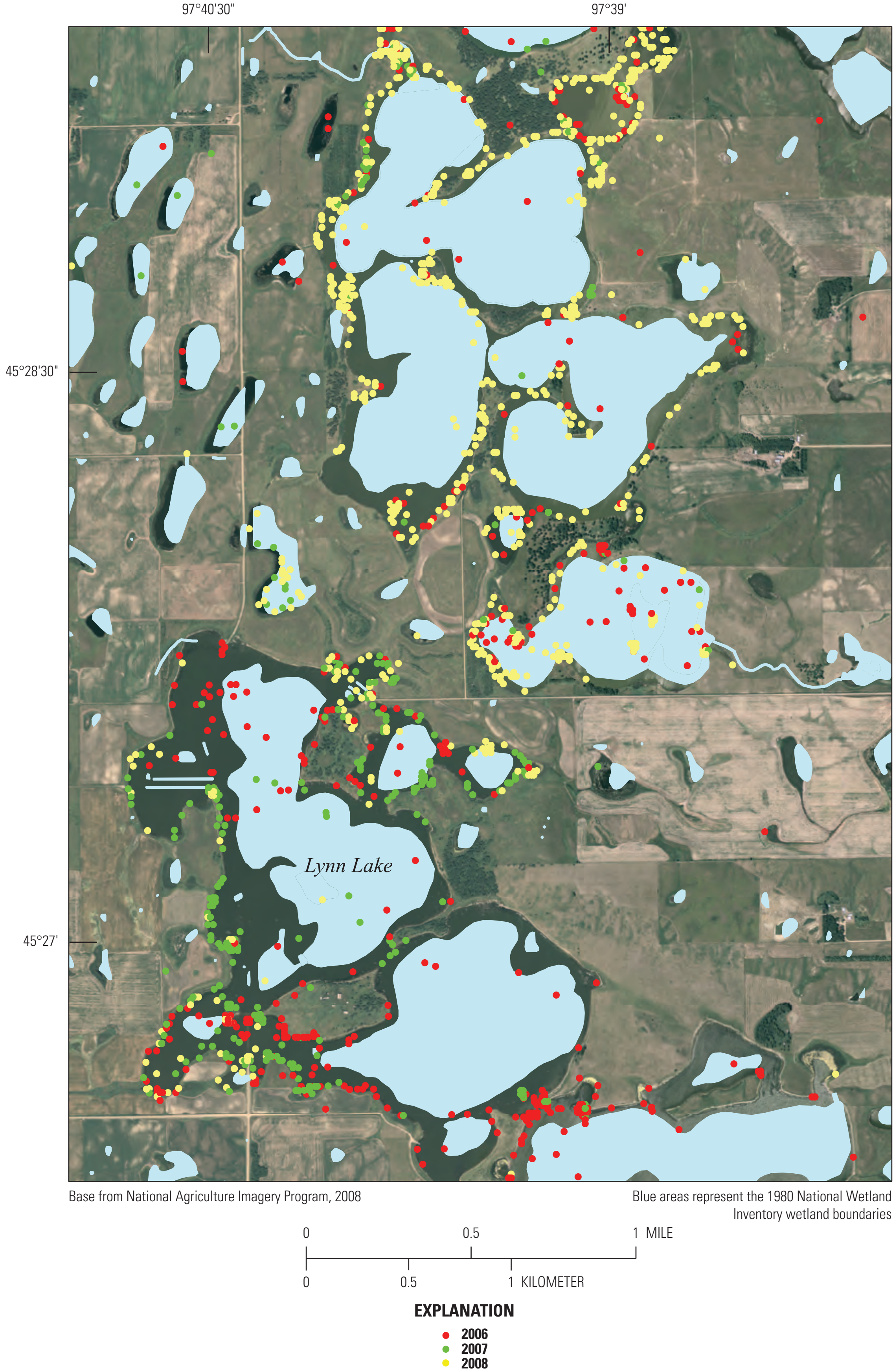


Figure 14. Locations of satellite-tracked American white pelicans foraging around Lynn Lake, South Dakota. Note the expansion of wetland area from 1980 to 2008 and that many of the 1980 wetlands were merged in 2008.

Overall Movements of Satellite-Tracked Pelicans

During 2005–9, 191,659 GPS locations were documented for 28 adult pelicans (fig. 15). Collectively, these locations spanned North America from Saskatchewan and Manitoba, Canada, in the north to the Pacific coast of Mexico in the south. Monthly summaries of the general locations used by each of the 28 satellite-tracked pelicans are given in appendix B. Maps of the locations of individual pelicans are provided in appendix C.

Nineteen satellite-tracked pelicans returned to the breeding region from wintering areas in at least 1 year; collectively, they returned to the breeding region 33 times (that is, 33 bird-years). Not all birds returned to the breeding region every year. For example, one male tagged at Medicine Lake (21428) wintered in Texas, returned as far north as South Dakota the next year, and then spent the subsequent 2 years in Mexico. In another case, a female tagged at Bitter Lake (64538) stayed in Texas and Mexico for 20 months before returning to South Dakota. Return trips to the breeding region occurred as early as April and as late as August, but typically occurred in May (17 bird-years) or June (11 bird-years).

Pelicans often moved over vast areas in what appeared to be exploratory flights. In other cases, pelicans covered vast distances in a short time to a specific destination. One example of the latter involved a female (21878) originally tagged at Bitter Lake; missing data prevented documenting the flights, but the end points were clear. On August 24, 2008, she was on a wetland in central Kansas; after a 28-hour data gap, she was in northeastern Mexico, where she spent at least a week on Laguna Jasso. After a data gap of 11 days, she was on a river in northeastern Oklahoma.

Activities of Satellite-Tracked Pelicans in the Breeding Region

Of 11 pelicans that received satellite transmitters at Bitter Lake, only one had a breeding effort there that was potentially successful (male 64537). The pelican was tagged on June 6, 2006, and, between mid-June and mid-August of that year, he appears to have made nearly 30 return trips to Subcolony 1 at Bitter Lake from foraging areas up to 34 km away (fig. 16). Round trips (reaching documented altitudes up to 1.0 km above ground level) occurred almost daily from early July through August 13, suggesting that this male was bringing food to a chick or chicks at the subcolony.

In 2007, this male (64537) returned to Subcolony 1 on Bitter Lake on May 13–14, but spent most of the breeding season to the northwest in the primary foraging area of the previous year, a complex of wetlands that includes Lynn Lake. The male used a tiny island in a wetland about 8 km south of Lynn Lake on 18 different days between May 23 and June 24, 2007. This island is white on NAIP imagery (taken during agricultural crop growing season); such white areas might result from many factors, but they are typical of land frequented by pelicans (for example, subcolony sites in Bitter Lake, fig 17). In 2008, the male returned to the Lynn Lake area on May 9 and used it throughout the breeding season. He did not return to the small island used in 2007; his movements focused within the Lynn Lake complex on another tiny white island, which he had visited frequently in 2006 between June 11 and August 15. In 2008, he used this site on 69 days between May 9 and the end of August. Although these two islands might only have been preferred resting areas, it is possible that some nesting occurred there.

A female (64534) tagged at Bitter Lake in 2006 made at least seven trips back to Subcolony 1 during June 9–25 of that year from foraging areas as far as 95 km away (fig. 18), attaining a maximum documented altitude of 1.0 km above ground. Her 10 trips between Bitter Lake and wetlands in Sargent County, N. Dak., took her 3–5 hours each. Her apparent nesting effort failed, however, because after June 25 she did not return to Bitter Lake; she remained in Sargent County for the rest of the breeding season. During her time in Sargent County, she made frequent trips to a small island that she used on 27 days between June 28 and the end of August 2006. If this was a second breeding attempt, it would represent a phenomenon rarely if ever documented in this species.

Another female (64538) tagged at Bitter Lake in 2006 made five return trips to Subcolony 1 during a 2-week period (June 14–28) that year (fig. 19). The highest documented altitude she attained was 1.5 km above ground. Her foraging areas were primarily in Brown County at wetlands up to 85 km away. After June 28, she only returned to Bitter Lake once (July 11), spending the majority of her time in Brown County, including on impoundments of the James River in Sand Lake NWR. In 2007, she did not spend any time in South Dakota; in 2008, she returned to South Dakota in late June and, again, spent most of the summer in Brown County. In 2008, she stayed primarily southeast of Sand Lake on a dammed section of the Crow Creek Drainage.

One female (64535) tagged at Bitter Lake in 2006 immediately left Day County and spent most of the summer on wetlands along the border of Brookings and Kingsbury counties. The most frequently used area was an island where she spent time during 24 different days between June 13 and the end of August (fig. 20). This is another site that might have been used by pelicans primarily for resting, but nesting activity cannot be ruled out.

One female (21913) tagged in 2005 at Chase Lake, N. Dak., spent much of the summer of 2006 in Brown County, S. Dak., especially on Sand Lake NWR and on Renzienhausen Slough and Game Production Area. In Sand Lake, she frequented an island on 28 days from June 14 to the end of August. In 2008, this female returned to Sand Lake during May 22–23 and July 17–August 14 and to this island on 15 of those days.

Several other satellite-tracked pelicans spent time in South Dakota during the breeding season and concentrated their activities for various periods on small islands or peninsulas. In at least three cases (Lake, Minnehaha, and Roberts

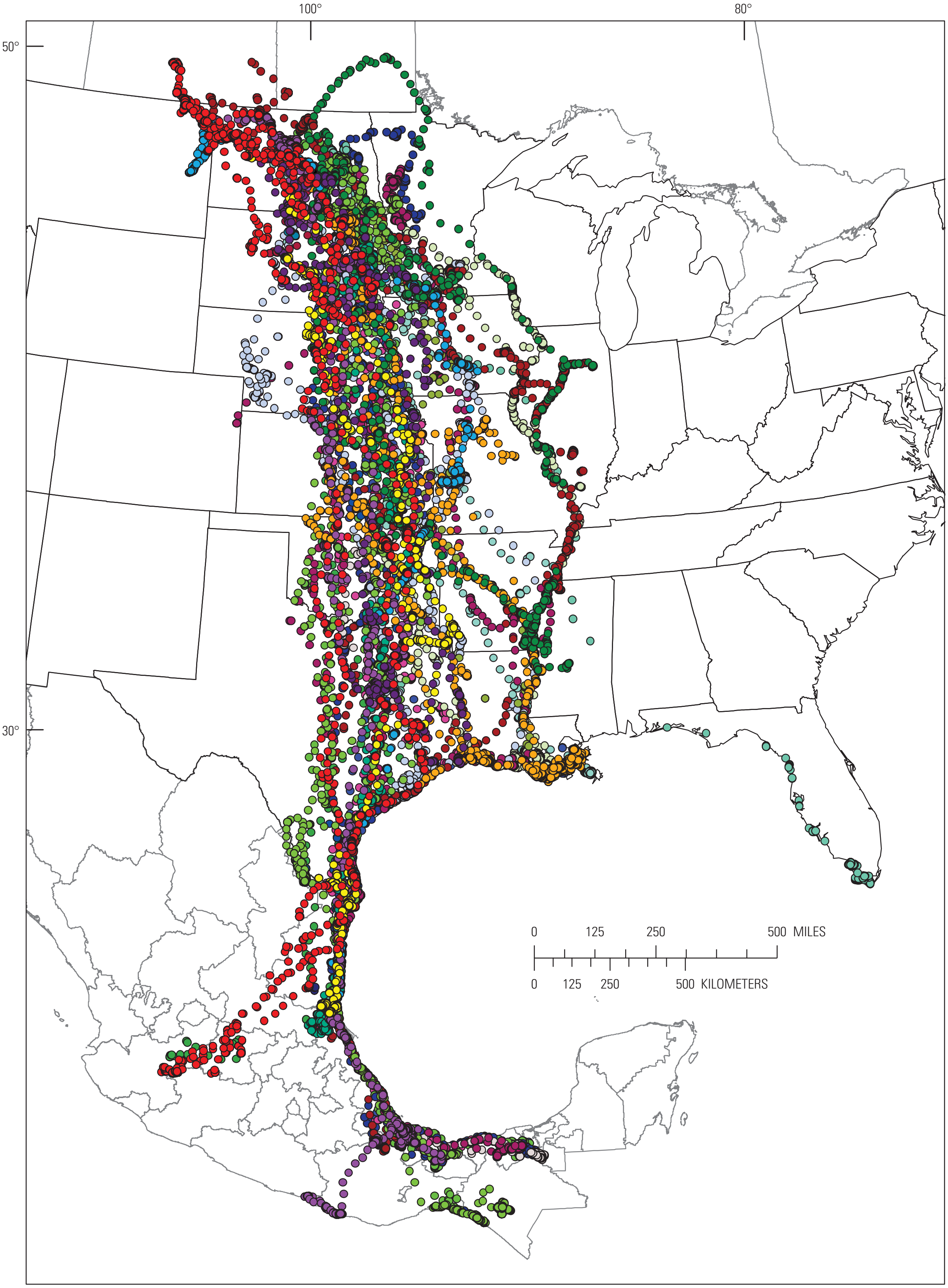


Figure 15. Locations of all 28 satellite-tracked American white pelicans during years of monitoring, 2005–9. Adult pelicans were tagged at Bitter Lake, South Dakota (11), Chase Lake, North Dakota (12), and Medicine Lake, Montana (5), breeding colonies. Individual pelicans are differentiated by colors.

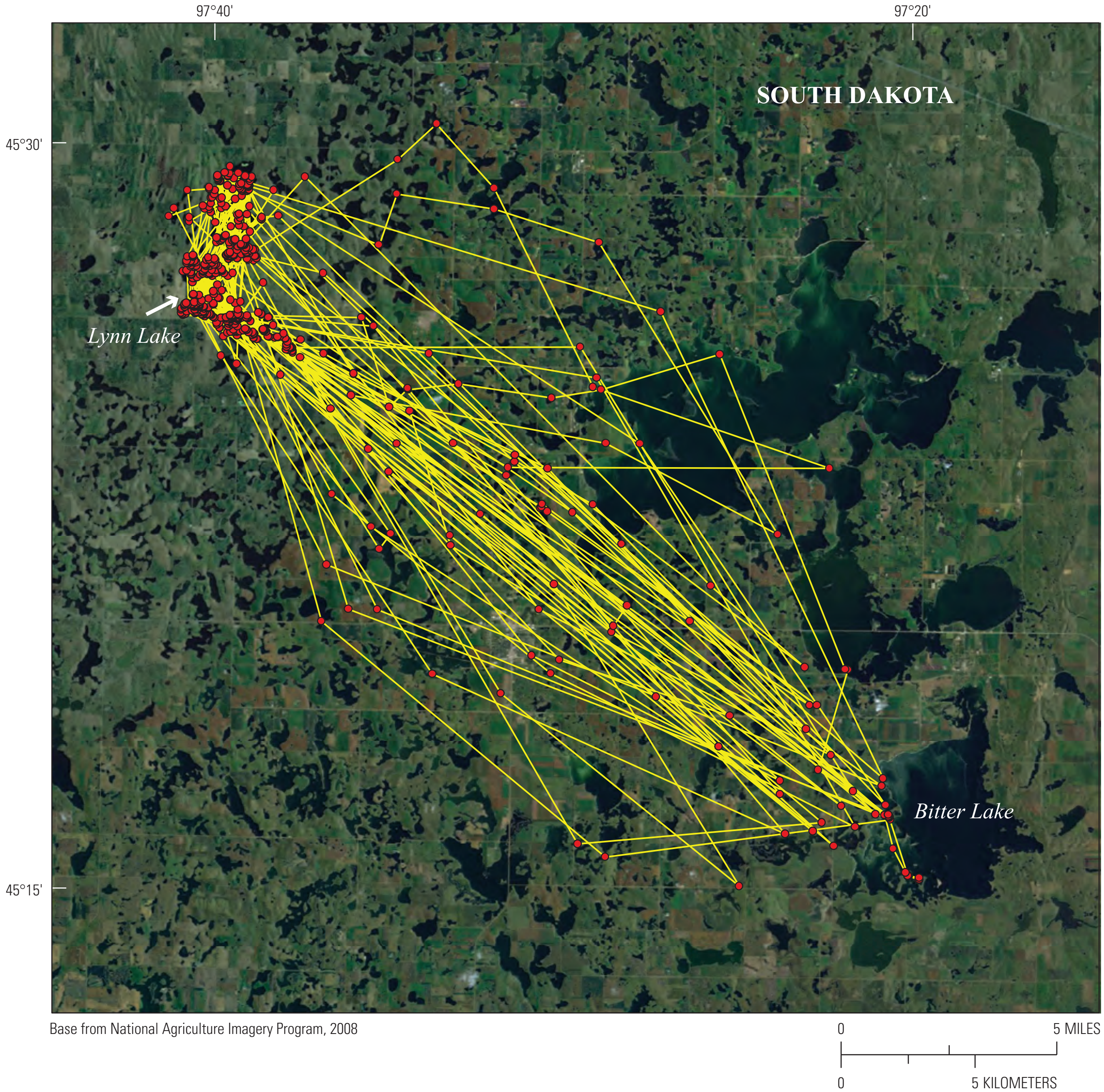


Figure 16. Locations of a male American white pelican, platform transmitter terminal (PTT) number 64537, from June 6 through August 31, 2006. During this time, he made about 60 trips between his breeding site on Bitter Lake and foraging areas in Day County up to 34 kilometers away (for example, Lynn Lake) in South Dakota. Dots connected by lines represent Global Positioning System (GPS) locations that are typically 1 hour apart. This pattern of movements most likely indicates that the male was feeding a chick at Bitter Lake.

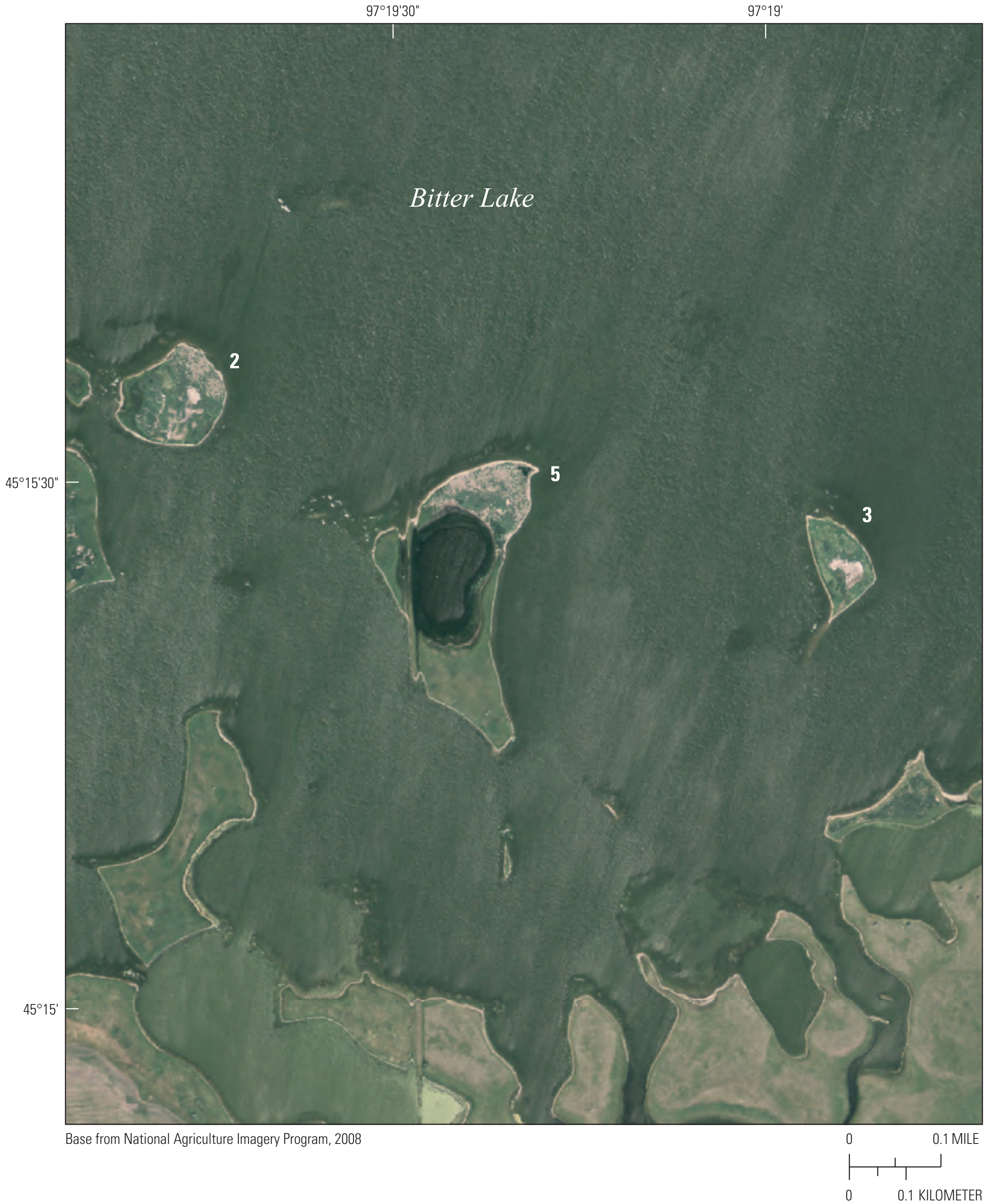


Figure 17. The islands with American white pelican Subcolonies 2, 3, and 5 at Bitter Lake, South Dakota. The areas frequently used by nesting pelicans appear lighter than surroundings as a result of vegetation removal (by nesting pelicans), pelican excrement, and possibly the presence of pelicans when the imagery was taken.

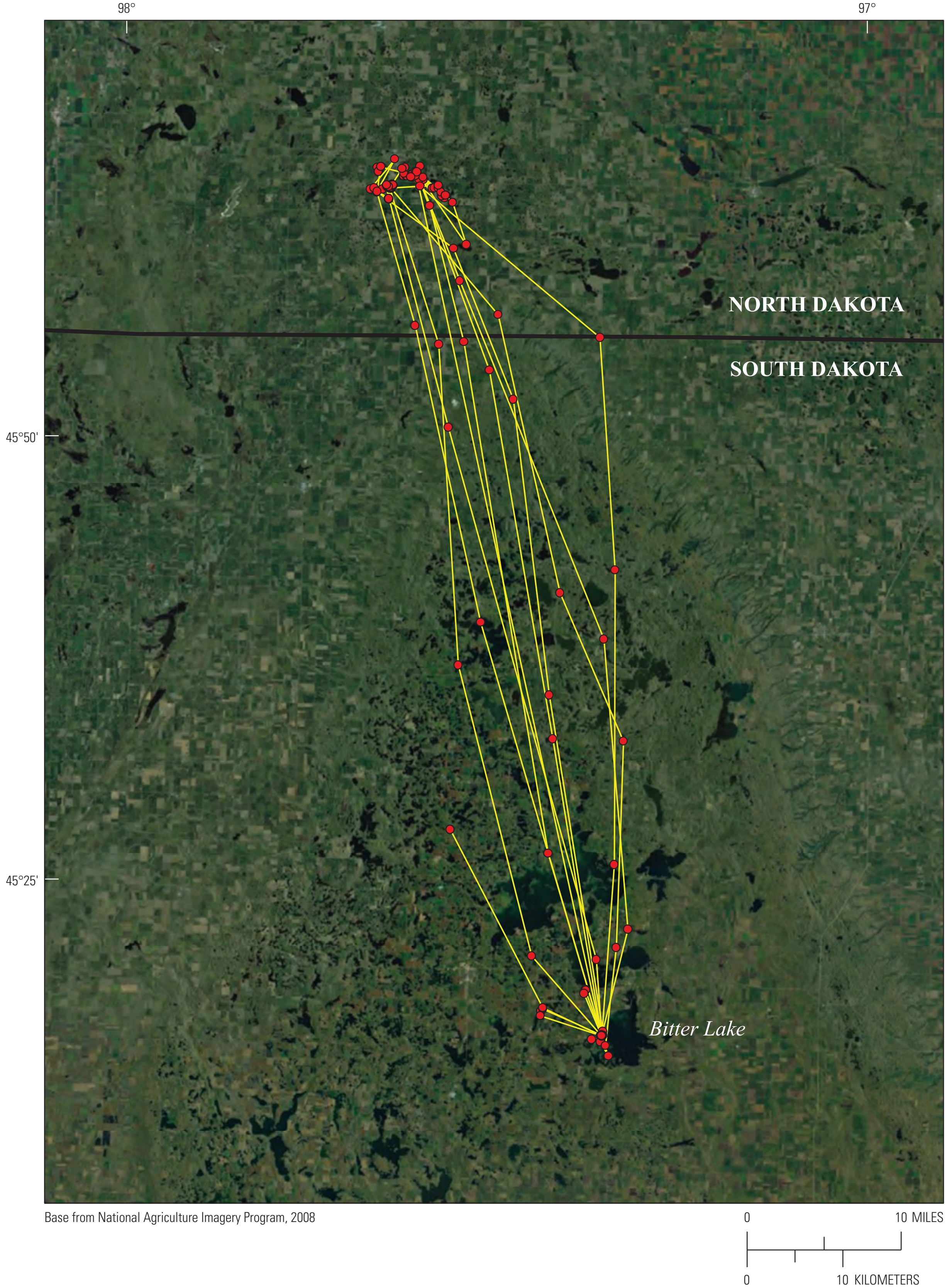


Figure 18. Locations of a female American white pelican, platform transmitter terminal (PTT) number 64534, during June 6–25, 2006. During this period, she made about 16 trips between Subcolony 1 on Bitter Lake, South Dakota, and foraging areas as far as 95 kilometers away in Sargent County, North Dakota. Dots connected by lines represent Global Positioning System (GPS) locations that are typically 1 hour apart.

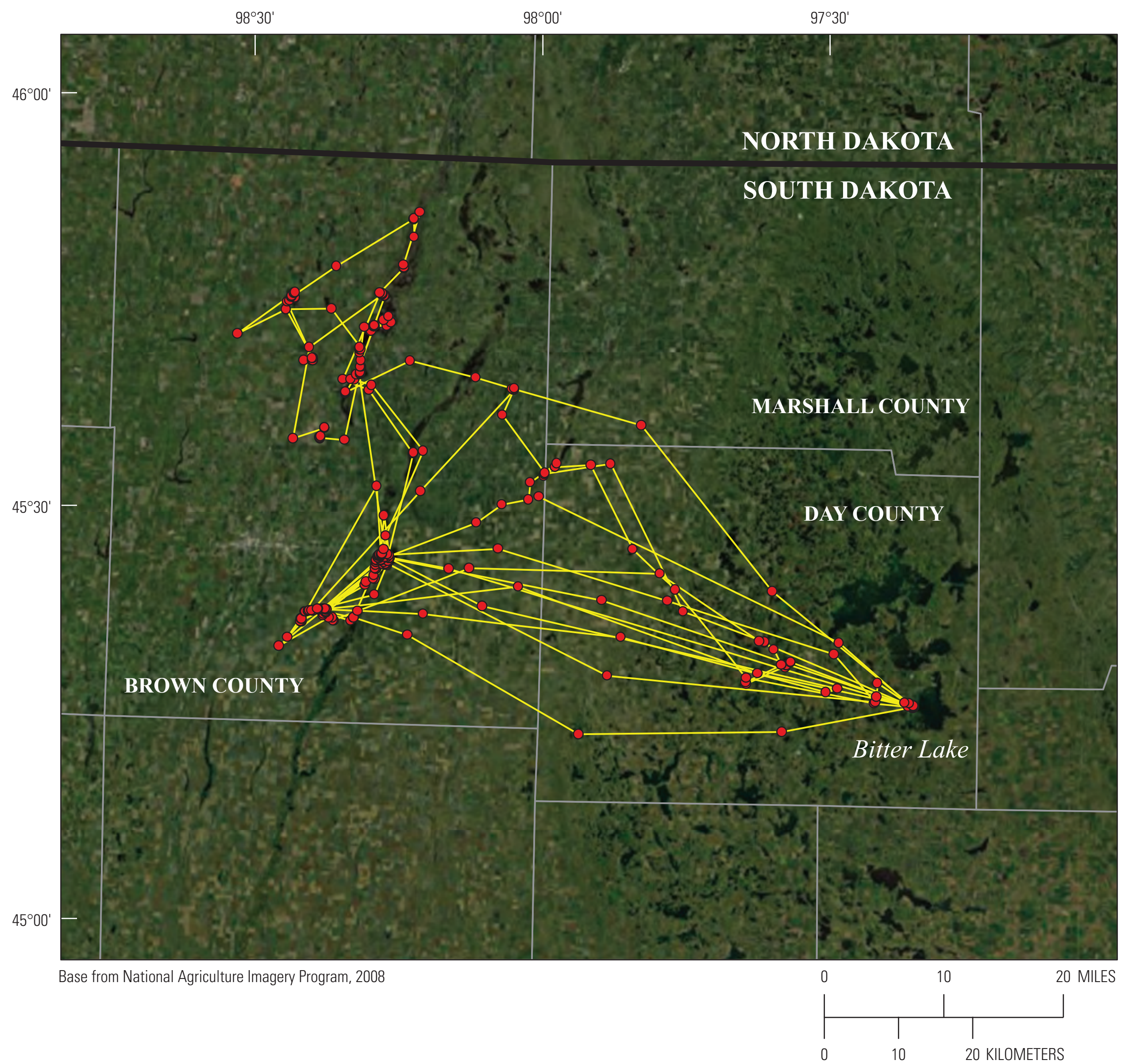


Figure 19. Locations of a female American white Pelican, platform transmitter terminal (PTT) number 64538, from June 6 to July 11, 2006. During this period, she made about 12 trips between Subcolony 1 on Bitter Lake and foraging areas as far as 85 kilometers away in Brown County, South Dakota. Dots connected by lines represent Global Positioning System (GPS) locations that are typically 1 hour apart.

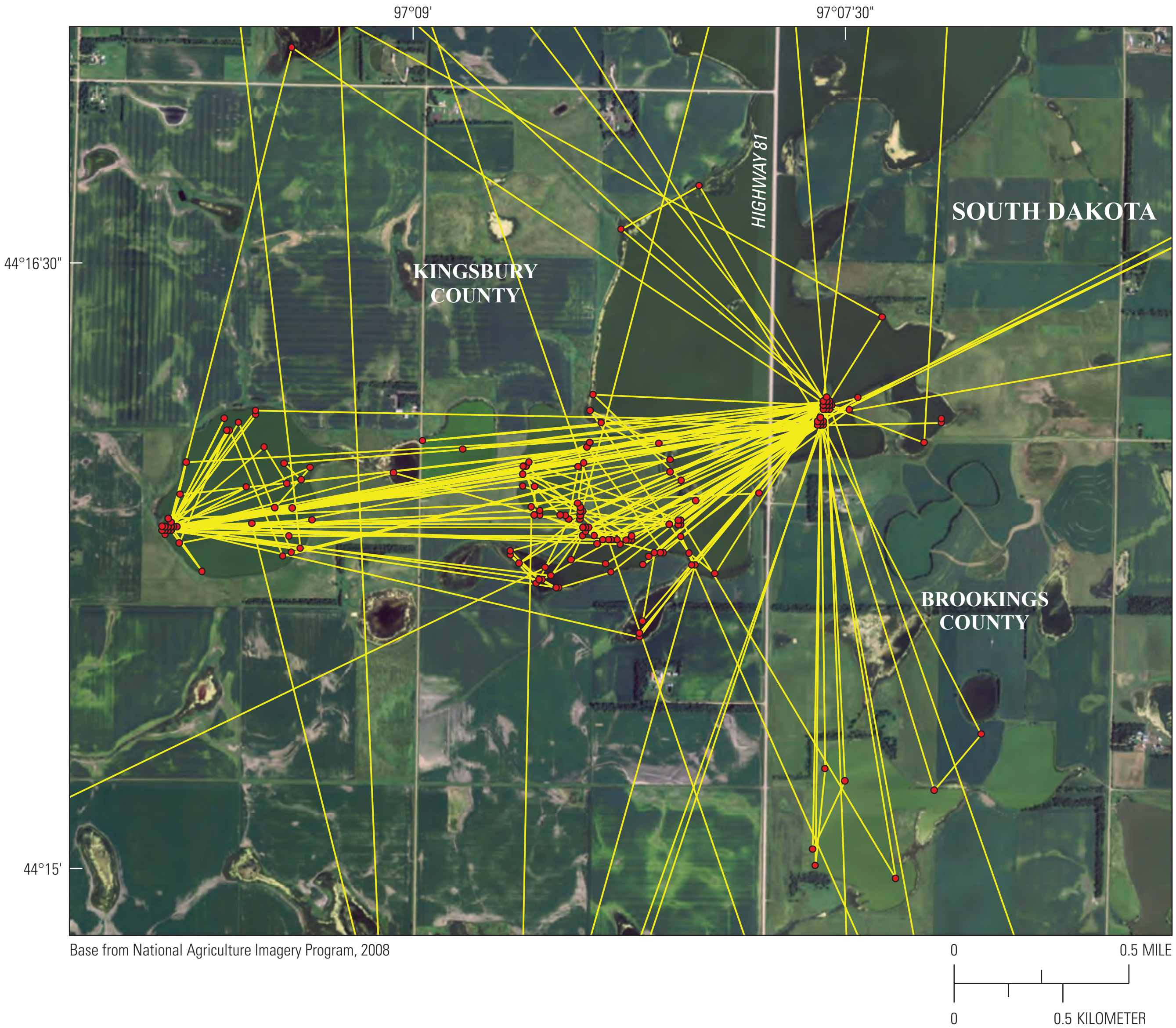


Figure 20. An area of use by a female American white pelican, platform transmitter terminal (PTT) number 64535, from June 13 to August 26, 2006. Her locations focused on an island (roughly 100 x 45 meters) in a wetland that straddled Brookings and Kingsbury Counties, South Dakota, during 10 days in June, 3 days in July, and 12 days in August 2006. Dots connected by lines represent Global Positioning System (GPS) locations that are typically 1 hour apart.

Counties), these sites appeared to be mainly white on the NAIP maps, typical of land areas used frequently by pelicans. However, high water levels in some areas may have made these sites subsequently unavailable to pelicans. For example, the island denoted as Subcolony 1 in Bitter Lake was inundated in 2009, and all Bitter Lake island subcolonies were inundated in 2010.

In addition to one potentially successful nesting effort by a pelican tagged at Bitter Lake, movement data for a pelican tagged at Chase Lake, N. Dak., provided evidence suggesting a successful nesting attempt. After being captured on July 10, 2006, this male (21722r) made 20 return trips to the Chase Lake colony between July 11 and August 19, primarily from feeding areas about 43 km to the south-southeast in the vicinity of Hein-Schaffer Lake (fig. 21). These trips occurred daily through July 29, suggesting that this male was feeding a chick at the colony. He reached a maximum documented altitude of 1.8 km above ground level. Because this male was tagged relatively late in the breeding season, his chick might have been nearly full grown by the end of July. He made eight more return trips to the colony from this feeding area in August before leaving the colony for the last time.

Another nesting attempt by a satellite-tracked pelican at a known colony occurred at Medicine Lake, Mont., in 2005. This male (21722) was captured on June 10 at Medicine Lake and, despite major gaps in data from this transmitter, at least seven return trips were documented to the colony through July 5 from foraging areas up to 174 km away on the Yellowstone River (fig. 22). The length of time spent at a single spot in the colony during return visits suggests that this male was taking his turn incubating eggs. However, he did not return to the colony after July 7, so the nesting effort probably failed.

The four pelicans thought to be feeding their chicks spent little time at the colony during visits. Most visits by three of these birds (21722r, 64537, 64538) were less than 1 hour. We had to interpolate some visits from flights in and out of the colony because the hourly GPS fixes were too far apart to catch the bird on the ground. These data suggest that the chicks being fed were already more than 2 weeks old and crèched; observations indicated that most adults visited crèched chicks only long enough to feed them. Of 30 return trips to Bitter Lake made by pelican 64537, 26 were less than 1 hour, 3 were 1–2 hours, and the final visit was 5 hours. In addition to these short visits, three of these birds also made overnight stays at the colony. Overnight visits were most common (four of seven) for the pelican (64534) that made foraging trips from Bitter Lake to Sargent County, N. Dak., over 90 km away.

Five satellite-tracked pelicans made numerous return trips to their nesting colony in the year they were tagged, and we were able to calculate the average time of return for 61 trips back to the colony (table 9). These average times concurred with the video data that showed earlier nest exchange times for nesting pelicans at Bitter Lake compared to Chase Lake. Three pelicans from Bitter Lake averaged return times just after 1300 CST, whereas the Chase Lake pelican consistently returned to his colony 1 to 1.5 hours later in the afternoon. The Medicine Lake pelican returned to his colony site in the morning from two short trips nearby (in or near Medicine Lake) but returned at 1500 MST from two longer trips made down the Yellowstone River.

Only two pelicans tagged at the Bitter Lake colony returned to the colony in subsequent years. Both returned to Subcolony 1 for less than a day: female 21893r for 19 hours on May 23–24, 2006, and (as mentioned above) male 64537 for 21 hours on May 13–14, 2007. Another pelican (21545) visited Bitter Lake colonies about a year after being tagged at Medicine Lake and spent 17 hours on Subcolonies 2 and 3 during May 3–4, 2006. Only two pelicans tagged at Chase Lake returned there in subsequent years: male 21913 spent about 4 days on Chase Lake's South Island (Subcolony 2) during May 22–26, 2006, and another 13 hours there on June 7–8; male 21917 spent nearly a day (22-hour span) on Chase Lake's North Island (Subcolony 1). None of the five pelicans tagged at Medicine Lake visited that colony in subsequent years.

GPS locations of all satellite-tracked pelicans that spent time in North Dakota and South Dakota are represented in figure 23. The five pelicans tagged at Medicine Lake spent considerable time in both North Dakota and South Dakota. Collectively, the five pelicans were located in North Dakota during 31 months of 9 bird-years and in South Dakota during 21 months of 9 bird-years. The 11 pelicans tagged at Chase Lake (excluding the bird that was shot locally in July 2005) collectively spent time in South Dakota during 60 months of 21 bird-years. Only two birds tagged at Bitter Lake ventured into North Dakota, collectively during 12 months in 4 bird-years. No pelicans tagged at Bitter Lake or Chase Lake visited Montana.

Activity Clusters in South Dakota and North Dakota

Clustering methods helped to identify several areas, in addition to known breeding colonies, that were repeatedly used by more than one satellite-tracked pelican. In North Dakota, excluding clusters at Chase Lake, five clusters were identified in 2005 and nine in 2006. In South Dakota, excluding clusters at Bitter Lake, 3 clusters were identified in 2005, 22 in 2006, 3 in 2007, and 1 in 2008. The centroids for all clusters (16 in North Dakota, 32 in South Dakota) are mapped in figure 24.

In North Dakota, the most frequently used area was in central Sargent County (southeastern North Dakota), where four pelicans tagged at Chase Lake and one from Bitter Lake spent over 3,600 hours on numerous small wetlands in 2006. Four pelicans tagged at Medicine Lake frequented the Missouri River in northwestern North Dakota (primarily along the border between Williams and McKenzie Counties) in 2005 and 2006; one of the four pelicans also used the area in 2007. In 2005, four pelicans tagged at Chase Lake spent about 400

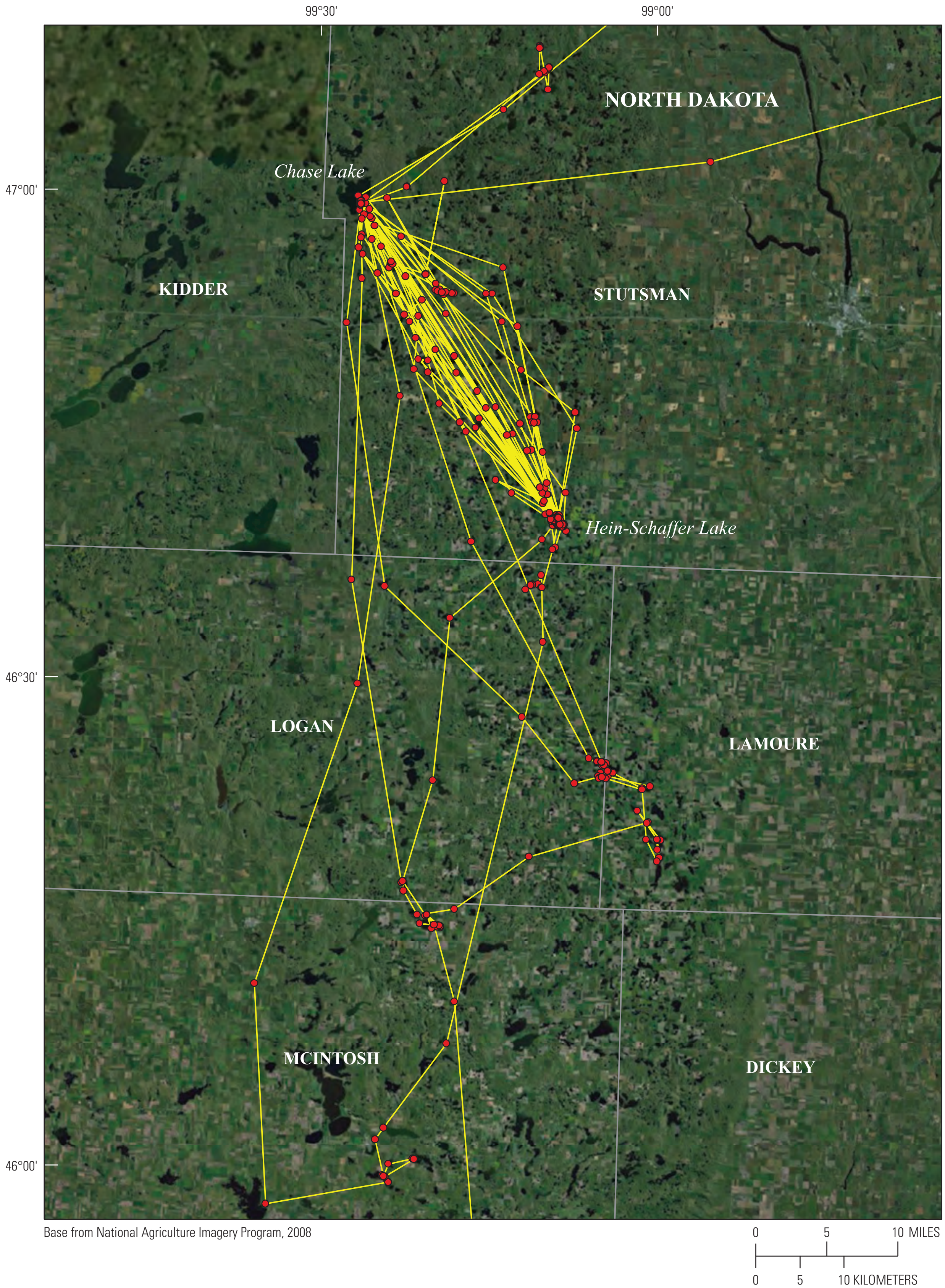


Figure 21. Locations of a male American white pelican, platform transmitter terminal (PTT) number 21722r, from July 11 to August 19, 2006. During this period, he made 40 trips between the Chase Lake colony and foraging areas in North Dakota, most of which were about 43 kilometers away. Dots connected by lines represent Global Positioning System (GPS) locations that are typically 1 hour apart.

