HOME RANGE AND MOVEMENT OF NUTRIA (*MYOCASTOR COYPUS*) AT SPRING LAKE IN CENTRAL TEXAS, WITH ANECDOTAL COMMENTS ON THE AMERICAN BEAVER (*CASTOR CANADENSIS*) OF THE SAME AREA

THESIS

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By

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Home range and movement data of nutria and beaver were collected using radio telemetry techniques from 16 December 2000 through 7 November 2001. A total of 14 nutria and three beaver were radio collared. Home range was calculated for eight nutria, four females and four males, and two beaver, one female and one male. The overall mean home range of the nutria was 2.74 ha. The mean home range of the four female nutria was 1.61 ha and 3.88 ha for the four male nutria. No significant difference in home range size was detected between females and males ($t = 1.26$, $P > 0.05$). The mean maximum linear distance traveled daily by the eight nutria was 276.46 m; females averaged 217.30 m and males averaged 335.62 m. No significant difference was found between mean maximum linear distance traveled between females and males ($t = 1.35$, $P > 0.05$). The mean home range of the two beaver was 3.72 ha. The mean maximum linear distance traveled by the three beaver was 853.28 m.

INTRODUCTION

Home range is the confined area in which animals carry out their daily activities. This area is limited by the structure of surrounding habitat, competition and territoriality with conspecific animals, and the distribution of food and cover (Litvaitis *et al.* 1996). Radio telemetry and mark and recapture techniques are methods commonly used for measuring an individual's home range. Radio telemetry techniques, first used in the 1960s (Cochran and Lord 1963), result in higher accuracy due to the freedom of researchers to locate a radio marked animal when desired.

A number of studies have been conducted using radio telemetry to estimate the home range of mammals, reptiles, amphibians, and birds. At Spring Lake, two other studies using radio telemetry techniques were completed. Aguirre (1999) studied space use patterns of the common snapping turtle (*Chelydra serpentina serpentina*). Hudson (1999) radio tracked raccoons (*Procyon lotor*) to estimate their home range.

Nutria *(Myocastor coypus),* semi-aquatic rodents found in Spring Lake, Hays County, Texas, first were introduced to California for the fur trade in 1899 (Evans 1970). They were not introduced to other parts of North America in large numbers to consume undesirable aquatic vegetation until the late 1930's (Willner 1982).

Today, this exotic pest can be found nationwide in 15 states and continues to expand its distribution (Bounds *et al.* 2001). Nutria generally weigh around 5.4 kg. After one year, females reach sexual maturity and begin breeding. Gestation periods average 130 days, and litter size is generally around five. Nutria are sedentary and tend to remain in one location throughout their life (Adams 1956).

Nutria compete with native wildlife species. The muskrat is being displaced by nutria, and waterfowl and migratory birds are losing valuable food and cover resources as a result of increased nutria populations (Bounds 2000). The feeding habits of nutria also are destructive to sensitive wetland ecosystems. Diet varies throughout the year and contains grasses, roots, stems, and leaves (Willner 1982). Nutria dig up an entire plant to eat a single root (Bounds *et al.* 2001). Not only does this destroy the plant, but also it causes soil erosion.

The food habits of nutria have been studied more extensively than their home range. Many of these studies have been conducted in Louisiana (Nyman *et al.* 1993, Taylor and Grace 1995, Wilsey *et al.*1991). Simpson (1980) and Swank and Petrides (1954) studied the food habits of nutria in Texas. Towns (2002) evaluated stomach contents of nutria at Spring Lake.

Coreil and Perry (1977) noted that it was difficult to radio collar nutria due to skin sensitivity to some collars but were able to successfully collar seven adults. Home range and movement of nutria using radio telemetry have since been studied in Mississippi (Lohmeier 1981), Louisiana (Coreil 1984), and Maryland (Ras 1999). In 2001, a three-year pilot study began in Maryland. The goal of this project, successful eradication of nutria in Maryland with the information gained from their radio telemetry study (Bounds *et al.* 2001). Studies also have been carried out on the movement of nutria using mark and recapture methods (Adams 1956, Robicheaux 1978, Ryszkowski 1966). In 1997, the distribution of nutria in their native habitats in Argentina was evaluated (Guichón and Cassini 1999).

In my study, radio telemetry was used to calculate the home range of nutria living in a unique spring-river system. From this study, movement and behavior of the rodents was analyzed. The information gathered may be useful in management strategies when attempting to control nutria populations. A widely recognized and successful method for controlling the growing nutria populations has not yet been accepted, and my research could add valuable insight.

MATERIALS AND METHODS

Study Site

Spring Lake is located in San Marcos, Hays County, Texas. Spring Lake is approximately an 8 ha reservoir that is fed by an estimated 200 springs arising from the Edwards Aquifer. The lake is dammed 460 meters downstream from the headwaters (Brune 1981). Water temperature at Spring Lake remains fairly constant at 21 ± 3 °C due to these springs (Groeger *et al.* 1997). The ecosystem present at this site is highly productive because of the constant temperature, constant water flow, and high water quality (Seaman 1997).

In 1946, Spring Lake was established as a theme park with glass-bottom boats, an underwater submarine theatre, and a swimming pig (Coley 2000). In 1994, Southwest Texas State University acquired Spring Lake and began converting the property from a theme park into a restored wetland dedicated to conservation, education, and research (Williamson 2001).

Spring Lake is located on the Balcones Escarpment Fault Zone, which is bordered to the west by the Edwards Plateau Region and to the east by the Blackland Prairie Region. The lake is separated into two sections; the main lake and the slough (Fig. 1). Natural springs arise in the northern part of the main lake. Much of the shore immediately surrounding this area is covered with concrete and buildings. The southern part of the main lake ends in two spillways emptying into the San Marcos River. The eastern section of Spring Lake, the slough, is fed by the Sink Creek Watershed. This area

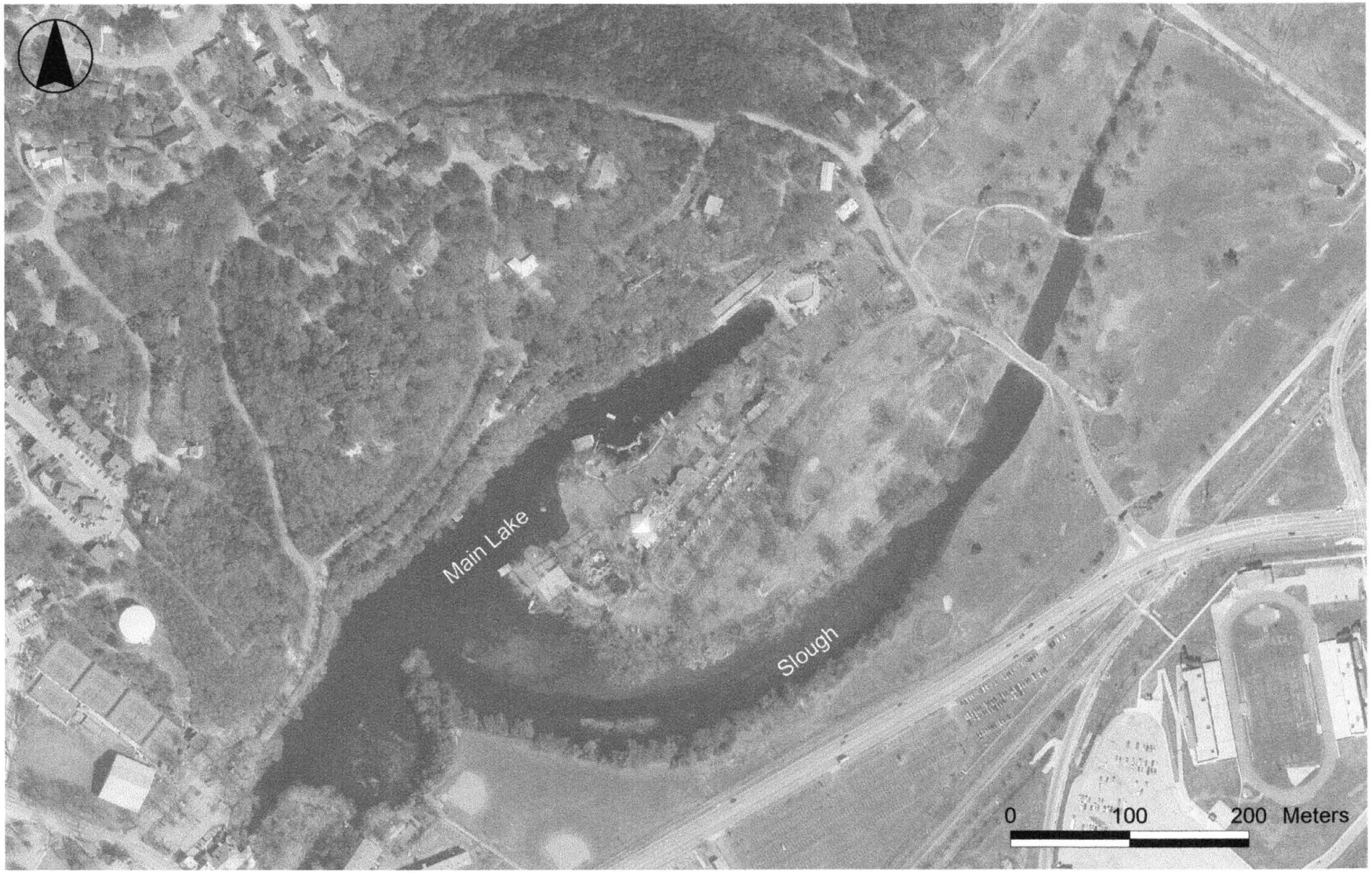

Figure 1. Digital Orthophoto of Spring Lake, Hays County, Texas.

is distinctly more stagnant than the main lake and receives minimal water flow. A golf course and softball fields border this backwater region.

Hydrilla (*Hydrilla verticillata*), a highly invasive species, was found submersed throughout the lake. A cutter-boat operated multiple times during the week cutting this species. Dense beds of the introduced elephant ears (*Colocasia esculenta*) lined a large portion of the main lake's shore. During Spring and Summer, dense mats of algae and macrophytes, including hydrilla, delta arrowhead (*Sagittaria platyphylla*), water hyacinth (*Eichhornia crassipes*), floating fern (*Ceratopteris thalictroides*), water lettuce (*Pistia stratiotes*), Brazilian parrot's feather (*Myriophyllum brasiliensis*), and lotis (*Nuphar lutea*) covered most of the surface of the slough and the southern part of the main lake. Plant species growing on the banks of Spring Lake included bald cypress (*Taxodium distichum*), American elm (*Ulmus americana*), hackberry (*Celtis spp.*), black willow (*Salix nigra*), box elder (*Acer negundo*), Japanese honeysuckle (*Lonicera japonica*), poison ivy (*Toxicodendron radicans*), and cattail (*Typha latifolia*).

During my study, a boardwalk was built over the slough along the northwest bank by the Southwest Texas State University Biology Department, Texas Parks and Wildlife Department, and U.S. Fish and Wildlife Service. Construction began on 20 February 2001 and was completed 6 December 2001. The boardwalk was opened to the public to promote wetland education. Reconstruction of the Spring Lake dam began 11 May 2001, and continued until the end of my study.

Capture and Marking Techniques

Small 81x25x31 cm Tomahawk live traps (Tomahawk Live Trap Company; Model #108) were set along the shores of Spring Lake in 25 different locations from 13 February 2001, through 7 November 2001. Trapping occurred on 43 nights for a total of 335 trap nights. The traps were set during late afternoon at the water's edge near a burrow or in areas where signs of nutria activity could be seen. Traps were checked the following morning. Traps were baited with carrots and sweet potatoes. In Louisiana, Ragan (1960) set up nutria feeding stations to test the preferred bait of nutria; carrots were taken by feral nutria 87.2 % of the time and sweet potatoes were taken 94.3 % of the time.

