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Summer Movements and Home Range of the Cooter Turtle, *Pseudemys concinna*, in Illinois

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The study of movement and home range provides insight into an organism's activity and habitat utilization. Initially such studies were conducted using long-term mark recapture data and various trailing devices but since the advent of small radio units, the main tool has been radiotelemetry. Spatial studies using radiotelemetry in turtles have increased, emphasizing terrestrial (Schwartz et al., 1984; Brewster and Brewster, 1991; Smith et al., 1997, 1999), semi-aquatic (Rowe and Moll, 1991; Lovich et al., 1992; Buhlmann, 1995; Lewis and Faulhaber, 1999; Lue and Chen, 1999; Goodman and Stewart, 2000; Piepgras and Lang, 2000), and marine species (Seminoff et al., 2002). Research on primarily aquatic species is most often concentrated on terrestrial forays and inter-populational movements (Cagle, 1944; Sexton, 1959; Gibbons, 1970; Obbard and Brooks, 1980; Congdon et al., 1983; Gibbons et al., 1983, 1990; Buhlmann and Gibbons, 2001).

Although important in understanding activity and habitat use, terrestrial movements comprise a small portion of turtle activity throughout the entire season. For the majority of the activity season, movements of freshwater turtles are restricted to aquatic environments and are mainly driven by resource acquisition (Moll and Legler, 1971; Schubauer et al., 1990). Recognizing the need for research during the aquatic period, several recent studies have dealt with the aquatic activity of lotic species in riverine habitats (Kramer, 1995; Jones, 1996; Magnusson et al., 1997; Plummer et al., 1997). Contrastingly, little research has focused on aquatic activity in lentic species inhabiting lacustrine systems (Schubauer et al., 1990). Such studies are essential for providing a comprehensive understanding of movement patterns and home range of freshwater turtles.

The river cooter, *Pseudemys concinna*, is a broadly distributed species (Ernst et al., 1994; Seidel and Dreslik, 1996) occupying both riverine and lacustrine habitats (Marchand, 1942; Fahey, 1987; Buhlmann and Vaughan, 1991; Dreslik, 1997, 1998) with previous radiotelemetric research conducted on a riverine population (Buhlmann and Vaughan, 1991). The objective of our study was to provide an estimate of movement and home range area for a population of *P. concinna* inhabiting a lacustrine system with the emphasis on aquatic activity.

Methods. — Round Pond is a 24.5 ha member of a chain of floodplain lakes located approximately 4 km west of the confluence of the Ohio and Wabash rivers in southeastern Gallatin County, Illinois. A detailed description of the habitat has been published previously (Dreslik, 1997). We used five single set fyke nets (Vogt, 1980) to capture turtles from 28 June to 29 July 1999. Fyke nets had a 107 cm diameter mouth; two 5.2 m wings, a 15.2 m lead, and 3.8 cm mesh size. We set nets parallel to the shoreline in a V-formation and elevated the rear chamber of the trap with a floating air filled plastic bottle to prevent drowning turtles accidentally. We notched the marginal scutes of all turtles following Cagle (1939), measured maximum plastral length (PL) with tree calipers (to the nearest mm), and weight using an electronic balance (to the nearest g). We used two-stage radio transmitters with whip antennae weighing approximately 80 g constructed by L&L Electronics (Mahomet, Illinois). All adult *P. concinna* captured were fitted with transmitter packages mounted on the rear of the carapace on the fourth or fifth pleural scute with the antennae facing posteriorly.

We radiolocated turtles daily between 0900–2000 hrs but on a few occasions turtles were radiolocated twice per day. When turtles were radiolocated twice per day, there was at least an 8 hr interval between radiolocations. To determine locations, we first recorded the GPS coordinates in Universal Transverse Mercator (UTM, NAD 83 map datum) for two reference points with a Garmin® 12 CX with waypoint averaging. To obtain the GPS location for each reference site, we used the mean of ten separate waypoint averaged measurements taken at each reference site. We placed a system of marker buoys around the lake then triangulated the location of each buoy to each reference location with compass bearings. For each turtle location, we recorded compass bearings to two marker buoys. All compass bearings were then computed to UTM grid coordinates following the triangulation methods outlined in White and Garrott (1990) and the coordinates were input into Arc-View® 3.2a.