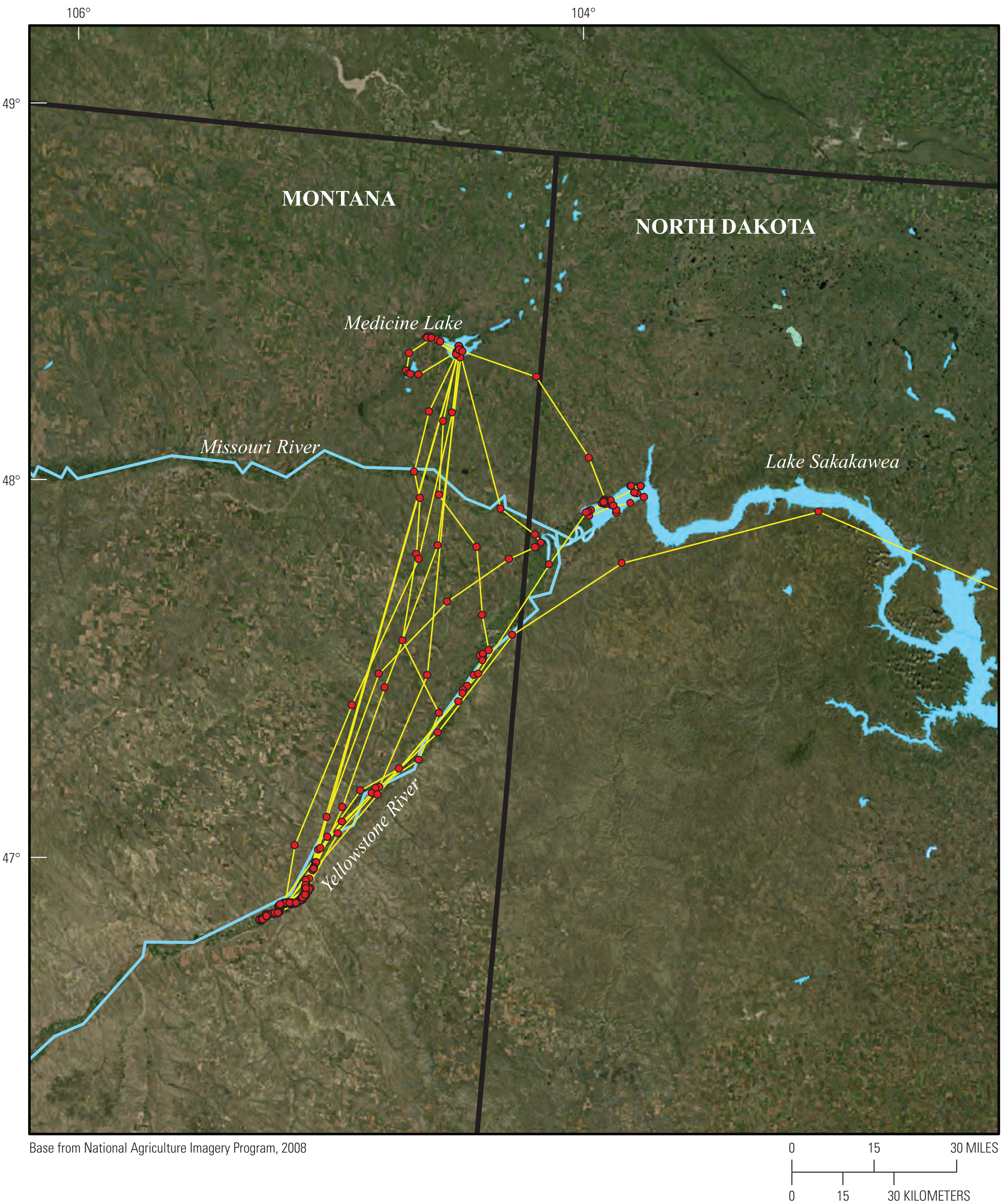


Figure 22. Locations of a male American white pelican, platform transmitter terminal (PTT) number 21722, from June 10 to July 7, 2005. Despite major data gaps from this bird's transmitter, we documented at least 14 trips between the Medicine Lake colony in Montana and foraging areas up to 174 kilometers away on the Yellowstone River. Dots connected by lines represent Global Positioning System (GPS) locations that are typically 1 hour apart.

Table 9. Times of return trips to breeding colonies at Bitter Lake (South Dakota), Chase Lake (North Dakota), and Medicine Lake (Montana) by five satellite-tracked American white pelicans during 2005–6.

[PTT, Global Positioning System (GPS) satellite-received platform transmitter terminal; GMT, Greenwich mean time; SD, standard deviation, in minutes; SE, standard error, in minutes; km, kilometer; CST, central standard time; MST, mountain standard time; ≤, less than or equal to]

Colony	PTT Number (Sex)	Year	Interval of return trips	Number of return trips	Average return time (GMT)	Average return time (local)	SD (min)	SE (min)	Typical distances to foraging sites (km)
Bitter Lake	64534 (F)	2006	June 9–25	7	1808	1308 CST	112	42	91–94
	64538 (F)	2006	June 14–28	5	1812	1312 CST	89	43	74–88
	65437 (M)	2006	June 10–Aug 13	25	1802	1302 CST	66	13	30–34
Chase Lake	21722r (M)	2006	July 11–29	15	2016	1516 CST	90	23	42–43
			Aug 4–19	5	2048	1548 CST	50	22	42–43
Medicine Lake	21722 (M)	2005	June 15–18	[1]2	1530	0930 MST			≤ 17
			June 20–July 7	[1]2	2100	1500 MST			88–177

[1]The bird made more than two trips but return times for other trips were unknown because of data gaps.

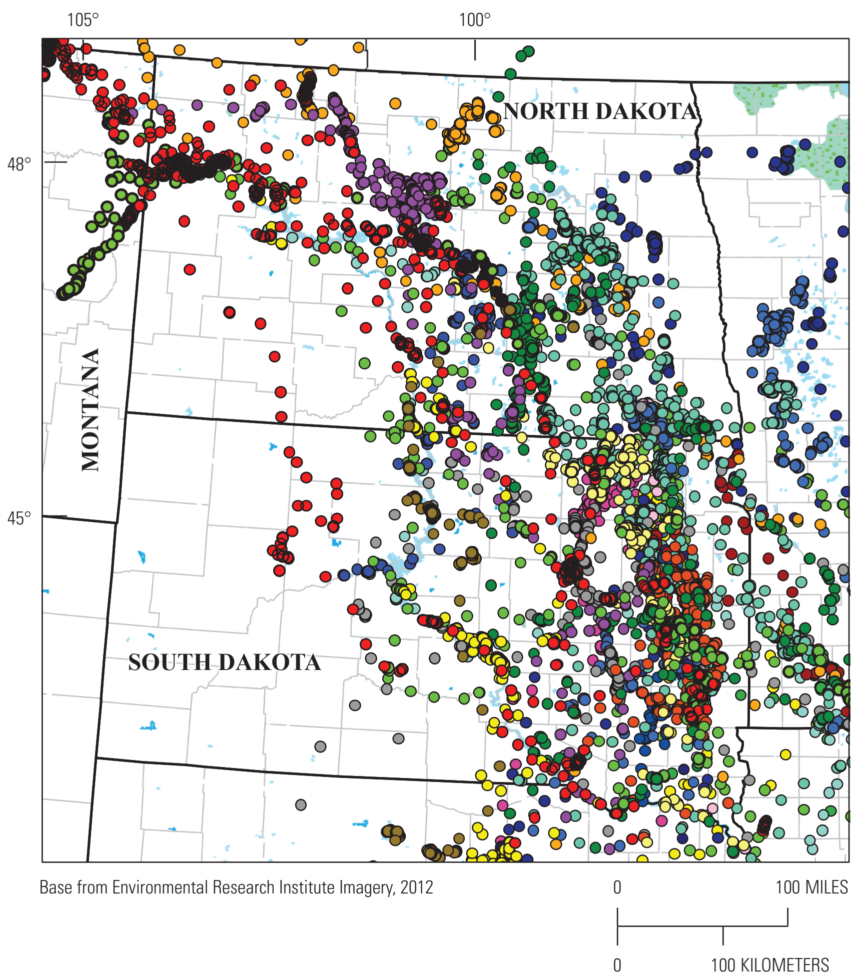


Figure 23. Locations of 28 satellite-tracked American white pelicans in North Dakota and South Dakota during 2005–8. Included are locations of 11 pelicans tagged at Bitter Lake, South Dakota, 12 tagged at Chase Lake, North Dakota, and 5 tagged at Medicine Lake, Montana.

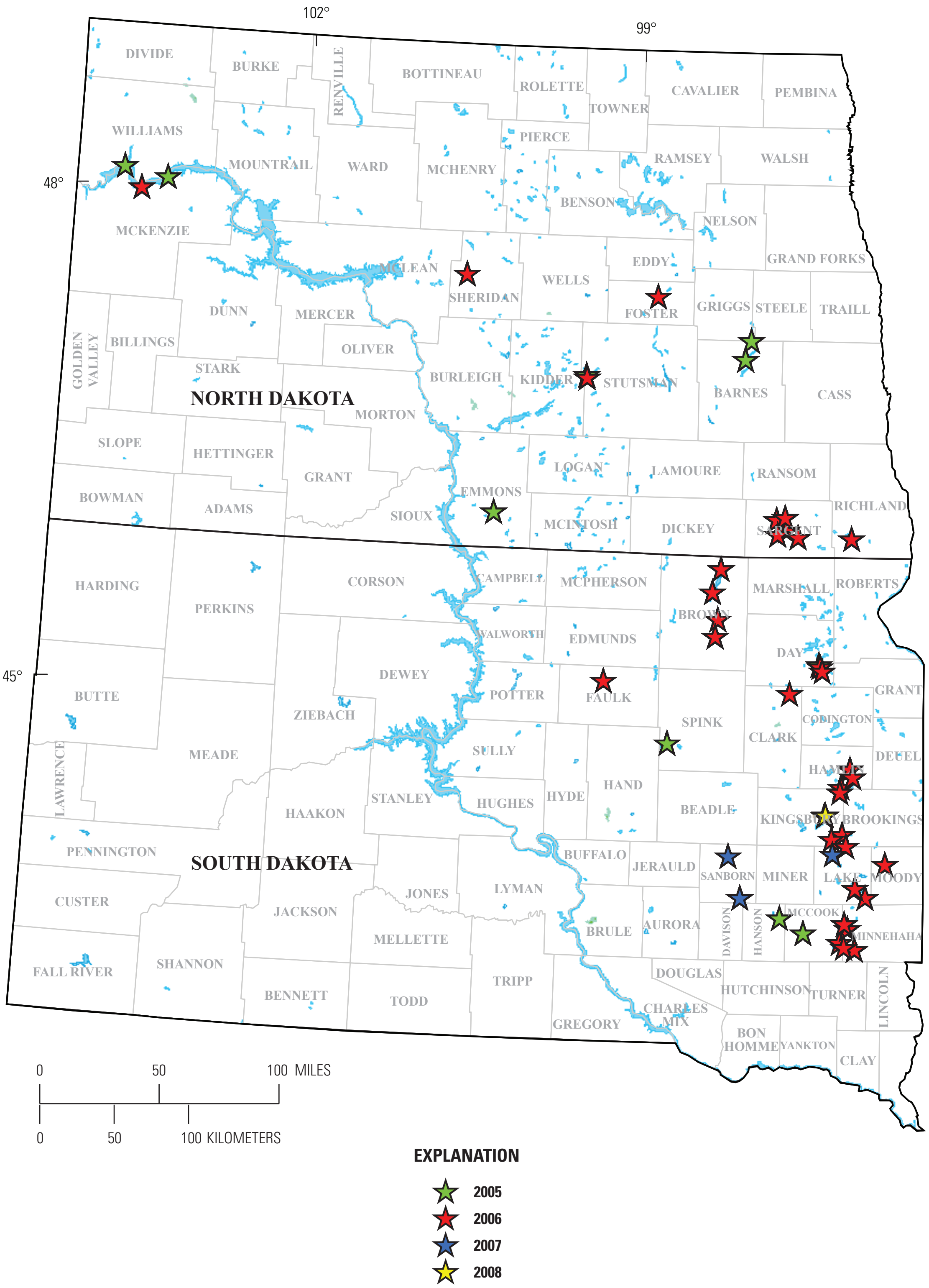


Figure 24. Centroids (stars) for clusters of locations of satellite-tracked American white pelicans in North Dakota and South Dakota during 2005–8. Each cluster had a minimum of 20 locations each for at least two pelicans within a year. (See Methods for details on the clustering analysis.)

hours on Lake Ashtabula (impounded Sheyenne River) north of Valley City in Barnes and Griggs Counties. In 2005, five pelicans (four from Medicine Lake, one from Chase Lake) all used the same small lake in south-central North Dakota (62-ha Baumgartner Lake, Emmons County); however, none of the birds overlapped temporally. Each was on the lake at a different time, ranging from mid-June to mid-October. In 2006, two pelicans originally tagged at Medicine Lake ventured as far as Sheridan County (central North Dakota), where they used several small wetlands for about 100 hours. In this case, although the locations of the two birds were in the same cluster, they were separated both spatially and temporally.

Of 32 clusters identified in South Dakota, 20 included pelicans tagged in North Dakota, Montana, or both. The South Dakota areas with the most clusters included northern and central Brown County (four clusters) and along the border between McCook and Minnehaha Counties (five clusters). The four clusters in Brown County represent locations of four pelicans (two from Bitter Lake, one from Chase Lake, one from Medicine Lake); collectively, these birds spent more than 1,500 hours on impoundments along the James River (Mud Lake Reservoir and Columbia Road Reservoir within Sand Lake NWR), on the James River east of Aberdeen, and on Putney Slough (including the lower Crow Creek Drainage System and Renzienhausen Slough). The five clusters near the McCook/Minnehaha County border (about 15 km west of Sioux Falls) represent locations of eight pelicans (four tagged at Bitter Lake, three from Chase Lake, one from Medicine Lake) in 2006; collectively, these birds spent almost 1,800 hours on small lakes and wetlands in this area. Another area of high activity in 2006 occurred 15 km to the north in southeastern Lake County where two clusters represent locations of six pelicans (four from Bitter Lake, one each from Chase and Medicine Lakes). Collectively, these birds spent more than 1,000 hours on a few small lakes and wetlands near Lake Madison (for example, Long Lake, Buffalo Slough).

Activities of Satellite-Tracked Pelicans in the Nonbreeding Region

All of the 26 satellite-tracked pelicans that survived the first summer migrated south during the fall (appendix B). During 2005–9, these pelicans collectively made 56 migratory trips south in the fall and 33 trips north in spring or summer to the breeding region. The speed of travel, number and length of stops, and type of sites used along the way (wetlands, lakes, reservoirs, rivers) were highly variable within and among pelicans. Individual birds rarely followed the same migratory path on their way south and north (appendix C), but they often roughly repeated southerly or northerly routes among years. The most precisely repeated routes were for the few birds that followed segments of the Mississippi River on their way south (21917, 21959, 64530) or north (21722r). Most routes cut overland on a roughly straight line.

Birds typically returned to the same general areas each winter. Mexico was the most frequented wintering area; 16 different pelicans spent at least 1 winter in Mexico, and collectively pelicans spent 34 bird-winters there (appendices B and C). Five pelicans spent at least 1 winter in Texas (8 bird-winters), and four pelicans spent at least 1 winter in Louisiana (10 bird-winters). One pelican wintered in Mississippi (3 bird-winters), and another wintered in Florida (1 bird-winter).

Some pelicans returned to very specific sites during winter. For example, a male pelican (21311) used the east side of Lake Chapala in west-central Mexico during the winters of 2005–6 and 2006–7. This case also illustrates the importance of imagery selection when examining the terrain beneath a pelican's GPS locations. Plotted on ESRI imagery from 2000, it appeared that pelican 21311 spent most of the winter in agricultural fields (fig. 25*A*). When the same points were plotted on Landsat 5 imagery from 2011, the bird's GPS locations followed the margins of a bay in the lake (fig. 25*B*); this shallow water is typical of pelican foraging habitats elsewhere.

The issue of temporally matching imagery and location data is important not only where water levels affect lake and wetland boundaries but also on coasts subject to storm erosion. For example, six of the satellite-tracked pelicans (in 12 bird-winters) used shallow water areas off the coast of Louisiana (fig. 26), which is frequently battered by tropical storms and hurricanes and impacted by many human activities.

Discussion

Status of the American White Pelican Population

The status of pelicans has improved since falling to population lows in the 1960s (King and Anderson, 2005). Despite overall improved status, the pelican remains a species of moderate conservation concern, primarily because of the concentration of birds on few breeding colonies (Kushlan and others, 2002). King and Anderson (2005) presented a conservative estimate of 157,000 individuals for the entire population of American white pelicans, of which 134,000 were categorized as breeding birds; however, there has never been a coordinated survey of the continental population, thus no reliable estimate of population size is available. Additionally, there is uncertainty about the exact numbers of breeding colonies in North America, particularly in Canada. In total, fewer than 50 active colonies have been documented; among those fewer than 20 have more than 500 nests (King and Anderson, 2005). During the years of this study, the four principal colonies in the northern plains annually comprised more than 42,000 nests (Bitter, Chase, Marsh, and Medicine Lake colonies; M.A. Sovada and P.J. Pietz, unpublished data) and thus accounted for 84,000 breeding adults. It is likely that these four colonies, along with smaller colonies in the region, account for half of the entire breeding population (King and Anderson, 2005).

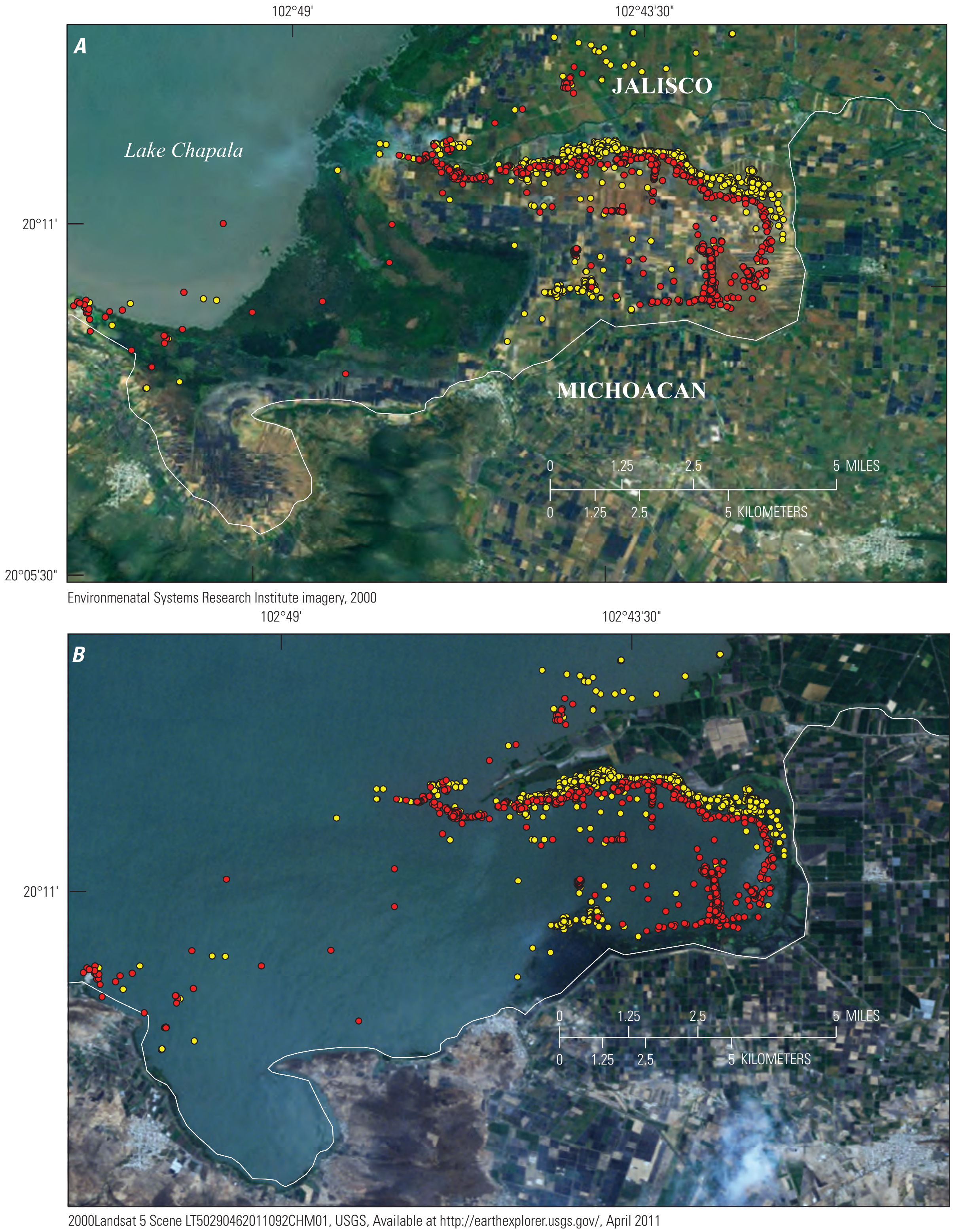


Figure 25. Locations of a male American white pelican, platform transmitter terminal (PTT) number 21311, on the east side of Lake Chapala, Mexico, during the winters of 2005–6 (yellow) and 2006–7 (red) plotted on imagery taken in (*A*) 2000 and in (*B*) 2011. Note that the area in which most of the bird's locations occurred was a patchwork of agricultural fields in 2000 and completely inundated in 2011.

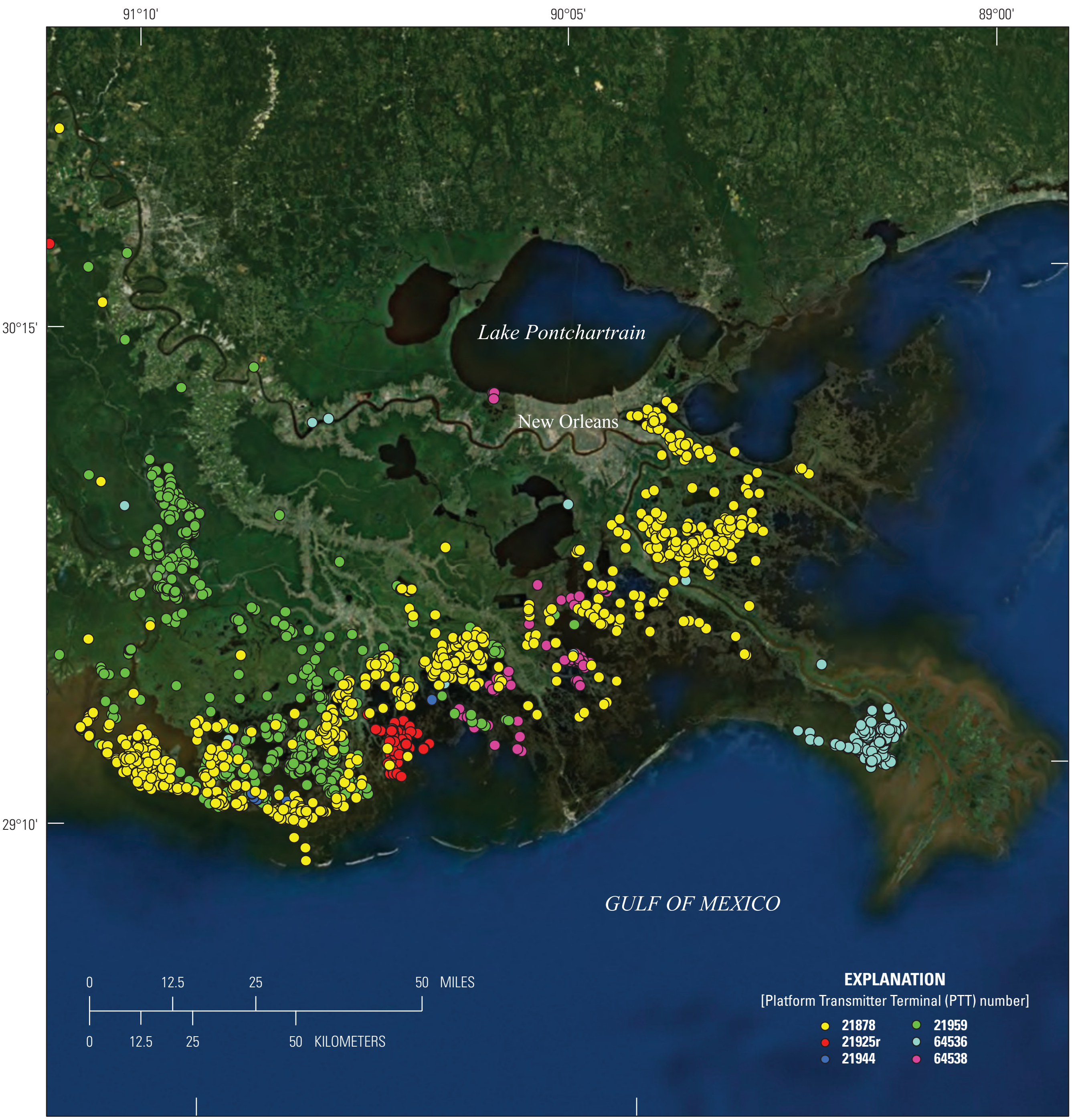


Figure 26. Locations of six satellite-tracked American white pelicans along the Louisiana coast near New Orleans during 2005–6 and 2008–9. These coastal habitats likely fluctuate as a result of storms and human activities. Four of these birds remained in this area over winter; two others moved on to winter in Mexico.

We observed a declining trend in the numbers of breeding pelicans at the colonies we studied, as well as the other major colonies in the region. Among explanations for the observed decline, the most plausible are: (1) chance variability, (2) poor recruitment resulting from loss of chicks to WNV and severe weather events in the past 5 years, (3) redistribution of breeding birds to new or smaller colonies that are not being monitored, or (4) a combination of the three. Annual variability in nest numbers is expected and has been documented at monitored colonies (Sovada and others, 2005). Poor recruitment would not be detected at colonies for several years because, although there is no conclusive evidence defining when pelicans first breed, most experts agree that breeding probably does not begin until 3 to 5 years after hatch. Therefore, if the substantial loss of chicks to disease impacts the number of nesting birds, a delay of several years would be expected before there is a decline in recruitment to the breeding population. Because adult pelicans are not severely affected by WNV or weather, it is difficult to assess the influence of these factors on population trends at this time. Population models suggest that, in the long run, adult survival is more critical than chick survival to population sustainability (M.A. Sovada and P.J. Pietz, unpublished data). There is some evidence providing anecdotal support for redistribution of nesting pelicans. While the major colonies declined, there have been a few observations of small numbers of pelicans pioneering new breeding sites in the region. We observed a colony initiated in 2007 in North Dakota that persisted and grew; in contrast, other sites were observed where colony establishment was attempted and aborted in a single year.

Behavior and Ecology in the Breeding Region

Until research began in 2004 to investigate the impact of WNV on pelican chicks, few extensive investigations of pelican breeding in the northern plains had been conducted (Strait and Sloan, 1975; Johnson and Sloan, 1978; Lingle and Sloan, 1980; Evans, 1984). Little was known about some behaviors such as nest attendance, feeding rates, and chick behavior during early stages of nesting. These basic behaviors are sensitive to environmental factors such as food availability, predation, severe weather, and disturbance. Variation in these behavioral characteristics within or among colonies could be used to assess the sensitivity of the population to an environmental factor. Understanding the dynamics of these behaviors and their links to the environment could provide insights that would contribute to management decisions.

Most adults departed the colony to forage in early afternoon. Adults regularly formed flocks and took advantage of thermals that carried them to high altitudes. Similarly, some flocks were observed returning to the colony from high altitudes. Four satellite-tracked pelicans that made trips to and from a breeding colony (likely feeding chicks) flew as high as 1.8 km above ground level during these trips. Use of thermals saves energy for the pelicans and is commonly observed throughout their range (Knopf and Evans, 2004). Knopf and Evans (2004) suggest that the pelicans use lower portions of thermals for wandering flights, mid-thermal heights for commuting flights, and the upper reach of thermal columns for cross-country flights. The reliance on thermals for traveling greater distances may explain the difference in time of returns to the Medicine Lake colony by a satellite-tracked pelican from local (0930 MST) and distant (1500 MST) foraging areas. The differences between the Bitter Lake and Chase Lake colonies in average time of returns (of satellite-tracked pelicans) and nest exchanges (on video) may reflect a difference in the time thermals developed at the two sites.

Video data supported our expectations of the decline in feeding frequency and the increase in feeding-bout length as chicks aged. This expectation was based on the assumption that smaller chicks consume less food at one time and need to be fed more frequently than larger chicks. The finding that more frequent feedings occurred at successful nests suggests that these chicks may have been better fed and, thus, in better condition than chicks at unsuccessful nests. Chicks in good body condition likely are less vulnerable to adverse weather. Our data on adult pelicans' frequency of nest exchanges and chick feedings suggested that insufficient food deliveries can result in chick mortalities.

Additionally, nests that failed were poorly attended relative to successful nests. When not attended by a parent, chicks suffered harassment by other pelicans. Harassment included jabbing, biting, tossing, and, as described by Somers and others (2007), forced copulation. In one case on our video, an unattended chick less than a week old was forced away from its nest bowl by an unrelated adult; the chick never returned to the nest.

Beyond the video records, it was difficult to document the cause and timing of nest failures for two main reasons. First, if gulls (*Larus* spp.) depredated young chicks, no evidence remained to indicate why the nest failed. Second, to avoid unduly disturbing the colony, observations of small chicks at nests, alive or dead, were only made opportunistically.

The sample of nests that were remotely monitored with video confirmed what has been documented in other sources (Schaller, 1964; O'Malley and Evans, 1982); most adult pelicans with chicks exchanged places at the nest daily. However, data from some nests with chicks under video surveillance revealed unusual delays in exchanges between pair members tending the nests (for example, two exchanges were 3 or more days apart), or failure of a pair member to return to the nest at all. Eventually the bird tending the nest would walk away for short periods or not return, leaving chicks unattended. These vulnerable chicks sometimes died of exposure or were depredated by gulls. The proximate cause of death might have been predation or exposure, but the ultimate cause could have been limited food resources resulting in delayed return of the second adult, or some other factor (for example, weather) interfering with return of the second adult.

In contrast, direct connections between weather events and chick deaths were relatively clear-cut. Results underscored the potentially devastating effects of cold, wet, and windy conditions on chick survival, especially during the critical transition period between brooding and crèching.

The high death rate among second-hatched chicks at two-chick nests that we monitored was anticipated. Previous studies have documented high death rates for second chicks. Johnson and Sloan (1978) reported only 3 percent survival of second chicks to 2 weeks of age, which is similar to what we observed. Previous studies have documented siblicide as a major source of chick mortality (Johnson and Sloan, 1978; Cash and Evans, 1986). Pelicans are considered an obligate brood-reducing species (Cash and Evans, 1986). Even though many of the second-chick losses in this study did not fit the criteria for siblicide, most, if not all of the second chicks were vulnerable to other mortality factors because they were weakened by abuse from an older sibling.

Few instances of mammalian predation were documented, as expected given that the colonies were on islands a significant distance from the mainland. Gull predation on eggs was expected and a few incidents of gull predation were recorded at camera-monitored nests. Gulls eating eggs that had rolled out of nests and at unattended nests were regularly observed. On rare occasions, gulls were observed taking away unattended chicks that were less than 5 days old. This occurred when there was a disturbance causing adults to step off their nests; most disturbances were caused by other adult pelicans. Unexpectedly, predation of young chicks by black-crowned night-herons from under sleeping adult pelicans also was documented. All of the night-heron activity occurred in the same general area, which suggests a unique circumstance of an individual night-heron focusing on chicks as a food source.

Our finding that pelicans primarily used shallow areas of lakes and semipermanent wetlands to forage is consistent with behaviors and food habits reported in other studies. For example, Anderson (1991) found that pelicans largely forage along shorelines at water depths of 0.3–2.5 m. Our telemetry data illustrated this behavior. Furthermore, several studies of food resources report that pelicans' primary food resources were crayfish, salamanders, and rough fish (such as carp); these foods occur in shallow areas of lakes and wetlands (Knopf and Evans, 2004). These food items also were the most frequent contents that we observed in regurgitates at our colonies.

The behavior data collected at two colonies provide insights on breeding phenology, feeding rates for chicks at nests, adult nest attendance, and causes of chick mortality. Unfortunately, movement data for only a handful of satellite-tracked adult pelicans tending nests were collected. These individuals used diverse foraging sites and flew varying distances and directions from their nesting colonies. The distances flown were within the maximum in published accounts for Chase Lake (Johnson and Sloan, 1978). The frequencies of return trips to nesting colonies and the amount of time spent at the colonies were consistent with expectations (Knopf and Evans, 2004) for individuals tending eggs (one case) and chicks (several cases).

With additional such data, more could have been learned about the influence of foraging distances and the amount of time spent away from the colony on chick rearing. Our original intent was to use data from satellite-tracked pelicans to help assess patterns of nest attendance, foraging ranges and locations, and (by visiting GPS locations away from the nesting colony) characteristics of foraging and loafing sites used by breeding pelicans. By simultaneously monitoring pelicans from multiple colonies in the region, we expected to better differentiate between local and region-wide influences on productivity and identify differences and similarities in foraging habitats for pelicans from different colonies. The pelicans with satellite transmitters returned to the breeding region, but regrettably, data show evidence of only about five breeding attempts at known colonies (all in the year they were tagged), and only one or two potentially successful nesting efforts. Nevertheless, the information collected from breeding efforts by satellite-tracked pelicans, combined with data from video cameras and direct observations, can provide a baseline for future comparisons of similar data collected under different conditions.

Migration Patterns and Wintering Areas

During 2005–8, satellite-tracked pelicans collectively made 89 migratory trips south from or north into the breeding region. The general migration corridor defined by their GPS locations corroborates that derived from pelican band recoveries in earlier studies based in Saskatchewan (Houston, 1972), North Dakota (Strait and Sloan, 1975), and Minnesota (King and Grewe, 2001). The thousands of GPS locations obtained during these migration movements provide an unprecedented amount of information on specific sites used by pelicans throughout the central United States in the early 21st century. These data can be used to evaluate sites of importance to pelicans in the nonbreeding season.

King and Grewe (2001) reported a large increase in pelican recoveries around aquaculture areas in the Mississippi River flood plain of Arkansas, Louisiana, and Mississippi after 1985, possibly reflecting pelicans' attraction to this rapidly increasing source of food or an increased likelihood that pelicans would be killed or recovered near aquaculture areas. Very few satellite-tracked pelicans spent any time in the vicinity of aquaculture sites, and only one bird wintered there. Pelican 21722r spent much of the 2006–7 winter amid and on aquaculture ponds in Arkansas and Mississippi but spent most of the subsequent two winters more than 50 km east of the flood plain on a reservoir in Mississippi. The lack of use of aquaculture areas by satellite-tracked pelicans may reflect fidelity of these birds to other migration routes and wintering areas they already knew.

Wintering locations of satellite-tracked birds ranged from Florida to the Pacific coast of Mexico. A similar range of wintering locations can be derived from recoveries reported for pelicans banded at Marsh Lake, Minnesota, during 1972–98 (King and Grewe, 2001) and banded at various lakes in Saskatchewan during 1954–64 (Houston, 1972). Using aerial surveys during 1997–99, King and Michot (2002) obtained data on pelicans wintering in the Mississippi Delta region and the gulf coasts of Louisiana, Texas, and northeastern Mexico. Among the areas surveyed, the Louisiana coast had the highest numbers of pelicans; the pelicans used a variety of habitats on the coast, including fresh, brackish, and saline marshes. Although this was also an important wintering area for the satellite-tracked pelicans (16 percent wintered there), far more of the tracked birds wintered in Mexico (64 percent). The thousands of GPS locations obtained for wintering pelicans provide information on specific sites used, duration and timing of use, and movements among sites. Combined with appropriate imagery (that is, water levels similar to when the pelican was there), the type of habitat used at these sites also can be determined.

To assess habitat use, it is critical to use imagery that was taken under the same conditions that existed when the pelican was there. The consequences of a mismatch are illustrated for a sample of wetlands in the breeding region (fig. 14) and for a lake site used during winter (fig. 25). The latter is Lake Chapala, the largest natural freshwater lake in Mexico, which has been recognized as an important wintering habitat for pelicans (Global Nature Fund, 2011). It is also a principal water source for the city of Guadalajara; as a result of this, other anthropogenic factors, and variable rainfall, lake levels have varied by greater than 8 m, a considerable range for a lake with a maximum depth of 10.5 m (CEA Jalisco, 2011a,b; Global Nature Fund, 2011). The imagery from 2011 (fig. 25*B*) was acquired when lake levels were more than 3 m higher than they were when the 2000 imagery (fig. 25*A*) was captured. During the two winters that the satellite-tracked pelican was there, lake levels were about 2–3 m higher than in 2000, so the habitat is better represented by the 2011 imagery. Bathymetric maps of Lake Chapala (CEA Jalisco, 2011b) indicate that water depths in the part of the lake used by this pelican were likely 1–2 m.

Management Considerations

Identify, Monitor, and Protect Occupied Breeding Colonies in the Northern Plains

The status of many pelican breeding colonies across North America is unknown. With this uncertainty and with no coordinated search for new breeding colonies or monitoring of most active colonies, there is little understanding of the population dynamics of this species. Consequently, the population status of this species cannot be effectively evaluated. During the years of this study (2006–8), numbers of pelican nests declined at monitored colonies in the northern plains. Over this short period, annual variability in the numbers of nesting birds and the unknown number of pelicans breeding at undocumented colonies make it impossible to accurately assess changes in the regional population and, by default, the continental population. We recommend initiation of a coordinated regional or continental survey of breeding colonies. Once colony locations are identified, colony sites need to be protected from disturbance and other factors that influence productivity (see Mitigation of Threats section). Minimal monitoring (for example, nest counts and fledging counts) could provide enough information to assess population health. Ideally, survey data could be combined with information on population dynamics, mortality factors, and breeding and wintering habitats as part of a coordinated monitoring program. Evaluating the population status of the American white pelican is necessary to ensure a sustainable population.

Mitigation of Threats

Knopf and Evans (2004) identified (1) loss of breeding habitats, (2) loss of foraging habitats, and (3) disturbances at nesting areas as the most important factors limiting pelican populations. Our data revealed that disease (WNV) and severe weather can be added to that list.

Loss of Breeding Habitat

This study occurred during a wet cycle, with high precipitation levels and rising water conditions. During the years of this study, we observed inundation of nesting islands from one breeding cycle to the next, but found no indication that between-year habitat loss had any influence on the numbers of breeding birds at colony lakes. Returning adult pelicans successfully established new nesting areas at the lakes. At both colonies, rising water separated peninsulas from the mainland creating new islands, which were used for nesting by breeding pelicans. Historically, the various lakes in the area surrounding Bitter Lake have supported a large colony; that is, as water conditions fluctuated, the colony location varied to accommodate the change. However, persistence of colonies under such varying conditions is not assured. Vermeer (1970) reported loss of several colonies in Canada that were affected by fluctuations of water levels.

Rising or declining water levels within a breeding season should be of concern to managers. There are documented incidents of rising water destroying nests (Houston, 1962; Vermeer, 1970; S. Lockhart, Ontario Ministry of Natural Resources [Lake of the Woods colony], oral commun., 2007), of dry conditions allowing mammalian predators greater access to islands used by nesting pelicans, and of pelicans discontinuing use of a site once it is no longer separated from the mainland (Anderson and King, 2005; S. Comeau-Kingfisher, Lacreek National Wildlife Refuge, oral commun., 2007). Physical barriers protecting peninsula colonies have proved to be effective in preventing access by mammalian predators to colonies. At Medicine Lake NWR, pelicans nesting on a peninsula have been protected by a permanent fence that was built in 1982, which has successfully secured nests from access by mammalian predators.

Diminished quality of habitats used by nesting pelicans could also factor into the survival of chicks. At Chase Lake, we were surprised by the frequency and magnitude of chick deaths that were caused by severe weather. The chicks that died were largely in transition from being brooded to forming crèches. However, older chicks were not free from risk; 5- and 6-week-old chicks also died during or shortly after severe weather events. We believe the unusual magnitude of losses at Chase Lake was at least in part related to the inability of chicks at the south island (Subcolony 2) to form adequately sized crèches, which serve as a substitute for parental brooding. Adequately sized crèches provide thermal protection for the chicks. Most of the deaths occurred on the island with the most recently established nesting site. This circumstance developed because of shifts in colony locations forced by rising water levels that inundated some islands and created new islands (that is, cut-off peninsulas) during the past 10 years (Sovada and others, 2005). Ultimately, many pairs established nests on a newly formed island where habitat conditions were not entirely suitable. As the nesting season progressed, vegetation grew tall and dense on the island, causing individual or small groups of nests to become isolated. Under these conditions, chicks no longer being brooded were unable to get through the vegetation to reach each other to form crèches of adequate size. We observed lone birds or small isolated crèches of two to five birds. Chicks were observed shivering in 13+ °C (55+°F) temperatures. Because the size of a crèche does influence its function (Evans, 1984), under the unique circumstance that developed at Chase Lake, chicks were at risk of exposure during conditions that normally would have been ameliorated by the crèche. No management action has been applied (for example, clearing of pathways for the chicks to more easily congregate); however, even without intervention, the habitat conditions seemed to be improving as a result of persistent pelican activity reducing the height and density of the vegetation.

Severe Weather

Another factor that might exacerbate the habitat problems is earlier arrival of adults to the breeding grounds. First arrival dates of pelicans to Chase Lake are available for 37 of the past 44 years (Northern Prairie Wildlife Research Center, unpublished data). Pelicans are arriving about 16 days earlier than in the mid-1960s, so the vulnerable transition period between brooding and crèche falls about 2 weeks earlier for most birds. The cause of earlier returns is unknown, but it is believed the catalyst is conditions on the wintering grounds; perhaps global climate change is influencing the timing of the pelicans' migration. Usually breeding begins within a week of the pelicans' arrival on the colony site. Extended periods of rain and cold are more common in the first 2 weeks of June than the last 2 weeks of June, thus, more chicks are vulnerable to weather than 40 years ago.

Loss of Foraging Habitat

Because pelicans can fly 600 km to forage (Johnson and Sloan, 1978) and because there are plentiful wetlands in eastern South and North Dakota and western Minnesota, loss of foraging habitats is difficult to assess. The northern plains have been in a wet cycle since the mid-1990s so we did not observe breeding under dry conditions during this study. Johnson and Sloan (1978) proposed that extremely high rates of nest abandonment (75–99 percent) during their study were related to low water levels, which forced pelicans to travel farther and spend more time foraging. They further speculated that survival of young during their study was related to water conditions (that is, lower survival rates occurred when wetland conditions were drier). However, the initial drawdown of wetlands may benefit pelicans by concentrating prey and thus making them more vulnerable and accessible to pelicans (Lingle and Sloan, 1980). Prolonged drought, of course, eventually reduces the aquatic food base. After a very dry period that began in 1988, wet conditions returned dramatically in 1993, quickly restoring water in wetland basins (Krapu and others, 2004; Winter and Rosenberry, 1998). Numbers of breeding pelicans at Bitter Lake and Chase Lake colonies started to grow in the 1990s, possibly in response to the increased availability of ponds for foraging that began in 1993. Such conditions likely attracted breeding pelicans and improved recruitment (Johnson and Sloan, 1978).

During the wet period of our study, pelicans were using recently flooded areas that were not classified as wetland under the lower water levels of the 1980 NWI data. Inundation of vegetation surrounding the wetlands likely improved conditions for minnow production and for salamanders (Euliss and others, 2004; Herwig and others, 2010). Pelicans may have benefited from increases in minnow and salamander populations in newly flooded areas. Minnows and salamanders are among the most important food resources for pelicans in this region (Lingle and Sloan, 1980).

We expect variation in foraging conditions across the pelican's breeding range and among years. Data on adult pelicans' frequency of nest exchanges and chick feedings suggested some periods when chicks appeared to suffer from insufficient food deliveries. Although poor foraging conditions could significantly impact annual production of fledglings, it would not necessarily affect the population status over the long term.

Disturbance and Predation

Disturbances by humans (for example, direct, motorboats, low-flying planes) or predators (for example, gulls, coyotes, red foxes [*Vulpes vulpes*]), particularly during courtship and at the beginning of incubation, are documented causes of colony desertion by pelicans (Blokpoel 1971; Anderson and Keith, 1980; Bunnell and others, 1981; Findholdt and Diem, 1988; Doran and others, 2004). Typically, pelican colonies are found on islands, which provide some protection from mammalian predators or livestock; but mainland areas have been selected for nesting by some pelicans at both Bitter and Chase Lakes in the last decade. At both of these colonies, disturbance caused failures of nests on mainland sites. As reported earlier, at Bitter Lake in 2007, nests initiated at a new site along the south shoreline were abandoned after being disturbed by cattle, and a group of camera-monitored nests at the edge of the colony apparently failed as a result of an unknown disturbance. At Chase Lake, a peninsula successfully used by nesting pelicans for 5 years was abandoned in 2004 following disturbance by coyotes (Sovada and others, 2008). Others have reported abandonment of nesting sites following disturbance by coyotes (Bunnell and others, 1981; Findholdt and Diem, 1988). Bitter Lake is a popular lake for fishing and boating, and although we did not observed any losses caused by humans, it is likely that some disturbance caused by people offloading on the islands will occasionally occur in the future.