Once trapped, nutria were sedated by injecting a combination of ketamine HCl (ketaset), a dissociative anesthetic, and xylazine HCl (rompun), an analgesic sedative, with a two to one ratio, respectively (Bó *et al.* 1994). Weight was measured to the nearest pound by placing a dog harness on the animal and using a spring scale. Total length of body, length of tail, length of hind foot, and ear length were recorded in millimeters. Weight and linear measurements were analyzed with a t-test in Microsoft Excel. Hind foot length was used to assess the age of the individual. According to Adams (1956), an adult older than five months will have a hind foot length greater than 127 mm. Sex was determined by the presence or absence of a baculum. Equal numbers of males and females were radio collared. Passive Integrative Transponders (PIT) (AVID Microchips, 12 mm) were injected into the right thigh for future identification. The animal was placed back into the trap, allowed to recover, and released. The Institutional Animal Use and Care Committee number for this study was SWT-IACUC 2001-1.

A modified Lincoln-Peterson Index was used to calculate a population estimate (**N**) of the nutria living in Spring Lake (Nichols and Conroy 1996). Trapping data from two consecutive nights were used.

$$\mathbf{N} = [(n_1+1)(n_2+1)] / [(m_2+1)-1]$$

Where n_1 was the number of nutria caught on day one, all of which were marked and released; n_2 was the number of total nutria caught on day two; and m_2 was the number of marked nutria caught on day two.

Radio Telemetry Techniques

Radio collars (Wildlife Materials, Inc; LPM-2190M) placed around the nutria's neck consisted of a waterproof transmitter mounted to an adjustable leather strap. The transmitters emitted a signal on the 151 MHz band. Data were collected from canoe or by foot, using a three-element collapsible Yagi antenna and a portable receiver (Wildlife Materials, Inc.; TRX-1000S). Once a location was determined, it was plotted on a base map. Time, temperature, and any behaviors observed at the location were also recorded.

Radio telemetry data were collected from the time the first animal was collared, 15 February 2001, until 7 November 2001; when no signals were transmitted and the last collar was retrieved. The nutria's activity period was designated as 1900 hour through 700 hour. This 12-hour span was divided into six observation periods of two hours duration. Two locations per week on all collared individuals were recorded during randomly chosen observation periods. Each observation period was sampled equally. Locations were recorded periodically at other times to find burrow or nesting mat locations.

Global Positioning Systems (GPS) points at the previously recorded locations were taken at Spring Lake using GPS ProMARK X CP (Magellan; Serial #3D 000123) and a Multi-Path Resistant Antenna (Magellan; Model #39017). Magellan post-processing software (MSTAR; Version 2.06) then was used to perform differential processing of the GPS points with GPS data from the Continually Operating Reference Stations (CORS) in Austin, Texas. This improved the accuracy of the points to within a few meters.

The data were imported into GIS software (ArcView; Version 3.2a) and used to create minimum convex polygons to calculate home range area and maximum linear distance traveled for adult nutria (Ostro *et al.* 1999, Powell 2000). These polygons then were overlaid onto a Digital Orthophoto (1997) with one foot resolution (Figs. 1-12). The Digital Orthophoto was provided by Capital Area Planning Council (CAPCO). Comparisons then were made between individuals and sexes with t-tests in the Microsoft Excel.

RESULTS

Capture and Marking

Out of 335 trap nights, only 128 traps were triggered. Species of animals caught in traps are presented in Table 1. When an adult nutria of the desired sex was caught, a radio collar was placed around the neck. All other animals were released. Sex, ketaset and rompun dosages, weight, total length, length of tail, length of hind foot, ear length, and whether the individual's home range was calculated are indicated in Table 2.

The weight of individuals ranged from 3.6 kg to 5.9 kg; females weighed an average of 4.4 kg and males weighed an average of 5.1 kg. Total length ranged from 660 mm to 960 mm; females averaged 839 mm and males averaged 859 mm. Tail length ranged from 200 mm to 430 mm; females averaged 382 mm and males averaged 371 mm. Hind foot length ranged from 130 mm to 150 mm; females averaged 133 mm and males averaged 138 mm. Ear length ranged from 20 mm to 32 mm; females averaged 25 mm and males averaged 24 mm. T-tests were performed to determine if there was a significant difference between females and males regarding weight ($t = 1.91$, $P > 0.05$), total length ($t = 0.43$, $P > 0.05$), tail length ($t = 0.33$, $P > 0.05$), hind foot length ($t = 1.27$, $P > 0.05$), and ear length ($t = 0.49$, $P > 0.05$). No significant difference was detected. Female N14 was excluded from these calculations because she was not considered to be an adult according to hind foot length.

The population estimate of nutria found at Spring Lake using the modified Lincoln-Peterson Index at the beginning of my study, February, was 16 individuals.

Table 1. Trap Success at Spring Lake, Hays County, Texas, in 2001.

Status of trap	Number of Trap Nights
Unsprung (no response)	207
Sprung (empty)	6
Nutria (*Myocastor coypus*)	102
Raccoon (*Procyon lotor*)	17
Canvasback (*Aythya valisineria*)	1
Oppossum (*Didelphis virginiana*)	1
Swamp Rabbit (*Sylvilagus aquaticus*)	1
Total trap nights	**335**

Table 2. Radio Collared Nutria at Spring Lake, Hays County, Texas, in 2001.

Individual	Sex	Ketaset (ml)	Rompun (ml)	Weight (kg)	Total Length (mm)	Tail Length (mm)	Hind Foot Length (mm)	Ear Length (mm)	Home Range Calculated
N3	M	0.65	0.35	5.9	960	430	150	29	√
N4	F	0.65	0.35	4.5	880	360	140	27	√
N5	F	0.45; 0.50*	0.15; 0.15*	4.5	910	410	135	28	√
N6	F	0.35	0.15	5.0	890	430	140	27	√
N7	F	0.35	0.15	3.6	795	350	130	20	√
N8	M	0.65	0.35	4.5	855	425	138	20	
N9	M	0.52	0.38	5.4	950	380	135	25	
N11	M	0.35	0.15	5.7	910	400	135	20	√
N12	M	0.30	0.00**	4.5	820	360	130	20	√
N13	M	1.00	0.00**	5.0	880	380	140	20	
N14	F	0.80	0.00**	2.7	720	360	120	23	
N15	M	0.80	0.00**	4.5	860	370	140	32	
N16	M	1.60	0.00**	4.5	660	200	130	24	
N17	M	0.80	0.00**	5.4	840	395	145	25	√

* Indicates individuals that were sedated multiple times.

** Rompun unavailable beginning in May.

Home Range

A total of 14 adult nutria, nine males and five females, were radio collared between 15 February 2001 and 21 September 2001. Individuals were tracked from 15 February 2001 through 23 October 2001. Trapping continued through 7 November 2001 in an attempt to retrieve defunct radio collars. A total of 291 unique locations were recorded during this time period. A summary of home range (hectares) including the dates through which the individuals were tracked, the number of locations obtained for each individual, and the reason some individual's home ranges were not calculated are presented in Table 3.

Home range was calculated for only eight of the 14 nutria. Of these eight nutria, locations were recorded from 27 days to 202 days obtaining eight to 53 unique points. This variation in number of unique points per animal was due to radio collars falling off, the battery of the radio collars dying, or the individual nutria dying. The home range size varied from 0.86 ha to 8.82 ha. The mean home range of the four females was 1.61 hectares (Fig. 2) and 3.88 hectares for the four males (Fig. 3). The overall mean home range of the nutria was 2.74 ha. A t-test was performed to determine if there was a significant difference in home range size between females and males ($t = 1.26$, $P > 0.05$). No significant difference was detected. Home range maps of all individuals are presented in Appendix I. Areas of non-habitat were removed from the minimum convex polygon for N3.

The maximum linear distance traveled from each individuals burrow for the eight nutria also was calculated (Table 4). Maximum linear distances traveled per day varied from 143.33 m to 474.97 m. The average distance traveled by females was 217.30 m and

Table 3. Home Range for Radio Collared Nutria at Spring Lake, Hays County, Texas, in 2001.

Individual	Sex	Date Collared	Ending Date	Number of Locations	Home Range (ha)	Reason Home Range Not Calculated
N3	M	2/15/2001	6/8/2001	42	8.82	
N4	F	2/15/2001	9/4/2001	47	1.14	
N5	F	2/16/2001; 5/23/2001*	5/16/2001; 8/20/2001*	53	0.96	
N6	F	2/17/2001	5/9/2001	21	1.36	
N7	F	3/5/2001	8/7/2001	41	2.97	
N8	M	3/6/2001	5/9/2001	4	-	Moved downstream beyond study site area
N9	M	4/1/2001	4/19/2001	7	-	Lethargic animal who died; little movement
N11	M	4/27/2001	7/16/2001	24	2.14	
N12	M	6/25/2001; 9/4/2001*	6/29/2001; 10/23/2001*	14	3.69	
N13	M	6/26/2001	8/20/2001	14	-	Locations believed to have been taken after collar fell off animal
N14	F	9/1/2001	9/4/2001	2	-	Too few points; collar fell off
N15	M	9/1/2001	9/13/2001	4	-	Too few points; collar fell off
N16	M	9/7/2001	9/13/2001	3	-	Too few points; collar fell off
N17	M	9/21/2001	10/17/2001	8	0.86	

* Indicates individuals that were radio collared multiple times.

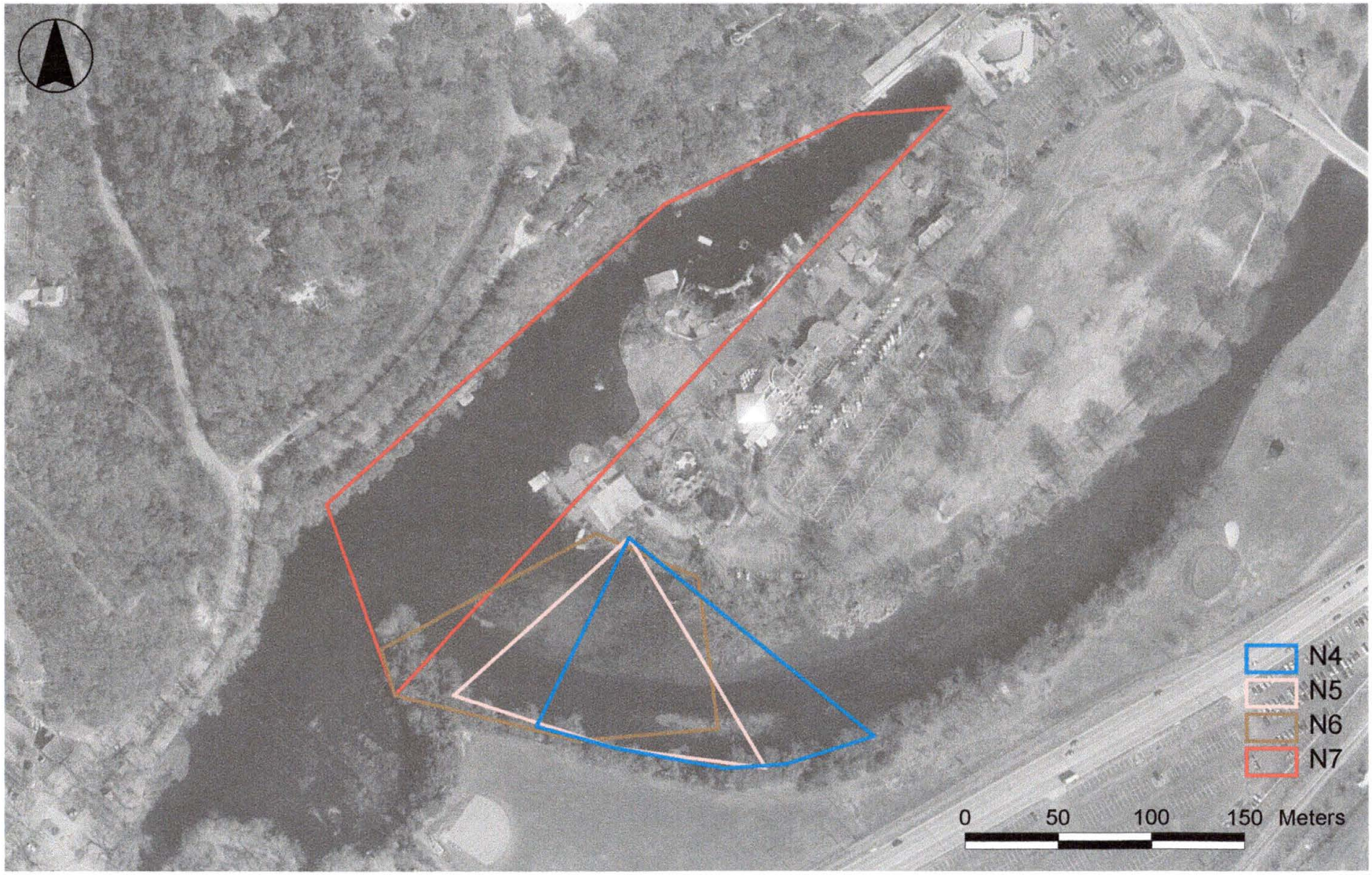

Figure 2. Home Range for Four Female Nutria at Spring Lake, Hays County, Texas, in 2001.