We calculated the mean and maximum distance between successive radiolocations and total distance moved. To examine possible sample size biases in movement parameters, we regressed maximum, mean, and total distance moved to the number of radiolocations with individuals as the sampling unit. Minimum convex polygons (MCP; Mohr, 1947) were constructed in Arc-View® 3.2a using the Animal Movement extension (Hooge and Eichenlaub, 1997). We selected the MCP method because of its simplicity, flexibility in shape, ease in calculation, and the minimal effects of autocorrelated locations on polygon size (White and Garrott, 1990). However, there are two drawbacks to the MCP method. First, home range estimates may increase indefinitely with an increasing number of radiolocations (Jenrich and Turner, 1969) and the polygon may include habitats unavailable to the study organism. To address the first drawback, we performed a regression on all MCP areas

Table 1. Movement statistics (m), minimum convex polygon (MCP) area (ha), and number of radiolocations for *P. concinna* radiotracked at Round Pond, Gallatin County, Illinois, during summer 1999. PL = mm, mass = g.

	PL	Mass	Daily Movement Max.	Mean	Total	MCP Area	*n*
Females							
F1	198	1014	459	116	2437	4.6	22
F2	198	943	115	59	1353	1.8	24
F3	288	3500	622	118	1769	7.1	16
F4	213	1221	188	94	2248	3.5	25
F5	193	962	375	133	1328	9.2	11
F6	219	1315	173	77	1078	3.1	15
Mean			321.9	99.4	1702.1	4.9	
St dev			197.3	28.8	546.6	2.8	
Males							
M1	241	1976	629	311	2179	—	8
M2	185	823	133	58	576	7.2	11
M3	197	1001	339	134	1841	3.4	16
Mean			366.9	167.5	1531.8	5.3	
St dev			249.2	130.1	845.2	2.7	
Grand Mean			336.9	122.1	1645.3	5.0	
St dev			200.9	76.9	610.3	2.6	

versus the respective number of radiolocations to determine if MCP area depended upon the number of radiolocations. If a significant relationship occurs, then the MCP areas are dependent upon the number of radiolocations and thus biased. Our second approach used Incremental Area Analysis (IAA), which pools all radiolocations for an individual, then resamples using bootstrapping to generate a series of home range estimates from 3 to *n* radiolocations (Hooge and Eichenlaub, 1997). If the bootstrap estimates of home range asymptote as the number of radiolocations increase, then a sample size bias is not present with respect to an individual. Because these are aquatic turtles tracked when overland forays are expected to be minimal, we did not need to consider potential habitat biases.

Results. — We radiolocated 6 female and 3 male adult *P. concinna* 8 to 26 times each between 8 July and 29 July 1999 for an average duration of 2.5 weeks per turtle (Table 1). Our sample size was too small for statistical comparisons of movement and home range area between sexes. Maximum (p = 0.309, r^2 = 0.146, n = 9), mean (p = 0.136, r^2 = 0.288, n = 9), and total distance moved (p = 0.322, r^2 = 0.140, n = 9), were independent of sample size. On average, turtles moved 122 m between successive radiolocations (Table 1). Despite having only 8 radiolocations, turtle M1 ranked third in total distance moved and made the largest move (Table 1; Fig. 1). Because male M1 moved into a privately owned pond and did not return to Round Pond during the remainder of the study, we were unable to make additional radiolocations. On average, females moved less than males and male movements appeared more variable (Table 1). However, if M1 is considered an outlier, the standard deviations of female and male movements are similar.

Overall, MCP area was an accurate measure of home range size because it was independent of the number of radiolocations (r^2 = 0.073, p =0.518, n = 8). Individually, IAA revealed we required at least 15 radiolocations to adequately determine home range area over this period. Although F5 and M2 had the largest home ranges for each sex, IAA determined that 11 radiolocations were inadequate for representing home range area. The majority of the 148 radiolocations were clustered in the shallower northern half of Round Pond (Fig. 1). However, some individuals (M1, F3, F5) utilized the northern two-thirds of Round Pond (Fig. 1). Only 18 radiolocations were in open water > 6 m deep.