On the breeding grounds, but away from the colony sites, instances of harassing or killing pelicans occur because some people wrongly believe that foraging pelicans have an impact on game fish or bait fish. Pelicans in the northern plains mainly forage in shallow waters, eating salamanders, crayfish, minnows, and "rough" fish (for example, carp) of little recreational or economic value (Lingle and Sloan, 1980); thus, most often this harassment is unwarranted.

There are multiple opportunities to protect colonies from disturbance by people and mammalian predators. Raising public awareness of pelicans' minimal impact on game fish through education could be the first step toward acceptance of pelicans foraging on lakes and reservoirs alongside anglers. Simple measures could be engaged to protect colonies during the breeding season, such as posting of islands (and enforcement) to deter colony access by anglers or boaters. Nesting islands could be further protected by developing a core area around the island, in which human access is limited or banned during the breeding season. Restricting aircraft from flying low over colonies during critical nesting periods could be an additional protective measure. Potential losses to coyotes or other mammalian predators could be minimized if, when mammalian predators are stranded on islands following ice out, there is an effort to remove them prior to the return of pelicans in the spring. If peninsular or other mainland nesting sites are to be maintained, predator barrier fences will be required. Additionally, research and monitoring at colony sites should be conducted from a distance whenever possible (for example, using spotting scopes or blinds).

Other Management Consideration

There are some pieces of information that would be valuable to collect annually in order to track potential issues for the pelican population. Aerial photographs of colonies during peak nesting would provide indications of changing nest numbers, nesting sites, and water levels. Estimates of numbers of chicks fledged (aerial photographs or ground counts) are more difficult to acquire but would be useful for detecting significant reproductive success or failure. Banding of a subsample of chicks in late June or early July, followed by an end-of-the-season sweep for bands (that is, banded chicks that died), would provide an estimate of mortality rates of older chicks (those that normally would fledge) and fledging rates. These data also could provide insight to changes in the influence of WNV on productivity. Combining these pieces of information would allow managers to track colony productivity and alert them to major changes.

Final Thoughts

Data from surveillance cameras, direct observations, pelicans with transmitters, and the WNV evaluation contribute to our understanding of pelican biology in the northern plains, and provide a foundation for conservation and management decisions that potentially affect the entire population of American white pelicans. Protection of colonies is an important element in the management of breeding pelicans. Although it is generally difficult (if not impossible) to manage for effects of water-level changes, WNV, and weather events, knowledge of these effects can provide information of critical importance for resource-allocation decisions made at higher levels. For example, to the extent that some of these effects relate to regional and global climate change, they could have bearing on national-level decisions made by various government agencies.

References Cited

Anderberg, M.R., 1973, Cluster analysis for applications: New York, Academic Press, 359 p.

Anderson, D.J., and Keith, J.O., 1980, The human influence on seabird nesting success—Conservation implications: Biological Conservation, v. 18, p. 65–80.

Anderson, D.W., and King, D.T., 2005, Introduction—Biology and conservation of the American white pelican: Waterbirds, v. 28 (Special Publication), p.1–8.

Anderson, J.G.T., 1991, Foraging behavior of the American white pelican (*Pelecanus erythrorhynchos*) in western Nevada: Colonial Waterbirds v. 14, p. 166–172.

Blokpoel, H., 1971, Fox predation on a bird island: Blue Jay, v. 29, p. 32–34.

Bunnell, F.L., Dunbar, D., Koza, L., and Ryder, G., 1981, Effects of disturbance on the productivity and numbers of white pelicans in British Columbia—Observations and models: Colonial Waterbirds, v. 4, p. 2–11.

Cash, K.J., and Evans, R.M., 1986, Brood reduction in the American white pelican (*Pelecanus erythrorhynchos*): Behavioral Ecology and Sociobiology, v. 18, p. 413–418.

CEA Jalisco, 2011a, Lago de Chapala: La Comisión Estatal del Agua, Guadalajara, Jalisco, México, accessed October 25, 2011, at *http://www.ceajalisco.gob.mx/chapala.html*.

CEA Jalisco, 2011b, Sistema Estatal de Información del Agua: La Comisión Estatal del Agua, Guadalajara, Jalisco, México,accessed October 25, 2011, at *http://www.ceajalisco.gob.mx/sia/*.

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E T., 1979, Classification of wetlands and deepwater habitats of the United States: U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., 131 p.

Doran, P.J., Whalen, M., Riener, K., and Fitzner, L., 2004, American white pelican (*Pelecanus erythrorhynchos*), *in* Larsen,E., Azerrad, J.M.,and Nordstrom, N., eds., Management recommendations for Washington's priority species. v. IV: Birds. Olympia, Wash., Washington Department of Fish and Wildlife, p. 2.1–2.7.

Dorr, B., King, D.T., Harrel, J.B., Gerard, P., and Spalding, M.G., 2005, The use of culmen length to determine sex of the American white pelican: Waterbirds, v. 28, p. 102–106.

Drilling, N.E., 2007, South Dakota statewide colonial and semi-colonial waterbird inventory with a plan for long-term monitoring— Final Report: SDGFP Wildlife Division Report 2008–01A, RMBO Technical Report # M–Colony-SD–04, Brighton, Colorado, Rocky Mountain Bird Observatory, 80 p.

Dunstan, T.C., 1972, Radio-tagging falconiform and strigiform birds: Raptor Research, v. 6, p. 93–102.

Environmental Systems Research Institute, 2011, ArcGIS Desktop: Release 10: Redlands, Calif., Environmental Systems Research Institute.

Euliss, N.H., Jr., LaBaugh, J.W., Fredrickson, L.H., Mushet, D.M., Laubhan, M.K., Swanson, G.A., Winter, T.C., Rosenberry, D.O., and Nelson, R.D., 2004, The wetland continuum—A conceptual framework for interpreting biological studies: Wetlands, v. 24, p. 448–458.

Evans, R.M., 1984, Some causal and functional correlates of crèching in young white pelicans: Canadian Journal of Zoology, v. 62, p. 814–819.

Evans, R.M., 1997, Parental investment and quality of insurance offspring in an obligate brood-reducing species, the American white pelican: Behavioral Ecology, v. 8, p. 378–383.

Findholdt, S.F., and Diem, K.L., 1988, Status and distribution of American white pelican nesting colonies in Wyoming—An update: Western North American Naturalist, v. 48, p. 285–289.

Gaunt A.S., and Oring, L.W., 1999, Guidelines for the use of wild birds in research: Washington, D.C., Ornithological Council, 52 p.

Global Nature Fund, 2011, Living lakes: Lake Chapala, Mexico: Global Nature Fund, Radolfzell, Germany Internationale Stiftung für Umwelt und Natur, accessed October 25, 2011, at *http://www.globalnature.org/15605/LIVING-LAKES/America/Lake-Chapala/02_vorlage.asp*.

Herwig, B.R., Zimmerman, K.D., Hanson, M.A., Kosti, M.L., Younk. J.A., Wright, R.W., Vaughn, S.R., and Haustein, M.D., 2010, Factors influencing fish distributions in shallow lakes in prairie and prairie-parkland regions of Minnesota, USA: Wetlands, v. 30, p. 600–619.

Houston, C.S. 1962, Hazards faced by colonial birds: Blue Jay, v. 20, p. 74–77.

Houston, C.S. 1972, Recent Saskatchewan banding of the white pelican: Blue Jay, v. 30, p. 24–27.

Johnson, R.F., Jr., and Sloan, N.F., 1978, White pelican production and survival of young at Chase Lake National Wildlife Refuge, North Dakota: Wilson Bulletin, v. 90, p. 346–352.

King, D.T., and Anderson, D.W., 2005, Recent population status of the American white pelican—A continental perspective: Waterbirds, v. 28 (Special Publication), p. 48–54.

King, D.T., and Grewe, A.H., Jr., 2001, Movements and mortality of American white pelicans banded at Marsh Lake, Minnesota: North American Bird Bander, v. 26, p. 57–60.

King, D.T., and Michot, T.C., 2002, Distribution, abundance and habitat use of American white pelicans in the Delta region of Mississippi and along the western Gulf of Mexico coast: Waterbirds, v. 25, p. 410–416.

King, D.T., Paulson, J.D., Leblanc, D.J., and Bruce K., 1998, Two capture techniques for American white pelicans and great blue herons: Colonial Waterbirds, v. 21 p. 258–260.

Knopf, F.L., and Evans, R.M., 2004, American white pelican (*Pelecanus erythrorhynchos*). *in* Poole, A., ed.,. The birds of North America: Ithaca, N.Y., Cornell Laboratory of Ornithology.

Kushlan, J.A., Steinkamp. M.J., Parsons, K.C., Capp, J., Cruz, M.A., Coulter, M., Davidson, I., Dickson, L., Edelson, N., Elliot, R., Erwin, R.M., Hatch, S,. Kress, S., Milko, R., Miller, S., Mills, K., Paul, R., Phillips, R., Saliva, J.E., Sydeman, B., Trapp, J., Wheeler, J., and Wohl, K., 2002, Waterbird conservation for the Americas—The North American Waterbird Conservation Plan: Version 1, Washington, D.C., Waterbird Conservation for the Americas, 78 p.

Krapu, G.L., Reynolds, R.E., Sargeant, G.A., and Renner, R.W., 2004, Patterns of variation in clutch sizes in a guild of temperate-nesting dabbling ducks: Auk, v. 121, p. 695–706.

Lingle, G.R., and Sloan N.F., 1980, Food habits of white pelicans during 1976 and 1977 at Chase Lake National Wildlife Refuge, North Dakota: Wilson Bulletin, v. 92, p. 123–125.

Littell, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D., and Schabenberger, O., 2006, SAS for mixed models, 2d ed.: Cary, North Carolina, SAS Institute Inc., 813 p.

Manly, B., McDonald, L.L., Thomas, D.L., McDonald, T.L., and Erickson, W.P., 2002, Resource selection by animals—Statistical design and analysis of field studies, 2d ed.: Boston, Mass., Kluwer Academic Publishers, 177 p.

North Dakota Game and Fish Department, 2012, Species of conservation priority: North Dakota Game and Fish Department, accessed September 19, 2012, at *http://www.gf.nd.gov/conservation-nongame-wildlife/species-conservation-priority*.

O'Malley, J.B.E., and Evans, R.M., 1982. Flock formation in white pelicans: Canadian Journal of Zoology, v. 60, p. 1024–1031.

SAS Institute. 2010. SAS OnlineDoc 9.2., Cary, N.C**.,** SAS Institute Inc. *http://support.sas.com/documentation/92/index.html*.

Schaller, G.B., 1964. Breeding behavior of the white pelican at Yellowstone Lake, Wyoming: Condor, v. 66, p. 3–23.

Service Argos, 2008, User's manual: Landover, Md., Servos Argos, Inc.

Somers, C.M., Kjoss,V.A., and Brigham, R.M., 2007, American white pelicans force copulations with nestlings: Wilson Journal of Ornithology, v. 119, p. 279–283.

South Dakota Department of Game, Fish and Parks, 2006, South Dakota comprehensive wildlife conservation plan: Wildlife division report 2006–08: Pierre, South Dakota Department of Game, Fish and Parks, 421 p.

South Dakota Department of Game, Fish, and Parks, 2012, Rare, threatened or endangered animals tracked by the South Dakota Natural Heritage Program, accessed October 29, 2012, at *http://gfp.sd.gov/wildlife/threatened-endangered/rare-animal.aspx*.

Sovada, M.A., King, D.T., Ericson, M., and Gray, C., 2005, Historic and current status of breeding American white pelicans at Chase Lake National Wildlife Refuge, North Dakota: Waterbirds, v. 28 (Special Publication), p. 27–34.

Sovada, M.A., Pietz, P.J., Converse, K.A., King, D.T., Hofmeister, E.K., Scherr, P., and Ip, H.S., 2008, Impact of West Nile virus and other mortality factors on American white pelicans at breeding colonies in the northern plains of North America: Biological Conservation, v. 141, p.1021–1031.

Strait, L.E., 1973, Population dynamics of a white pelican population, Chase Lake National Wildlife Refuge, North Dakota: Houghton, Mich., Michigan Technological University, M.S. Thesis, 76 p.

Strait, L.E., and Sloan, N.F., 1975, Movements and mortality of juvenile white pelicans from North Dakota: Wilson Bulletin, v. 87. p. 54–59.

Vermeer, K., 1970, Distribution and size of colonies of white pelicans, *Pelecanus erythrorhynchos,* in Canada: Canadian Journal of Zoology, v. 48, p. 1029–1032.

Winter, T.C., and Rosenberry, D.O., 1998, Hydrology of prairie pothole wetlands during drought and deluge—A 17-year study of the Cottonwood Lake wetland complex in North Dakota in the perspective of longer term measured and proxy hydrological records: Climate Change, v. 40, p. 189–209.

Appendixes A–C

Appendix A. Number of American white pelican nests monitored with video recordings, number of hours that nests were monitored, and breakdown of hours by nest contents.

[Video recordings were made at pelican breeding colonies at Chase Lake, North Dakota, and Bitter Lake, South Dakota, 2006–8]

Year	Nests	Hours monitored by nest contents				
		All nests	1 Chick	2 Chicks	1 or 2 Chicks (number uncertain)	Eggs
Bitter Lake						
2006	9	2,364	1,736	305	0	323
2007	25	3,873	1,587	833	543	910
2008	48	7,848	5,086	1,049	754	959
Chase Lake						
2006	26	3,693	2,947	564	34	148
2007	53	5,214	2,706	1,073	725	710
2008	9	2,485	1,475	731	0	279

Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.

[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
							Bitter Lake							
2005	July 27	21878-F							SD	SD	SD, NE	NE, IA, KS, AR, LA	LA	LA
2006		21878-F	LA	LA	LA	LA	LA, AK, MO	MO, KS	KS, NE, SD, ND	ND, SD	SD, NE-IA, KS	KS, OK, AR, LA	LA	LA
2007		21878-F	LA	LA	LA	LA	LA	LA, TX, OK, KS, SD	SD, ND	SD	SD, KS, MO	MO	MO, AR, LA	LA
2008		21878-F	LA	LA	LA, TX	LA	LA, TX, OK, KS	KS	KS	KS, MX	OK, MO, AR, LA-MS	MS, LA	LA	LA
2009		21878-F	LA	PTT turned off										
2005	July 27	21945-F							SD	SD	SD, KS, OK	OK	OK, TX	tx*
2006		21945-F	tx*	tx*	tx*	tx*	tx*	tx*	tx*	tx*	tx*	TX	tx*	TX
2007		21945-F	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	TX last fix Nov 29	
2005	July 28	21893r-F							SD	SD	SD	SD, OK	OK, TX	TX, MX
2006		21893r-F	MX	MX	MX	MX, TX	TX, OK, KS, SD (at BL colony May 23–24)	SD	SD	SD	SD, NE, OK	OK, TX	TX, MX	MX
2007		21893r-F	MX last fix Jan 18											
2006	June 06	21925r-M						SD (at BL colony June 6–10, 15–16)	SD, MN, IA	IA-MN	MN, IA, KS, OK	OK, TX, LA	LA	LA
2007		21925r-M	no data	no data	no data	LA, AR, KS, MO	IA, MN, SD	IA last fix June 4						

Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.—Continued

[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
							Bitter Lake—Continued							
2006	June 06	64532-F						SD	SD	SD	SD	SD, KS, OK	TX	TX, MX
2007		64532-F	MX last fix Jan 18											
2006	June 06	64534-F						SD, ND (7 return trips to BL colony June 10–25)	ND	ND	ND, SD, KS	OK, TX, MX	MX	MX
2007		64534-F	MX	MX	MX	MX	MX, TX, OK, KS, NE, SD	SD, ND	ND	ND	ND, SD, OK	OK, TX, MX	MX	MX
2008		64534-F	MX	MX	MX	MX	MX	TX, MX	MX	MX	MX	MX	MX last fix Nov 19	
2006	June 06	64535-F						SD	SD	SD	SD, NE, KS	KS, OK	TX, MX	MX
2007		64535-F	MX	MX	MX last fix Mar 8									
2006	June 06	64536-M						SD, MN	MN	MN, IA, MO-NE, KS	KS, MO, AR-TN-MS	AR, LA	LA	LA
2007		64536-M	LA	LA	LA	LA, MS, AR, OK, KS	KS, MO, IA, MN, SD, ND	MN, SD	SD, MN	MN, NE, MO, KS, OK	OK, KS	KS, LA	LA	LA last fix Dec 17

Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.—Continued

[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
							Bitter Lake—Continued							
2006	June 06	64537-M						SD (5 return trips to BL colony June 13–28)	SD (15 return trips to BL colony July 3–31)	SD (10 return trips to BL colony Aug 1–13)	SD, NE, KS, OK	OK, TX	TX	TX, MX
2007		64537-M	MX	MX	MX	MX	MX, TX, OK, KS, SD (at BL colony May 13–14)	SD	SD	SD	SD, NE, KS, OK	OK, TX	TX	TX, MX
2008		64537-M	MX	MX	MX	MX, TX, OK, KS	KS, MN, SD	SD	SD	SD	SD, NE-IA, KS-MO, OK	OK, TX, LA	TX	TX, MX
2009		64537-M	MX	PTT turned off										
2006	June 06	64538-F						SD (5 return trips to BL colony June 15–28)	SD (at BL colony July 11)	SD	SD, KS, OK, AR	AR, LA	LA, TX	TX, MX
2007		64538-F	MX	MX	MX	MX	MX	MX, TX	TX	TX	TX	TX	TX, MX	MX
2008		64538-F	MX	MX	MX	MX	MX	MX, TX, KS, NE, SD	SD	SD	SD, KS, OK	OK, TX, LA	LA	LA, TX, MX
2009		64538-F	MX	PTT turned off										
2006	June 06	64539-M						SD	SD, MN	MN	MN, MO	KS	OK, TX, MX	TX, MX
2007		64539-M	MX	MX	MX	MX	MX, TX, OK, KS, SD	SD	SD	SD	SD	SD, KS, OK	OK, TX	TX
2008		64539-M	TX	TX	TX	TX last fix Apr 15								

Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.—Continued

[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
							Chase Lake							
2005	May 26	21893-F					ND	ND	ND dead	PTT re-deployed at BL 2005				
2005	May 26	21922-M					ND, SD	SD, ND	ND	ND, SD last fix Aug 21				
2005	May 31	21917-M					ND	ND, SD, MN	MN, IA	MN, IA, IL	IL	IL, MO-TN, AR, MS	TN-MO, AR, LA, TX	TX, MX
2006		21917-M	MX	MX	MX	MX	MX, TX, OK, KS, SD, ND (at BL colony May 24–25)	ND, SK, MB	ND	ND, MN, IA, IL	IL	IL, AR, MS, LA	AR, TX, MX	MX
2007		21917-M	MX	MX	MX	MX, TX	TX, OK, KS	OK, KS, MN, IA	MN-IA	MN, IA, IL	IL, MO-TN, AR-MS	AR-MS-LA	AR last fix Nov 22	
2005	June 01	21932-M						ND, MN	MN, IA	MN-IA	IA, MO	MO, OK, TX	TX	TX
2006		21932-M	TX	TX	TX	TX, OK	OK, KS, NE,	NE, SD	SD	SD	SD, NE, OK, TX	TX	TX	TX
2007		21932-M	TX	TX	TX	TX, OK	OK, KS, NE	NE, SD	SD	SD	SD, NE, KS, OK, AR	AR, TX	TX	tx*
2008		21932-M	no data	TX	no data	TX, OK, KS	KS, NE, SD, MN	MN, SD	MN-IA	MN, IA	IA, KS, MO, OK, AR	AR-MS, LA, TX	TX	TX
2009		21932-M	TX	TX PTT turned off										

Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.—Continued

[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
							Chase Lake—Continued							
2005	June 03	21913-F						ND	ND	ND	nd*	SD, KS, OK, TX	TX, MX	MX
2006		21913-F	MX	MX	MX	MX	TX, OK, IA, MN, SD, ND (at BL colony May 22–26)	ND, SD (at BL colony June 7–8)	SD	SD, ND	SD, NE, KS, OK	OK, TX, MX	MX	no data
2007		21913-F	MX	MX	MX	MX	MX, TX, OK, SD, ND, MN	MN, ND	MN, SD	SD	SD	SD, NE, KS, OK, TX, MX	MX	MX
2008		21913-F	MX	MX	MX	MX, TX, OK, KS, SD	SD, MN	ND, MN	MN, ND, SD	ND, SD	ND, SD	SD, KS, OK, TX	OK, TX, MX	MX
2009		21913-F	MX	PTT turned off										
2005	June 04	21925-M						ND, SD	SD	SD, NE	NE	NE	NE, KS dead	PTT redeployed at BL 2006
2005	June 04	21959-M						ND, MN, WI	IA-IL, MN-WI	MN-WI-IA	MN-WI-IA-IL-MO	IA-IL-MO-TN-AR-MS	AR-MS, LA	LA
2006		21959-M	LA	LA	LA	LA	LA, TX, OK, KS, IA, SD, MN	MN	MN	MN	MN, IA, MO-IL	IL-MO-KY, LA	LA	LA
2007		21959-M	LA	LA	LA	LA	OK, SD, MN, IA	MN	MN	MN, IA	IA-IL-MO	IL	AR-MS, LA	LA
2008		21959-M	LA	LA	LA	LA, TX, OK	OK, KS, IA, MN	MN, WI	WI last fix July 23					

Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.—Continued

[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
							Chase Lake—Continued							
2005	June 16	21944-F						ND	ND, MN	MN	MN, IA	IA, MO	MO, AR, LA	LA, TX, MX
2006		21944-F	MX	MX	MX	MX	MX, TX	MX, TX, OK, CO, SD	SD, ND	ND, SD	SD, KS, OK	OK	OK, TX, MX	MX
2007		21944-F	MX	MX	MX	MX	MX, TX, OK	OK,KS, NE, IA, SD	SD	SD, NE, KS	KS, AR, MS	AR-MS-LA	MS-LA	LA, TX, MX
2008		21944-F	MX	MX	MX	MX	MX, TX	TX, KS, SD	SD, MN	MN-IA	OK last fix Sept 21			
2006	June 01	64530-F							ND	ND	ND, SD, MN, IA-IL-MO	MO-IL, MS, FL	FL	FL
2007		64530-F	FL	FL	FL	FL	FL last fix May 13							
2006	June 01	64531-F						ND	ND	ND	ND, SD, KS	TX	TX, MX	MX
2007		64531-F	MX	MX	MX	MX	MX, TX	TX, OK last fix June 12						
2006	June 01	64533-F						ND, SD, MN	MN, ND	ND	ND, SD, NE-IA, KS	TX	TX, MX	MX
2007		64533-F	MX	MX	MX	MX	MX,TX, OK, KS	KS, OK, NE, SD	SD	SD	SD, NE, KS, OK	OK, TX	TX, MX	MX
2008		64533-F	MX	MX	MX	MX	MX, TX	TX, KS, NE	TX, KS, NE	SD	SD, NE, KS, OK	OK	OK, TX, MX	MX
2009		64533-F	MX	PTT turned off										

Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.—Continued

[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
							Chase Lake—Continued							
2006	July 10	21722r-M							ND (15 return trips to CL colony July 11–29)	ND, SD, NE (5 return trips to CL colony Aug 4–19)	NE, KS, OK	OK, AR, MS	MS	MS, AR
2007		21722r-M	AR	AR, MS	MO-IL	IL	IL, MN, MB, ND, IA	IA, MN, ND	ND	ND, SD, NE, KS	KS, OK	OK, AR-MS	MS	MS
2008		21722r-M	MS	MS	MS, TN-AR, IL-MO	AR, IL, IA-IL, MN-WI	IA-IL	IA-WI, MN-WI	SD	SD	SD, NE, KS, OK, AR, MS	AR-MS	AR-LA-MS	MS
2009		21722r-M	MS	PTT turned off										
							Medicine Lake							
2005	June 07	21428-M						MT, ND, SD	SD	SD, NE	SD, NE, KS	KS, OK, TX	TX	TX
2006		21428-M	no data	no data	TX	TX, AR	AR, OK, KS	KS, SD	SD	SD	SD, NE, KS, OK	OK	OK, AR, TX	AR, TX, MX
2007		21428-M	TX, MX	MX	MX	MX	MX	MX	MX	MX	MX	MX	MX	MX
2008		21428-M	MX	MX	MX	MX	MX, TX	MX	MX	MX	MX	MX	MX	MX last fix Dec 14
2005	June 07	21545-M						MT, ND	ND	ND, SD, IA, MO, KS	KS, OK	OK, TX	TX	TX
2006		21545-M	TX	TX	TX	TX, OK, KS, NE, SD	SD, ND	ND, SD (at BL colonies on June 3–4)	SD, MN	MN, IA, MO	MO, KS, OK, TX, LA	LA, TX	TX last fix Nov 18	

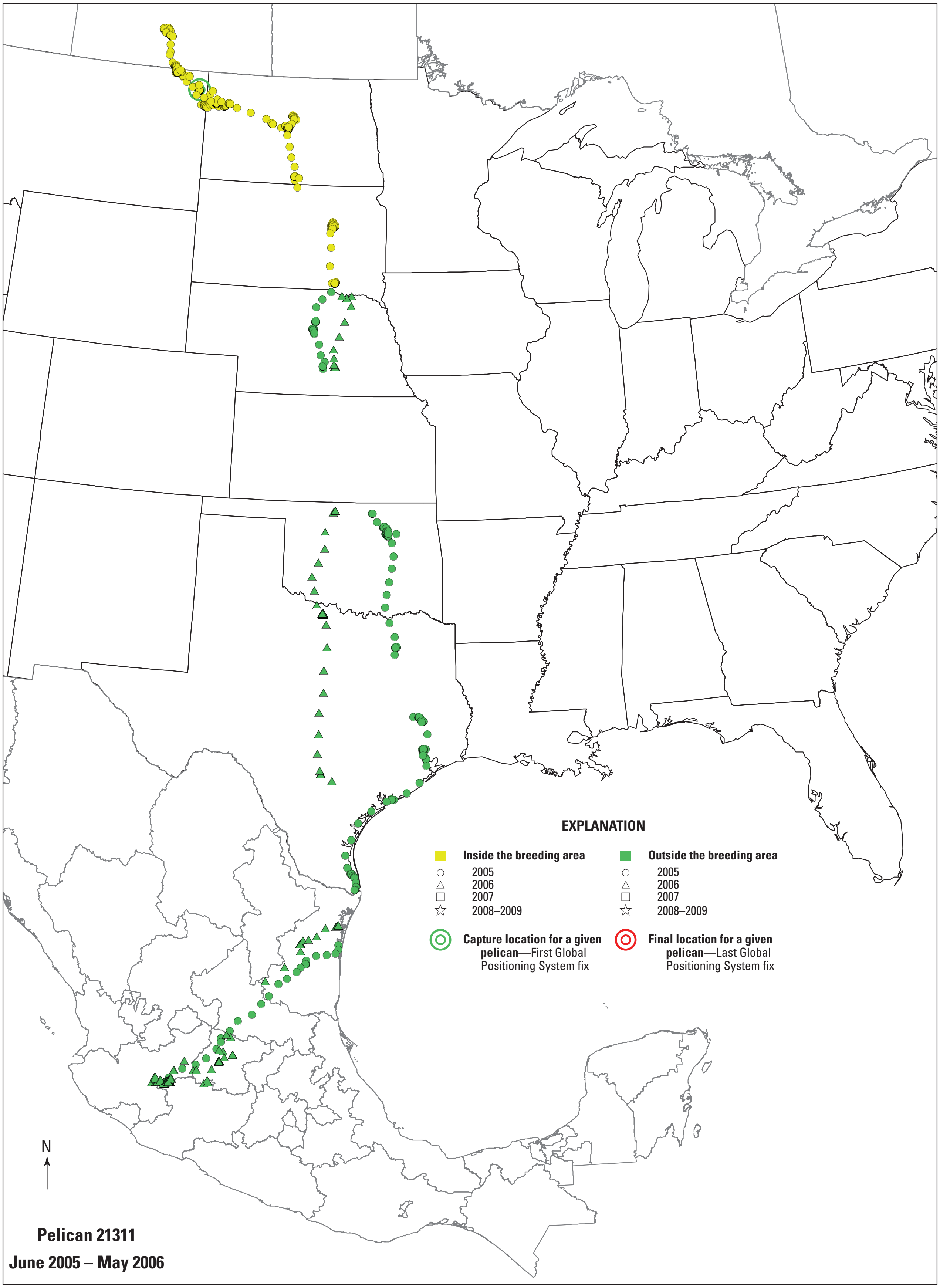
Appendix B. Monthly locations of American white pelicans tagged with Global Positioning System (GPS) satellite-received transmitters (platform transmitter terminals [PTT]), 2005–9. Adult pelicans were captured at three northern plains colonies (Bitter Lake, South Dakota; Chase Lake, North Dakota; Medicine Lake, Montana) in 2005 and 2006.—Continued

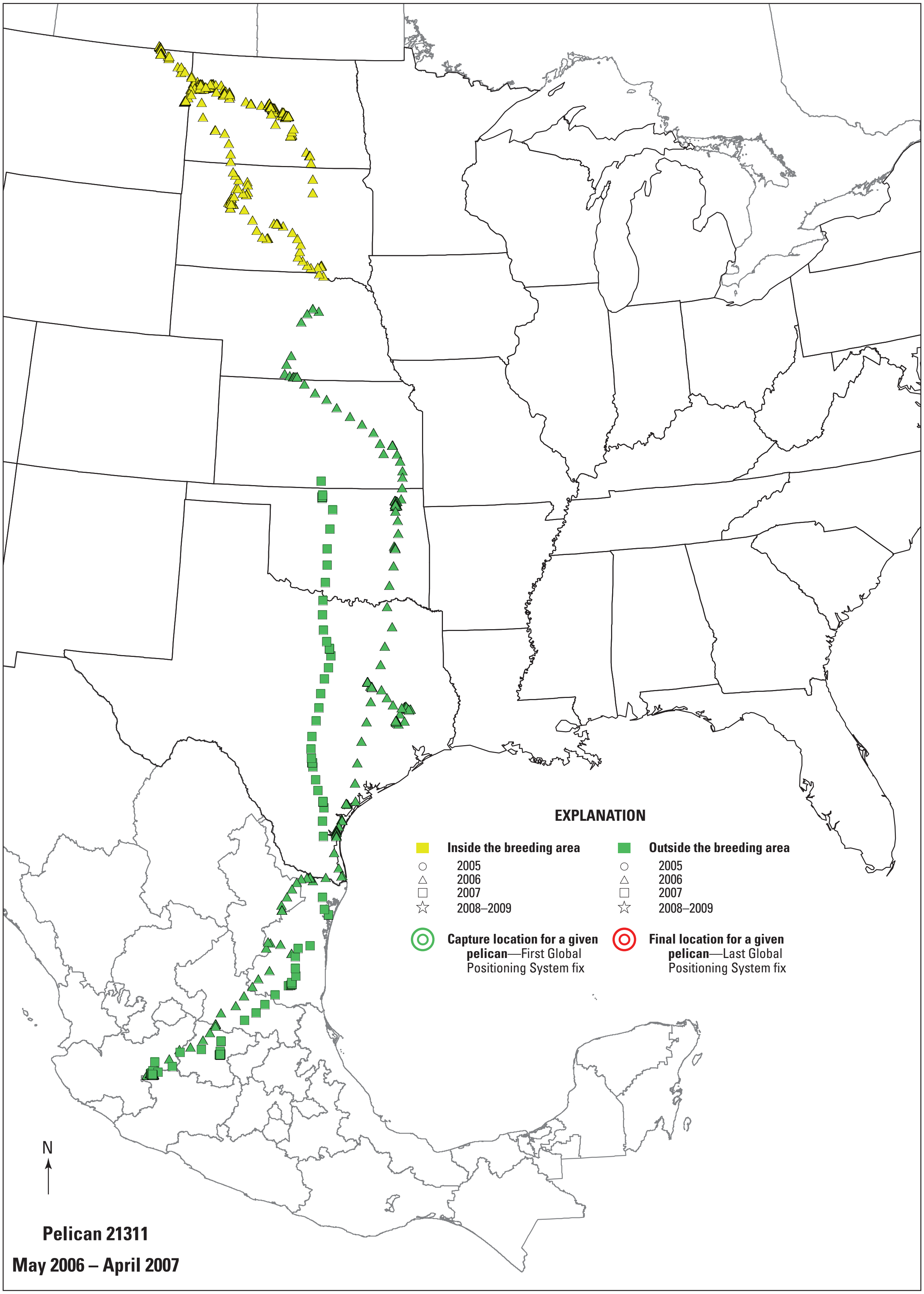
[Capitalized 2-letter abbreviations for each pelican's locations (U.S. states, Canadian provinces, Mexico) are listed wherever GPS data indicated that the bird was not flying (defined by speed of less than or equal to 3 kilometers per hour; thus, if the bird merely flew over a state, then that state is not listed). Location abbreviations are joined by hyphens when the pelican's locations were primarily on the border between states (for example, a river). Lower case 2-letter abbreviations followed by an asterisk indicate that we received some satellite location data (best accuracies plus or minus 150 meters) during that month, but no GPS locations (accuracies plus or minus 18 meters). AR, Arkansas; CO, Colorado; IL, Illinois; IA, Iowa; FL, Florida; KS, Kansas; LA, Loisiana; MB, Manitoba; MX, Mexico; MN, Minnesota; MO, Missouri; MS, Mississippi; MT, Montana; NE, Nebraska; ND, North Dakota; OK, Oklahoma; SK, Saskatchewan; SD, South Dakota; TN, Tennesee; TX, Texas; lower case and *, satellite fix only–no GPS data; BL, Bitter Lake; CL, Chase Lake; ML, Medicine Lake; ≥, greater than or equal to]

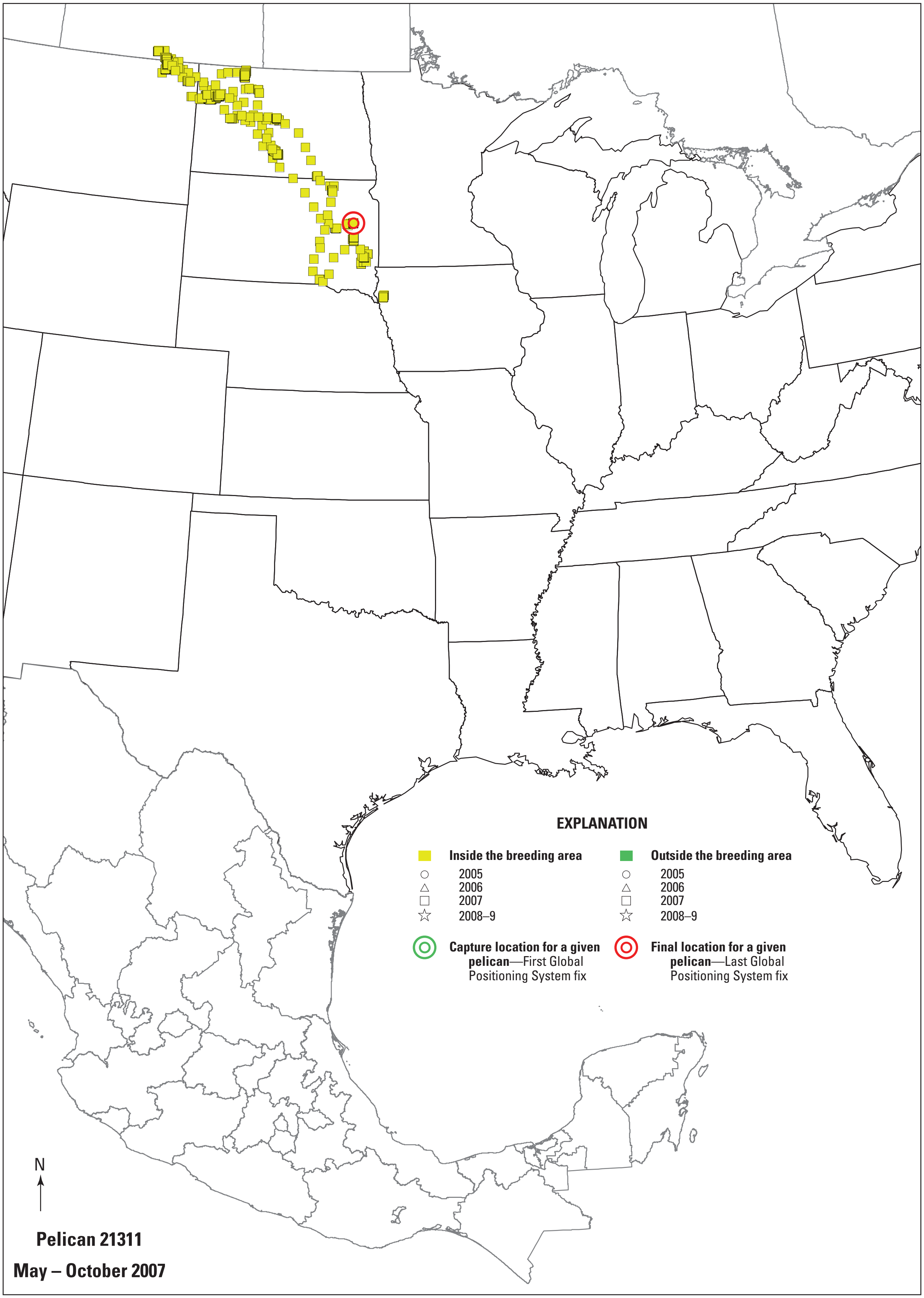
Year	Capture date	PTT No.-Sex	January	February	March	April	May	June	July	August	September	October	November	December
								Medicine Lake—Continued						
2005	June 08	21311-M						MT, ND, SK (at ML colony June 10–16, 22–23)	SK, MT, ND	ND	ND, SD, NE, KS	NE, OK, TX	TX, MX	MX
2006		21311-M	MX	MX	MX	MX	TX, OK, NE, SD, ND, SK	ND, SK, MT	ND	ND	ND, NE, KS, OK, TX	TX, MX	MX	MX
2007		21311-M	MX	MX	MX	MX, TX, OK	IA, SD, ND, MT	MT, ND, SK	SK, ND	ND, SD	SD dead	last fix Oct 8		
2005	June 09	21546-F						MT, ND	ND	ND	ND	ND, SD, KS, OK	OK, TX	TX, MX
2006		21546-F	MX	MX	MX	MX	MX, TX, OK	TX, OK, NE, SD, ND	ND	ND	ND, SD, NE, KS, OK	OK, TX, MX	MX	MX
2007		21546-F	MX	MX	MX	MX last fix Apr 1								
2005	June 10	21722-M						MT, ND (at ML colony on 16 days; ≥ 5 return trips in June)	MT, ND (at ML colony July 5–7)	MT, ND, SD, MN, IA	IA	IA, MO	MO, OK, TX	TX, MX
2006		21722-M	MX	MX	MX dead	PTT redeployed at CL 2006								

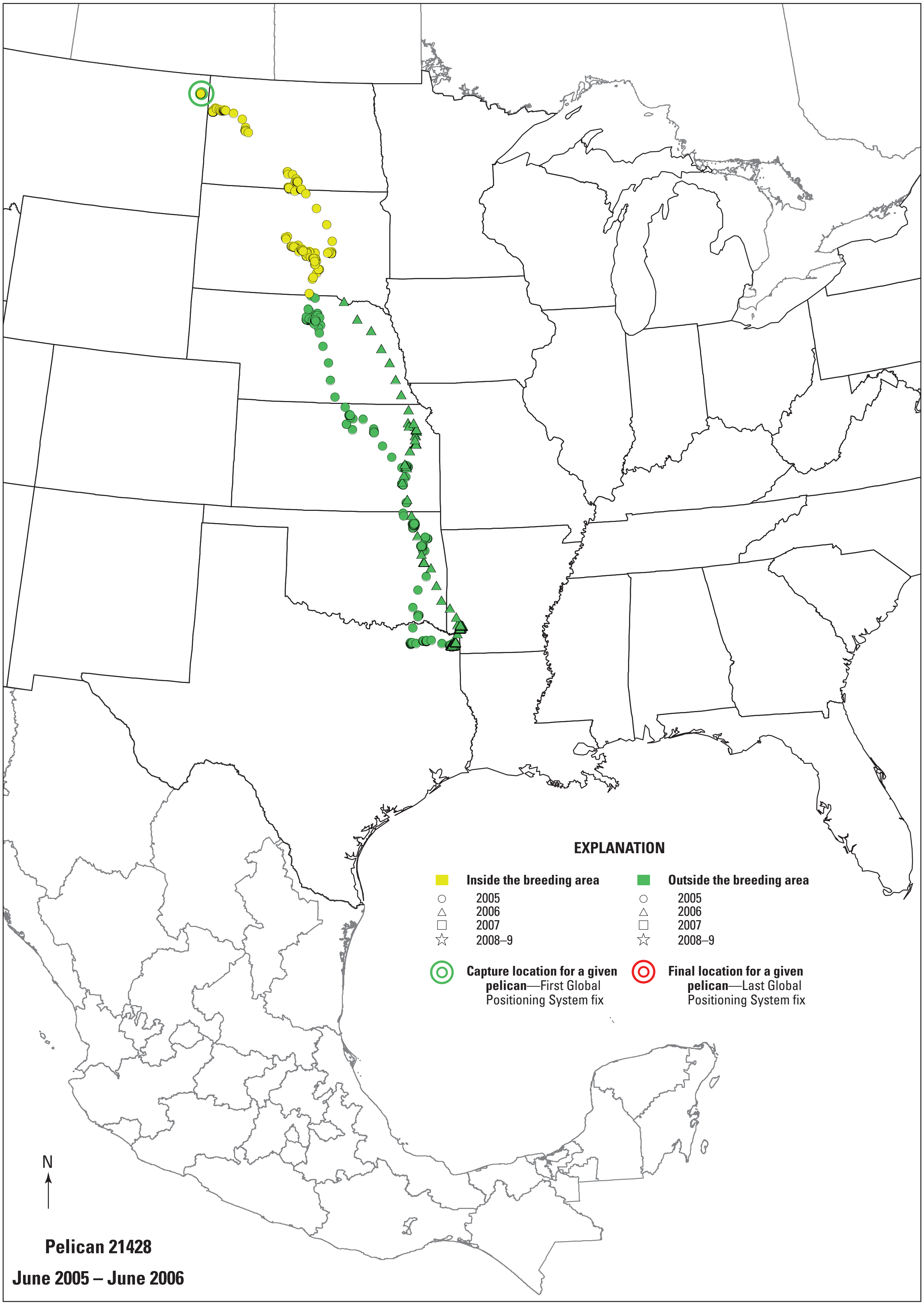
Appendix C. Maps including the locations of the satellite-tracked American white pelicans, 2005–9.