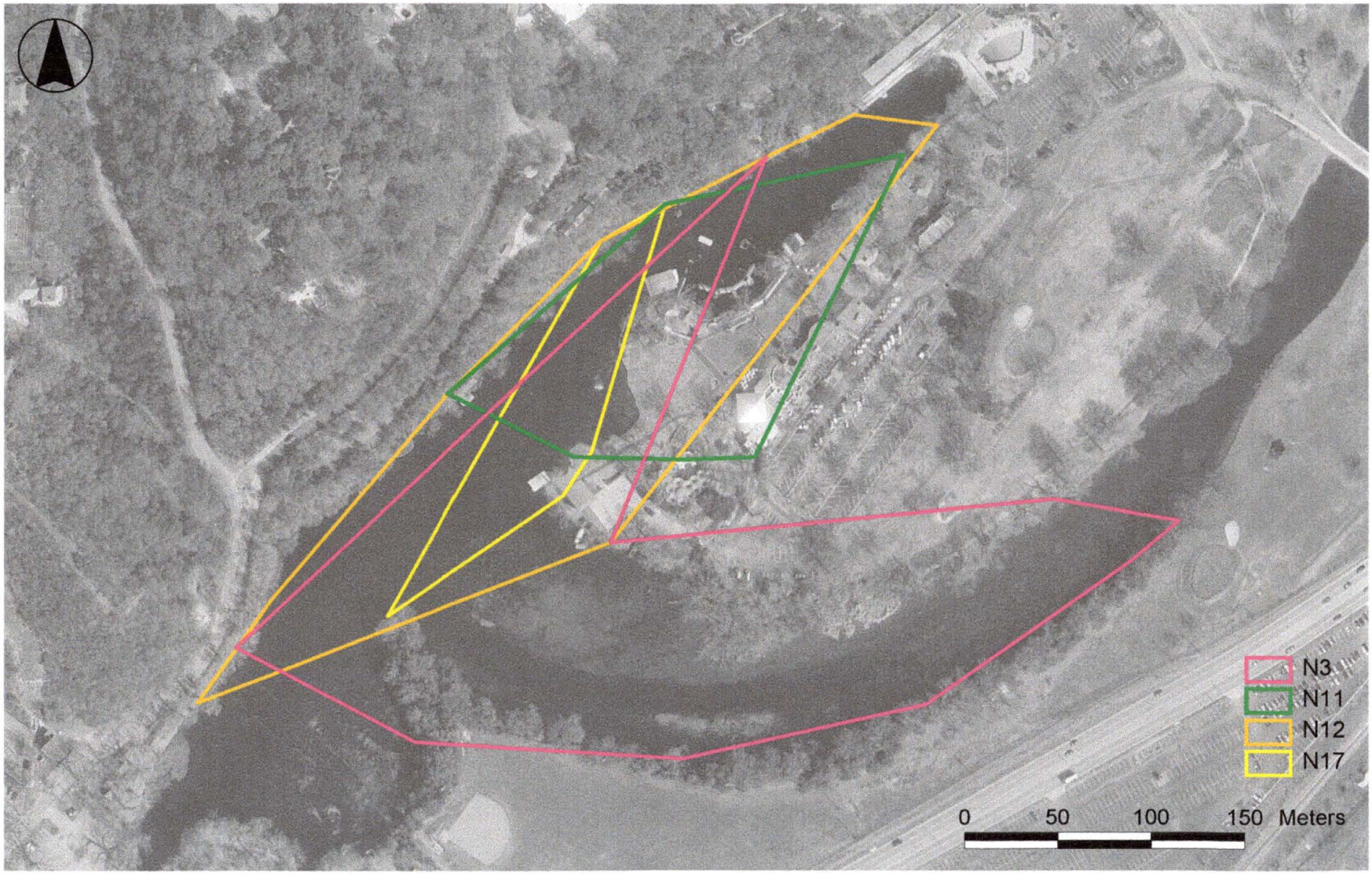

Figure 3. Home Range for Four Male Nutria at Spring Lake, Hays County, Texas, in 2001.

Table 4. Maximum Linear Distance Traveled for Radio Collared Nutria at Spring Lake, Hays County, Texas, in 2001.

Individual	Sex	Maximum Linear Distance Traveled (m)
N3	M	410.02
N4	F	168.99
N5	F	143.33
N6	F	159.56
N7	F	397.33
N11	M	201.83
N12	M	474.97
N17	M	255.67

males averaged 335.62 m. Three of the four females traveled less than 168.99 meters, and all four males traveled over 201.83 m. A t-test was performed to determine if there was a significant difference in maximum linear distance traveled between females and males ($t = 1.35$, $P > 0.05$). No significant difference was detected.

Burrows of each individual were located within their home range. Two of the females, N4 and N5, shared a burrow on the northern bank of the slough. In the warmer months, these nutria did not spend daytime hours in their burrow. They were found on nesting beds, padded down herbaceous vegetation covered by a canopy of shrubs or overhanging vegetation areas along the bank near each other. Male N3 and female N6 also shared a burrow. This burrow was located at the base of an uprooted tree in the slough. An unmarked juvenile nutria was observed entering this burrow alongside N3. Female N7 and male N12 spent hours of daylight enclosed by a cement path and a cement wall located close to a vacant hotel near the headwaters of the main lake. It was suspected that their "burrow" was located in a pipe or drainage. Male N11 spent the majority of his time near man-made structures alongside the main lake. During the day he slept under vegetation or a dock in a wetland demonstration area. Male N11 also was seen during the day in hedges planted alongside a building. The burrow of N17, a male, was located in the main lake, behind a cracked cement wall in a densely vegetated area.

Behavior

The nutria were primarily crepuscular and nocturnal with activity from dusk until dawn. Individuals were most active after sunset, but no time period in the night proved to have more activity than the other. Only two of the 14 nutria changed their daily activities

due to temperature. Females N4 and N5 reduced their activity during the hotter months. These two females remained on the south bank of the slough for the entire summer. All other nutria did not change their habits due to ambient temperature.

The majority of the time when a collared individual was located, the nutria was resting; hidden along side the bank in vegetation. Many locations were recorded with the individual swimming. At times, the nutria would emit a loud, horn-like call while in the water; possibly a defense or warning call. Grooming behavior also was observed. Nutria sat on the edge of the bank or in shallow water, grooming themselves. This activity may have contributed to the fact that seven out of the total 14 collared animals slipped the radio collar off of their neck. Many of the nutria looked as though they lost weight over the summer. This also might have contributed to the fact that six out of these seven collars fell off in late summer. Interactions with beaver also were observed. Nutria often were located a few meters from the mouth of a beaver burrow. Adolescent nutria were observed swimming near feeding beaver. I did not observe any agonistic interaction between the two species.

Mortality

Two male nutria died during my study. Male N9 was tracked for 19 days. Male N11 died after 81 days. Female N7 was tracked for 156 days, and on day 32, a fetus was found under her while in a trap.

DISCUSSION

Capture and Marking

Nutria were easily captured during the nine-month period of trapping at Spring Lake; some repeatedly. This could have possibly been a result of the carrots and sweet potatoes used for bait. A difference in behavior between sexes was observed while in the trap. Male nutria generally behaved aggressively, whereas most females were passive.

Nutria exhibit no sexual dimorphism in body size (Atwood 1950). No significant difference between females and males regarding weight and linear lengths were found. Males averaged slightly heavier; the average weight of females was 4.4 kg and males averaged 5.1 kg. Ras (1999) had similar findings with females having an average weight of 4.66 kg and males averaging 5.16 kg.

The nutria population was estimated at 16 individuals using a modified Lincoln-Peterson Index. Based on my field observations, this was an underestimate. On average, six traps were set during each night. Many were tripped by non-targeted species. If more traps had been used, the population estimate would have been more accurate. Nightly observations of the study site suggested that the population was larger.

Home Range

The overall mean home range of all nutria was 2.74 ha. The females had an average home range of 1.61 ha and males averaged 3.82 ha. No significant difference in home range size was found between females and males. Ryszkowski (1966) reported that females had more restricted movements than males in a marsh in Warsaw, Poland. Ras

(1999) studied 73 radio collared nutria over a year at Tudor Farms, Maryland, a private wildlife management area. She found females to have an average home range of 0.11 km^2 (11.00 ha) and males 0.09 km^2 (9.00 ha). Coreil (1984) studied seven radio collared nutria for a year in a southwestern Louisiana marsh area and estimated an average minimum home range of 60 ha. Lohmeier (1981) estimated the mean home range of four radio collared nutria, two males (2.26 ha) and two females (2.35 ha), to be 2.31 ha in a pond in the Hillside National Wildlife Refuge in Mississippi. Kays (1956) studied the ecology of nutria at Rockefeller State Wildlife Refuge in Louisiana and estimated the maximum home range of nutria to be 1,097 m^2 (0.11 ha).

Variances in home range sizes between studies may be due primarily to differences in the study area. Spring Lake most closely resembled the study site used by Lohmeier (1981). The area used in this study was a small 8 ha lake, similar to the 5 ha pond in the Hillside National Wildlife Refuge; unlike the 2,430 ha Tudor Farms (Ras 1999) and the 34,000 ha Louisiana marsh (Coreil 1984). Nutria utilized the area available to them. Spring Lake was surrounded by a golf course, softball fields, many roads, and a nearby university. The nutria in my study were unable to extend their home range due to human activity and possible interaction. This lake also had restricted emergent vegetation and no marsh regions, resulting in limited foraging resources. Therefore, nutria at Spring Lake almost exclusively foraged on the floating and submersed vegetation (Towns 2002).

The mean maximum linear distance traveled from each individual's burrow was 276.46 m; females averaged 217.30 m and males averaged 335.62 m. No significant difference in maximum linear distance traveled was found between females and males.

Nutria in the study by Ras (1999) traveled from 30 m to 1500 m. Ras also reported that there was no significant difference in distances traveled by females and males. Coreil (1984) reported the average daily movement to be 718 m. Robicheaux (1978) studied nutria at Rockefeller State Wildlife Refuge in Louisiana and found the average linear distance traveled by nutria was 226 m. In Robicheaux's study, 80.4 % of all nutria traveled less than 400 m. Adams (1956) suggested that nutria's daily cruising range did not exceed 183 m. Variances between studies may have been primarily due to differences in study sites.

Home range sizes and maximum linear distances traveled might have been larger if sample size was increased. Due to the difficulty of maintaining radio collars on individuals for long periods of time, my calculations may have been an underestimate.