Discussion. — The majority of movements of *P. concinna* were constrained within Round Pond's boundaries during the summer for two possible reasons. First, the habitat may provide ample resources, which are not uniformly distributed. Thus, movements between different aquatic habitats and within different regions of the pond are unnecessary. Although this explanation does not account for movements made in search of resources such as nesting sites and mates, the effects of these factors are minimized in our study because we focused on adults after the reproductive and nesting season. The movements we observed may be driven by foraging and thermal requirements. Primarily herbivorous throughout its range (Ernst et al., 1994), *P. concinna* is an algal specialist at Round Pound (Dreslik, 1999), thus food resources would be abundant in the shallower regions of the pond where light can penetrate to the benthos. This partially explains the concentration of locations in the shallower northern coves. Because no adults have been observed basking emergently at Round Pond, despite repeated surveys (Dreslik, unpubl. data), *P. concinna* may use warm shallow water for aquatic thermoregulation.

Because there are limited reports of overland movements in *P. concinna*, terrestrial environments may represent significant barriers (Minton, 1972). When aquatic environments are in close proximity, short over-land movements are possible. M1 made a short overland movement of 100–190 m (the minimum and maximum distances separating the ponds) from Round to Long Pond. Terrestrial movements of male turtles between aquatic habitats in several other species are well documented (Cagle, 1950; Sexton, 1959; Gibbons et al., 1990). Additionally, long-term studies indicate that some individuals, especially semi-aquatic species, utilize several aquatic habitats during their activity season and lifetime (Buhlmann, 1995; Burke et al., 1995; Buhlmann and Gibbons, 2001). Factors such as resource limitations, unfavorable environmental conditions, and maximizing reproductive success are postulated to drive inter-populational movements (Morreale et al., 1984; Gibbons et al., 1990). Because the overland distance between Round and Long ponds is short, some individuals may routinely move between the adjacent ponds. Two adult females captured in Long Pond in 1996 were subsequently recaptured in Round Pond in 1997 (Dreslik, unpbul. data). Although these movements may not represent overland travel because Round and Long ponds connect during flood events, they provide additional affirmation of individuals using both ponds.

Within an activity season, freshwater turtles are capable of moving great distances with males often making the