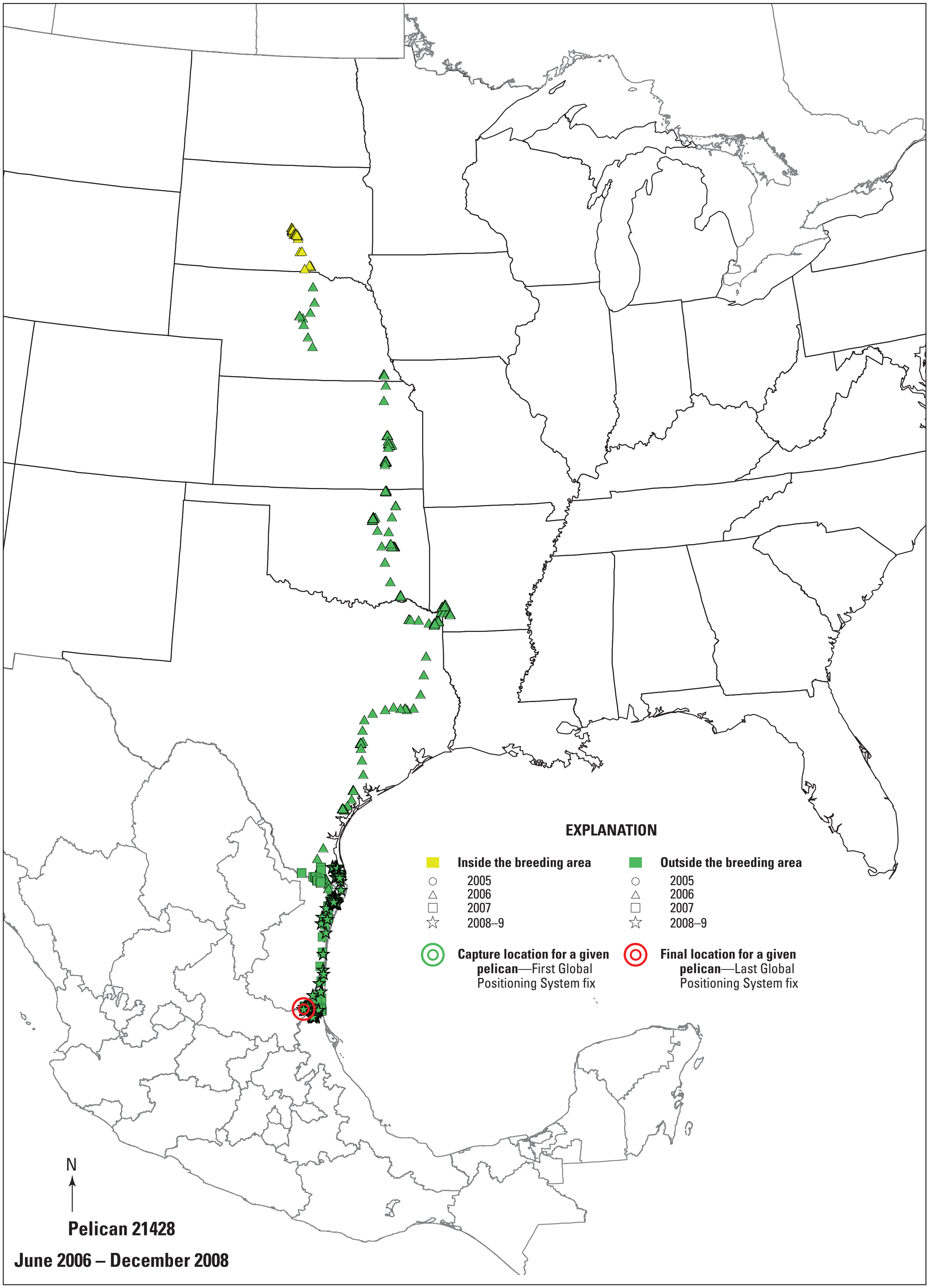
Maps of the locations of individual satellite-tracked American white pelicans are given in the order of their identifying number (platform transmitter terminal [PTT] number). For most birds, there is one map per migratory year. The first map for each bird includes locations starting from the time of capture and ending in the following year when the bird returned to the breeding region (that is, north of the southern border of South Dakota). Maps for subsequent years begin at the point the bird reentered the breeding region and continue through that summer and the subsequent migration to and from the wintering area. Location symbols change color when the bird was inside (yellow) and outside (green) the breeding region, and change shape with each calendar year (2005 = circles; 2006 = triangles; 2007 = squares; 2008–9 = stars). An open green circle indicates the capture location for a given pelican (first Global Positioning System [GPS] fix) and an open red circle indicates the final location obtained for that bird (last GPS fix).

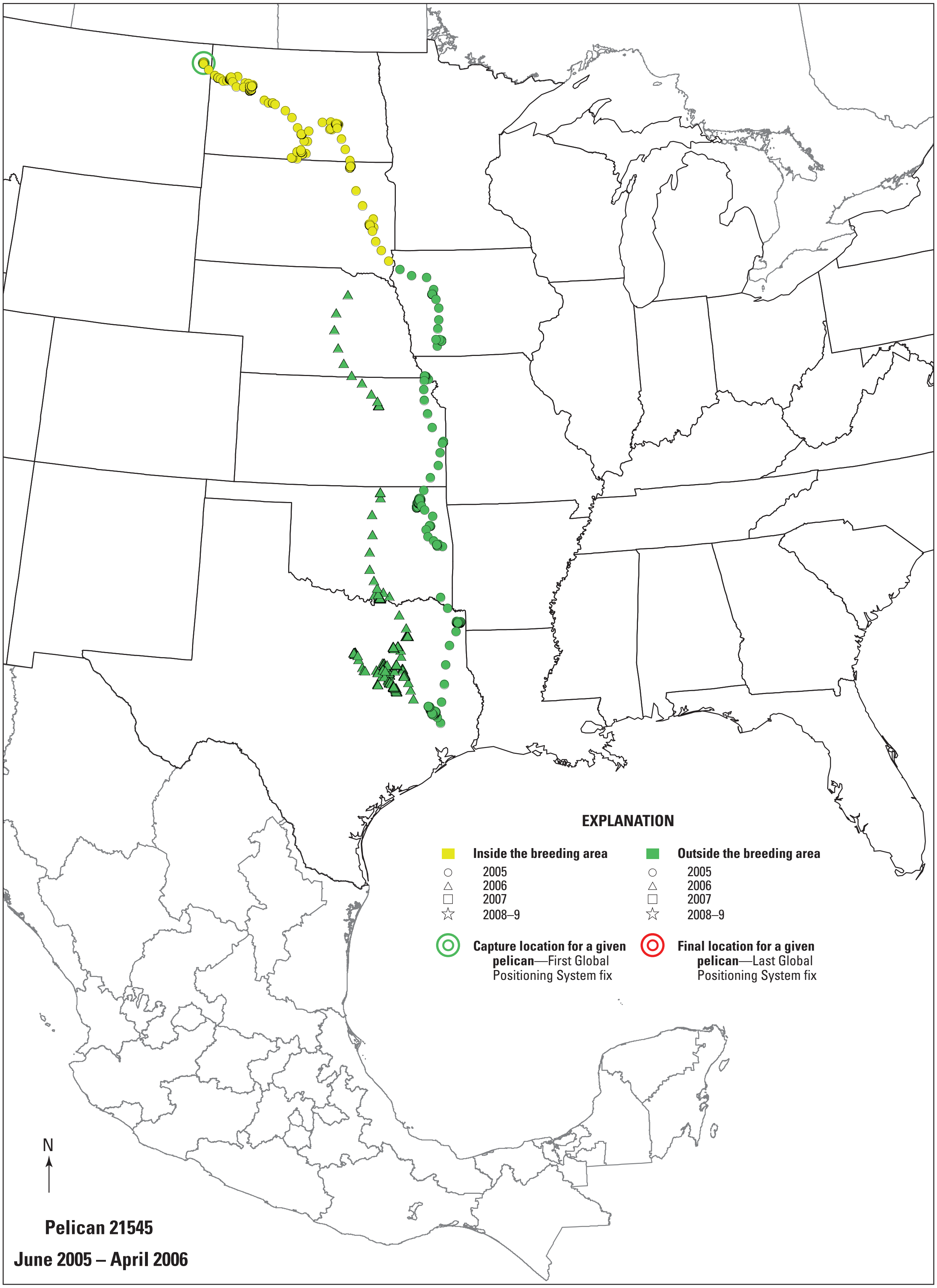

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–2009
Outside the breeding area
2005
2006
2007
2008–2009
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21311
June 2005 – May 2006

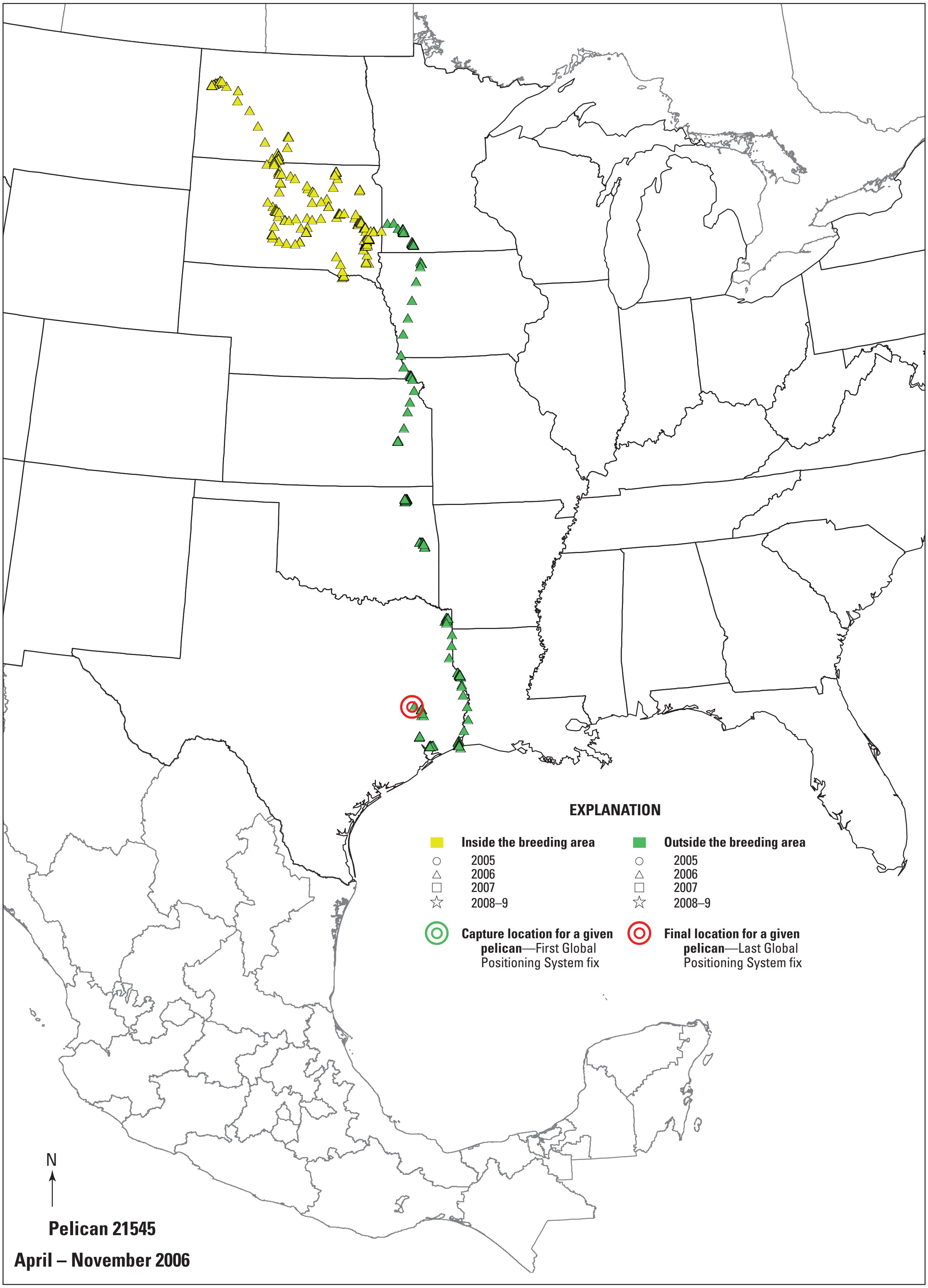

N
EXPLANATION
Inside the breeding area
2005
2006
2007
2008–2009
Outside the breeding area
2005
2006
2007
2008–2009
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
Pelican 21311
May 2006 – April 2007

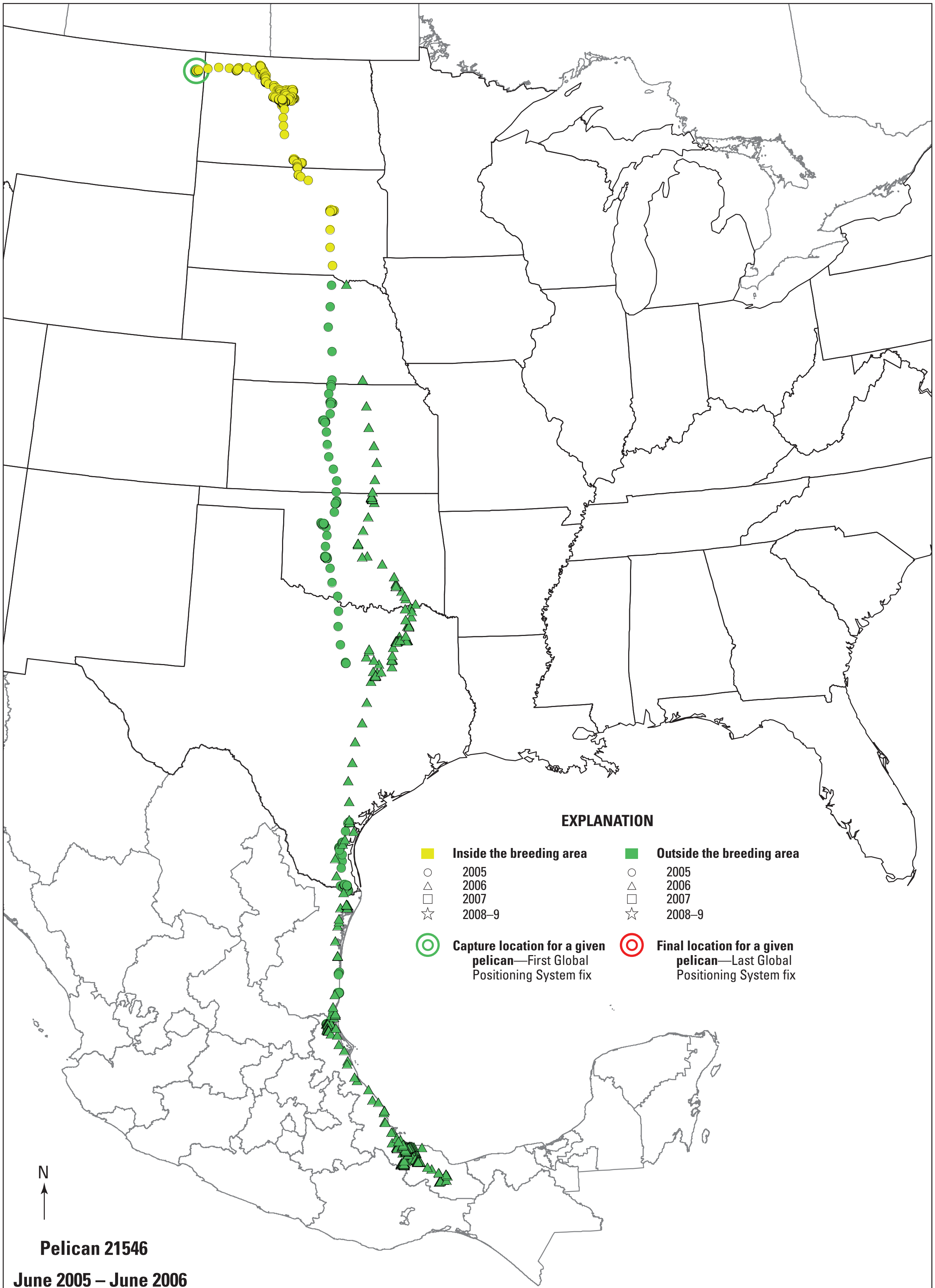

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21311
May – October 2007

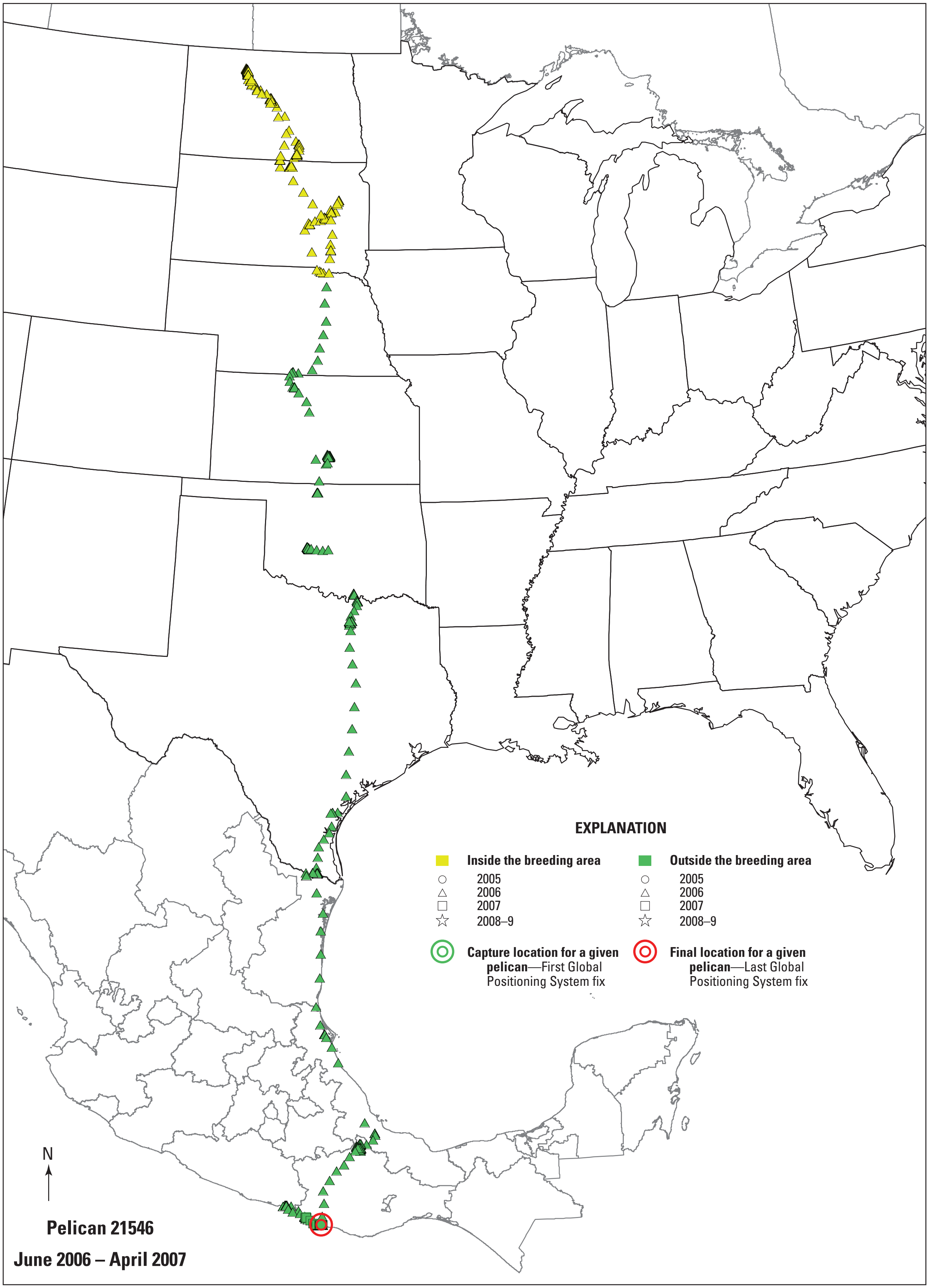

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21428
June 2005 – June 2006

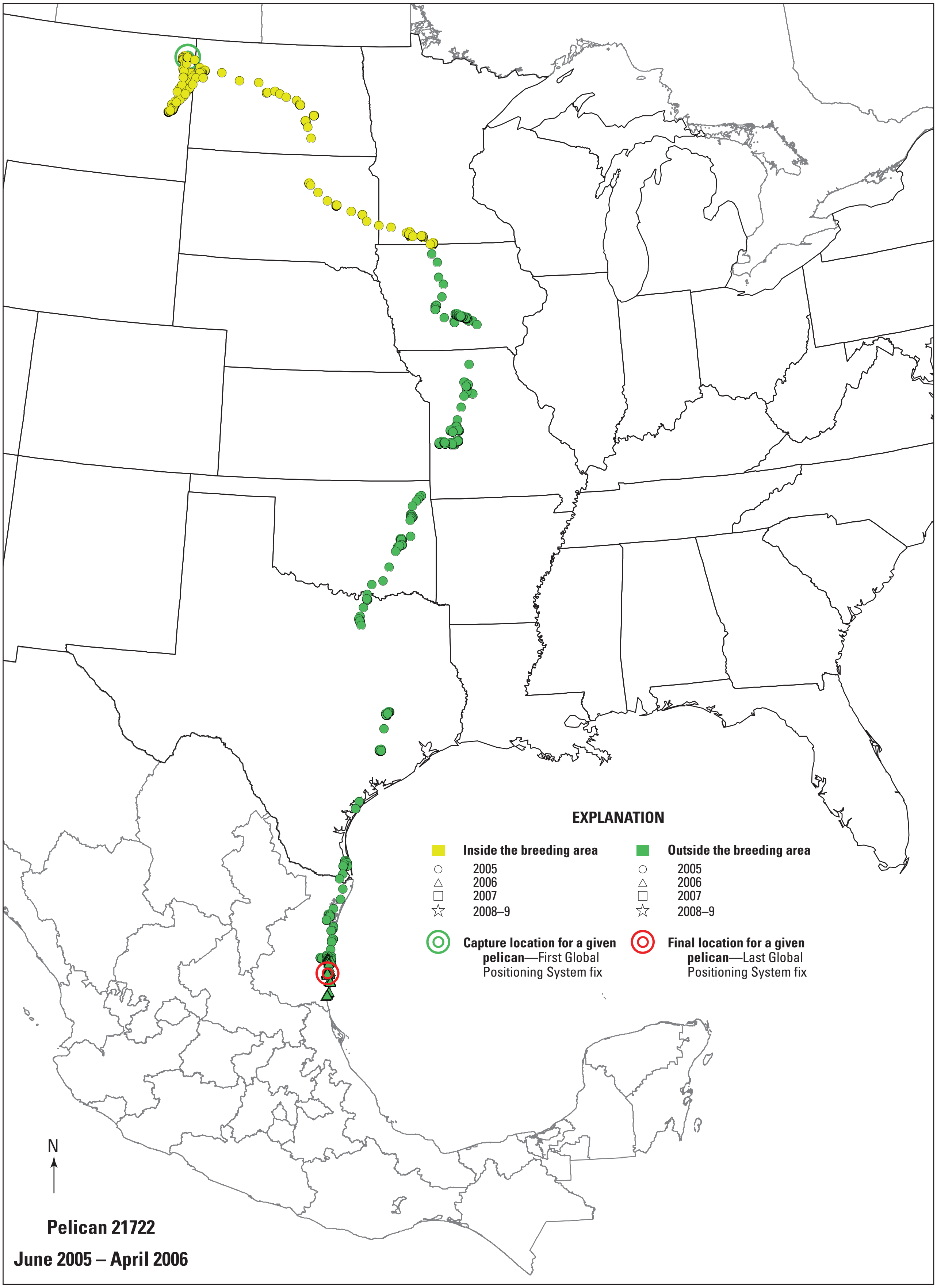

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21428
June 2006 – December 2008

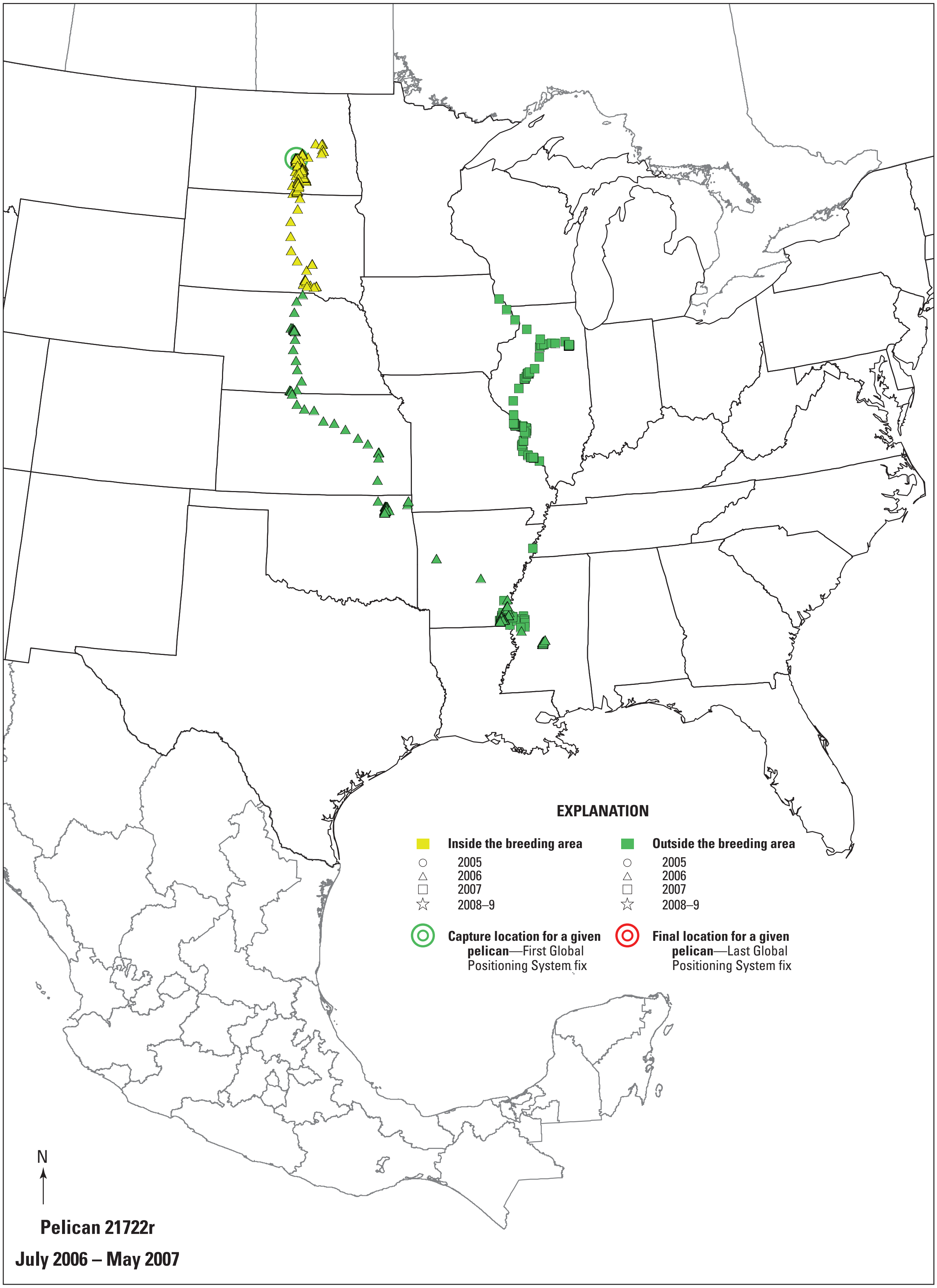

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21545
June 2005 – April 2006

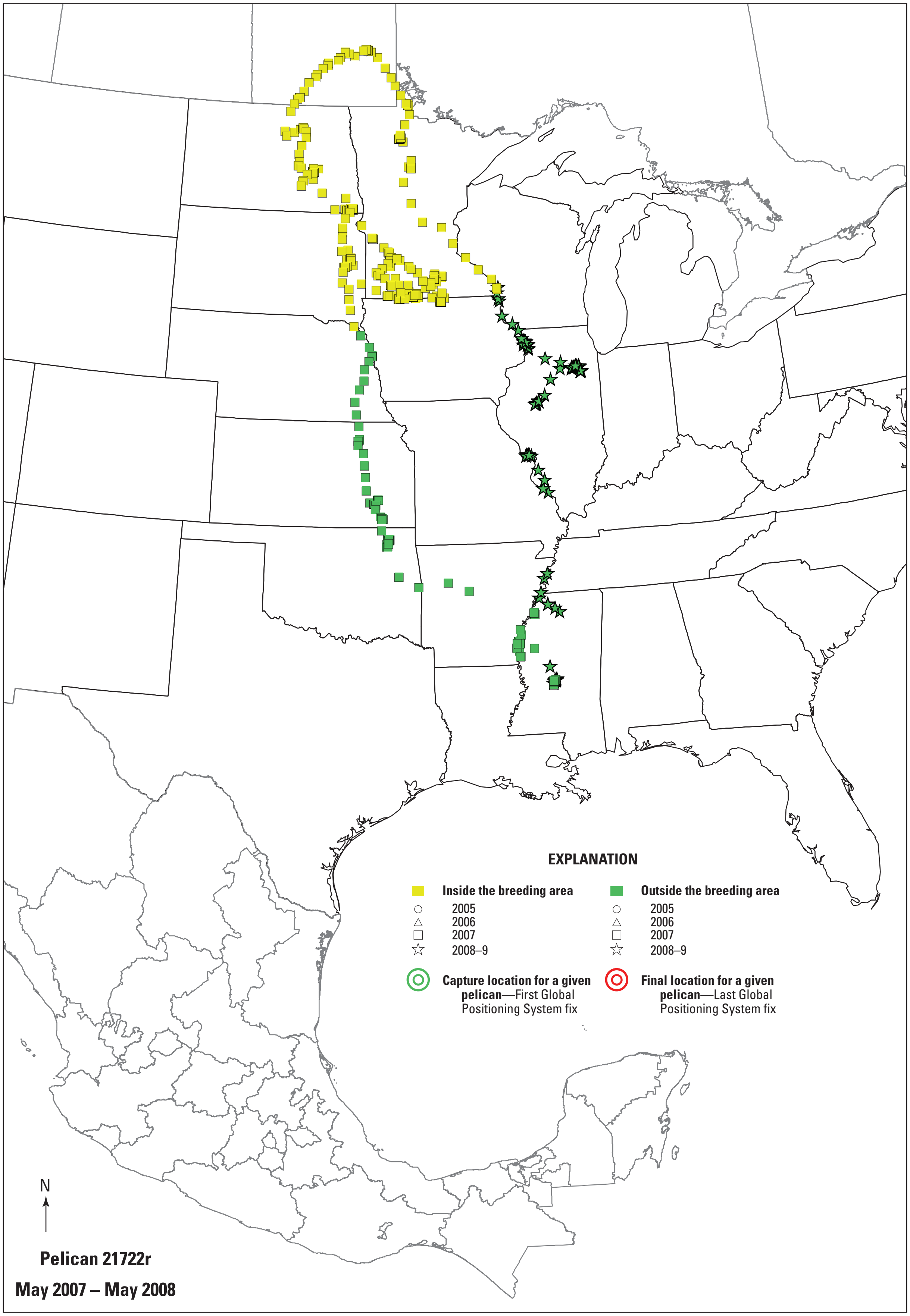

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21545
April – November 2006

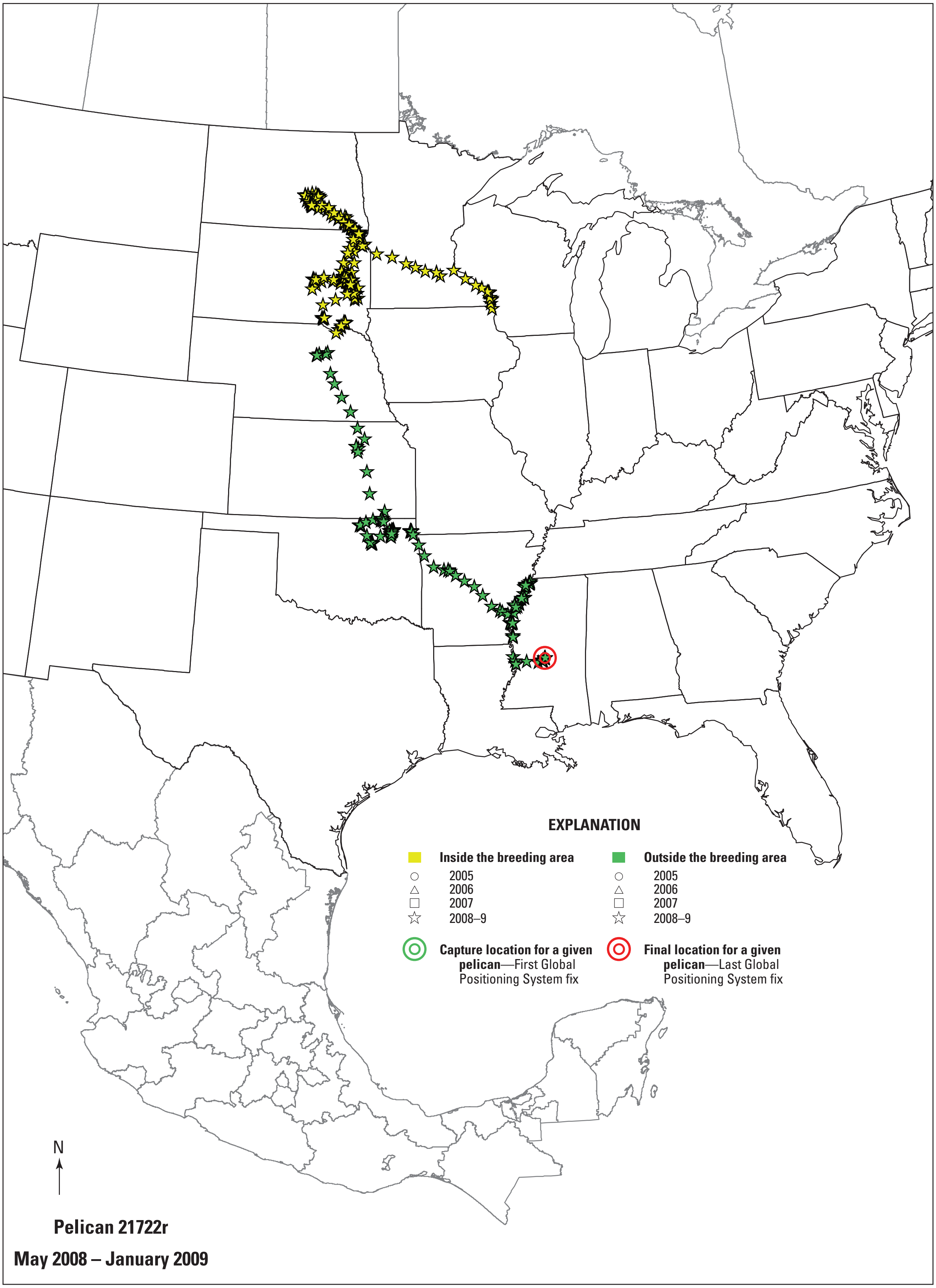

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21546
June 2005 – June 2006

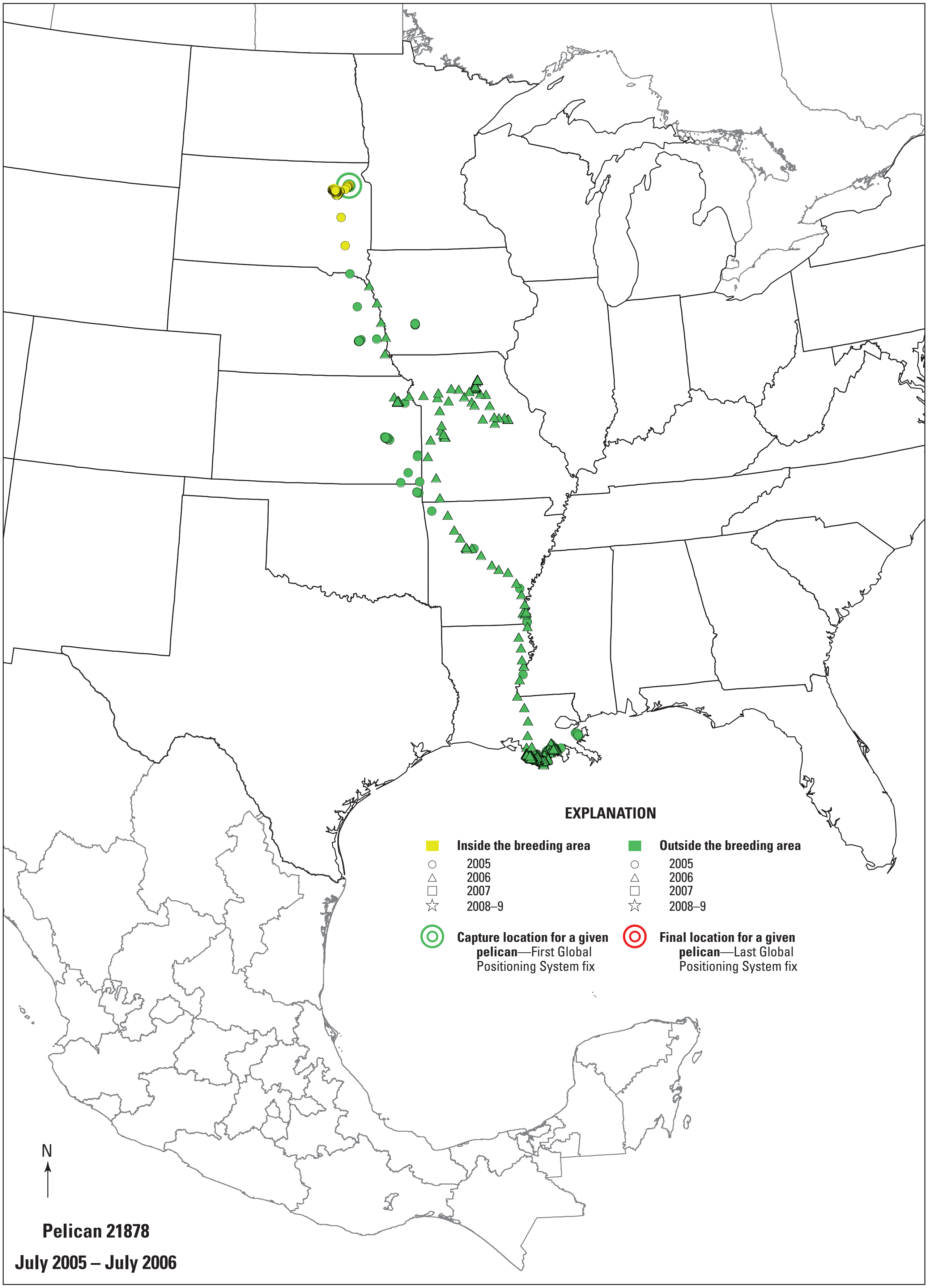

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21546
June 2006 – April 2007

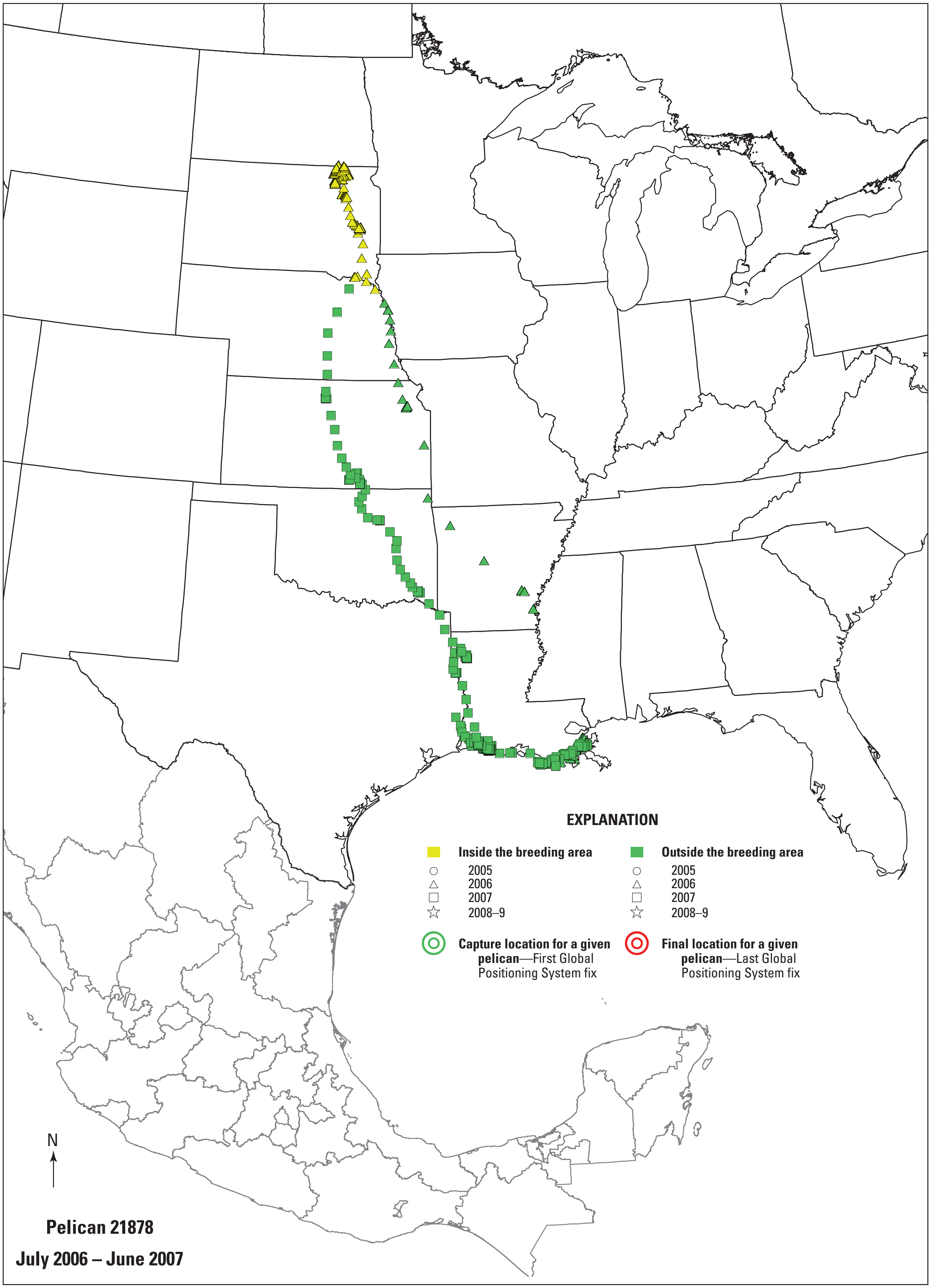

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21722
June 2005 – April 2006