Previous studies hypothesized that nutria did not exhibit territorial behavior except near the nesting site (Coreil 1984; Ryszkowski 1966). In my study, the home ranges of the nutria were restricted due to territoriality according to the definition given by Grier and Burk (1992). Overall, the individuals stayed either in the slough or in the main stream. Two out of the eight had limited movements in the adjacent territory, both male.

Burrows and nesting beds were dispersed throughout Spring Lake. Four of the nutria, male N3, female N4, female N5, and female N6, had typical underground burrows located at the water's edge. Of these, N4 and N6 spent daylight hours in summer sleeping on various nesting beds. Nesting beds have been observed in studies involving nutria (Adams 1956, Milne 1963, Swank and Petrides 1954). These two nutria stayed within a few meters of one another throughout the entire study. Gosling and Baker

(1988) found female nutria stayed near their mother and formed a cluster or kin group. Three nutria, female N7, male N12, and male N17, took advantage of man-made cement walls. These burrows were similar to those found by Atwood (1950) involving levees, dikes, and ditchbanks. Male N17 spent his daylight hours in or near man-made structures. Guichón and Cassini (1999) studied nutria in their native habitat in Argentina and found they avoided areas with human disturbance, "i.e., docks, houses, roads, recreational centers." Out of the eight collared nutria, three, female N4, female N5, and male N11, had multiple burrows or nesting beds. Ryszkowski (1965) found 39 % of 69 nutria occupied more than one shelter.

Behavior

Nutria were active from dusk until dawn. Nutria were seldom seen during daylight hours. Male nutria N11, that stayed around man-made structures, was seen a couple of times walking near a building or in a parking lot. He possibly moved because of disturbance by human activity. Other nutria remained in burrows or on nesting mats during the day.

Coreil (1984) found movement rates of nutria were greatest in the winter and home range estimates were larger in winter and spring. Two females, N4 and N5, reduced their activity during the hot summer. The remaining six nutria did not change their habits in relation to ambient temperature. Chabreck (1962) reported no change in activity based on air temperature.

The periodical calling by the nutria has been observed in other studies. Walther (1931) associated "long bleats" with annoyance. Warkentin (1968) observed nutria

"mooing" in a threatening manner. I found male nutria retreated when approached by a human and gave a horn-like call.

As stated before, grooming may have contributed to the loss of 50 % of radio collars. Weight loss also was a factor in collar loss. Bounds *et al.* (2001) found problems with nutria slipping radio collars off as a result of fluctuating weight.

Mortality

Two male nutria died during my study, N9 and N11. Male N9 was a mature animal that lived under a dock. He was found dead under the dock on day 19. Male N11 lost considerable weight during my study. His neck became smaller, allowing him to put one arm through his collar. On day 57, this nutria was sedated, and his collar was tightened to compensate for his weight loss. On day 81, he was found dead on a pathway.

Management Implications

A 1998 survey concerning the presence or absence of nutria was given to state departments of natural resource agencies (DNRs) and national wildlife refuges (NWRs) in the 48 contiguous states. Nutria were present in 15 states. Out of these, only 20 % of the DNRs and 9 % of the NWRs had conducted research on nutria. Whereas 53 % of the DNRs and 56 % of the NWRs reported that native species were affected by the presence of nutria (Bounds 2000).

A number of measures are being taken to try and control the invasive nutria. On 3 February 1999, Executive Order 13112 was signed by President William J. Clinton. This

Order established the National Invasive Species Council; a Council responsible for overseeing the control of invasive species by providing leadership, working with Federal, State, and International agencies, and implementing an Invasive Species Management Plan (Clinton 1999).

Many research projects have been conducted or are studying nutria. For instance, a three-year pilot project in Maryland began in January 2001 radio collaring 225 nutria. This project hopes to gather enough information about nutria ecology to eradicate them from the state (Bounds *et al.* 2001). It was modeled after a study in Great Britain, where nutria were successfully eradicated (Gosling 1989). Gosling's recommendations for successful eradication were "develop a pilot eradication program; study nutria movements; develop accurate population estimates; and initiate a proactive public relations campaign" (Bounds *et al.* 2001).

My study hopefully will provide valuable information about the daily activities of nutria in Texas. Studies on territory and home range in this state have not previously been studied. Knowing the basic ecology of an invasive species is the first step in understanding how to control their populations.

APPENDIX I

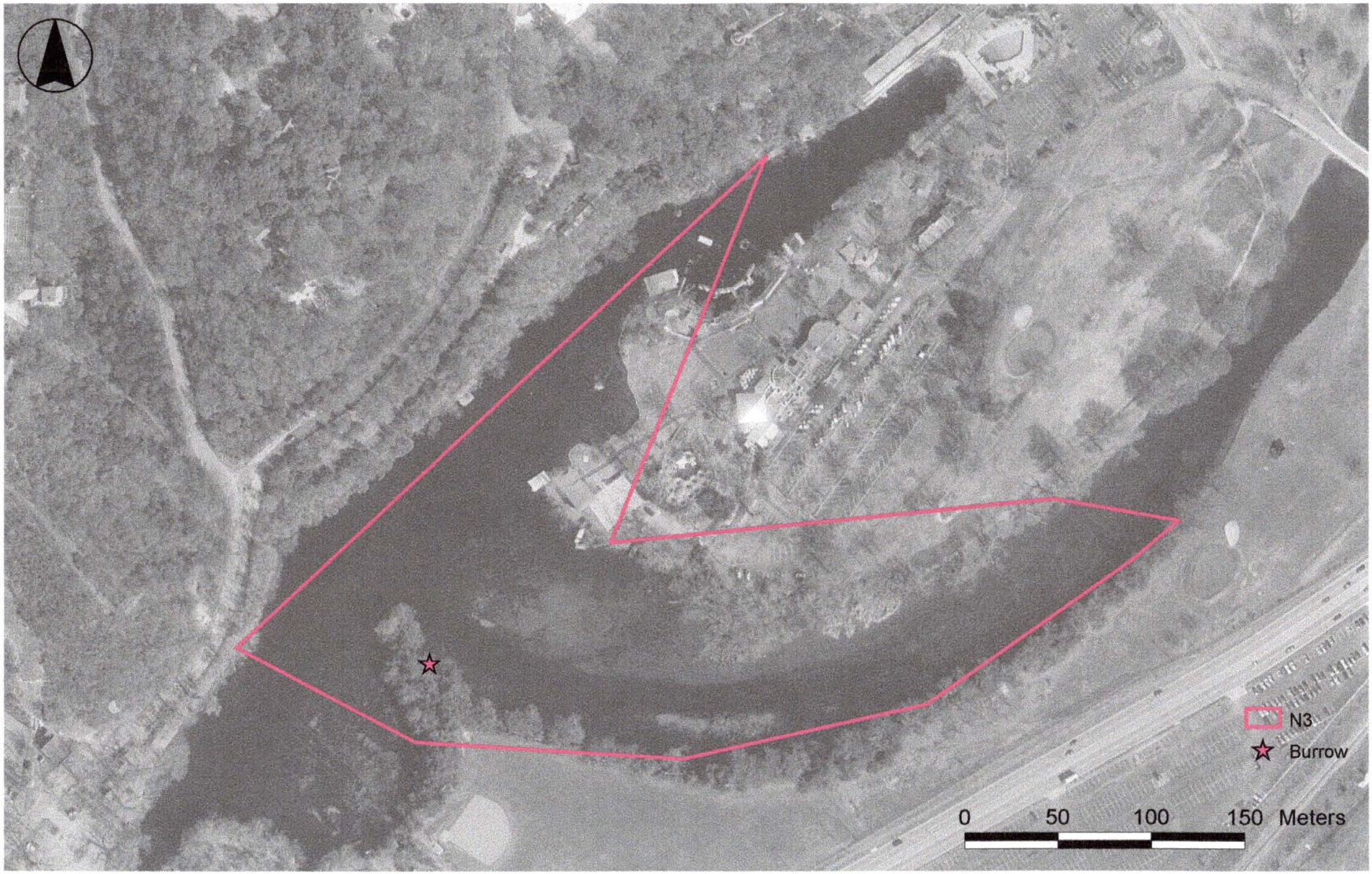

Figure 4. Home Range for Male N3 at Spring Lake, Hays County, Texas, in 2001.

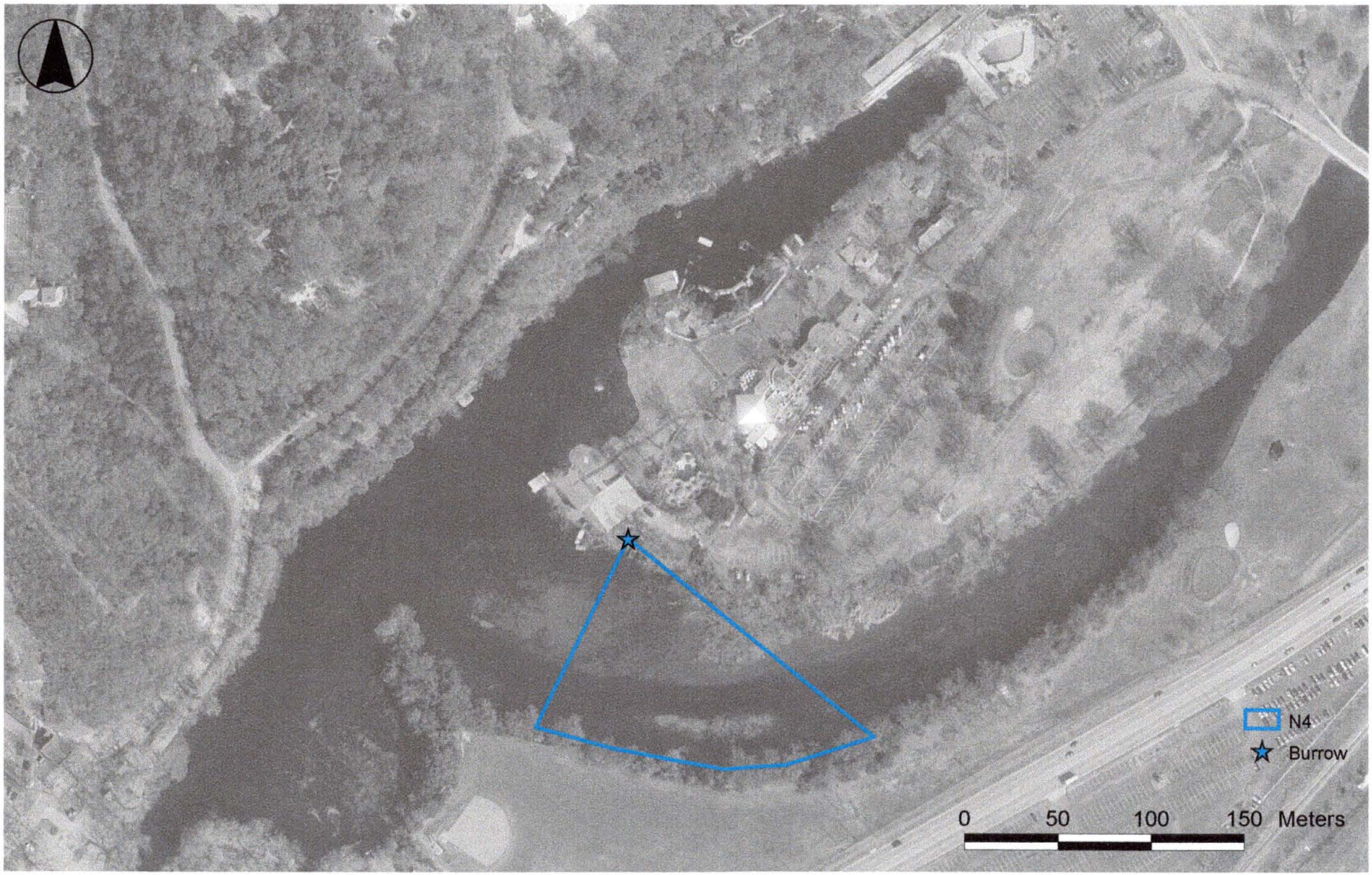

Figure 5. Home Range for Female N4 at Spring Lake, Hays County, Texas, in 2001.

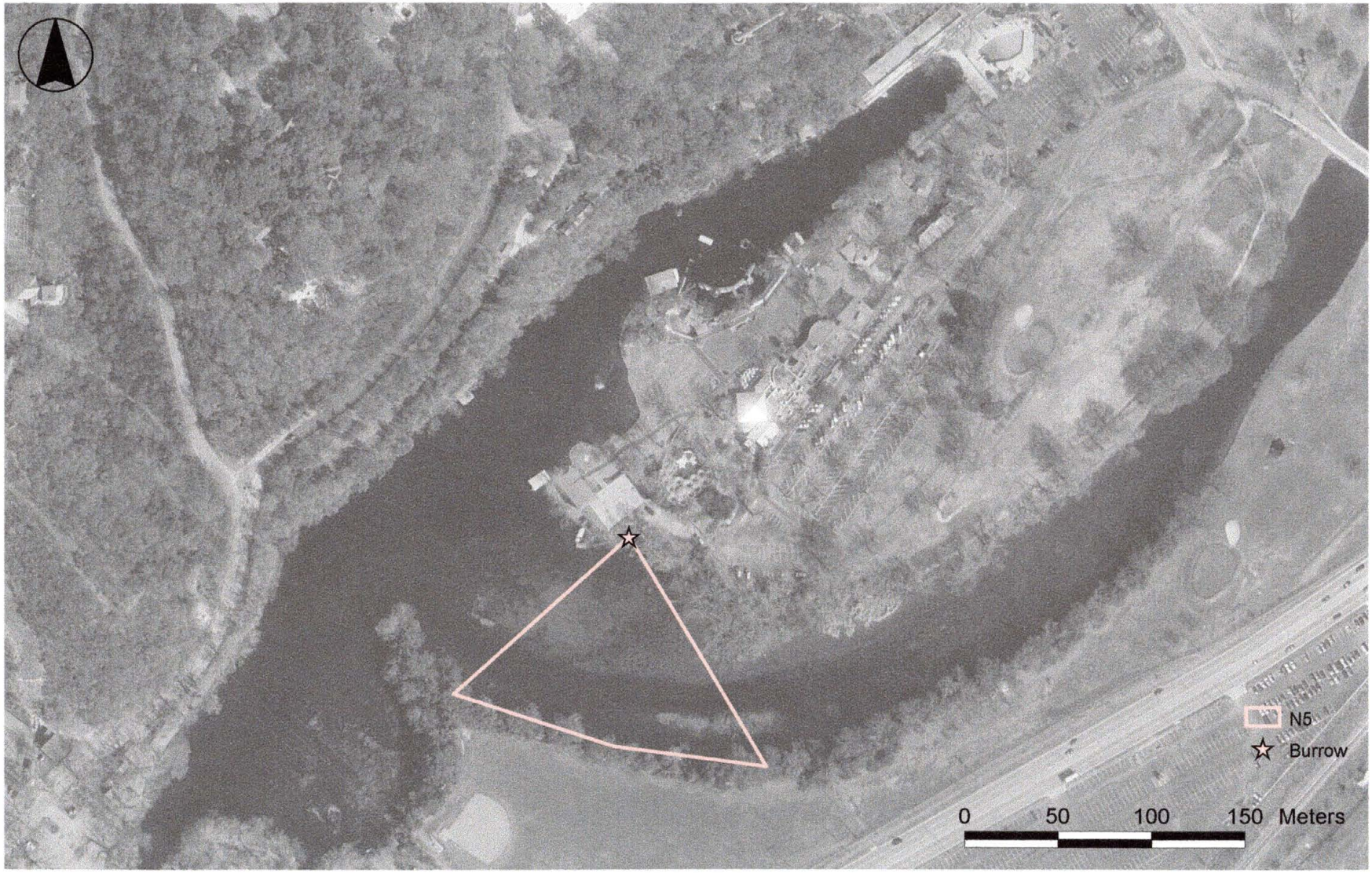

Figure 6. Home Range for Female N5 at Spring Lake, Hays County, Texas, in 2001.

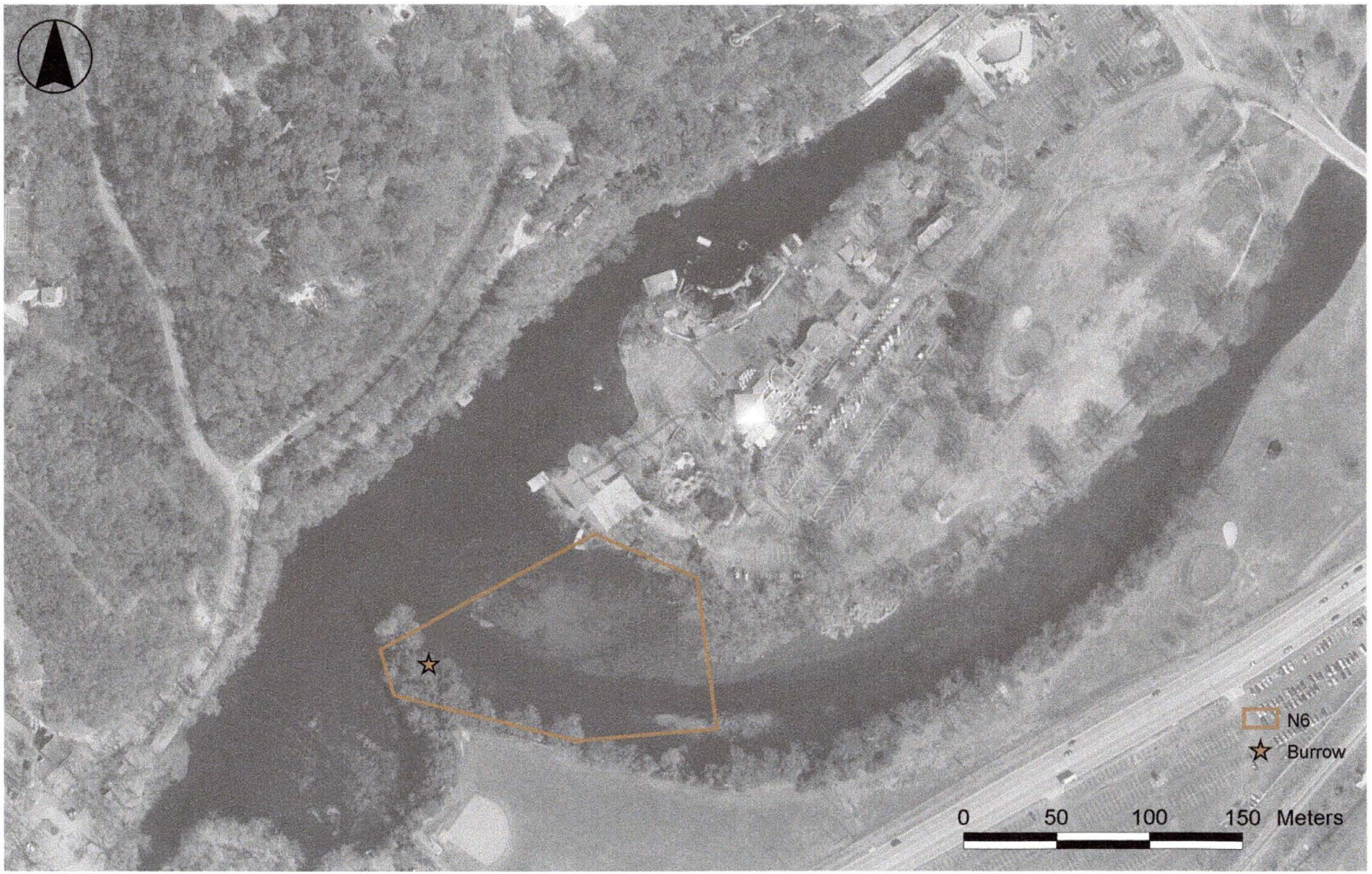

Figure 7. Home Range for Female N6 at Spring Lake, Hays County, Texas, in 2001.

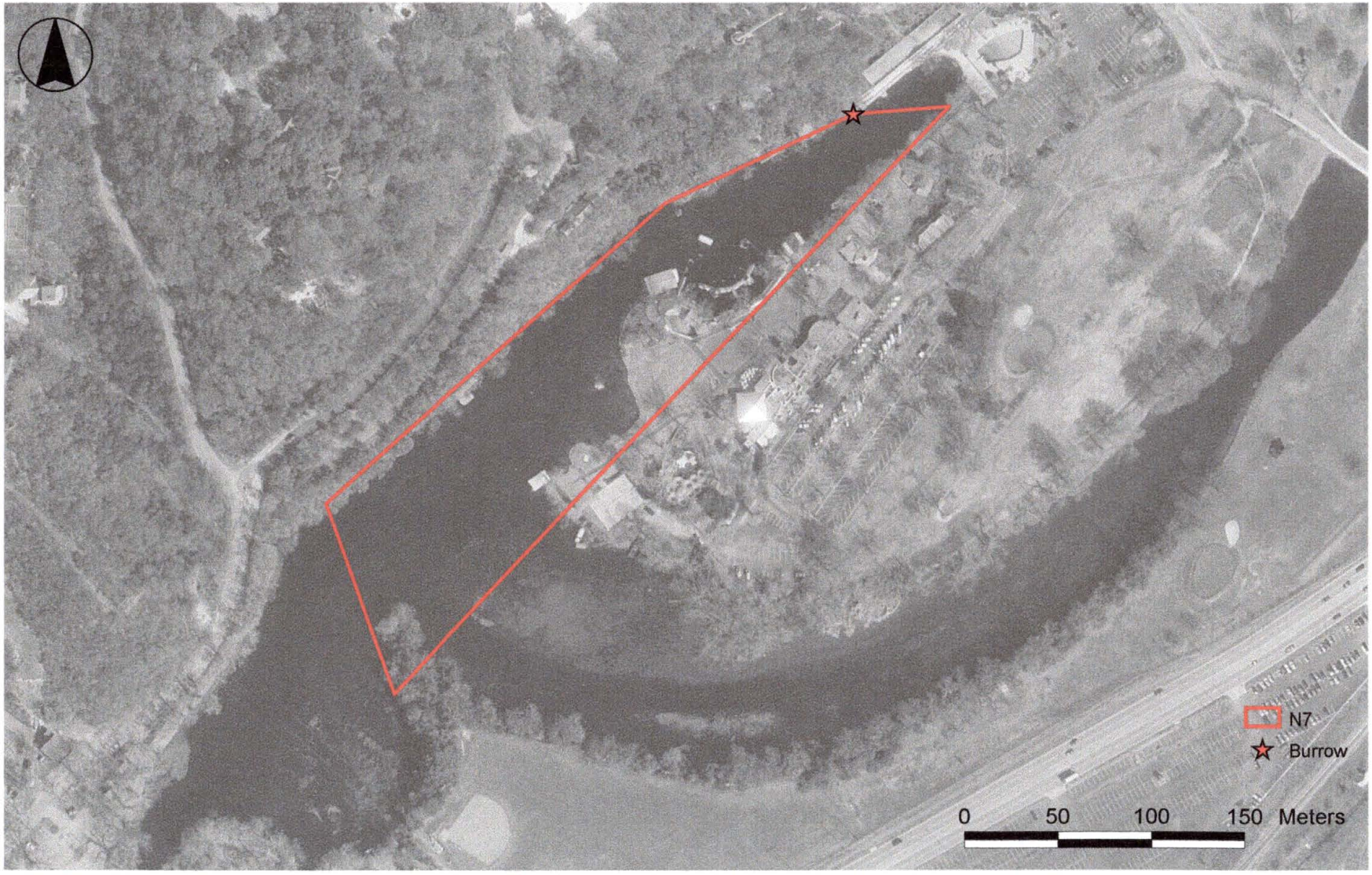

Figure 8. Home Range for Female N7 at Spring Lake, Hays County, Texas, in 2001.