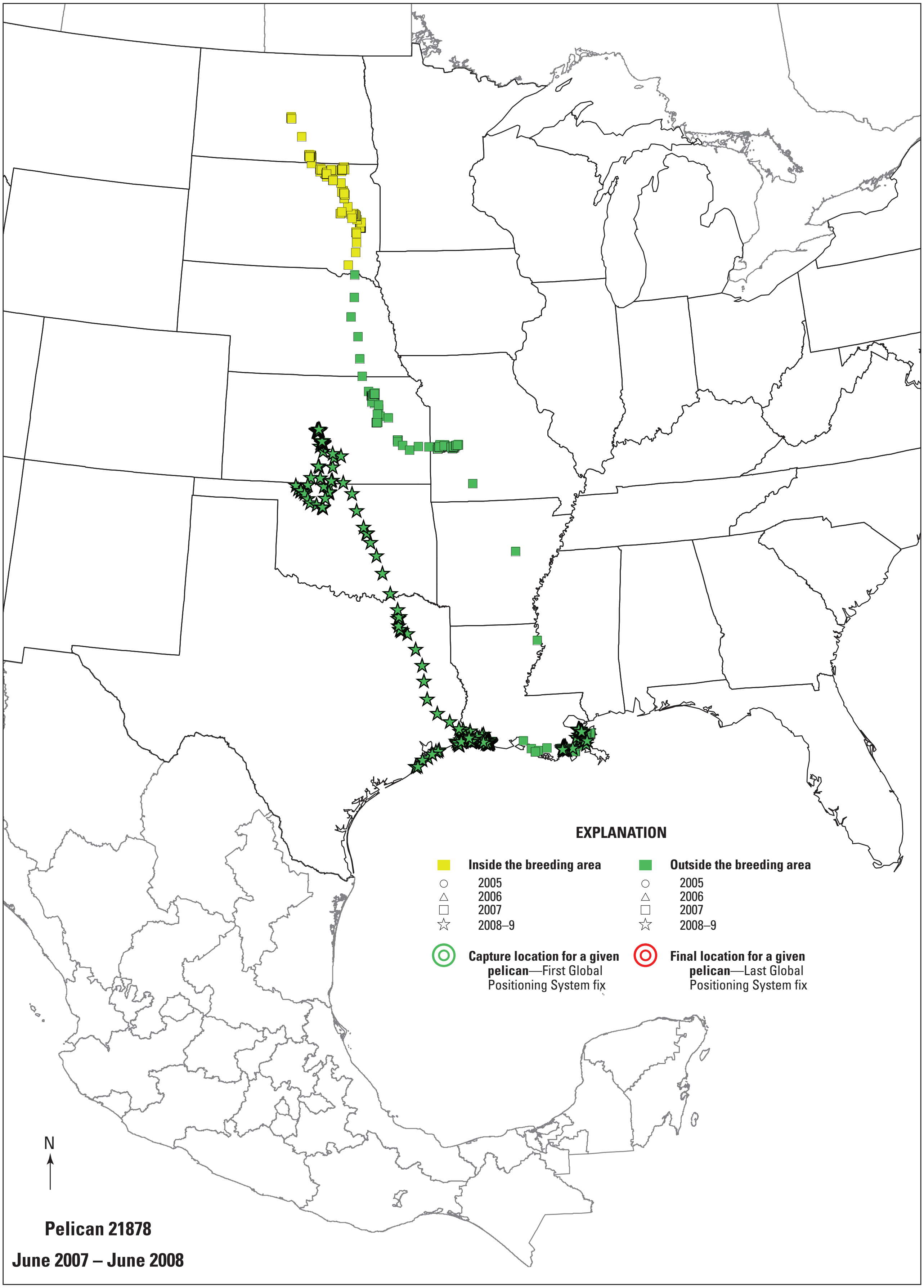

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21722r
July 2006 – May 2007

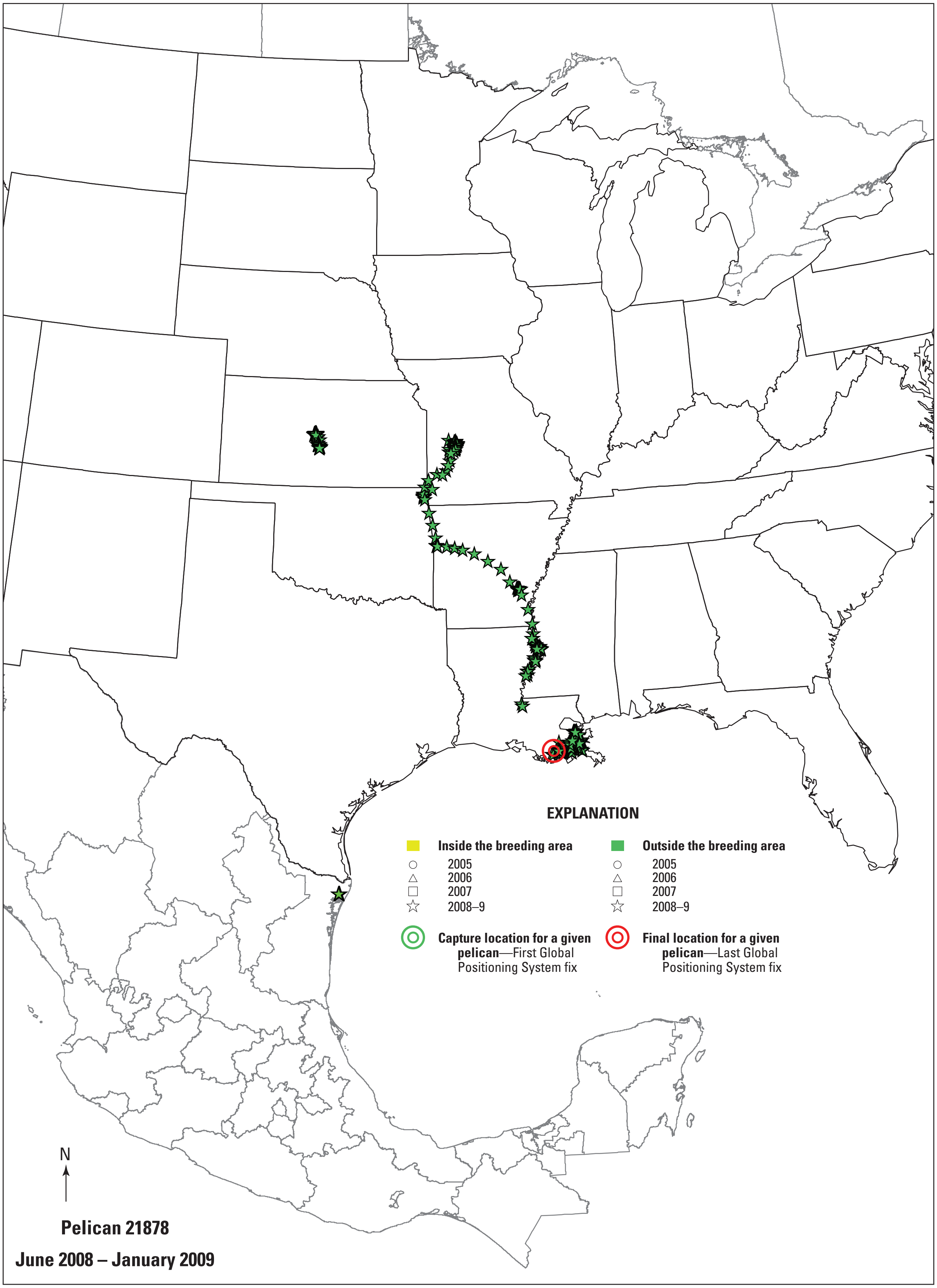

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21722r
May 2007 – May 2008

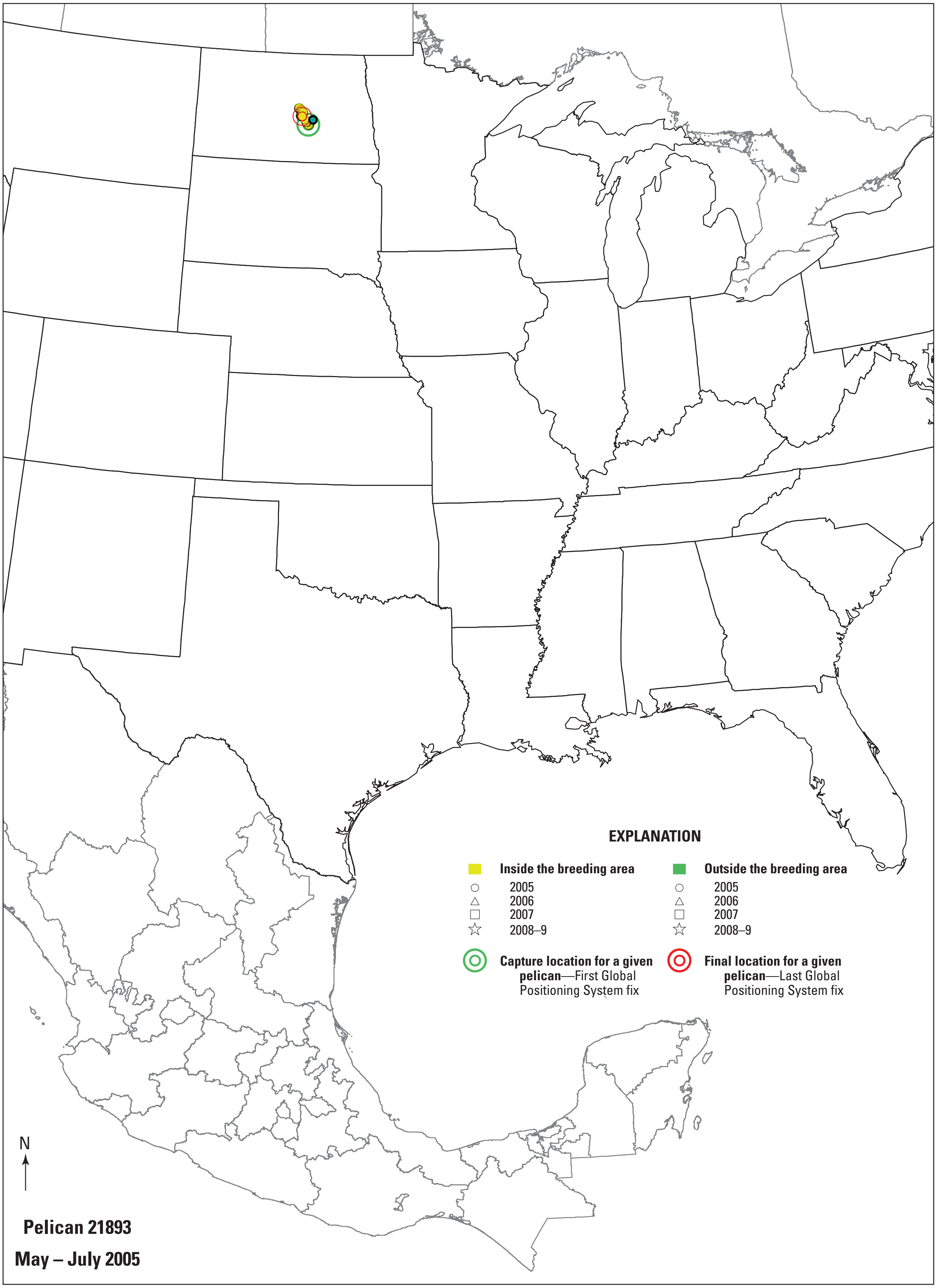

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21722r
May 2008 – January 2009

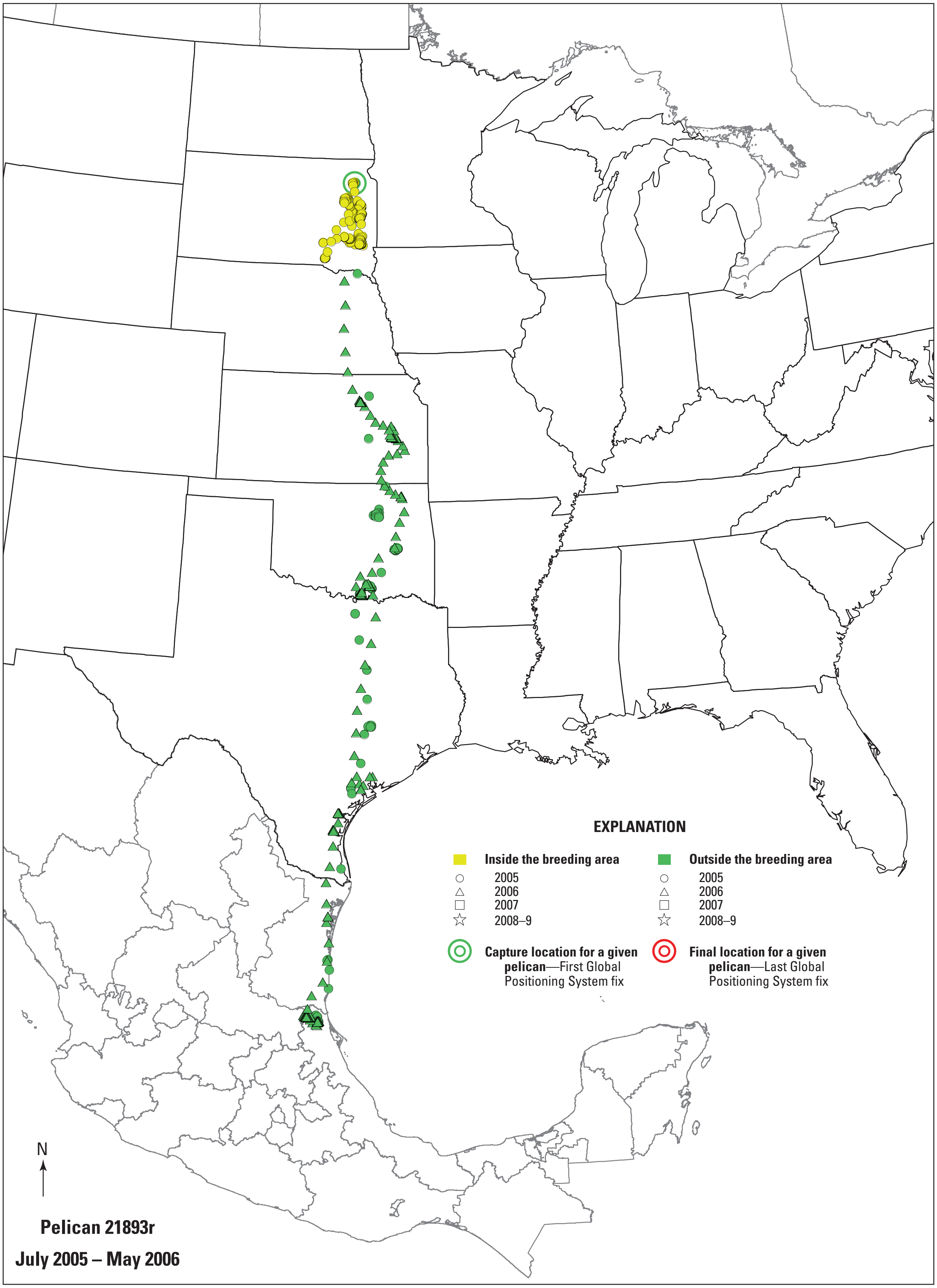

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21878
July 2005 – July 2006

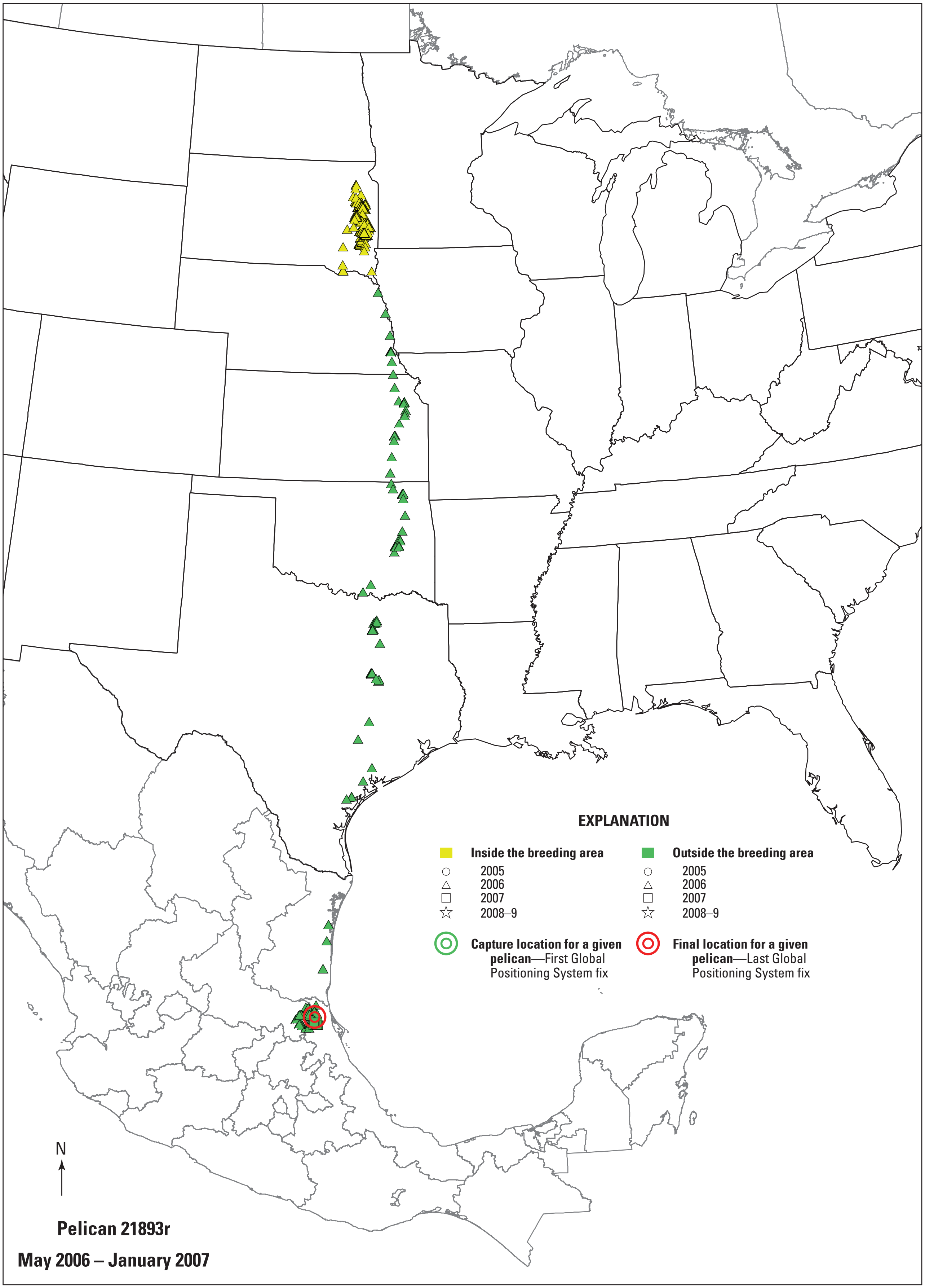

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21878
July 2006 – June 2007


EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21878
June 2007 – June 2008


EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21878
June 2008 – January 2009

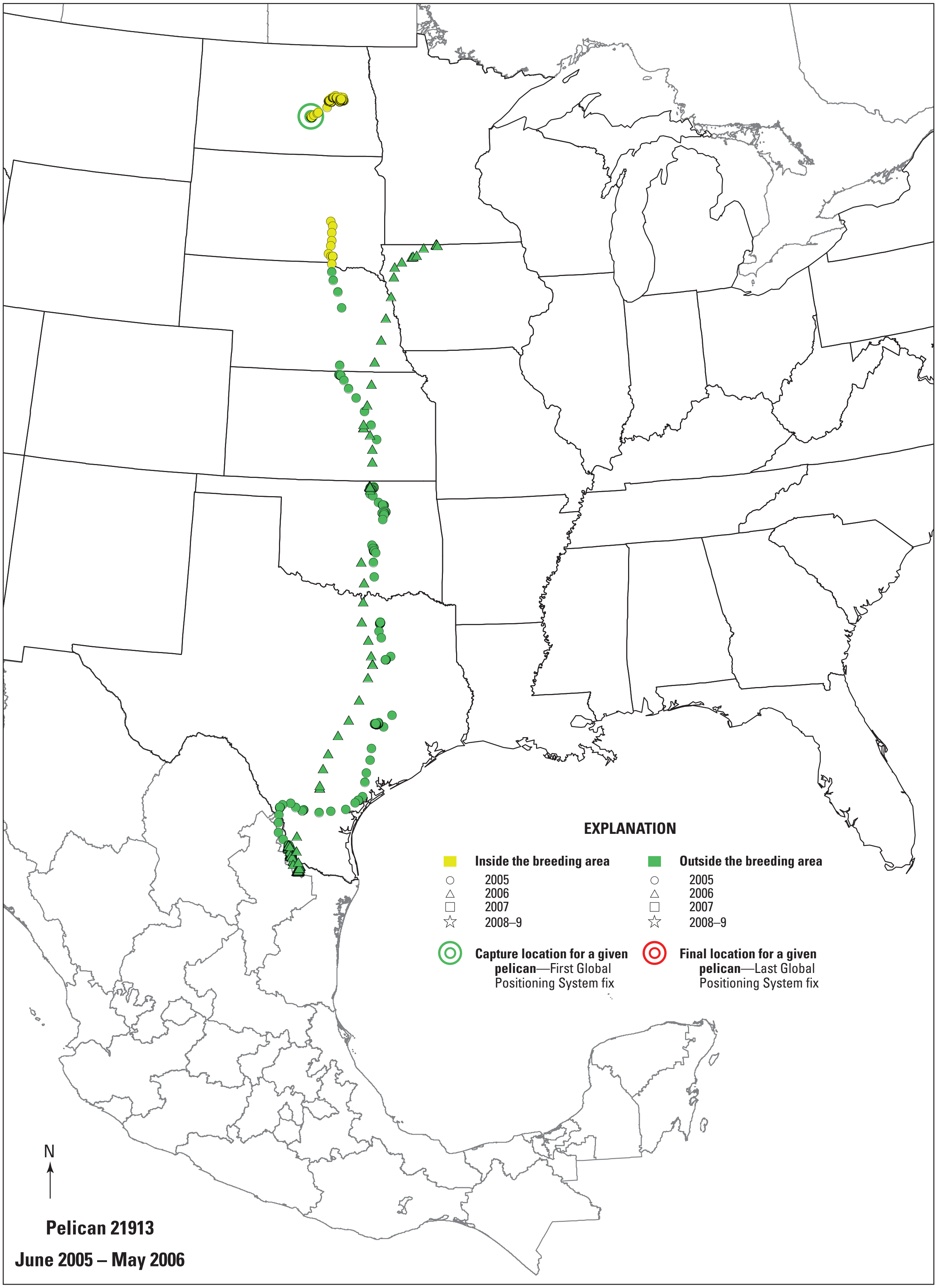

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21893
May – July 2005

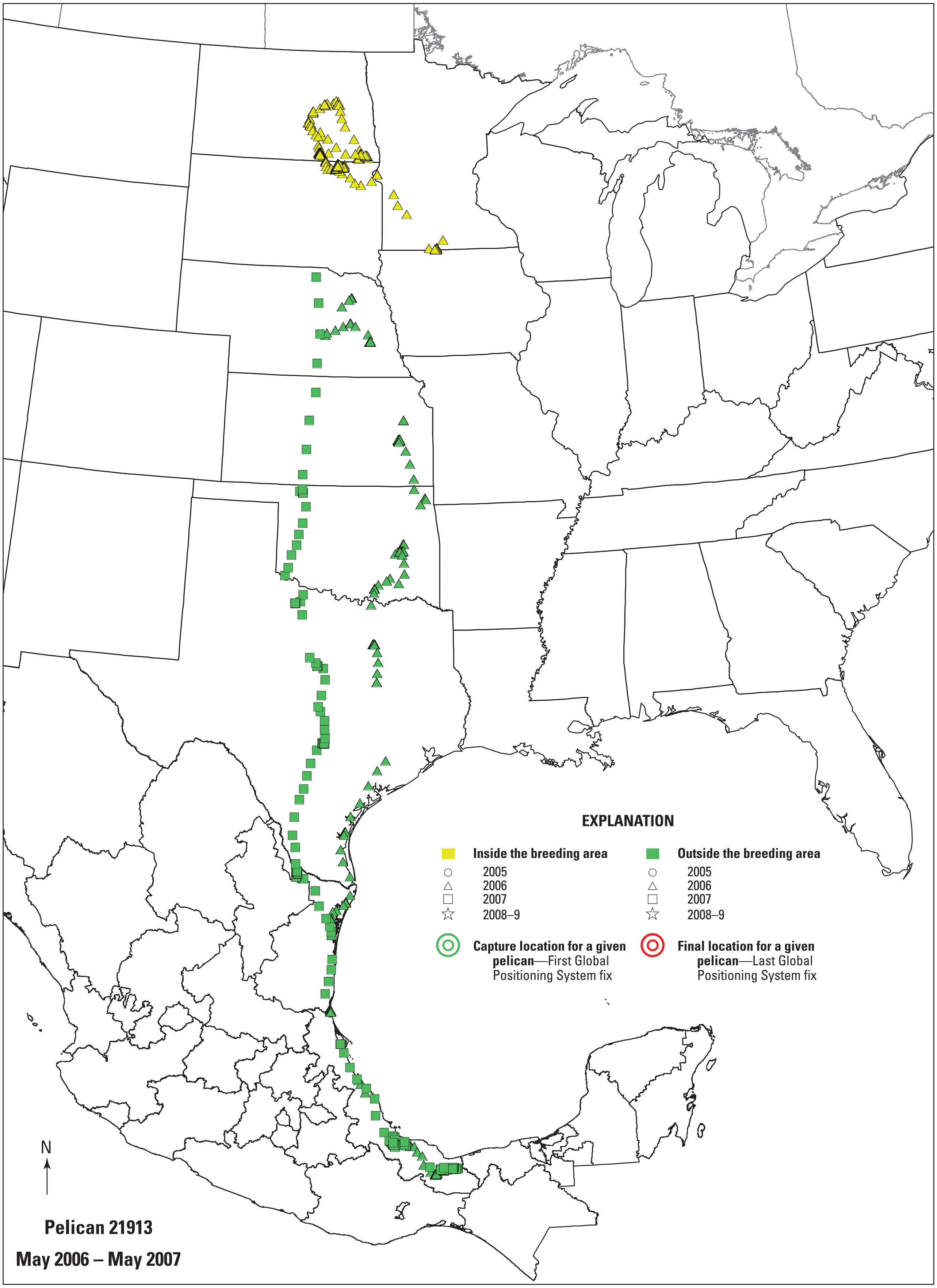

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21893r
July 2005 – May 2006

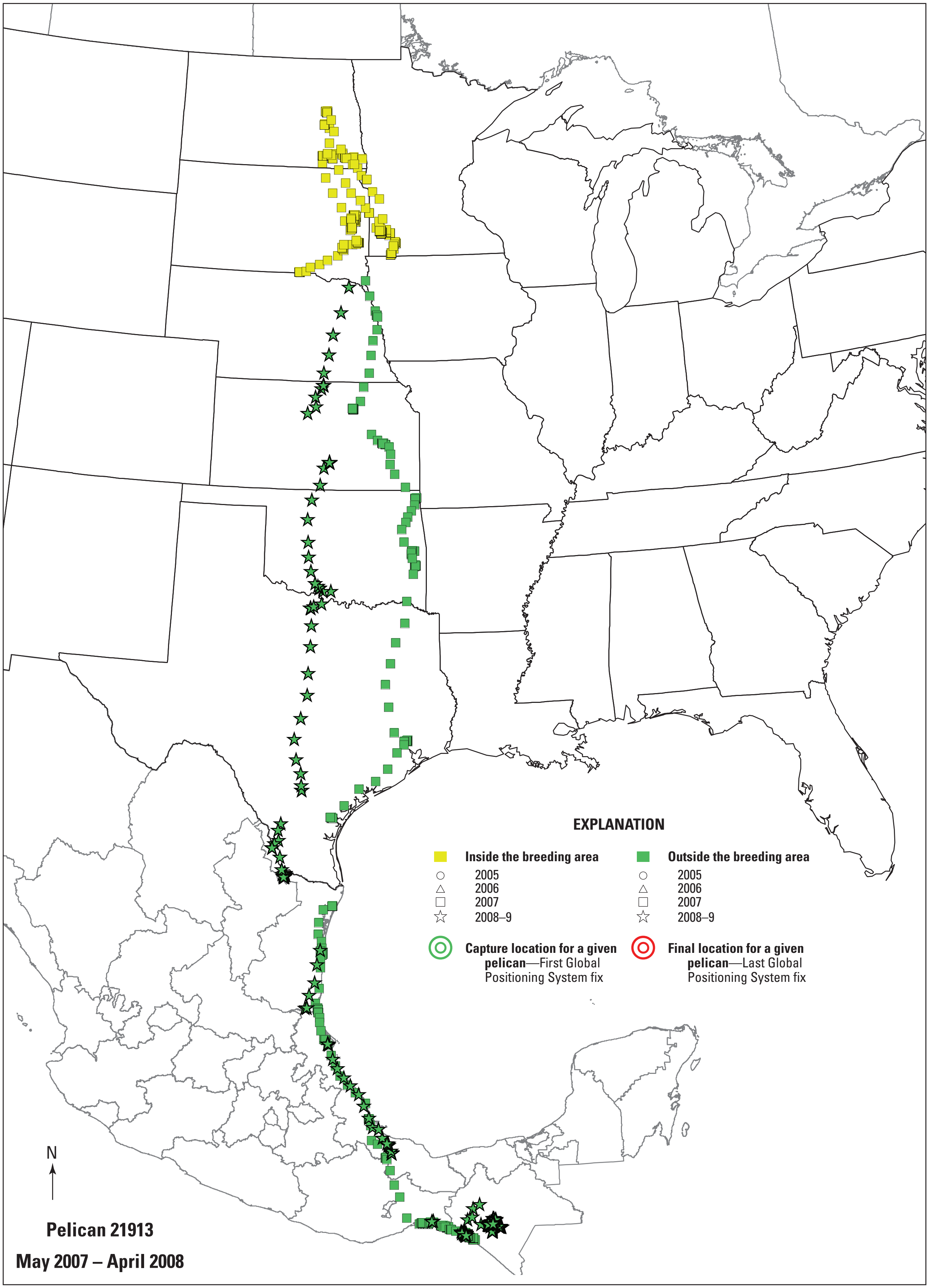


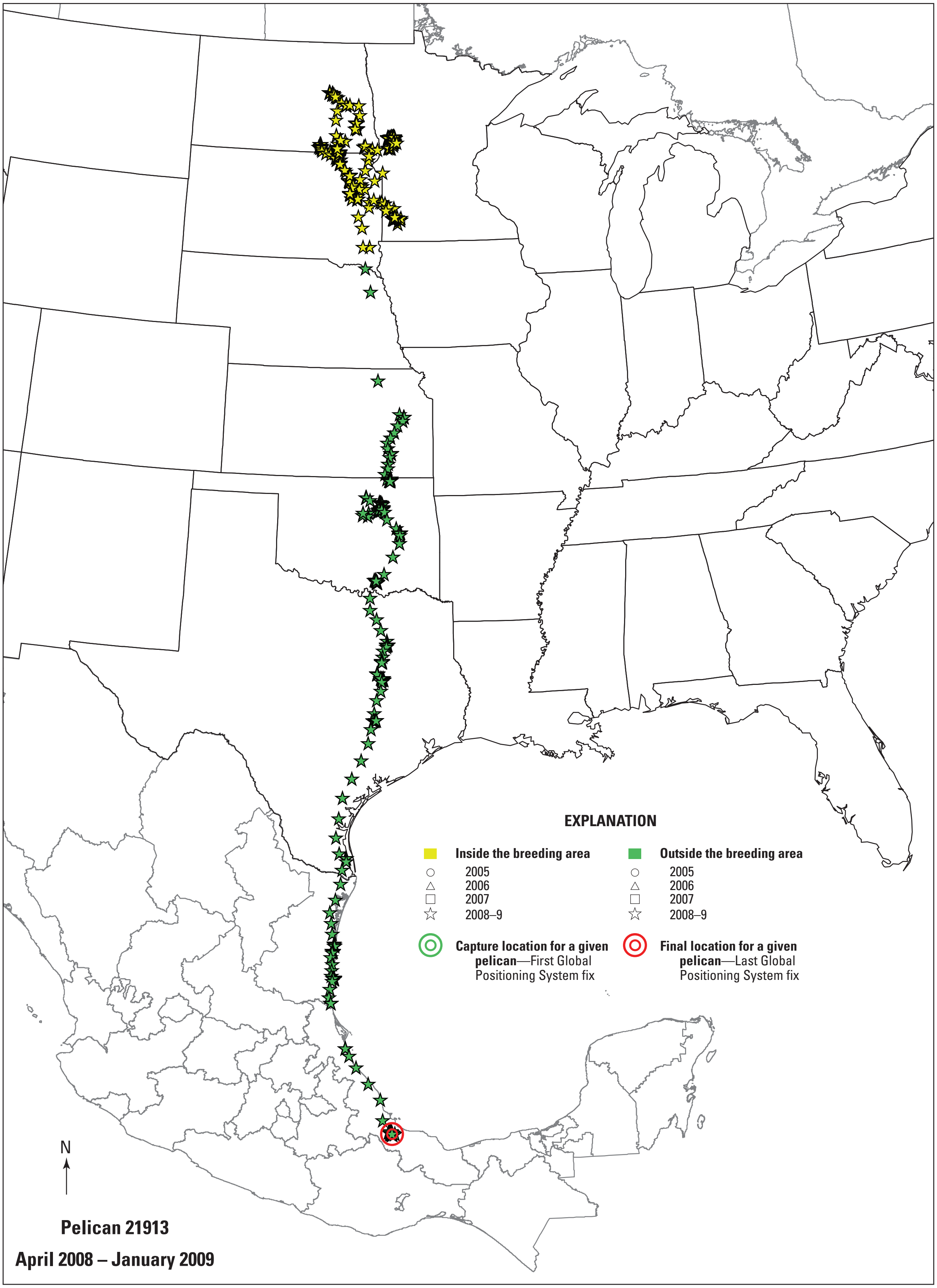
Pelican 21893r

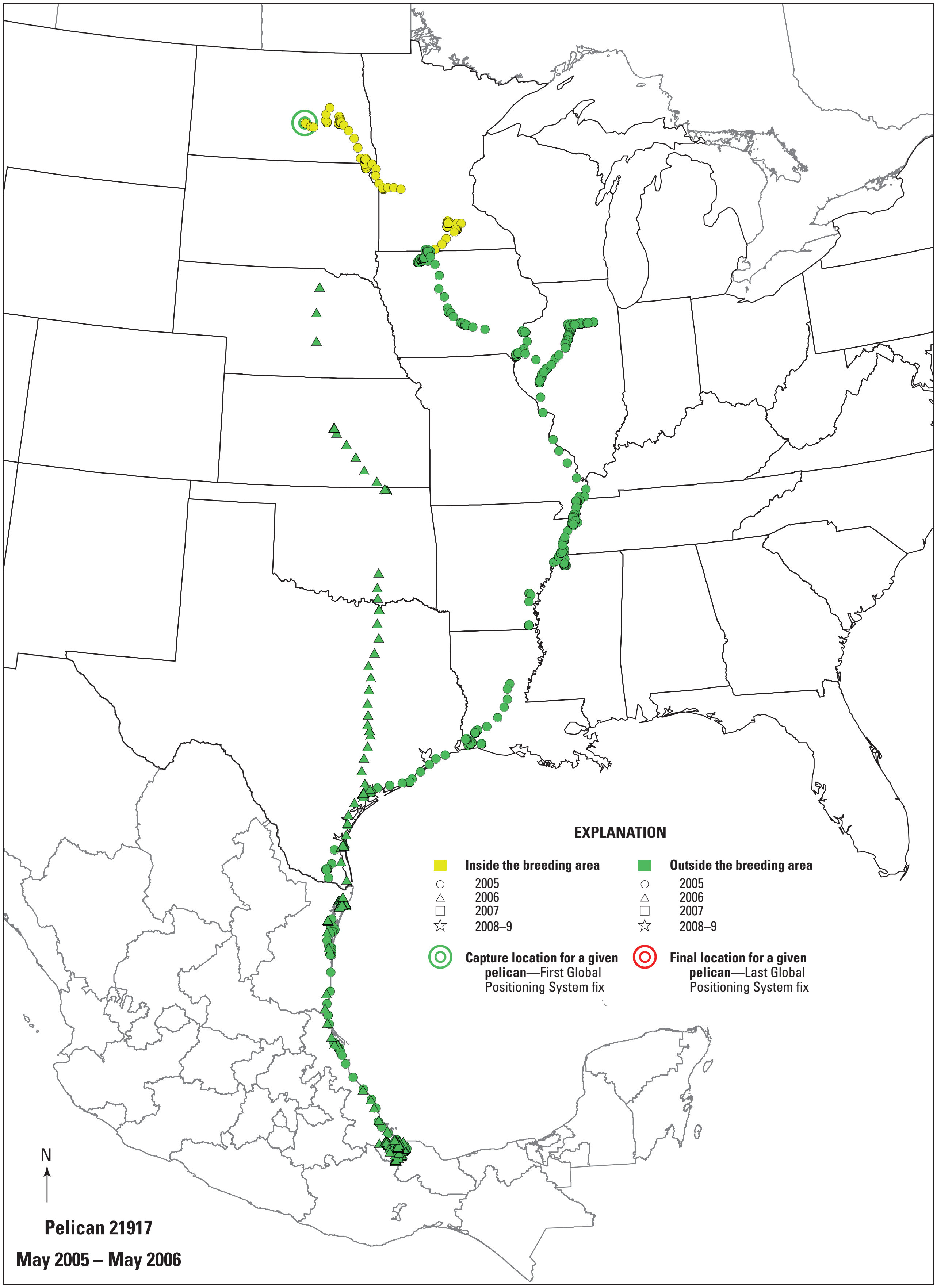
May 2006 – January 2007

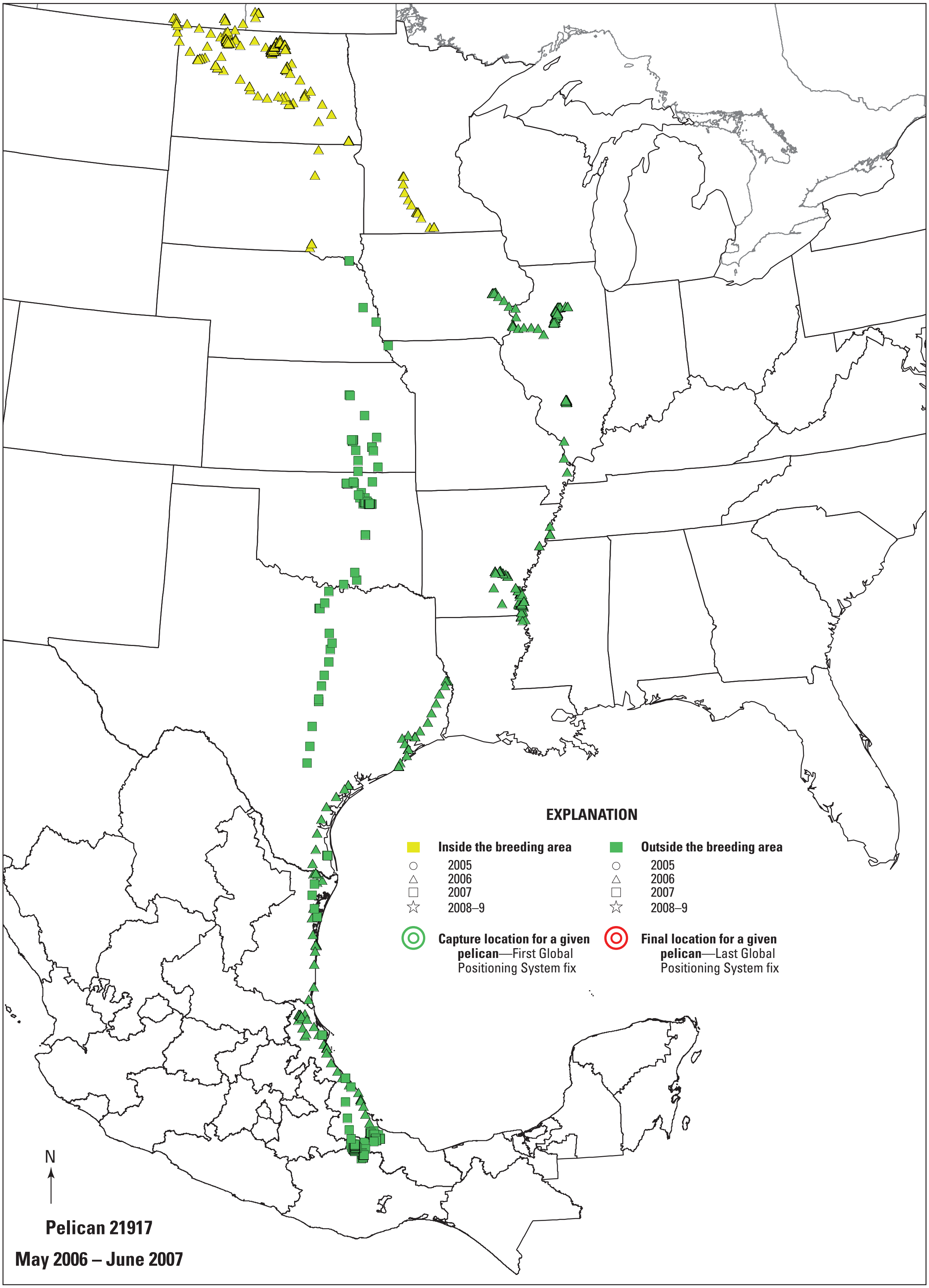

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21913
June 2005 – May 2006

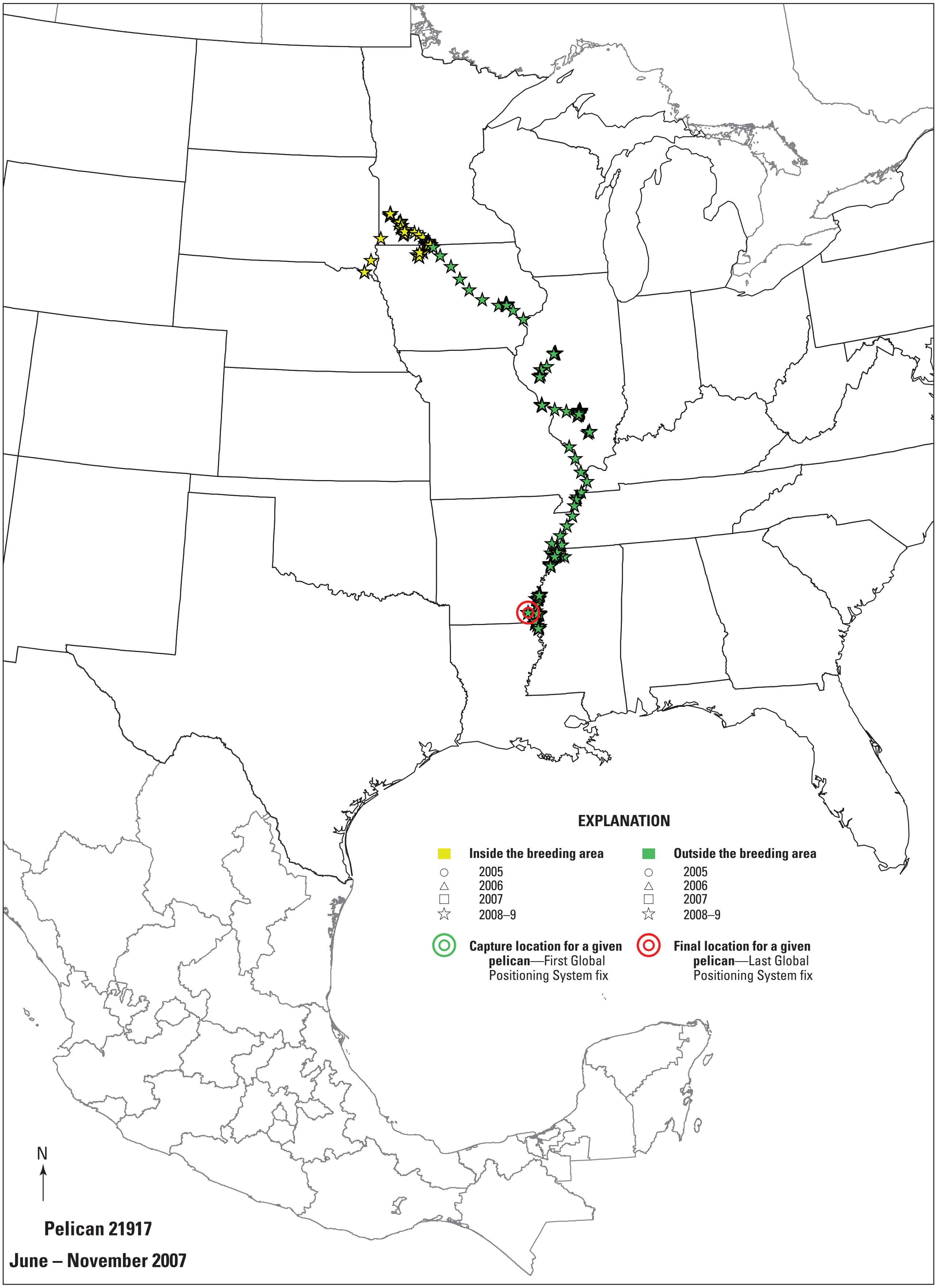

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21913
May 2006 – May 2007

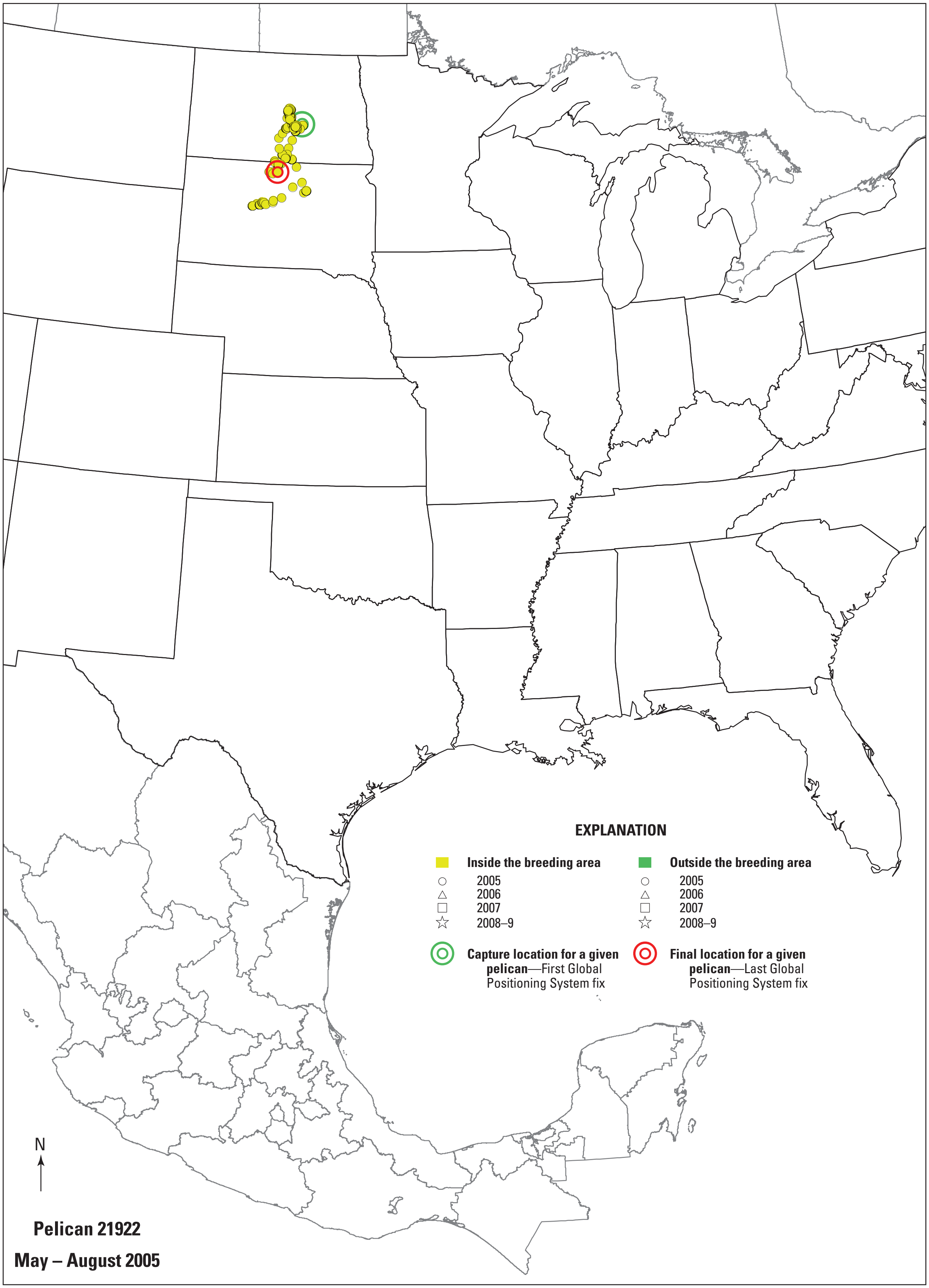

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21913
May 2007 – April 2008

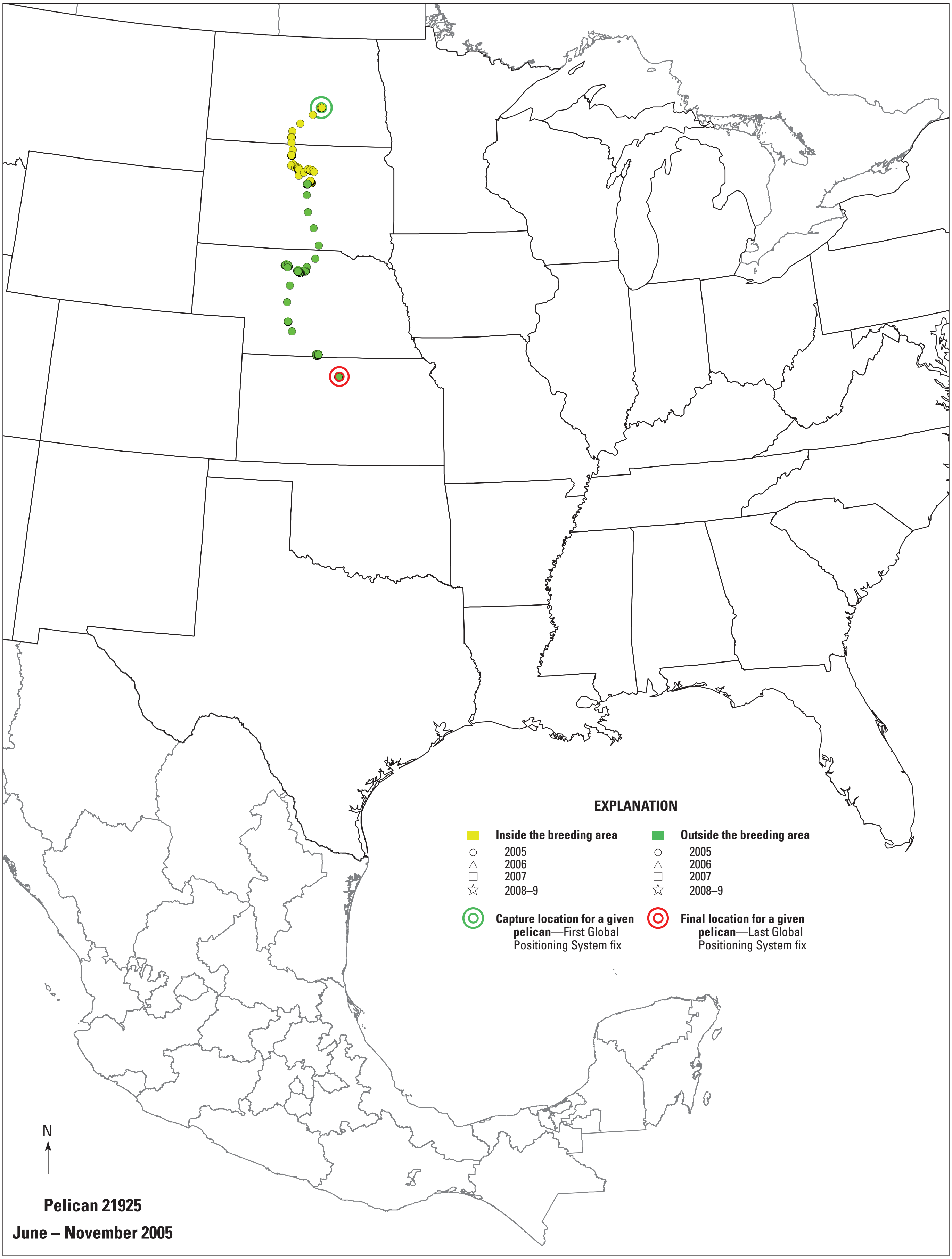

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21913
April 2008 – January 2009