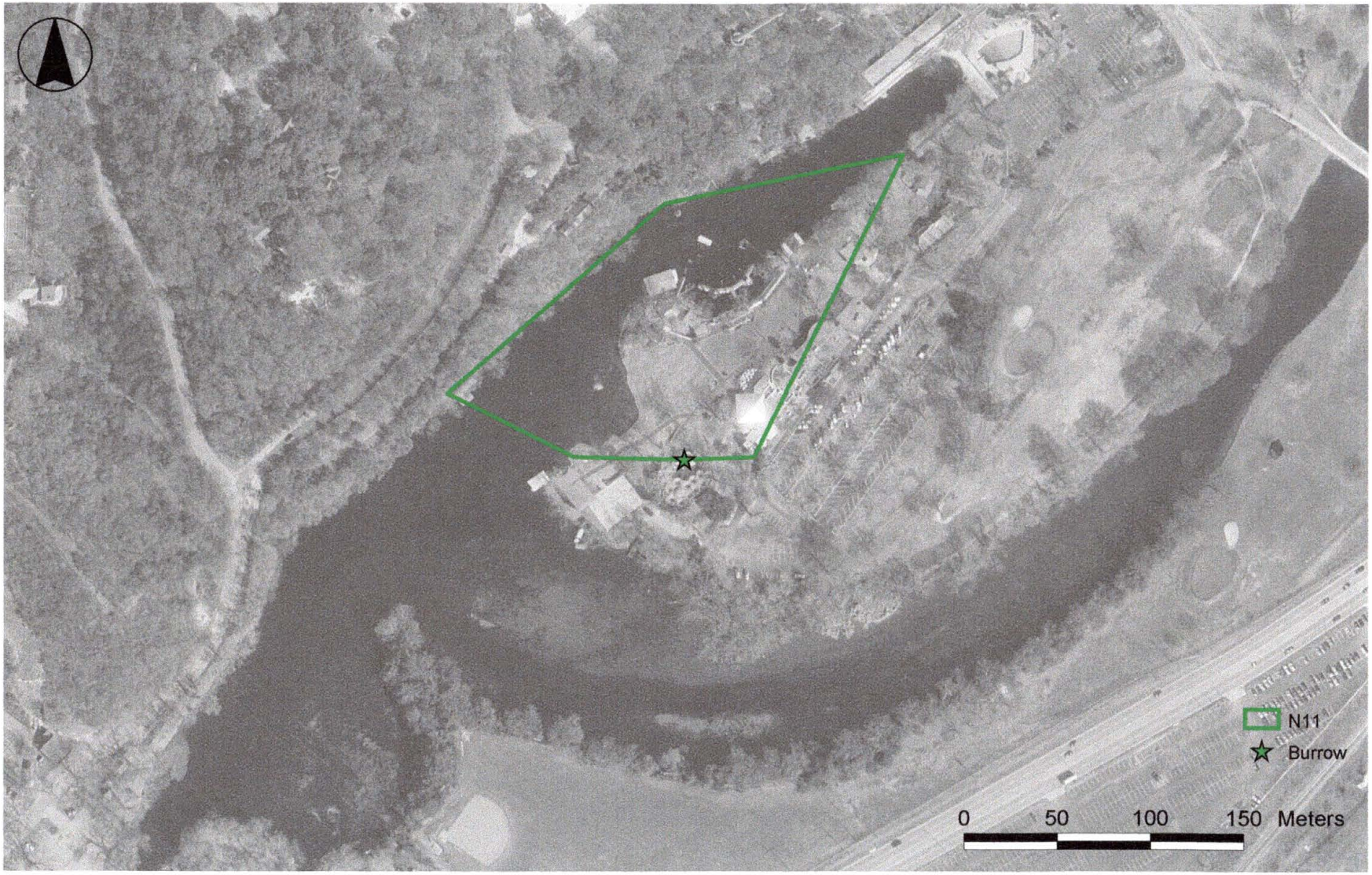

Figure 9. Home Range for Male N11 at Spring Lake, Hays County, Texas, in 2001.

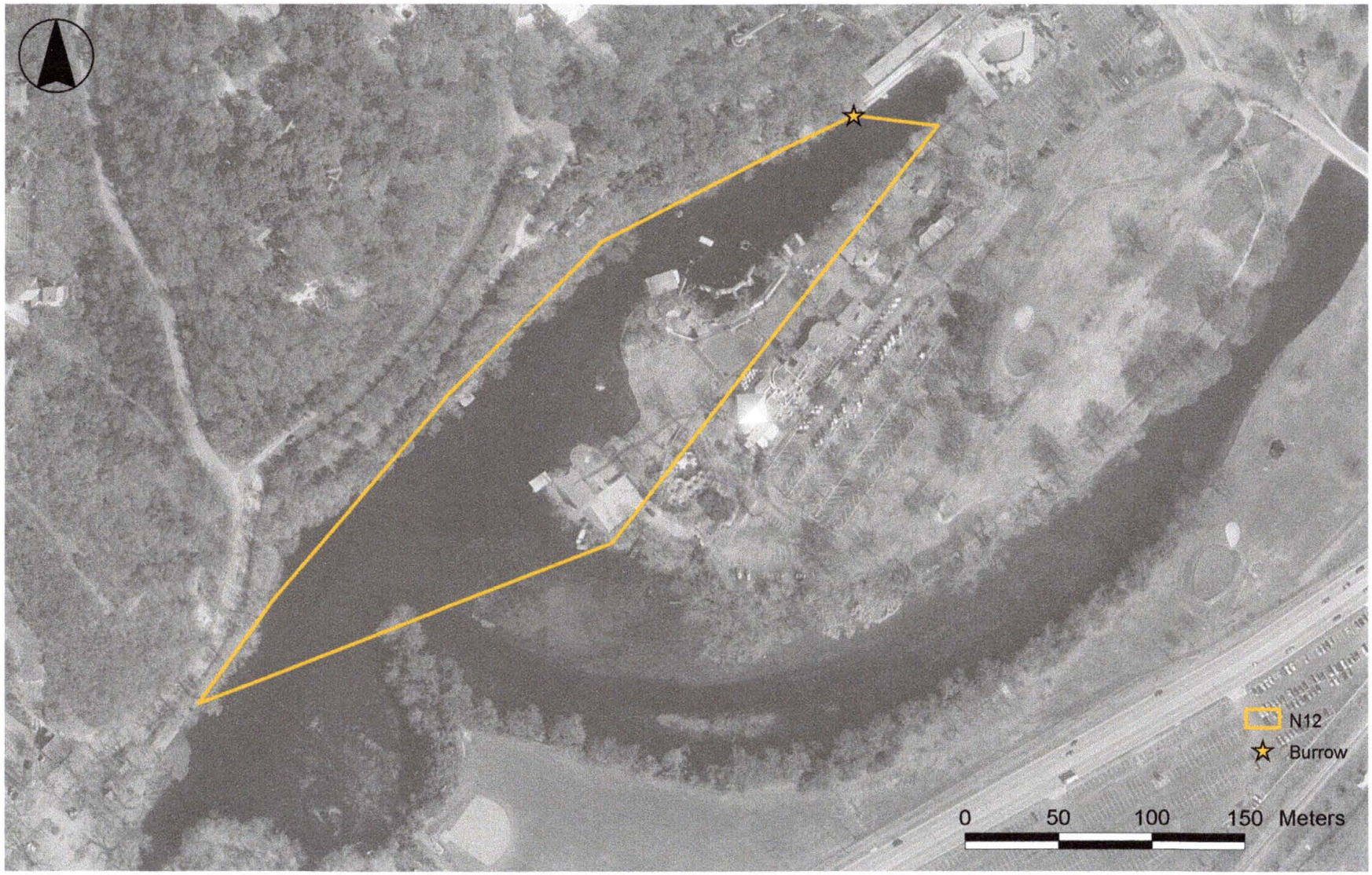

Figure 10. Home Range for Male N12 at Spring Lake, Hays County, Texas, in 2001.

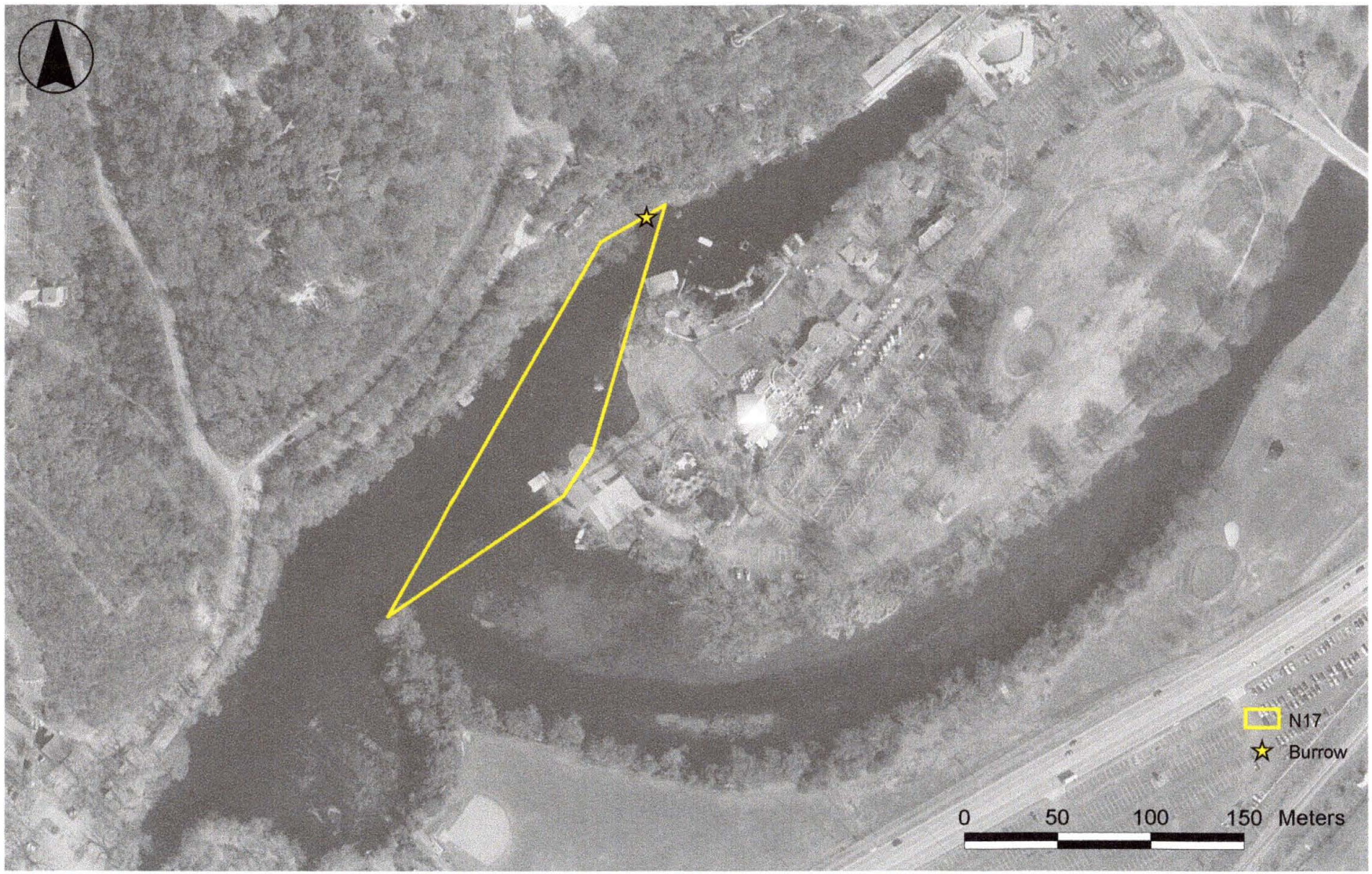

Figure 11. Home Range for Male N17 at Spring Lake, Hays County, Texas, in 2001.