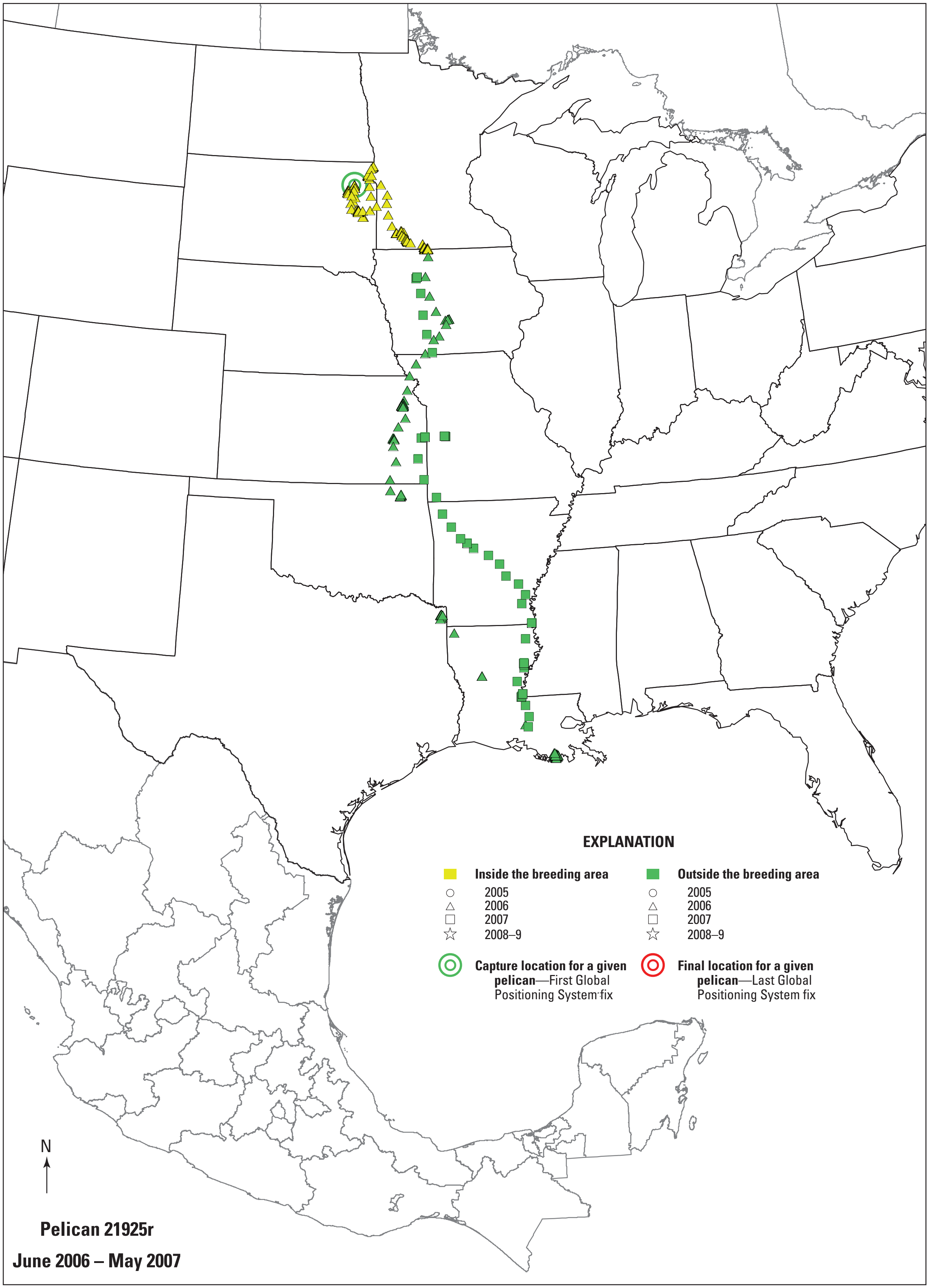

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21917
May 2005 – May 2006

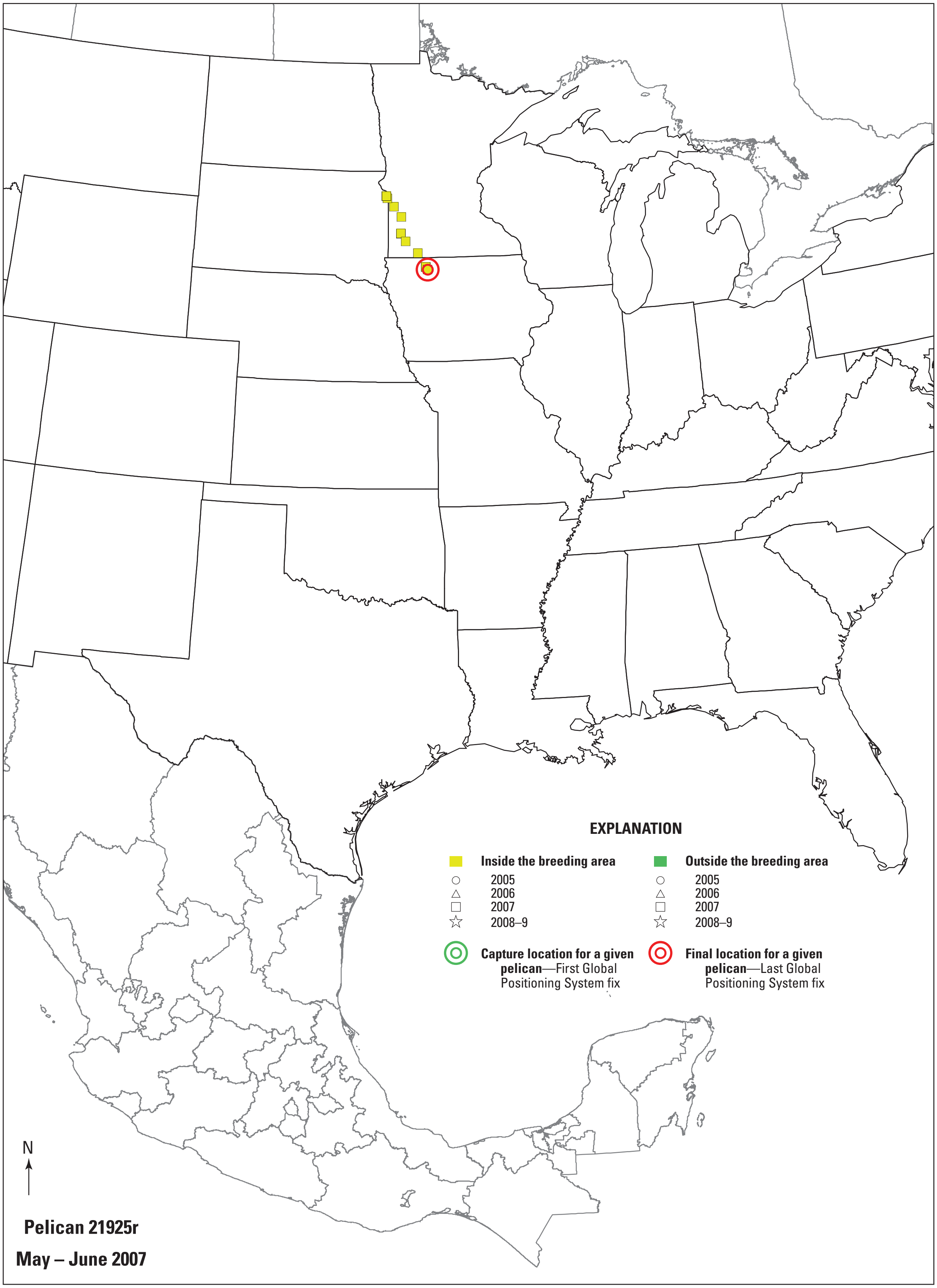

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21917
May 2006 – June 2007

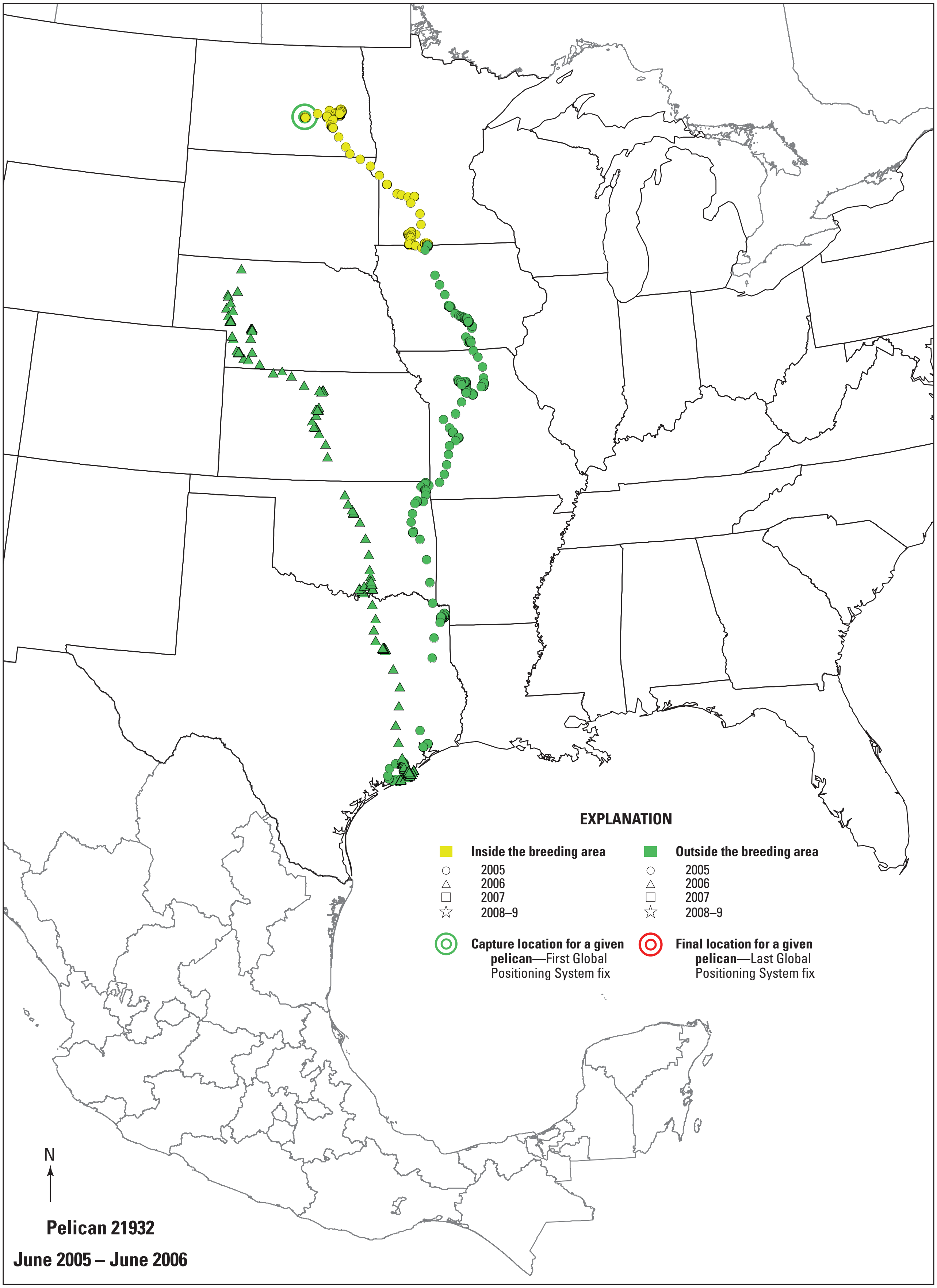

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21917
June – November 2007

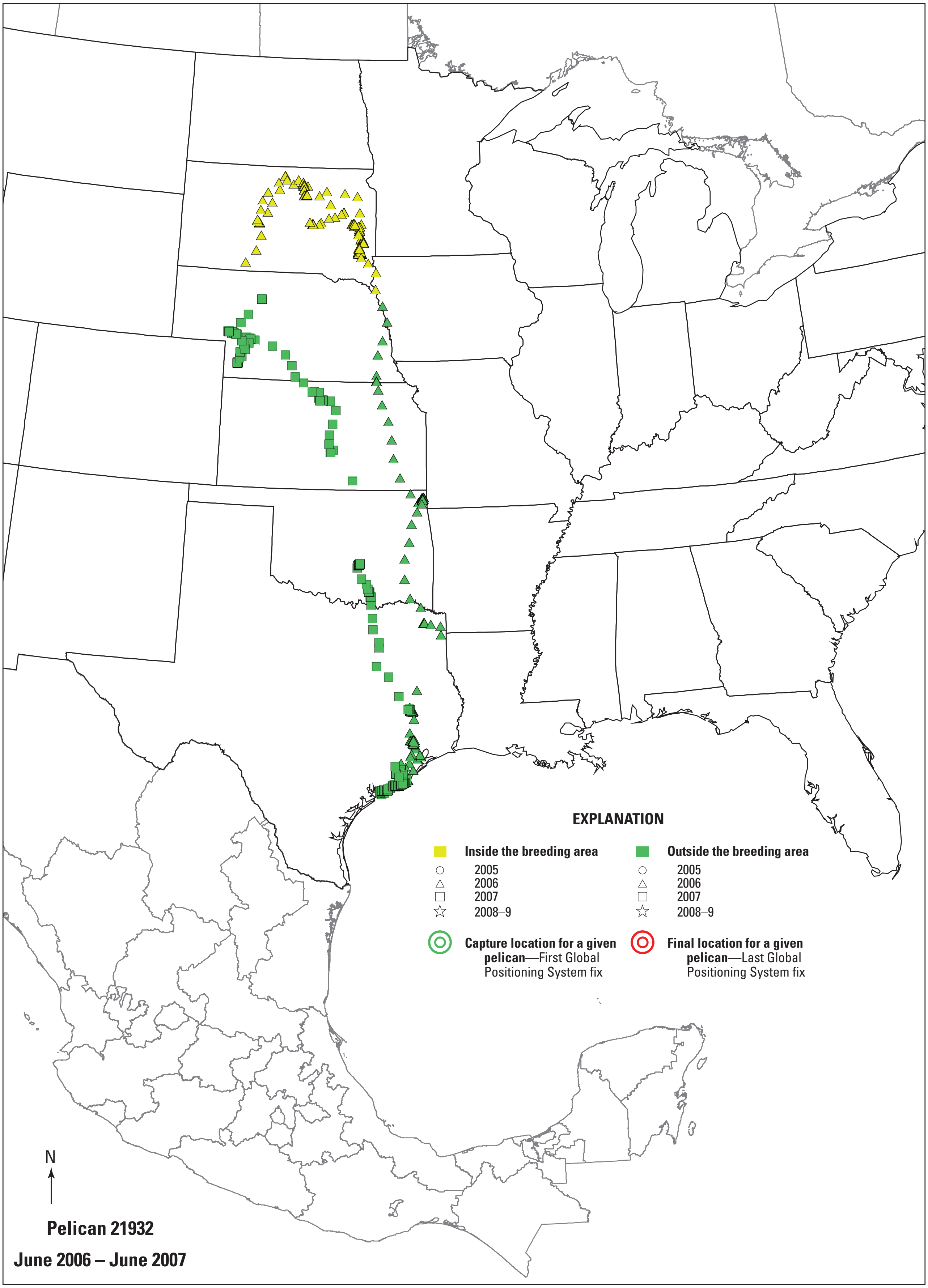

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21922
May – August 2005

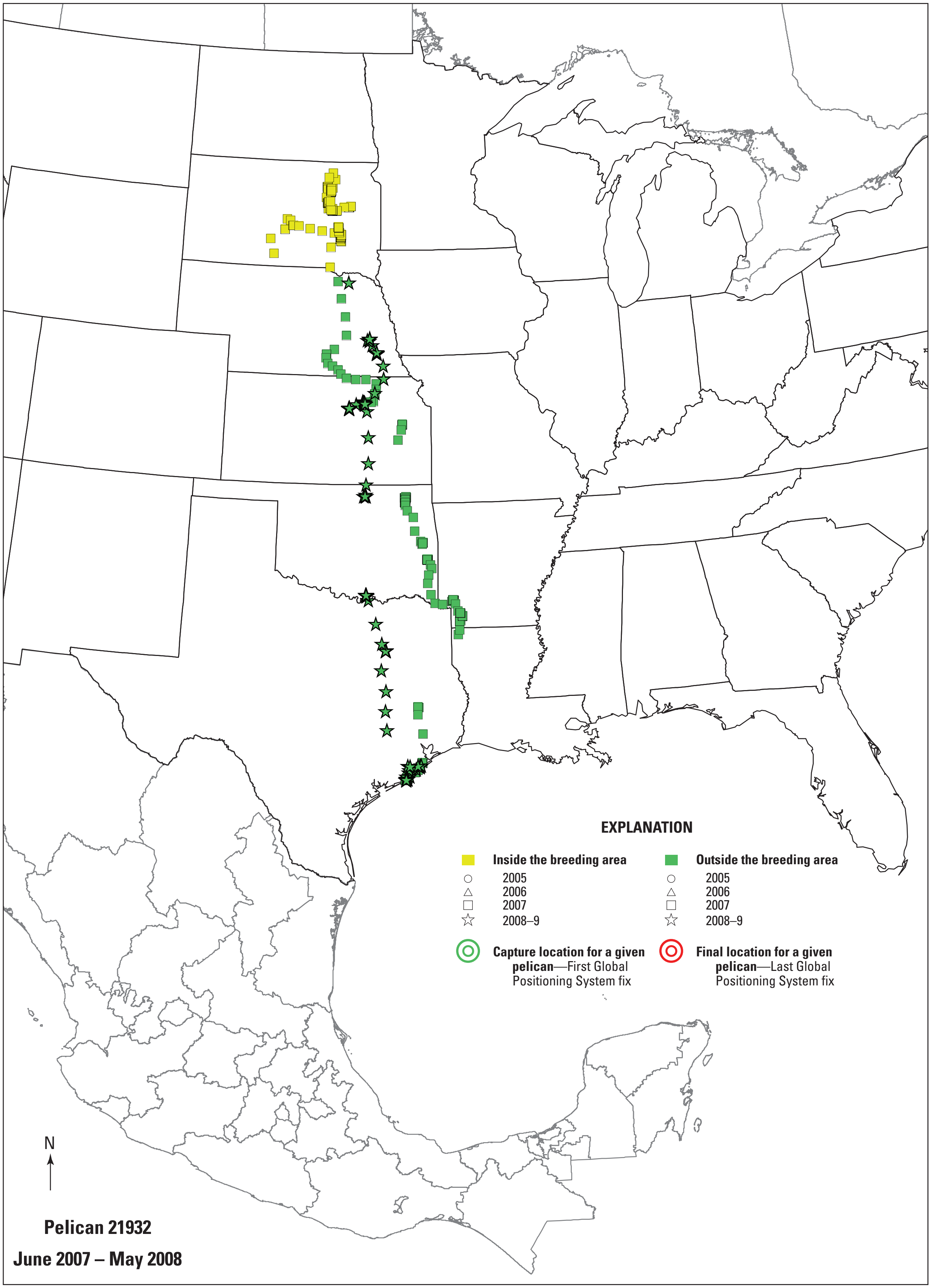

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21925
June – November 2005

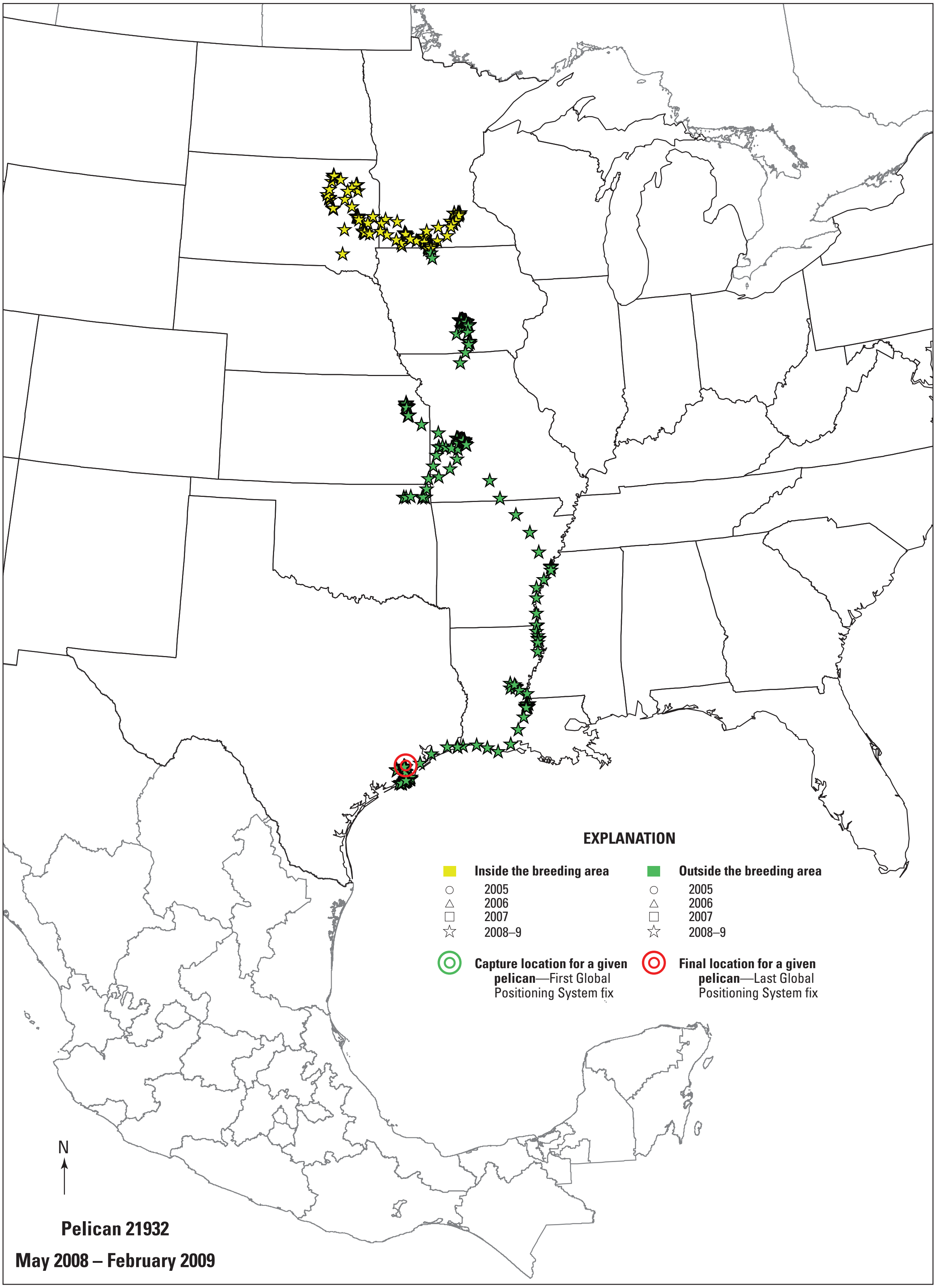

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21925r
June 2006 – May 2007

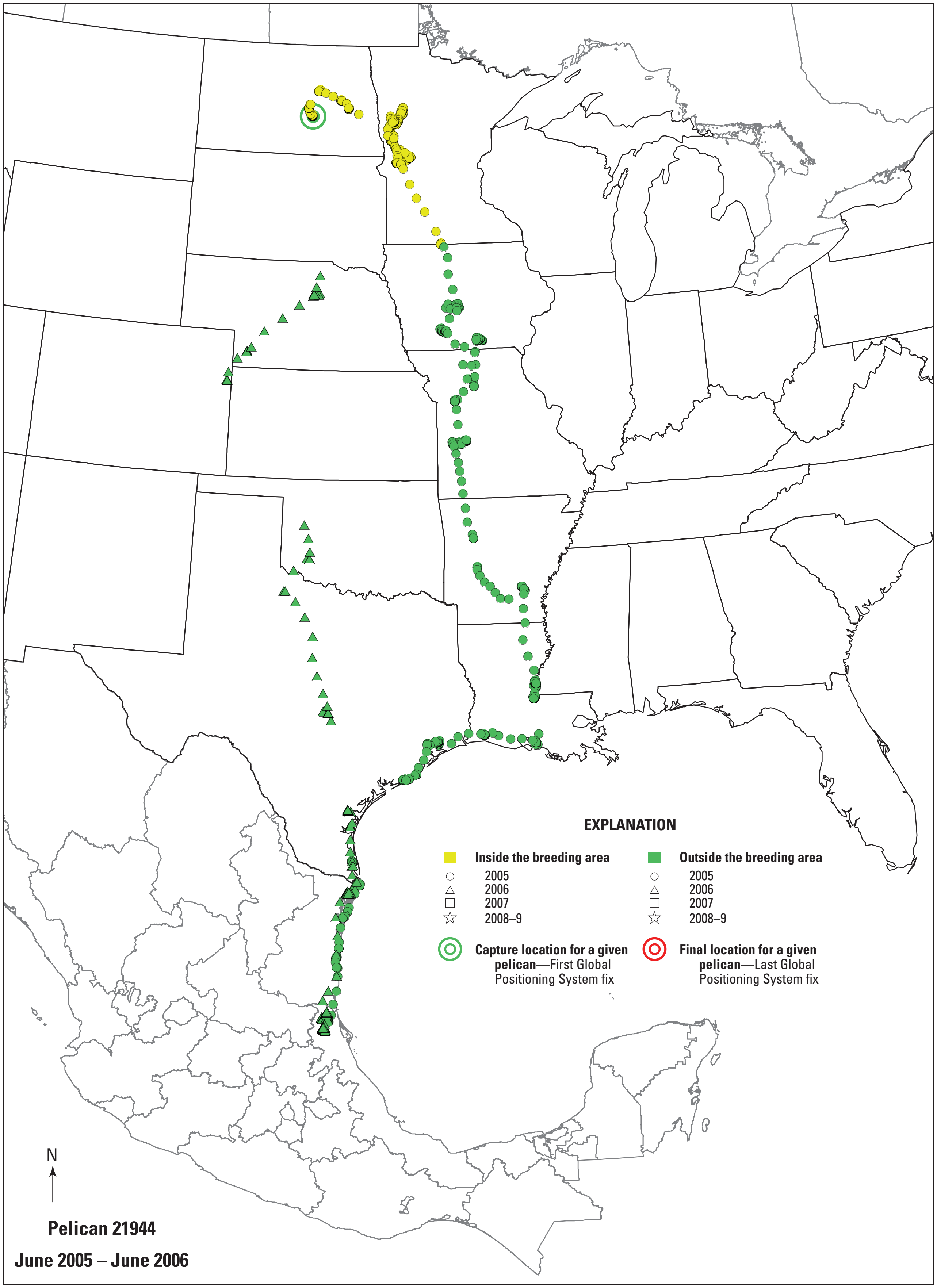

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21925r
May – June 2007

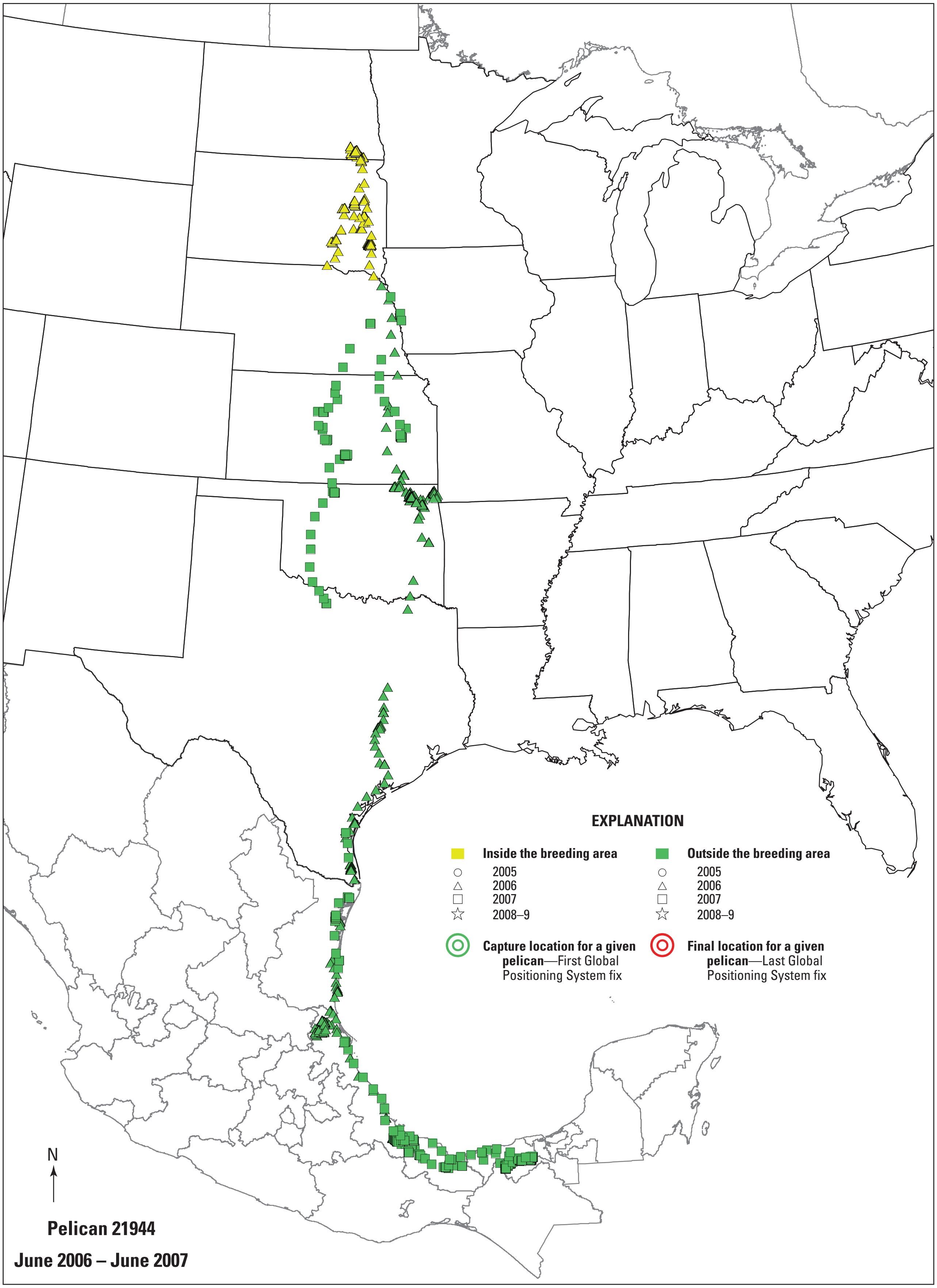

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21932
June 2005 – June 2006

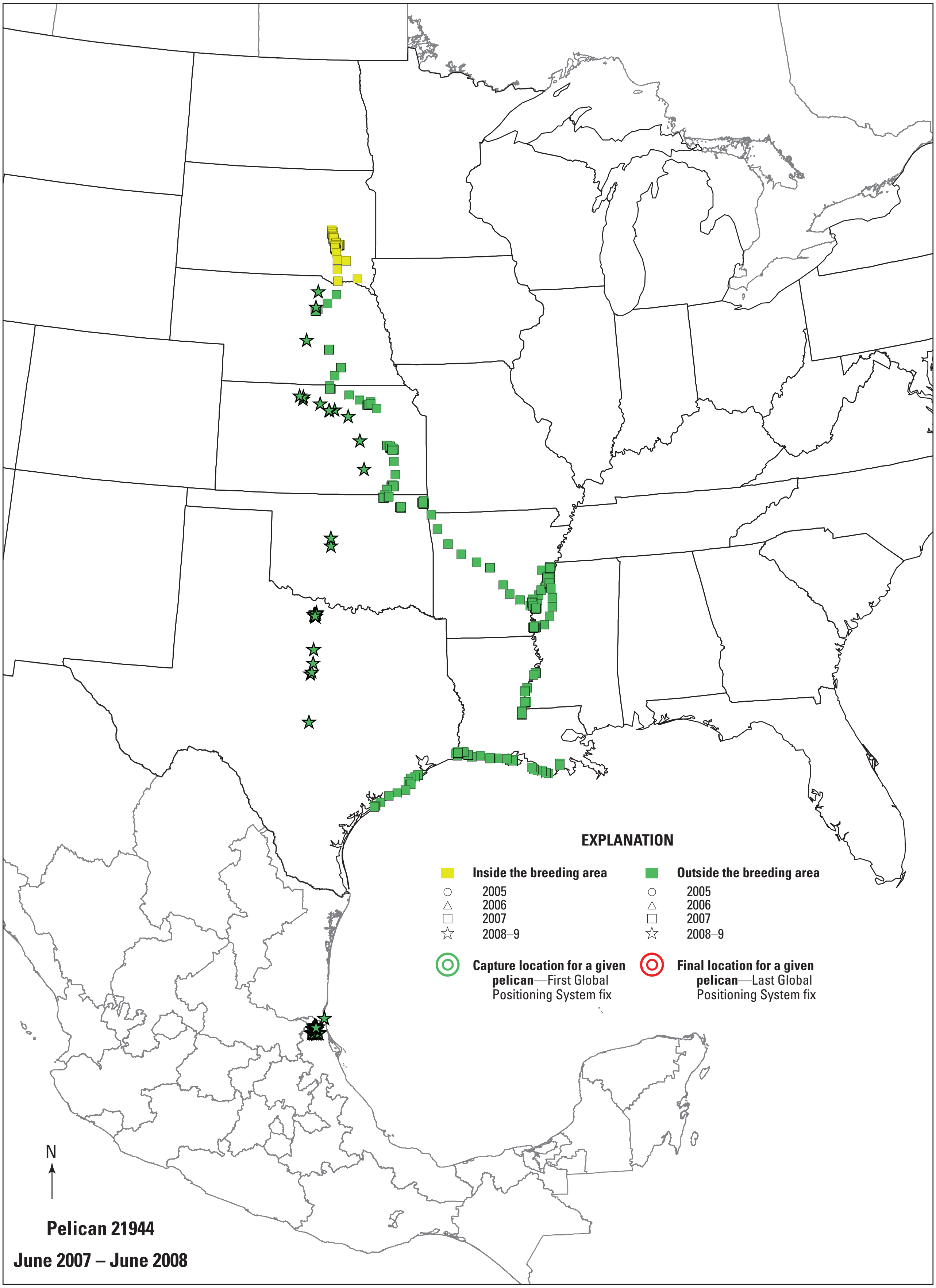

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21932
June 2006 – June 2007

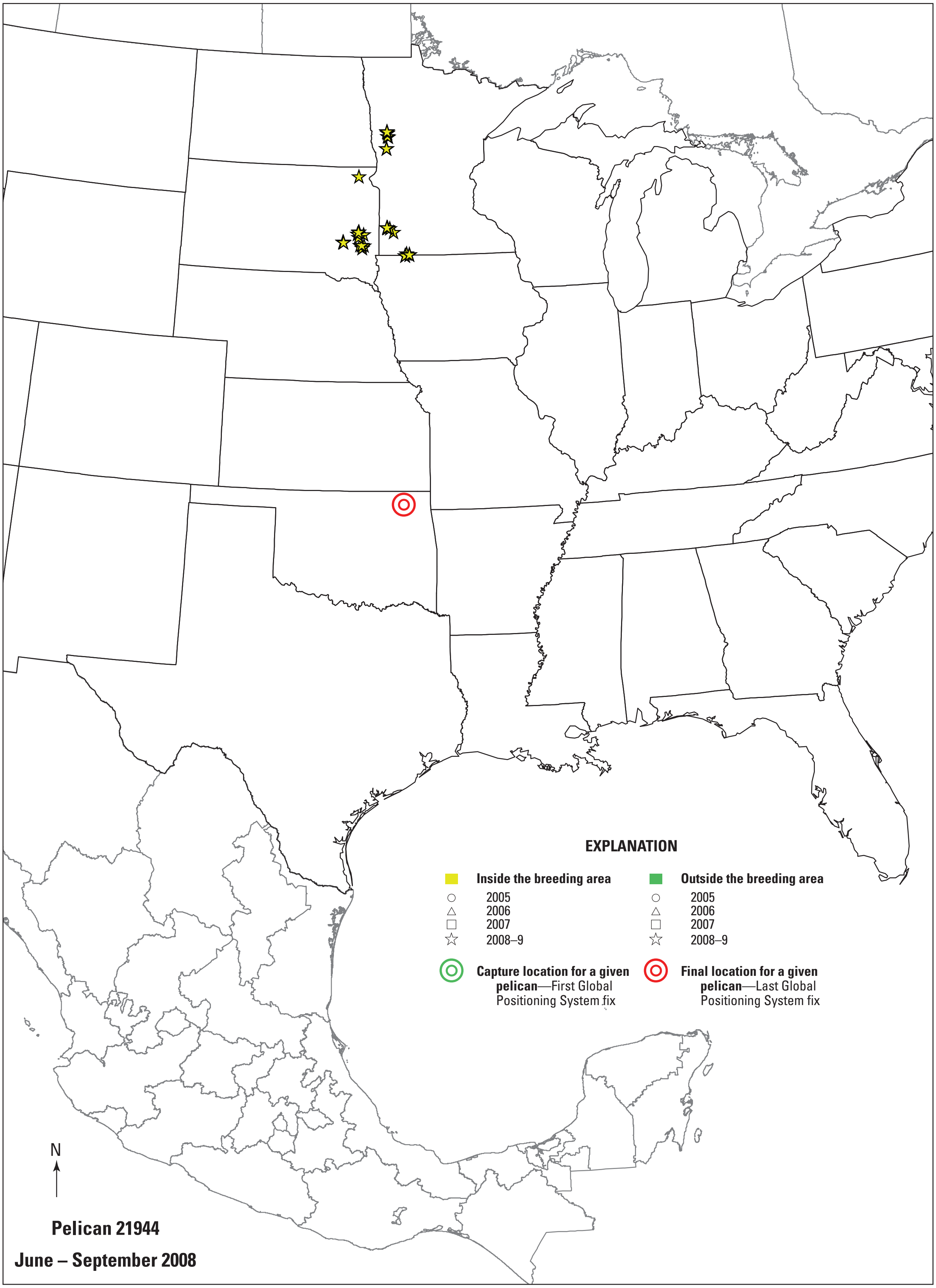

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21932
June 2007 – May 2008

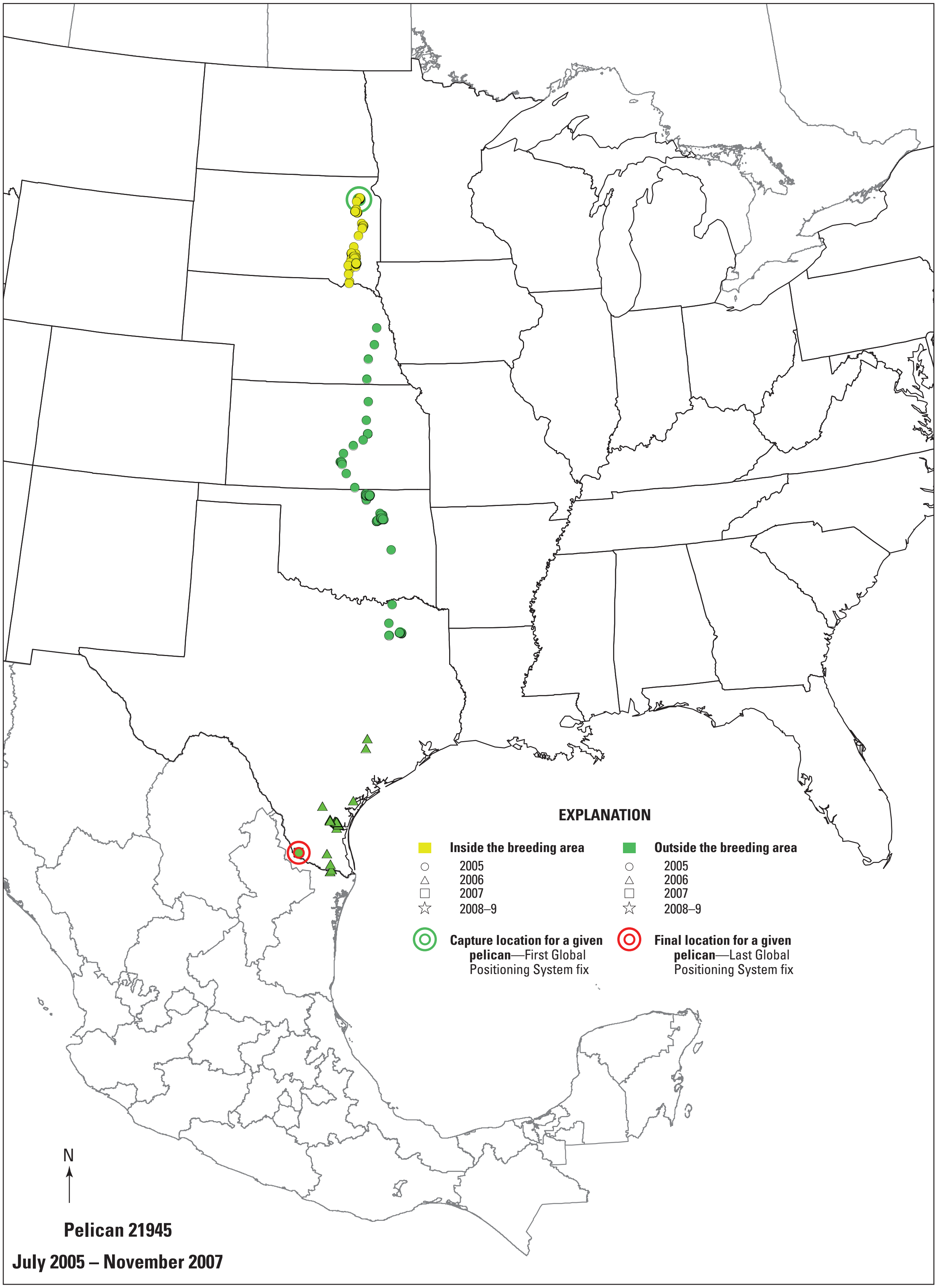

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21932
May 2008 – February 2009