APPENDIX II

HOME RANGE AND MOVEMENT OF BEAVER (*CASTOR CANADENSIS*) AT SPRING LAKE IN CENTRAL TEXAS

The American Beaver (*Castor canadensis*) are native semi-aquatic rodents that are found at Spring Lake. Beaver occupy all of the United States excluding a portion of Florida and the southwestern desert (Jenkins and Busher 1979). The beaver is much larger than nutria, having an average weight of 19.1 kg. The tail of beaver is dorsally flattened, and both males and females contain castor glands used in scent marking. Beaver become sexually mature by three years and breed between January and March (Hill 1982). The gestation period in females averages 110 days (Hediger 1970), and litter size ranges from three to four young. Diet depends on season, and includes bark, roots, leaves, and fruit. Beaver primarily remain in one location throughout their life, with some two-year olds dispersing (Hill 1982). The beaver at Spring Lake do not build dams, but burrow into the bank.

Different methods for successfully radio marking beaver have been explored. Davis *et al.* (1984) and Guynn *et al.* (1987) surgically implanted transmitters under the skin of beaver. This was proven to be a successful method. Rothmeyer *et al.* (2001) effectively tested a modified ear-tag for use as a radio telemetry transmitter.

Limited studies have been conducted on the home range and movement of beavers. In 1975, Busher followed seven beaver in California with radio transmitters tied around the base of their tails. Lancia (1979) radio collared and tracked 14 beaver in Massachusetts. Reinke (1986) implanted transmitters into seven beaver and tracked them in Tennessee. All three of these studies focused on activity patterns; home range

estimates were not obtained. In 1992, the food preferences of beaver along the San Marcos River, the river fed by the natural springs in Spring Lake, were studied by Kainer.

In my study, beaver were trapped using two 99x53 cm Tomahawk Bailey beaver traps (Tomahawk Live Trap Company; Model #801), a medium 107x38x51 cm Tomahawk live trap (Tomahawk Live Trap Company; Model #109.5), and a large 152x51x66 cm Tomahawk live trap (Tomahawk Live Trap Company; Model #110B). These traps were set along the shores of Spring Lake either on the bank or in shallow water in 21 different locations from 29 November 2000, through 5 February 2001. Manufactured castor was used to bait the traps. Trap success is presented in Table 5. Once a beaver was in a trap, the same data collection methods used for the nutria were executed. Sex, ketaset and rompun dosages, weight, total length of tail, length of hind foot, and ear length are reported in Table 6.

The length of time each beaver was followed, the number of locations obtained for each individual, home range, and maximum linear distance traveled for the three beaver tracked are presented in Table 7. Home range was calculated using minimum convex polygons for two beaver, male B1 and female B2 (Fig. 12). Areas of non-habitat were removed from the minimum convex polygon for B1. Their mean home range was 3.72 ha. Maximum linear distance traveled by the three beaver ranged from 198.38 m to 1966.05 m. The distance traveled between the two locations recorded for female B10 is shown in Figure 13 (1995 USGS, US Geological Survey, color infrared Digital Orthophoto Quadrangle, DOQ, with one meter resolution).

Female B2 never left the boundaries of Spring Lake, primarily staying around the mouth of her burrow. On multiple occasions, male B1 would travel beyond the dam of

Table 5. Trap Success for the American Beaver Using Different Types of Traps at Spring Lake, Hays County, Texas, from November 2000 through February 2001.

Status of trap	Tomahawk Bailey Beaver Trap	Medium Tomahawk Trap	Large Tomahawk Trap	Totals
Unsprung (no response)	72	40	48	160
Sprung (empty)	14	0	2	16
Beaver (*Castor canadensis*)	1	3	0	4
Raccoon (*Procyon lotor*)	1	2	11	14
Total trap nights	**88**	**44**	**61**	**194**

Table 6. Radio Collared Beaver at Spring Lake, Hays County, Texas, from December 2000 through June 2001.

Individual	Sex	Ketaset (ml)	Rompun (ml)	Weight (kg)	Total Length (mm)	Tail Length (mm)	Hind Foot Length (mm)	Ear Length (mm)
B1	M	2	1	18.6	1030	310	180	30
B2	F	0.65	0.35	9.5	-	-	-	-
B10	F	1.15	0.55	14.5	1020	300	175	30

Table 7. Home Range and Maximum Linear Distance Traveled for Radio Collared Beaver at Spring Lake, Hays County, Texas, from December 2000 through June 2001.

Individual	Sex	Date Collared	Ending Date	Number of Locations	Home Range (ha)	Maximum Linear Distance Traveled (m)
B1	M	12/16/2000	5/2/2001	38	6.15	395.40
B2	F	1/6/2001	4/2/2001	28	1.29	198.38
B10	F	4/25/2001	6/1/2001	2	-	1966.05

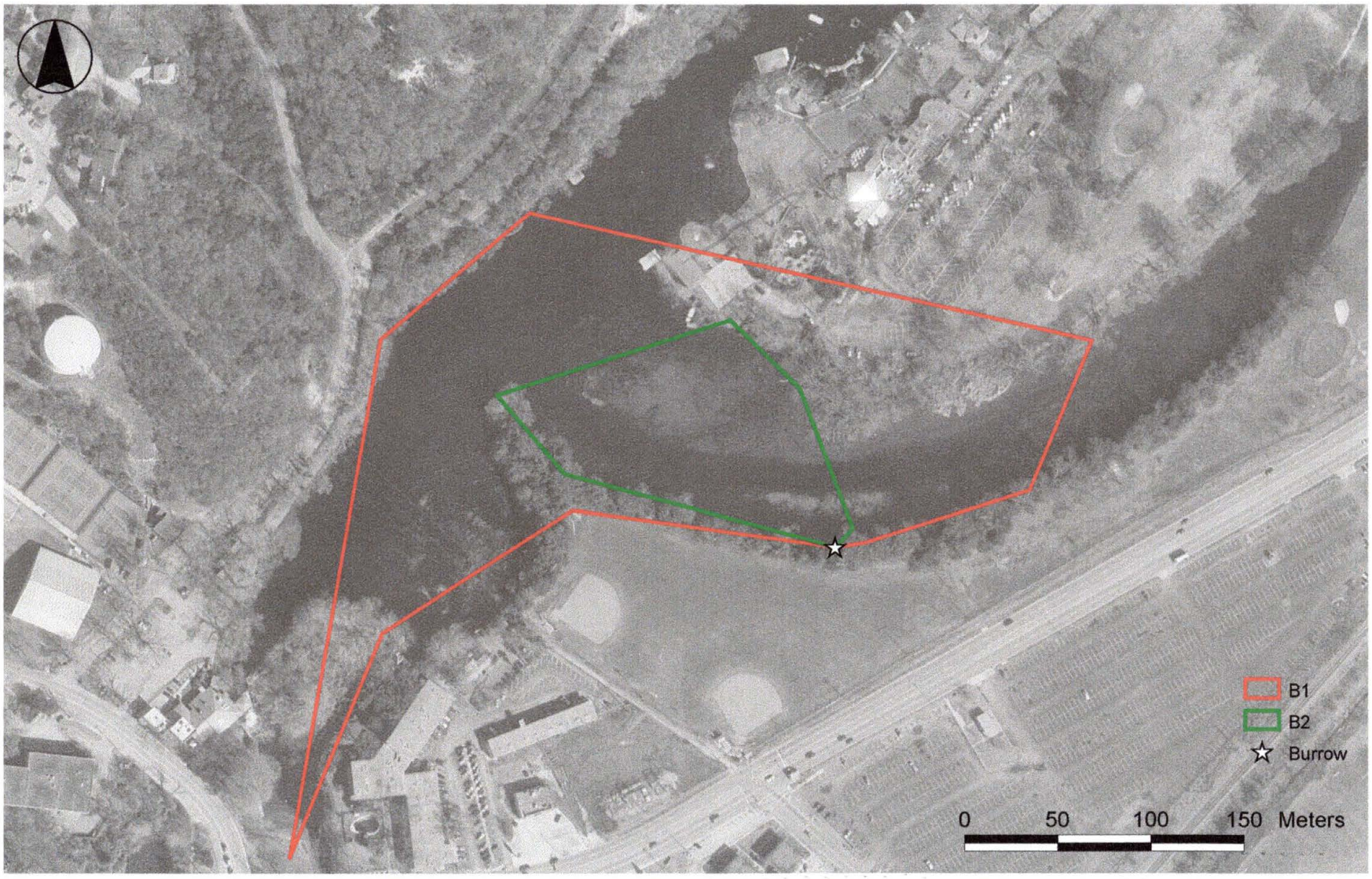

Figure 12. Home Range for Male B1 and Female B2 at Spring Lake, Hays County, Texas, from November 2000 through May 2001.

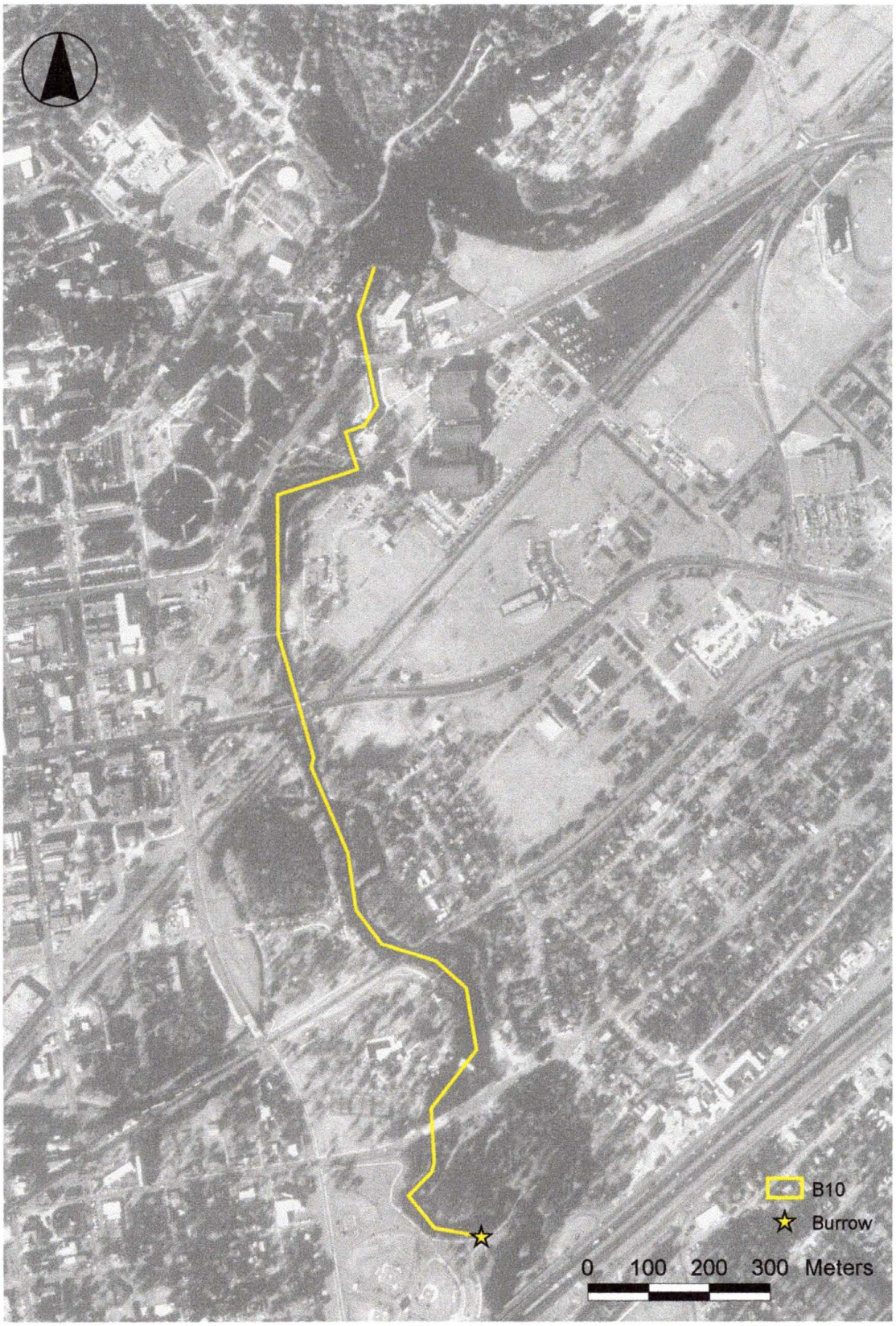

Figure 13. Distance Traveled by Female B10 from Spring Lake, Hays County, Texas, in Spring 2001.

the lake. On these nights, a location was not recorded. B1 and B2 shared a burrow on the south bank of the slough. At least two other uncollared adult beaver shared this burrow. In summer 2001, three kits were observed at this site. Female B10 was trapped on the bank of the Spring Lake dam. Her burrow was later located 1966.05 m downstream. A signal was not detected near Spring Lake following her initial capture.