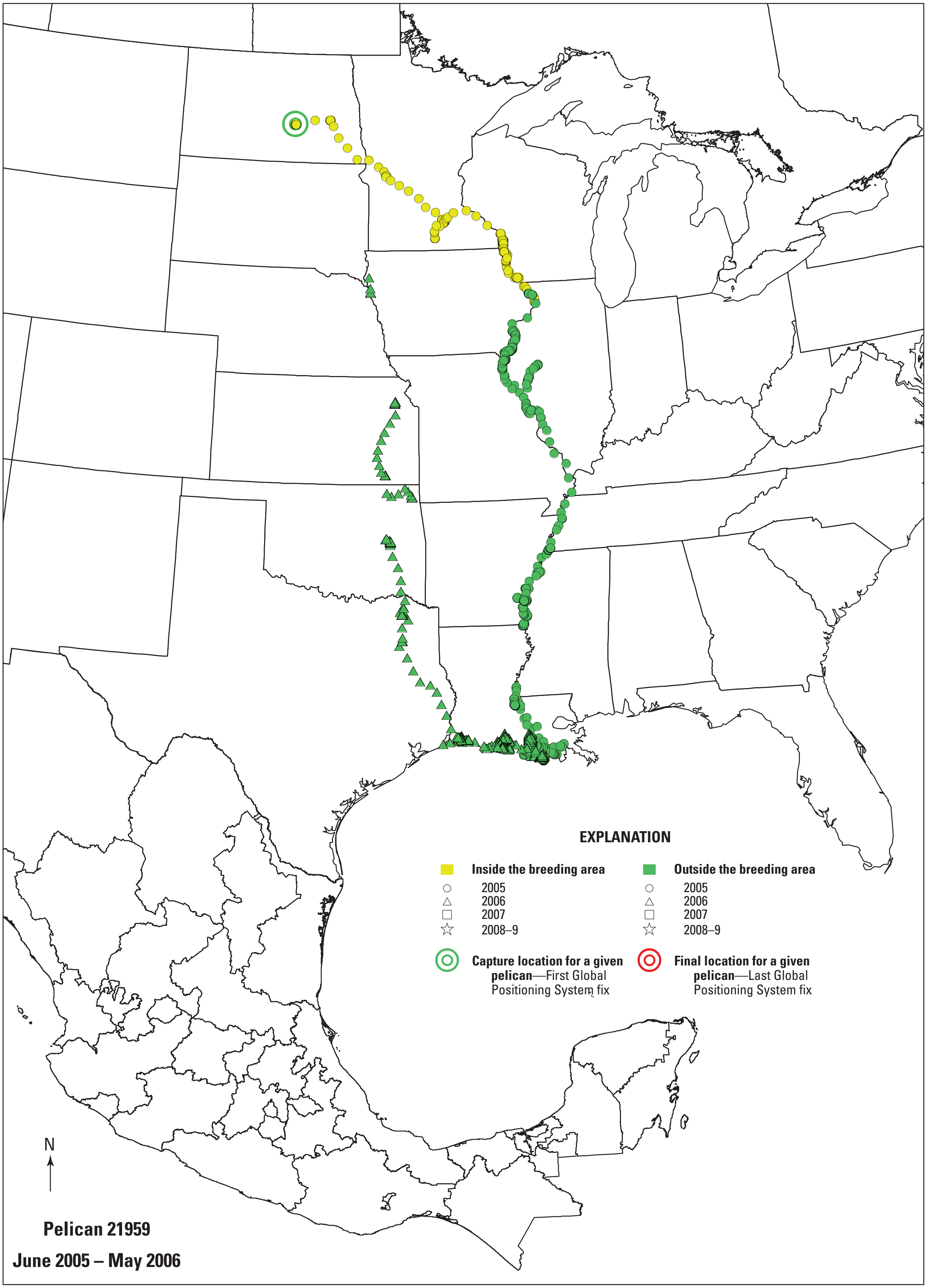

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21944
June 2005 – June 2006

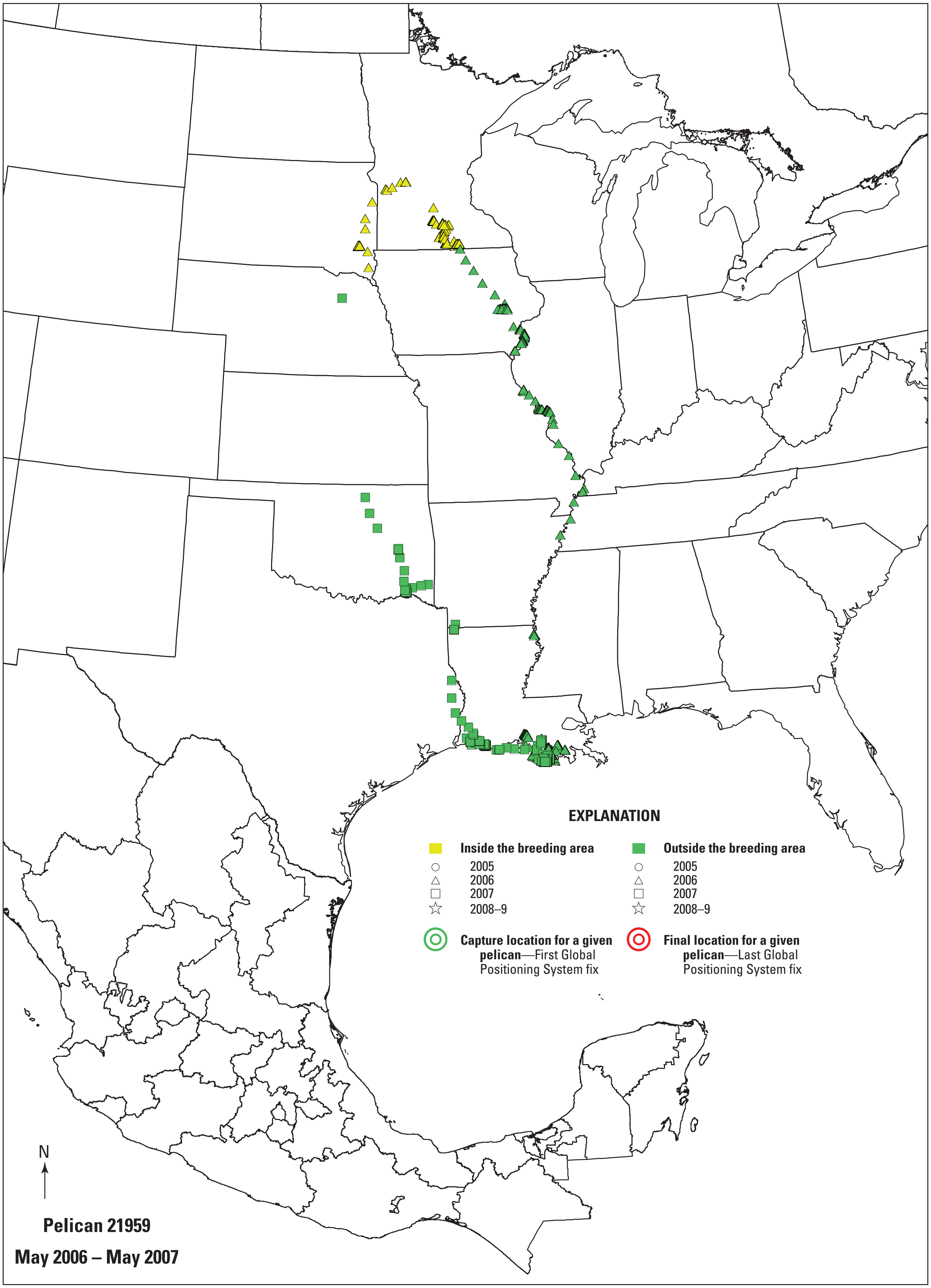

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21944
June 2006 – June 2007

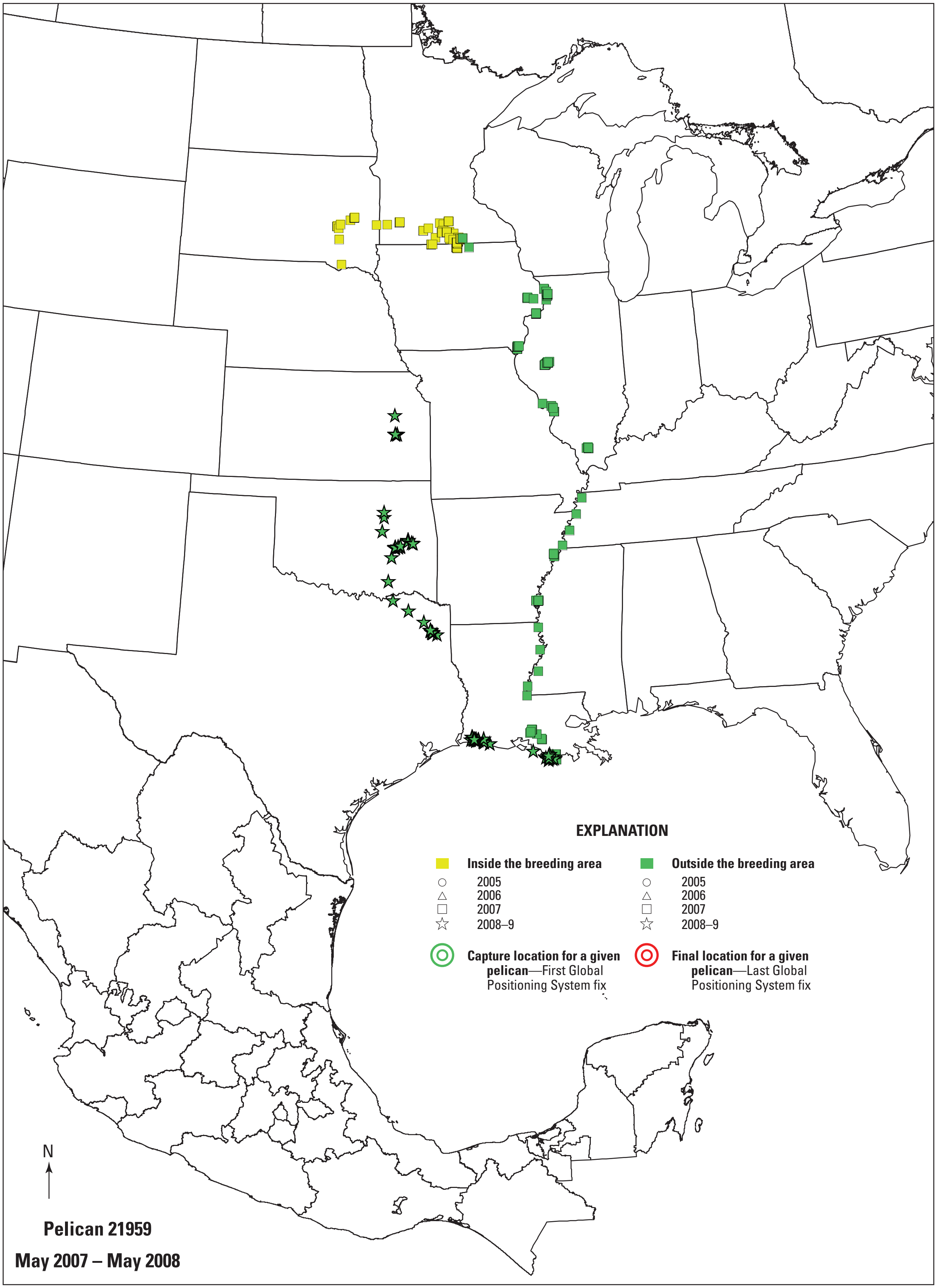

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21944
June 2007 – June 2008

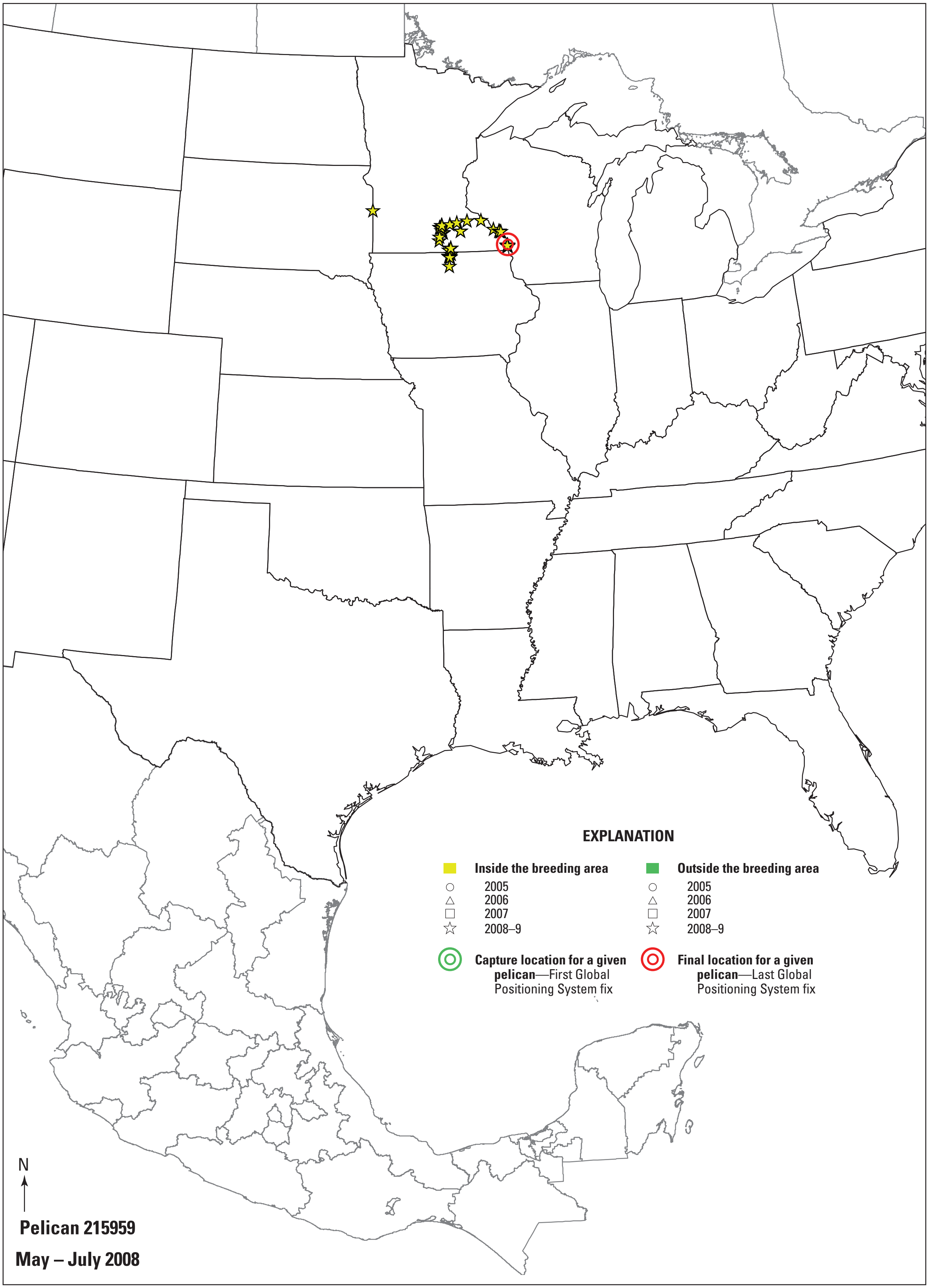

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21944
June – September 2008

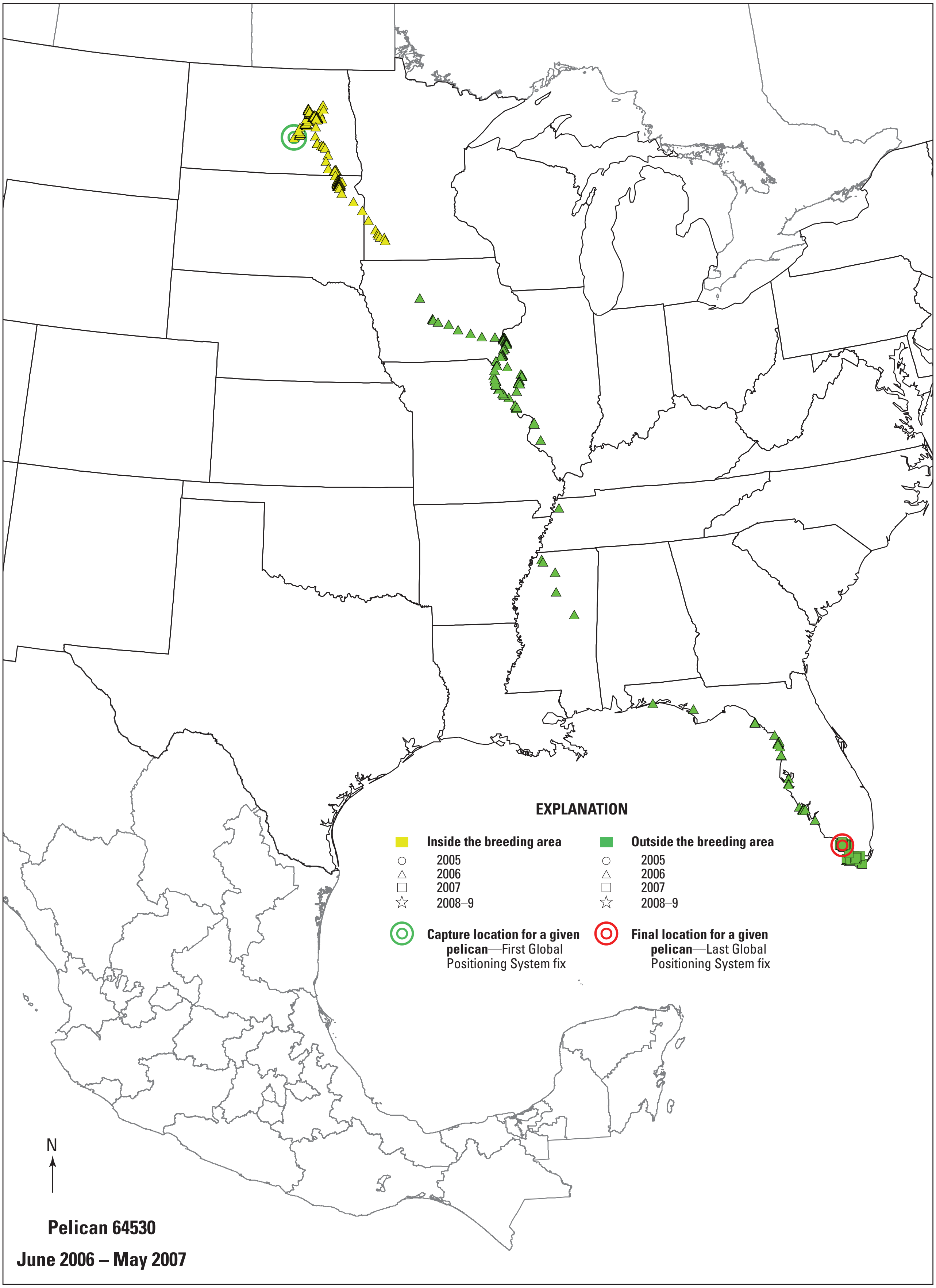

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21945
July 2005 – November 2007

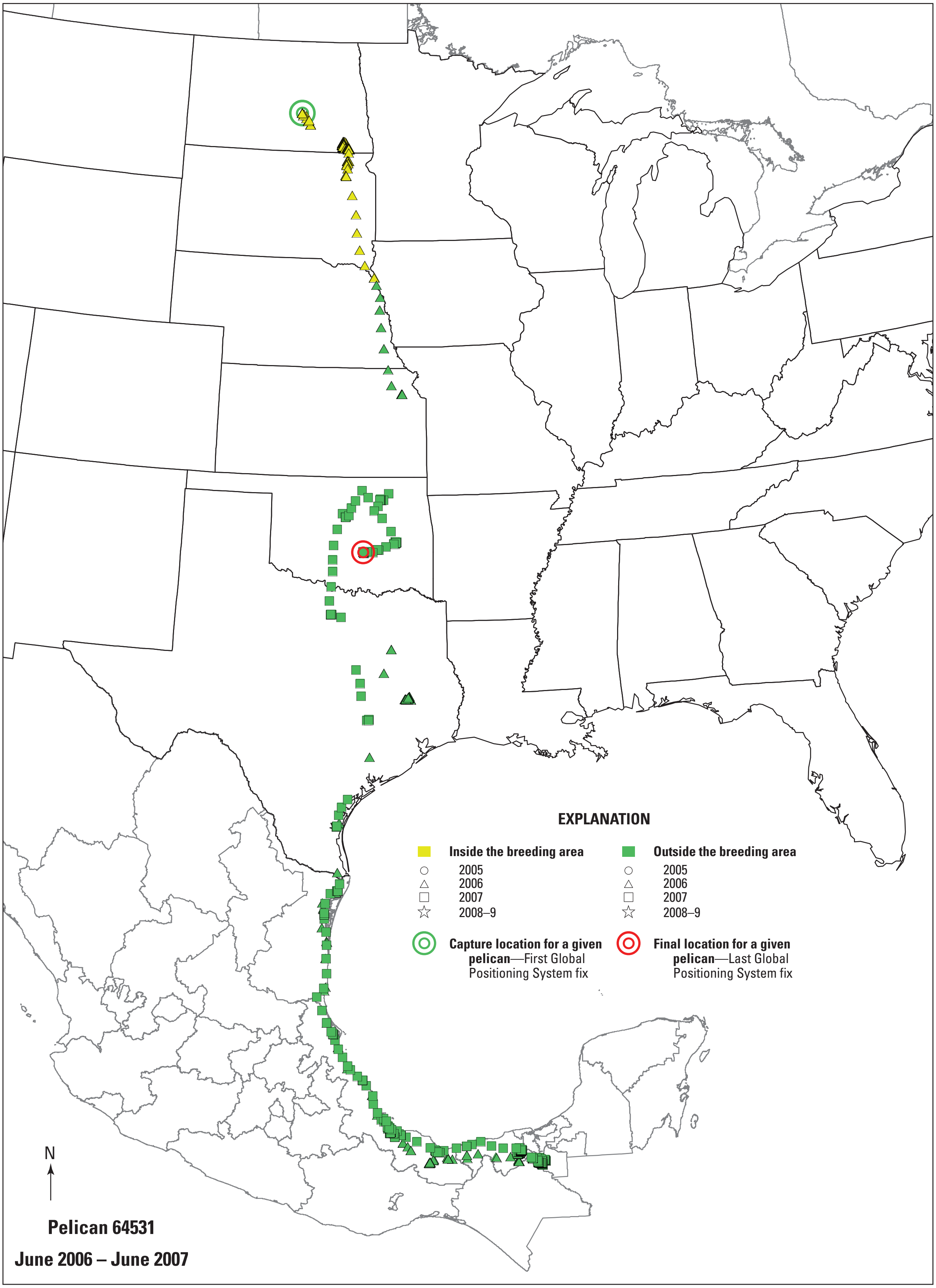

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21959
June 2005 – May 2006

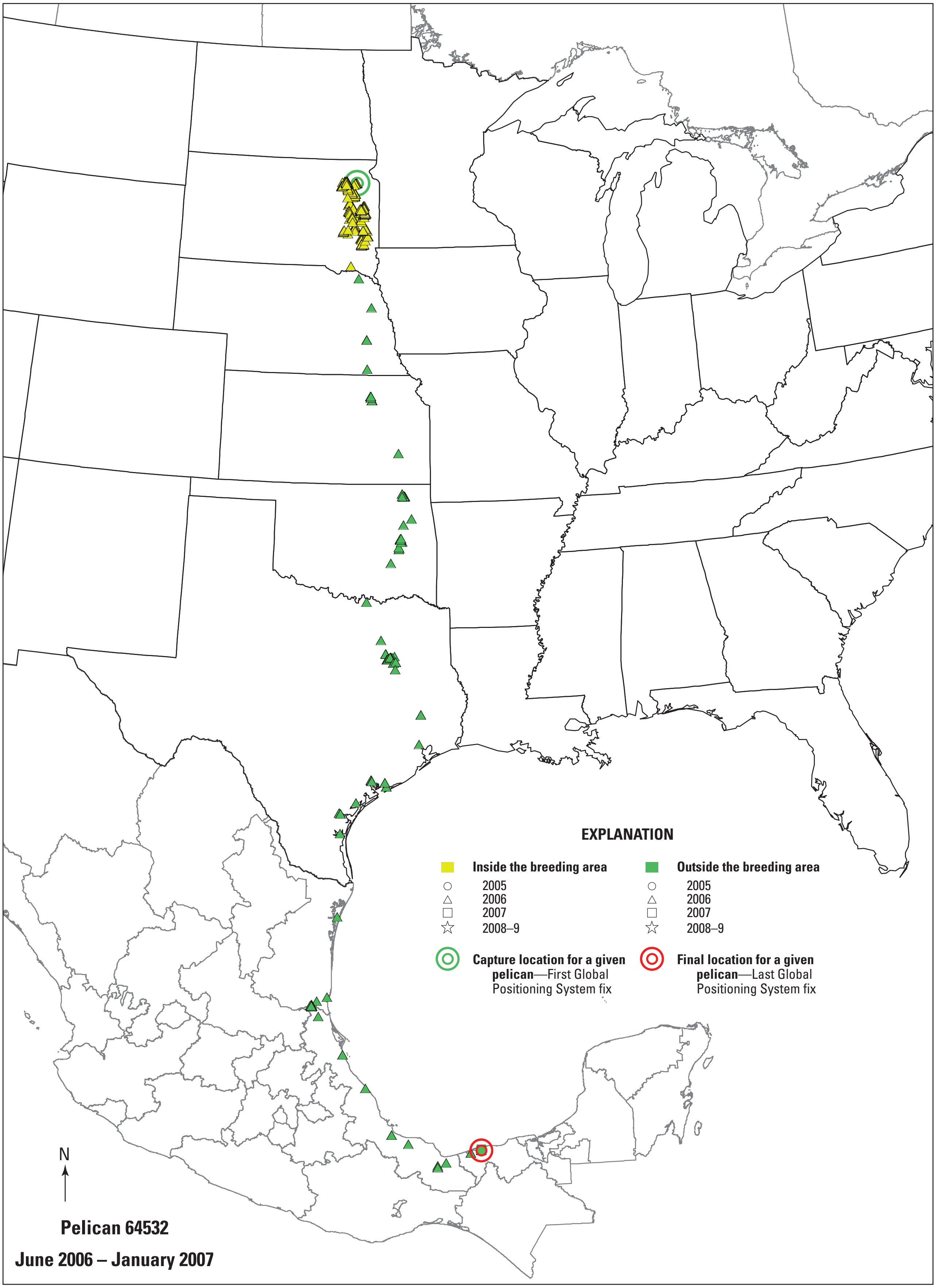

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21959
May 2006 – May 2007

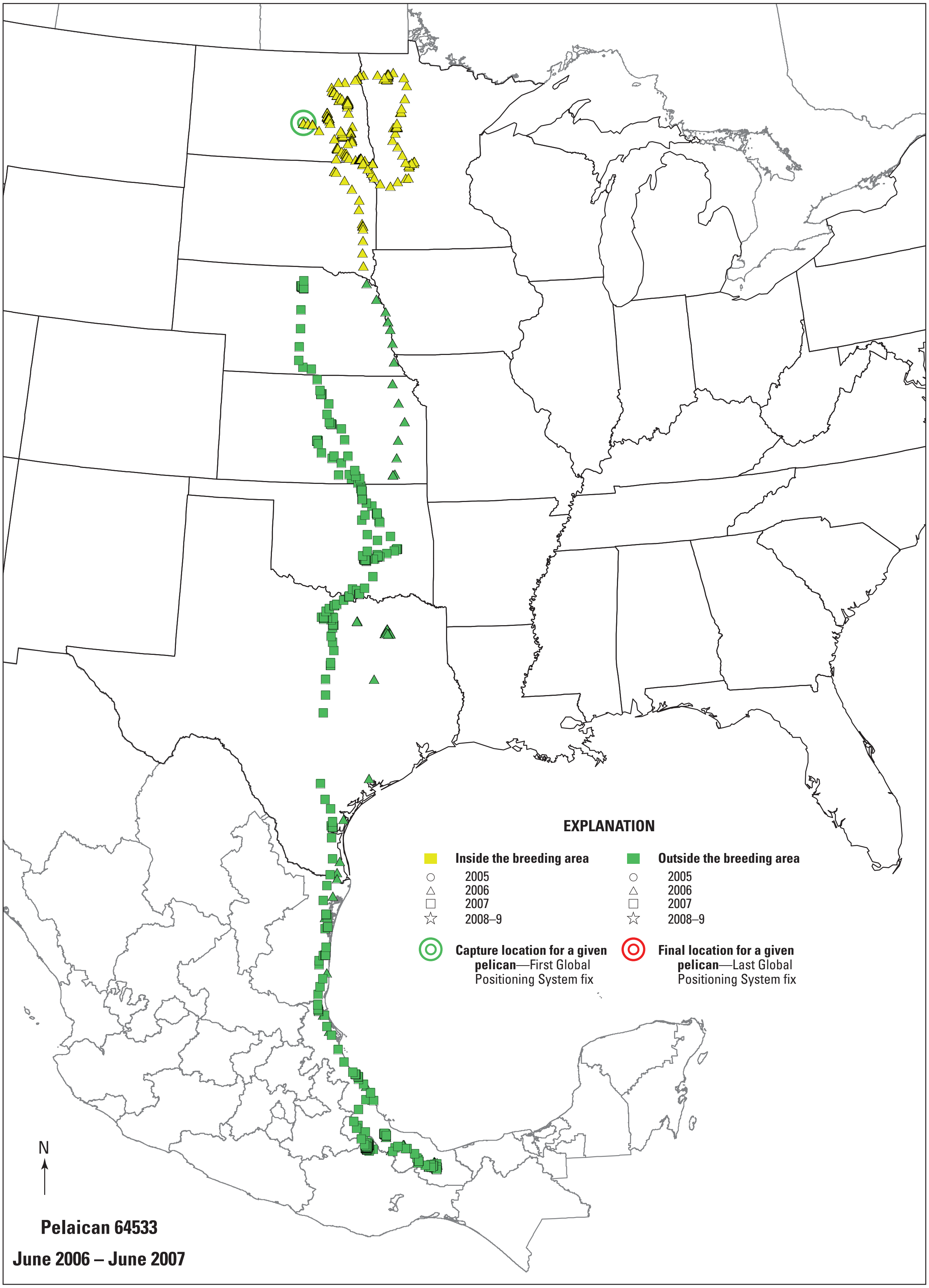

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 21959
May 2007 – May 2008

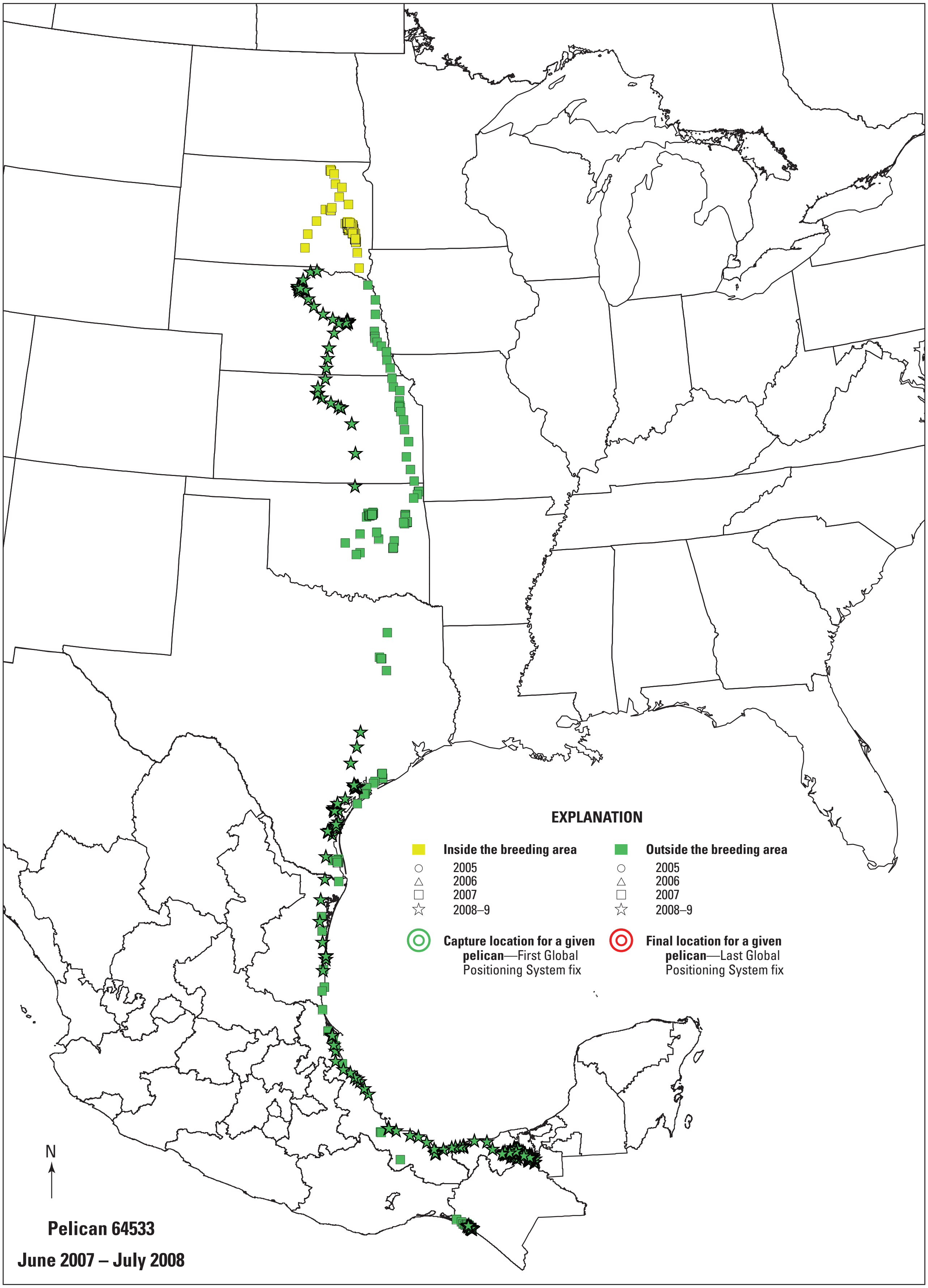

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 215959
May – July 2008

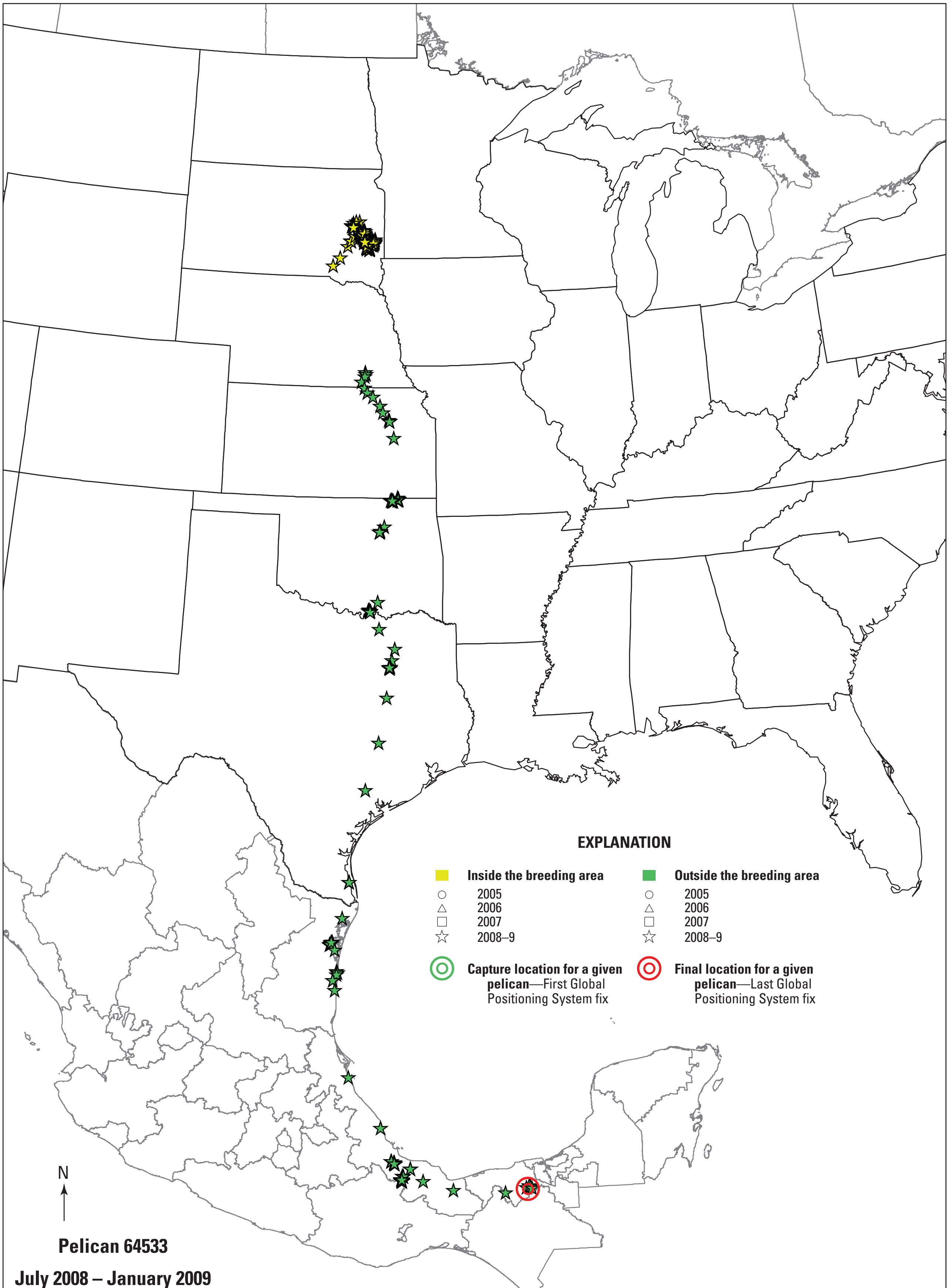

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64530
June 2006 – May 2007

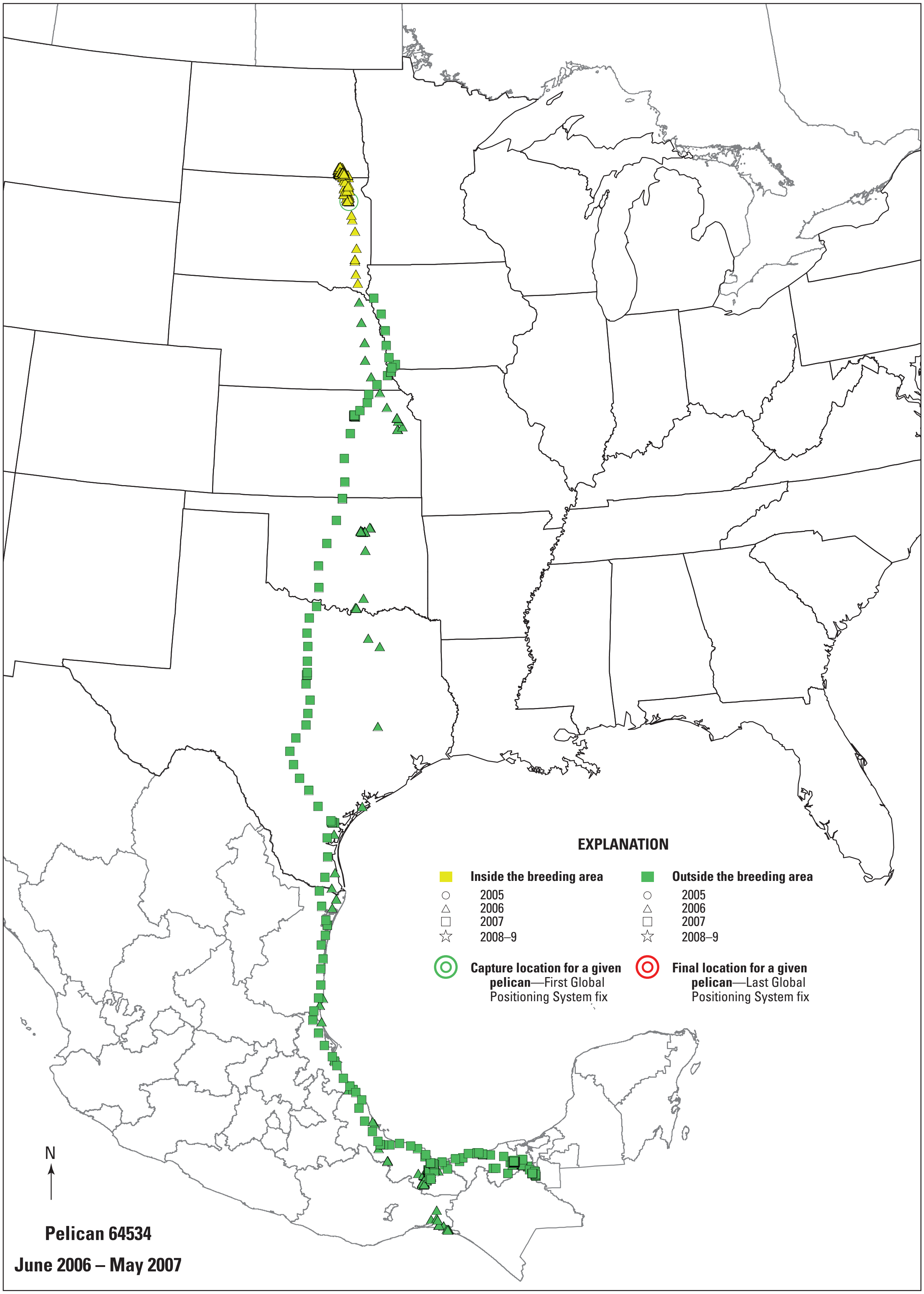

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64531
June 2006 – June 2007

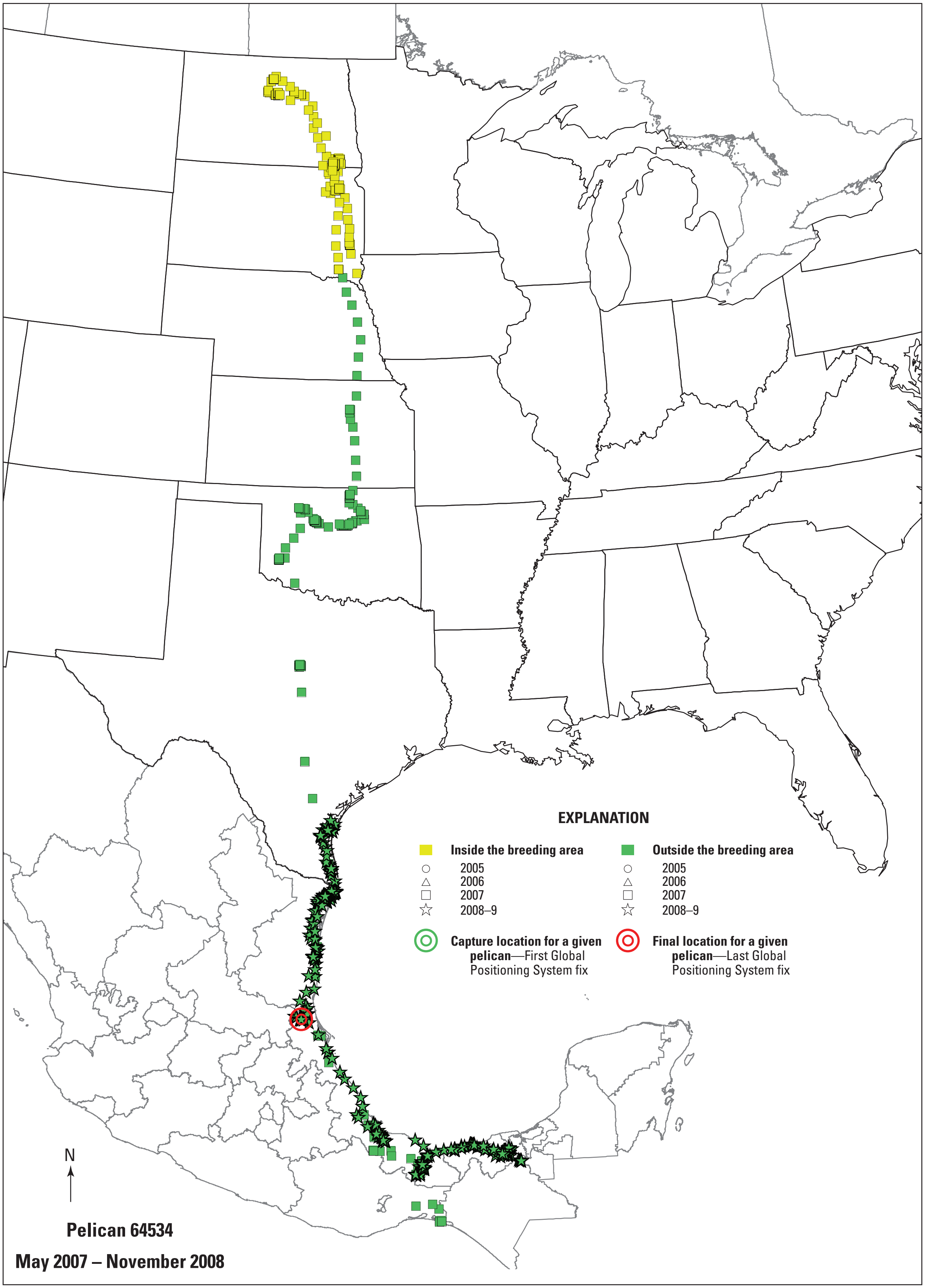

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64532
June 2006 – January 2007