Many problems arose during this study. Trapping beaver was extremely difficult and unproductive. The beaver would avoid traps even when they were in an area of high activity. Also, the Tomahawk Bailey beaver traps malfunctioned many times due to the traps being difficult to set at the desired sensitivity. Multiple times the trigger was knocked down, but the trap would not spring or only one side of the trap would spring. Traps also were found empty or triggered by a cut branch the beaver was carrying.

The collars also were damaged soon after they were placed on the beaver. Male B1 was tracked for 138 days. On day 69 the collar began to malfunction; some nights the mortality switch or a sporadic signal would be emitted while the animal was observed feeding or swimming. The battery of female B2's collar died after 87 days. This animal was observed on later dates with the collar intact around her neck. The collar on female B10 stopped broadcasting a signal after being followed for 38 days. One of these collars was recovered. The collar had teeth marks which cracked the waterproof seal around the transmitter.

I suspect these beaver would bite each others collars while grooming one another; therefore, I do not think radio collars are the best method for radio tracking beaver. Surgical implants would allow the individuals to be followed for a longer period of time.

LITERATURE CITED

Adams, W. H., Jr. 1956. The nutria in coastal Louisiana. Louisiana Academy of Sciences 19:28-41.

Aguirre, P. B. 1999. Space use patterns of the common snapping turtle (*Chelydra serpentina serpentina*) at the headwaters of the San Marcos River, Hays County, Texas. Thesis. Southwest Texas State University, San Marcos, Texas.

Atwood, E. L. 1950. Life history studies of nutria, or coypu, in coastal Louisiana. Journal of Wildlife Management 14:249-265.

Bó, R. F., F. Palomares, J. F. Beltrán, G. de Fillafañe, and S. Moreno. 1994. Immobilization of coypus (*Myocastor coypus*) with ketamine hydrochloride and xylazine hydrochloride. Journal of Wildlife Diseases 30:596-598.

Bounds, D. L. 2000. Nutria: an invasive species of national concern. Wetland Journal 12:9-15.

Bounds, D. L., T. A. Mollett, and M. H. Sherfy. 2001. The nutria nuisance in Maryland and the search for solutions. Aquatic Nuisance Species Digest 4:25-31.

Brune, G. 1981. The Springs of Texas. Vol. 1. Branch-Smith, Inc., Fort Worth, Texas.

Busher, P. E. 1975. Movements and activities of beavers, *Castor canadensis*, on Sagehen Creek, California. Thesis. San Francisco State University, San Francisco, California.

Chabreck, R. H. 1962. Daily activity of nutria in Louisiana. Journal of Mammalogy 43:337-344.

Clinton, W. J. 1999. Executive Order 13112 of February 3, 1999 – Invasive Species. National Agricultural Library of U.S. Department of Agriculture. http://www.invasivespecies.gov/laws/execorder.shtml.

Cochran, W. W., and R. D. Lord, Jr. 1963. A radio-tracking system for wild animals. Journal of Wildlife Management 27:9-24.

Coley, R. 2000. Aquarena Center. Southwest Texas State University. http://www.continuing-ed.swt.edu/aquarena/ (25 November).

Coreil, P. D. 1984. Habitat preferences, movements, and activities of adult female nutria in a southwestern Louisiana intermediate marsh area. Thesis. Louisiana State University, Baton Rouge, Louisiana.

Coreil, P. D., and H. R. Perry Jr. 1977. A collar for attaching radio transmitters to nutria. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 31:254-258.

Davis, J. R., A. F. Von Recum, D. D. Smith, and D. C. Guynn, Jr. 1984. Implantable telemetry in beaver. Wildlife Society Bulletin 12:322-324.

Evans, J. 1970. About nutria and their control. U.S. Fish and Wildlife Service Resource Publication 86:1-65.

Gosling, L. M., and S. J. Baker. 1988. Demographic consequences of differences in the ranging behavior of male and female coypus. Coypus Research Laboratory, Norwhich, United Kingdom.

Gosling, L. M. 1989. Extinction to order. New Scientist 4 March:44-49.

Grier, J. W., and T. Burk. 1992. Biology of Animal Behavior. Mosby Year Book, St. Louis, Missouri.

Groeger, A. W., P. F. Brown, T. E Tietjen, and T. C. Kelsey. 1997. Water quality of the San Marcos River. Texas Journal of Science 49:279-294.

Guichón, M. L., and M. H. Cassini. 1999. Local determinants of coypu distribution along the Luján River, eastcentral Argentina. Journal of Wildlife Management 63:895-900.

Guynn, D. C., Jr., J. R. Davis, and A. F. Von Recum. 1987. Pathological potential of intraperitoneal transmitter implants in beavers. Journal of Wildlife Management 51:605-606.

Hediger, H. 1970. The breeding behavior of the Canadian beaver (*Castor fiber canadensis*). Forma et Functio 2:336-351.

Hill, E. P. 1982. Beaver. Pp 256-281 *in* Wild Mammals of North America: Biology, Management and Economics (edited by J. A. Chapman and G. A. Feldhamer). John Hopkins University Press, Baltimore, Maryland.

Hudson, J. M. 1999. Home range of the raccoon (*Procyon lotor*), and the degree of interaction with domestic pets at Aquarena Center, San Marcos, Hays County, Texas. Thesis. Southwest Texas State University, San Marcos, Texas.

Jenkins, S. H., and P. E. Busher. 1979. *Castor canadensis*. Mammalian Species 120:1-8.

Kainer, M. A. 1992. Woody plant use and preferences by the American beaver (*Castor canadensis*) in Central Texas. Thesis. Southwest Texas State University, San Marcos, Texas.

Kays, C. E. 1956. An ecological study with emphasis on nutria (*Myocastor coypus*) in the vicinity of Price Lake, Rockefeller Refuge, Cameron Parish, Louisiana. Thesis. Louisiana State University, Baton Rouge, Louisiana.

Lancia, R. A. 1979. Year-long activity patterns of radio-marked beaver (*Castor canadensis*). Dissertation. University of Massachusetts, Amherst, Massachusetts.

Litvaitis, J. A., K. Titus, and E. M. Anderson. 1996. Measuring vertebrate use of terrestrial habitats and foods. Pp 254-274 *in* Research and Management Techniques for Wildlife and Habitats (edited by Theodore A. Bookhout). The Wildlife Society, Bethesda, Maryland.

Lohmeier, L. 1981. Home range, movements, and population density of nutria on a Mississippi pond. Journal of the Mississippi Academy of Sciences 26:50-54.

Milne, R. C. 1963. A habitat description and evaluation, semiquantitative food habit analysis, and population study of the nutria, *Myocastor coypus* (Molina) Kerr, on Hatteras Island, North Carolina. Thesis. North Carolina State College, Raleigh, North Carolina.

Nichols, J. P., and M. Conroy. 1996. Techniques for estimating abundance and species richness. Pp 177-234 *in* Measuring and Monitoring Biological Diversity; Standard Methods for Mammals (edited by D. E. Wilson, E. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster). Smithsonian Institution Press, Washington and London, England.

Nyman, J. A., R. H. Chabreck, and N. W. Kinler. 1993. Some effects of herbivory and 30 years of weir management on emergent vegetation in brackish marsh. Wetlands 13:165-175.

Ostro, L. E. T., T. P. Young, S. C. Silver, and F. W. Koontz. 1999. A geographic information system method for estimating home range size. Journal of Wildlife Management 63:748-755.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. Pp 65-110 *in* Research Techniques in Animal Ecology; Controversies and Consequences (edited by Luigi Boitani and Todd K. Fuller). Columbia University Press, New York, New York.

Ragan, J. G. 1960. Poison baits for nutria control. Thesis. The University of Southwestern Louisiana, Lafayette, Louisiana.

Ras, L. B. 1999. Population estimates and movements of nutria (*Myocastor coypus*) at Tudor Farms, Dorchester County, Maryland. Thesis. University of Maryland Eastern Shore, Princess Anne, Maryland.

Reinke, D. T. 1986. Centers of activity of beavers in a section of Tennessee-Tombigbee Waterway. Thesis. Mississippi State University, Mississippi State, Mississippi.

Robicheaux, B. L. 1978. Ecological implications of variably spaced ditches on nutria in a brackish marsh, Rockefeller Refuge, Louisiana. Thesis. Louisiana State University, Baton Rouge, Louisiana.

Rothmeyer, S. W., M. C. McKinstry, and S. H. Anderson. 2001. Use of modified ear-tag radio transmitters on beaver (*Castor canadensis).* Cooperative Fish and Wildlife Research Unit. Laramie, Wyoming.

Ryszkowski, L. 1966. The space organization of nutria (*Myocastor coypus*) populations. Symposia of the Zoological Society of London 18:259-265.

Seaman, J. R. 1997. Food habits of the Texas river cooter (*Pseudemys texana*) at Spring Lake, Hays County, Texas. Thesis. Southwest Texas State University, San Marcos, Texas.

Simpson, T. R. 1980. The influence of nutria on aquatic vegetation and waterfowl in east Texas. Dissertation. Texas A&M University, College Station, Texas.

Swank, W. G., and G. A. Petrides. 1954. Establishment and food habits of the nutria in Texas. Ecology 35:172-176.

Taylor, K. L., and J. B. Grace. 1995. The effects of vertebrate herbivory on plant community structure in the coastal marshes of the Pearl River, Louisiana, USA. Wetlands 15:68-73.

Towns, K. 2002. Food habits of nutria (*Myocastor coypus*) at Spring Lake, Hays County, Texas. Thesis. Southwest Texas State University, San Marcos, Texas.

Walther, A. R. 1931. The South-American swamp beaver. Becksche Buchruckerei, Noerdlingen. English version by C. R. Partik, Lantier, Quebec.

Warkentin, M. J. 1968. Observations on the behavior and ecology of the nutria in Louisiana. Tulane Studies in Zoology and Botany 15:10-17.

Williamson, P. S. 2001. Wetlands are wondrous. SWT Wetlands Project. http://www.bio.swt.edu/wlands/main.html.

Willner, G. R. 1982. Nutria. Pp 1059-1076 *in* Wild Mammals of North America: Biology, Management and Economics (edited by J. A. Chapman and G. A. Feldhamer). John Hopkins University Press, Baltimore, Maryland.

Wilsey, B. J., and R. H. Chabreck. 1991. Variation in nutria diets in selected freshwater forested wetlands of Louisiana. Wetlands 11:263-278.

VITA

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This thesis was typed by Melissa McCulley Denena.