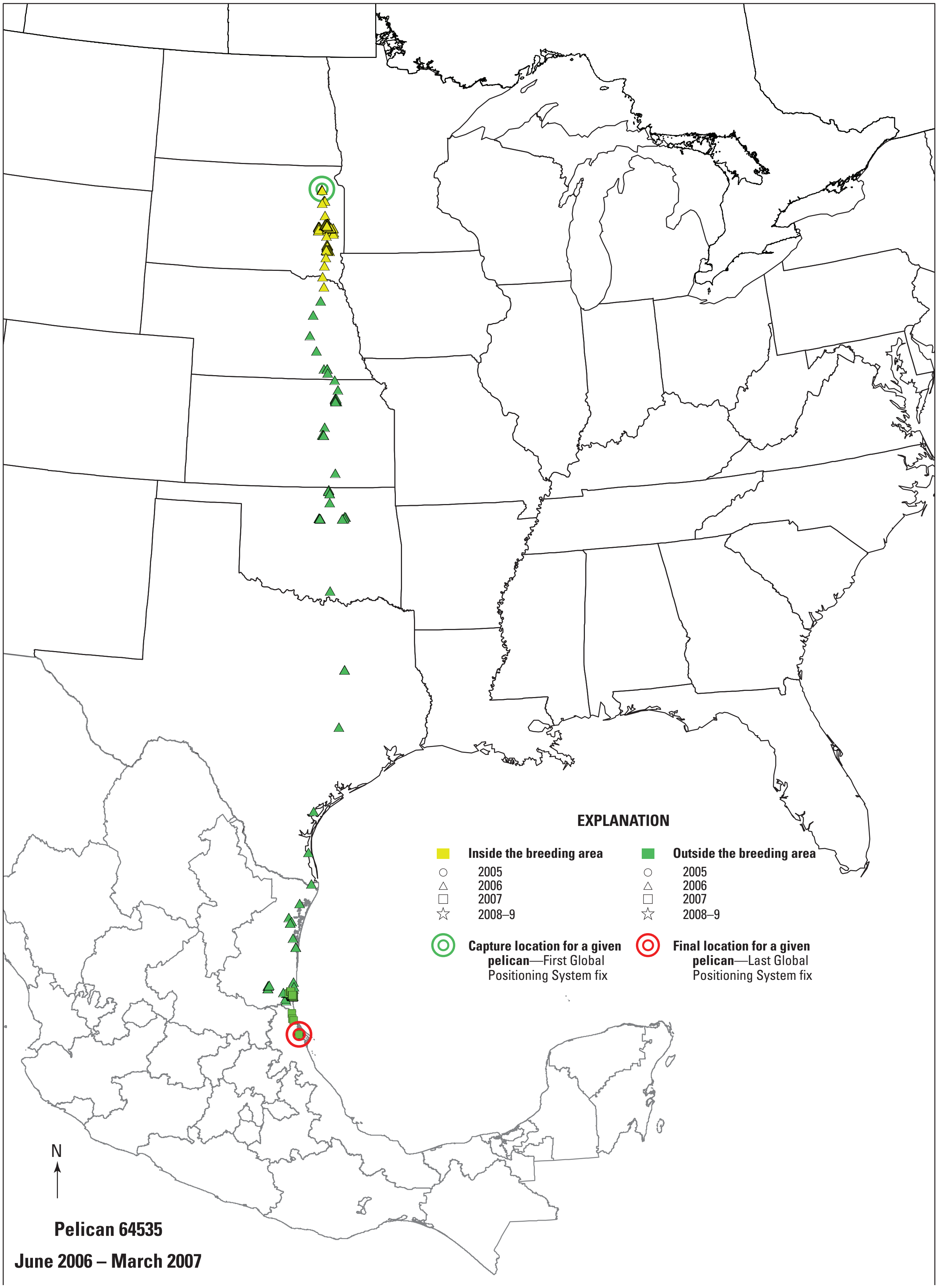

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelaican 64533
June 2006 – June 2007

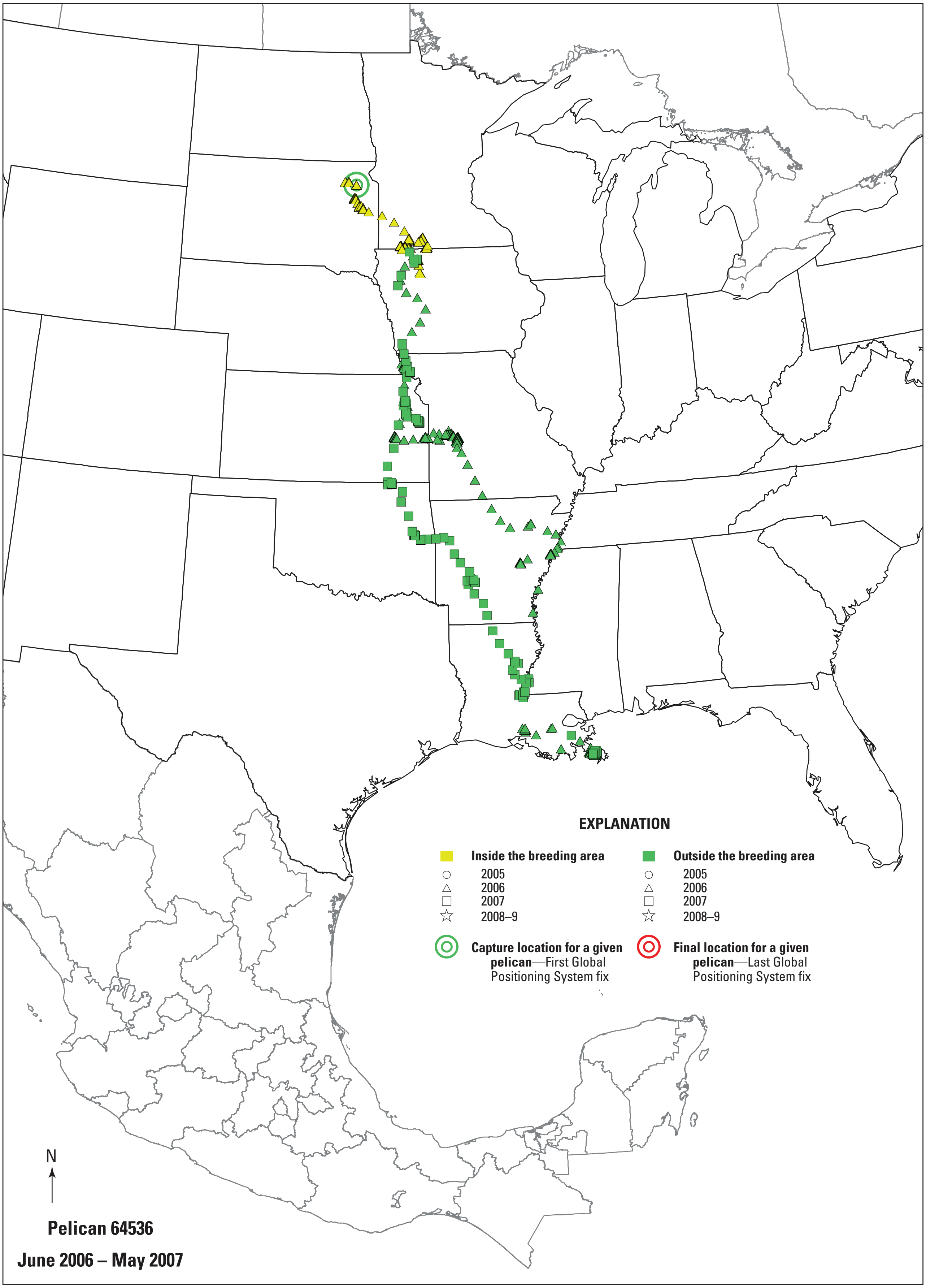

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64533
June 2007 – July 2008

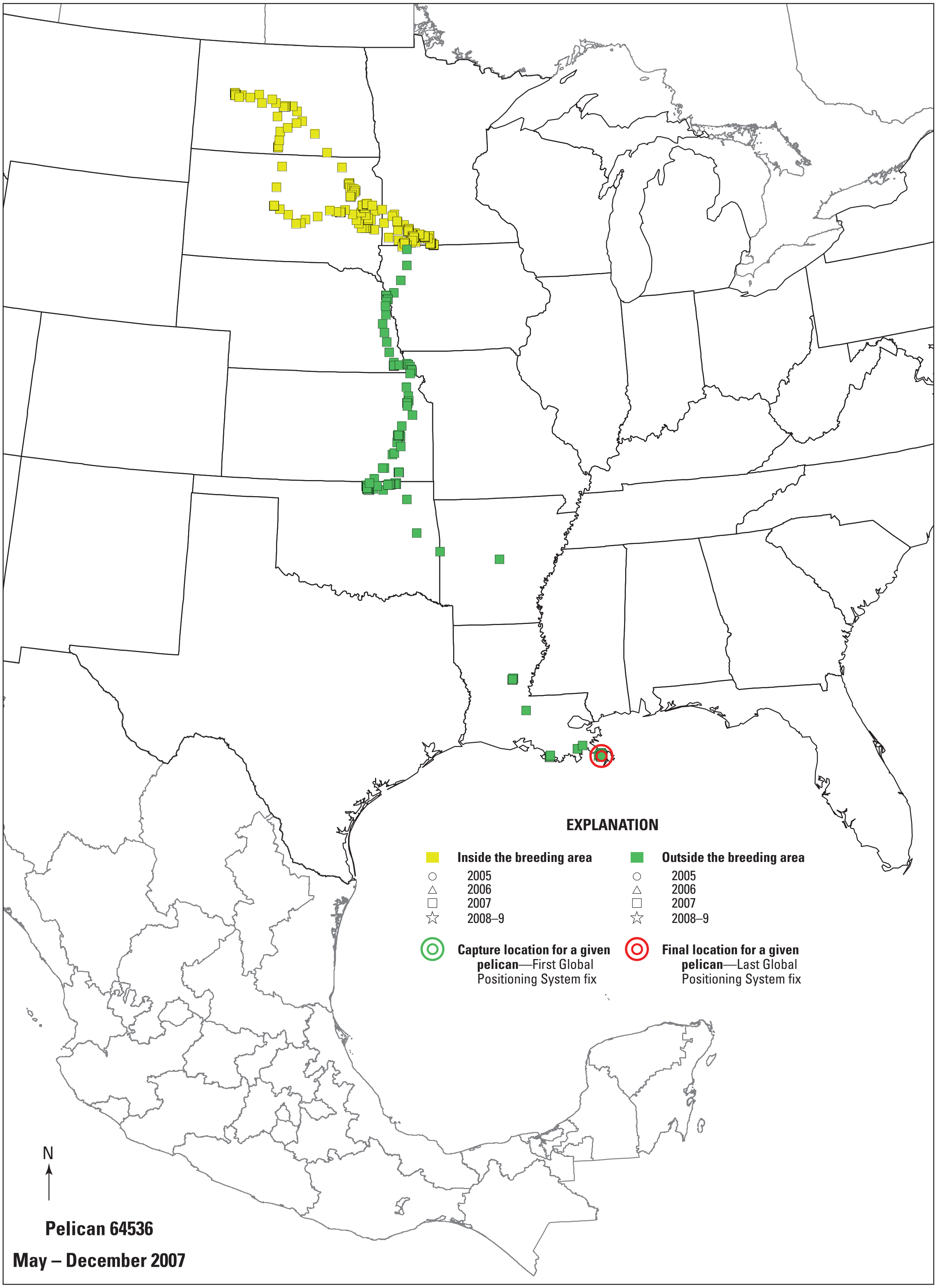

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64533
July 2008 – January 2009

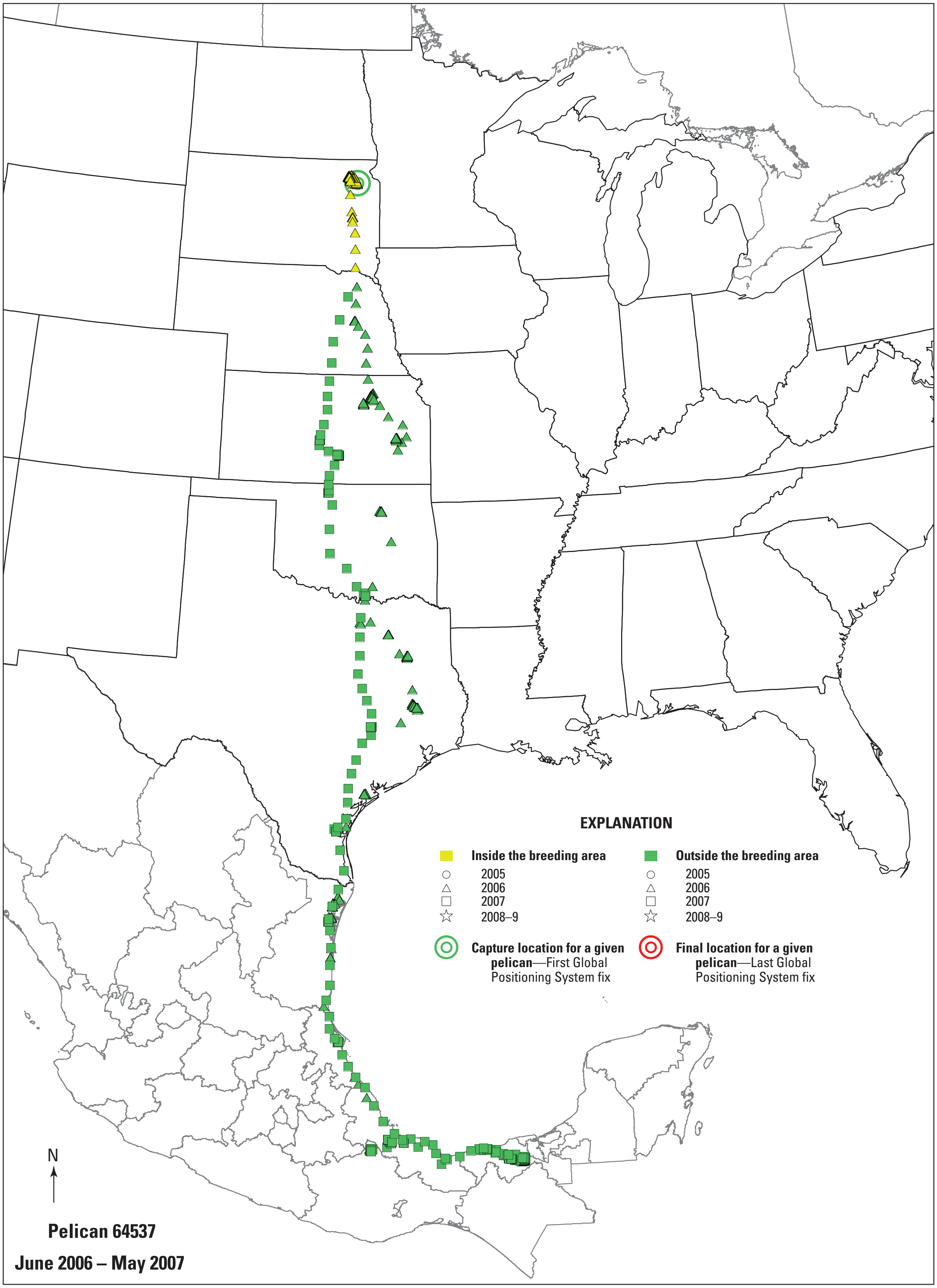

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64534
June 2006 – May 2007

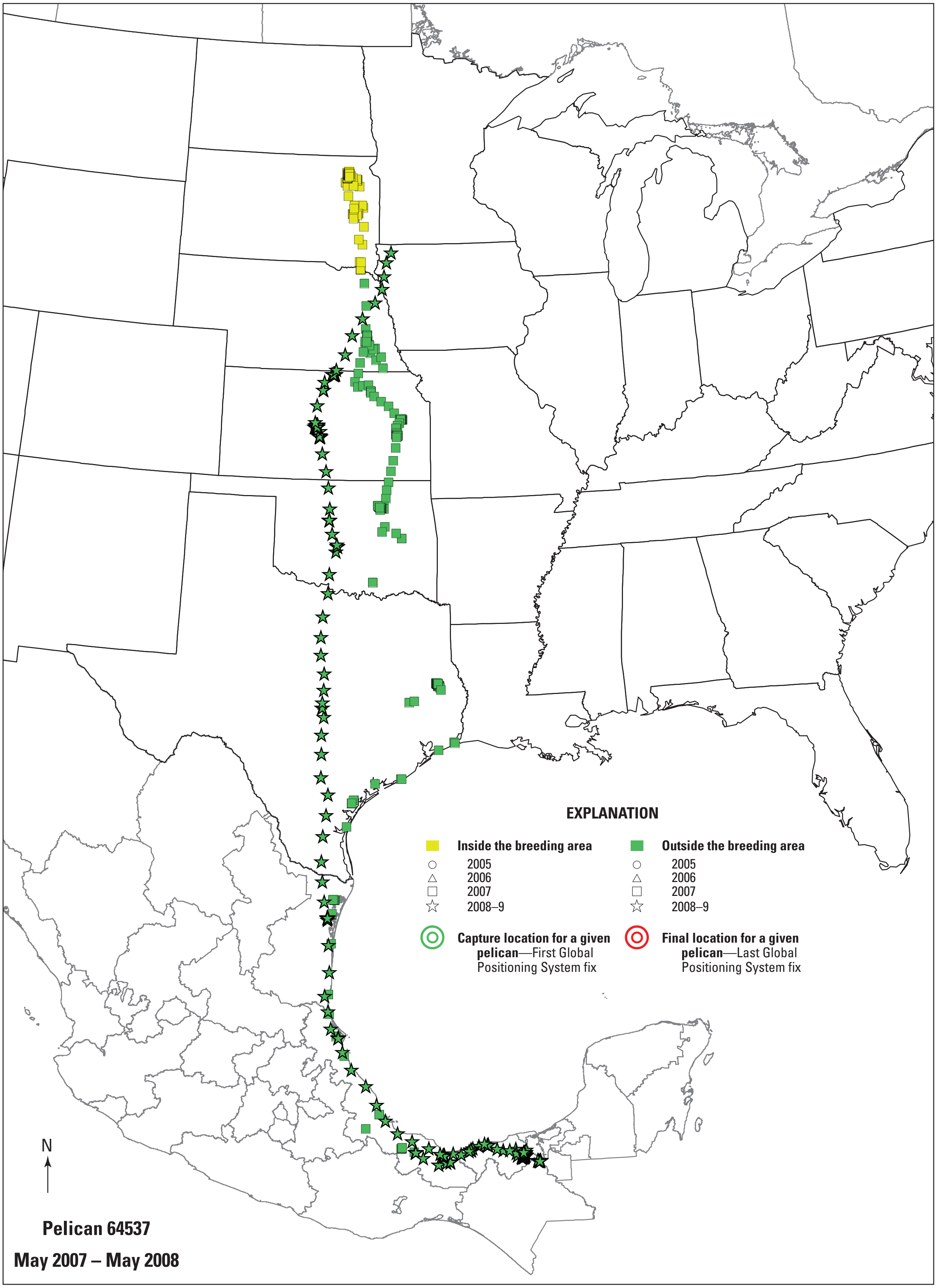

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64534
May 2007 – November 2008

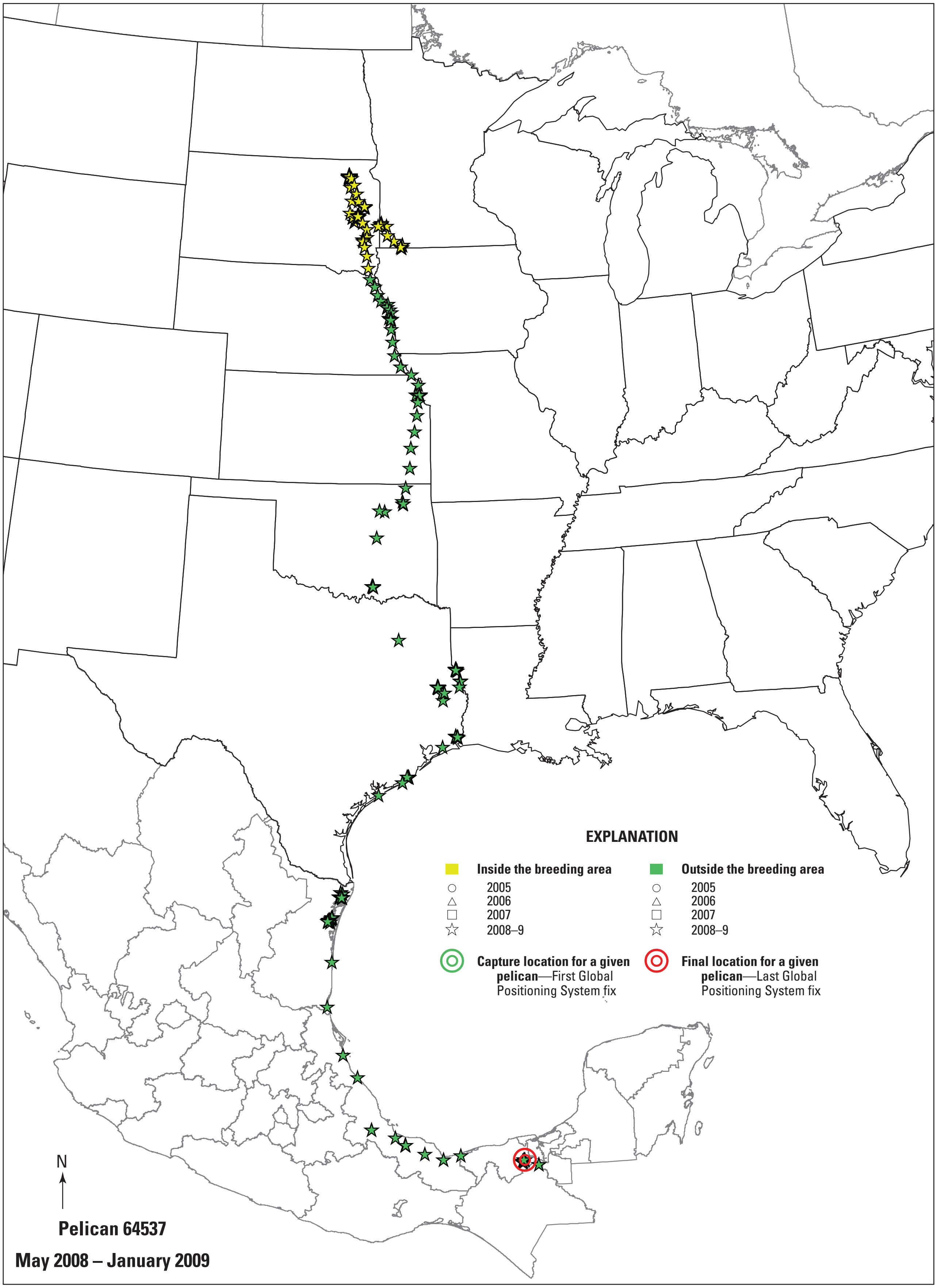

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64535
June 2006 – March 2007

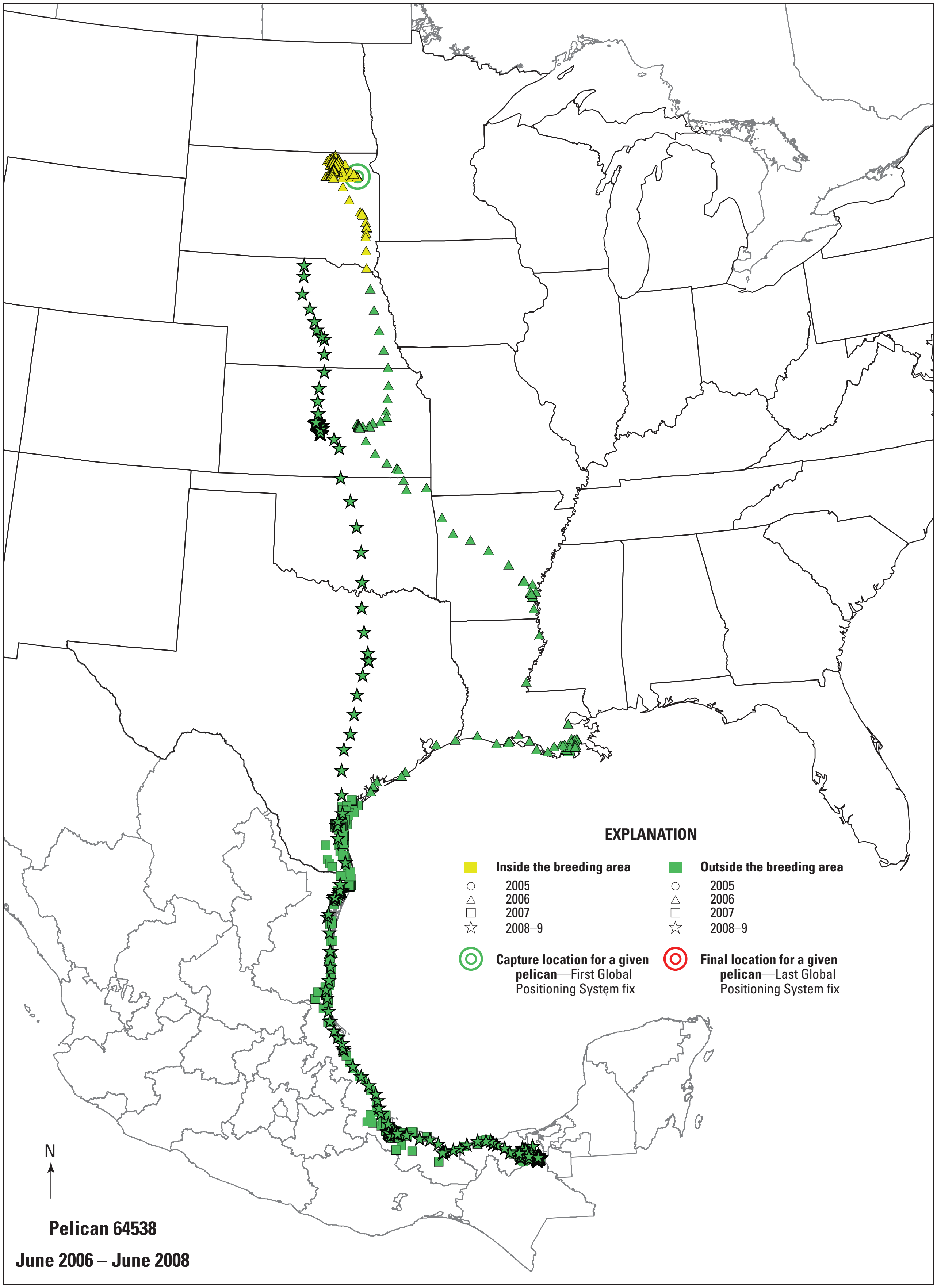

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64536
June 2006 – May 2007

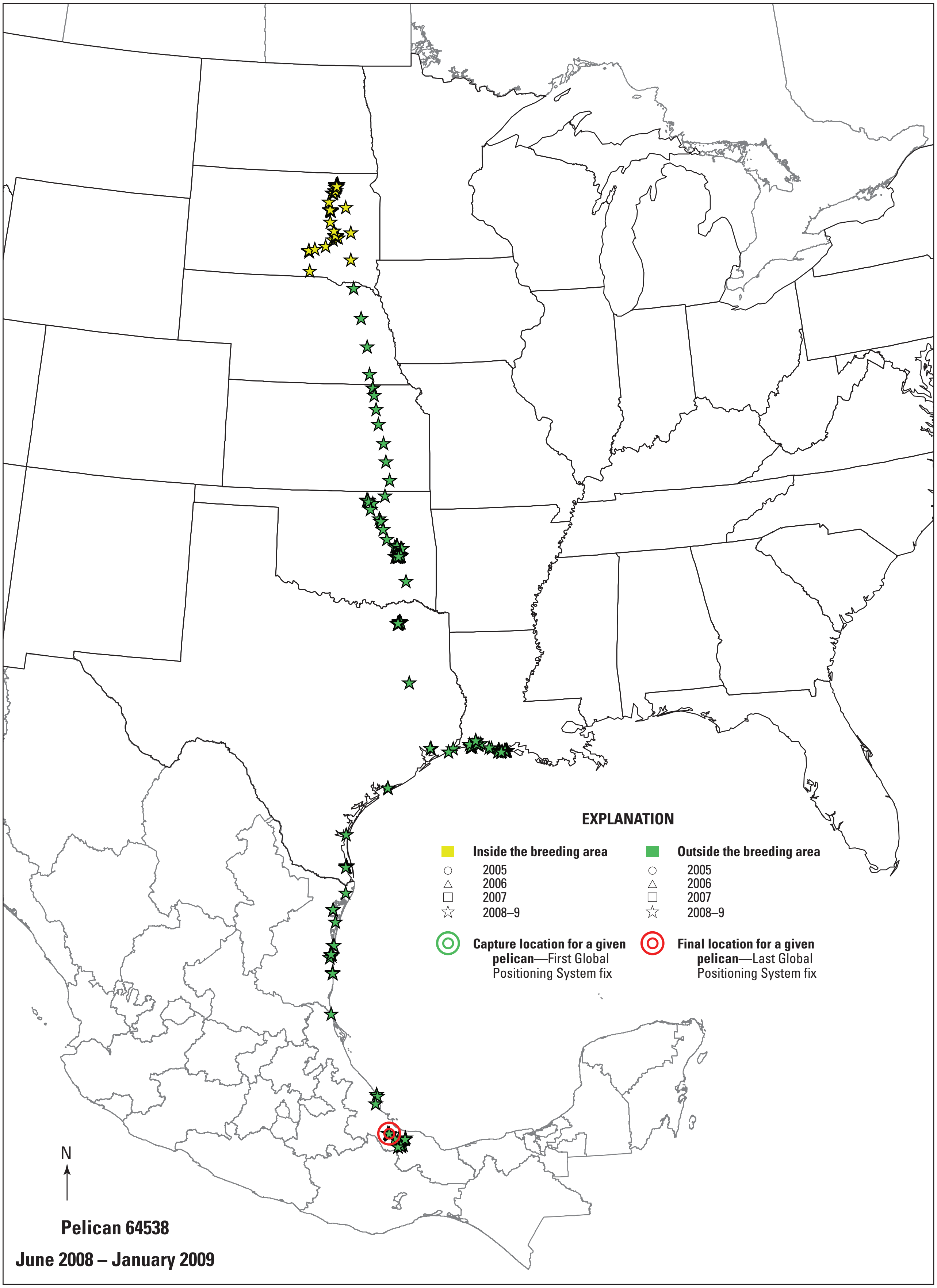

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64536
May – December 2007

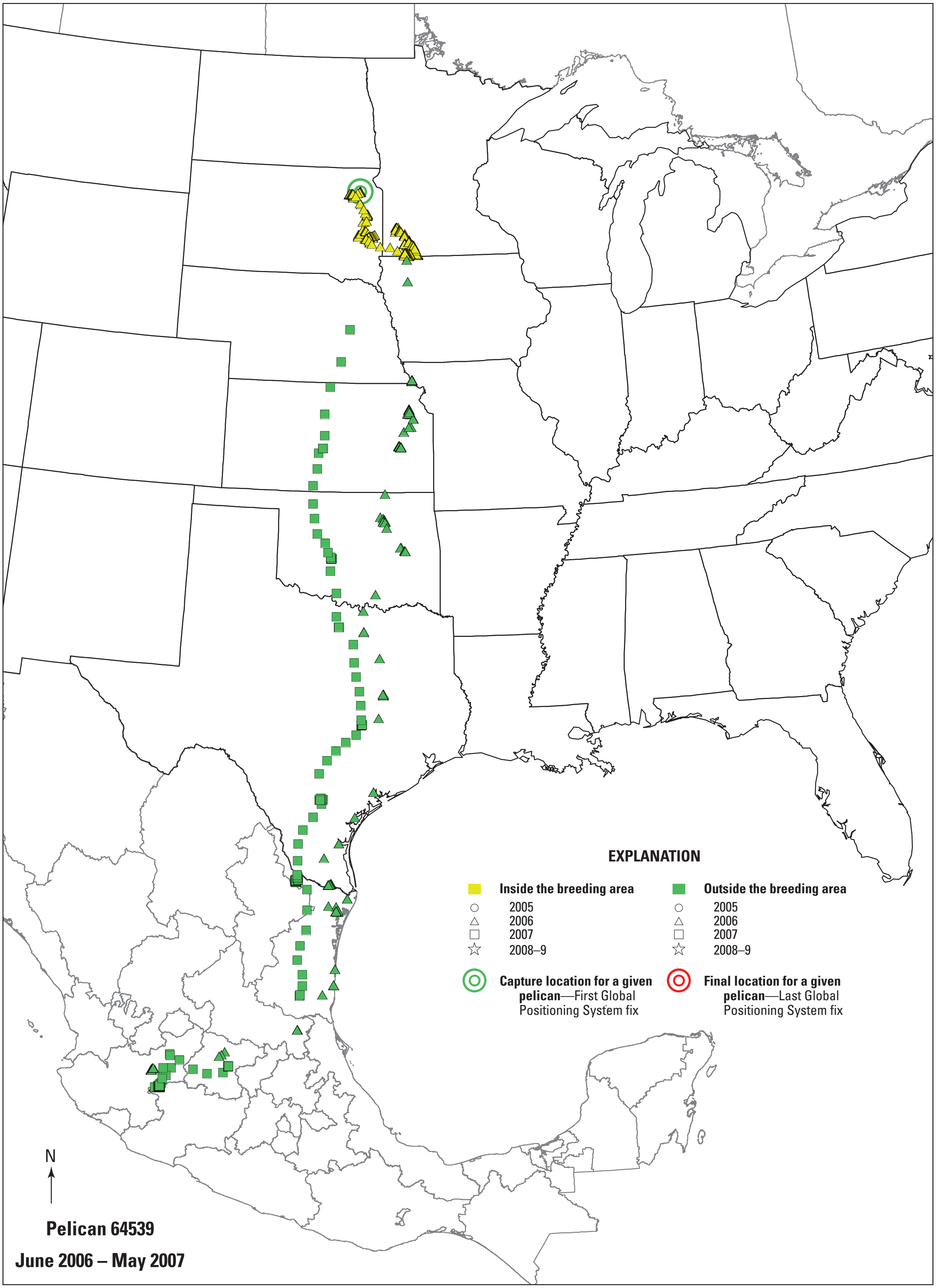

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64537
June 2006 – May 2007

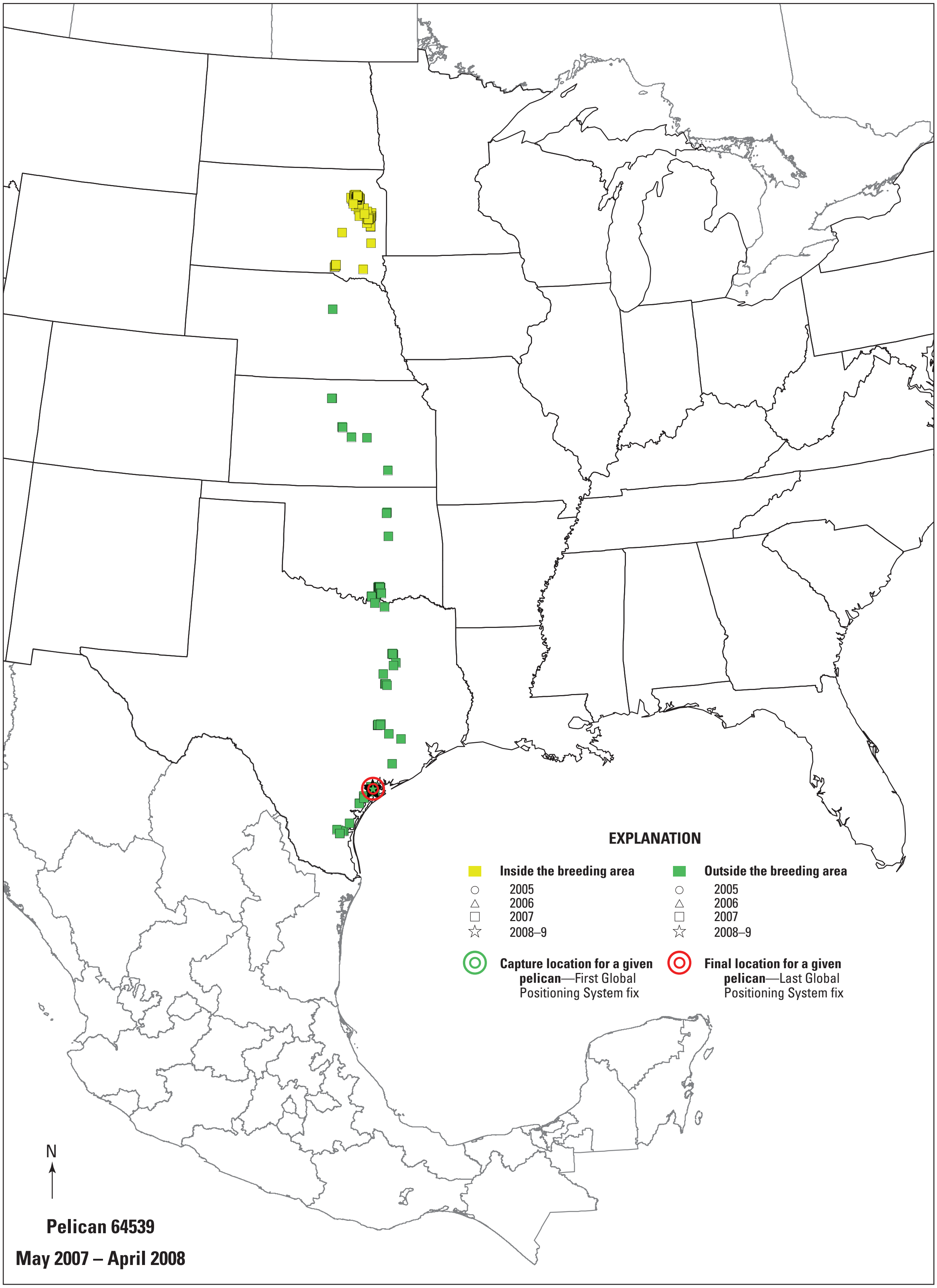

EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64537
May 2007 – May 2008


EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64537
May 2008 – January 2009


EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64538
June 2006 – June 2008


EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64538
June 2008 – January 2009


EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64539
June 2006 – May 2007


EXPLANATION
Inside the breeding area
2005
2006
2007
2008–9
Outside the breeding area
2005
2006
2007
2008–9
Capture location for a given pelican—First Global Positioning System fix
Final location for a given pelican—Last Global Positioning System fix
N
Pelican 64539
May 2007 – April 2008

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http://www.npwrc.usgs.gov/

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