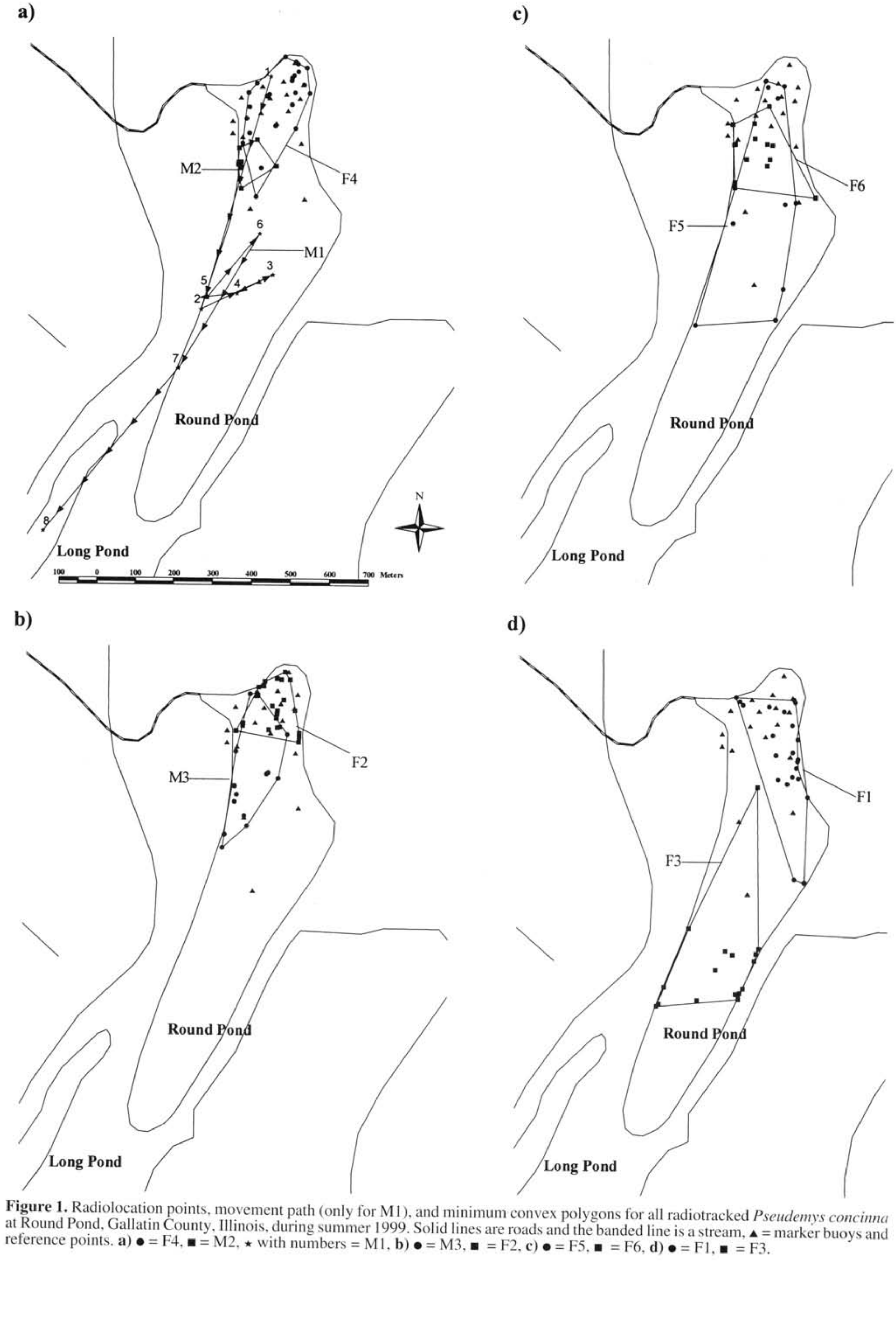

Figure 1. Radiolocation points, movement path (only for M1), and minimum convex polygons for all radiotracked *Pseudemys concinna* at Round Pond, Gallatin County, Illinois, during summer 1999. Solid lines are roads and the banded line is a stream, ▲ = marker buoys and reference points. **a)** ● = F4, ■ = M2, ★ with numbers = M1, **b)** ● = M3, ■ = F2, **c)** ● = F5, ■ = F6, **d)** ● = F1, ■ = F3.

longest movements (MacCullough and Secoy, 1983; Morreale et al., 1984; Pluto and Bellis, 1988). The variation of intra-populational movements, however, has received less attention than extra-populational movements (Gibbons et al., 1990). On average, *P. concinna* at Round Pond moved a maximum daily distance of 337 m, and total distance of 1.6 km. Mean daily movement was 122 m and based on limited data, females moved shorter daily distances than males. In comparison, daily movements of *P. concinna* inhabiting a riverine situation were greater, averaging 340 m (Buhlmann and Vaughan, 1991).

Three of our individuals moved $\geq$ 500 m between radiolocations. In rivers, *P. concinna* moved distances greater than 640 m between resightings and recaptures (Marchand, 1942), and a maximum movement of 777 m in the New River, West Virginia has been documented (Buhlmann and Vaughan, 1991). Further, some individuals in the New River moved 574 m in response to the flooding of basking sites (Buhlmann and Vaughan, 1991). Conversely, in the Tallapoosa River, Alabama, recaptured *P. concinna* were generally $\leq$ 100 m from their initial capture point (Fahey, 1987). The data suggest *P. concinna* is a vagile species capable of long-distance aquatic movements within a short time but to a lesser extent in lacustrine compared to riverine situations.

Because home range area was independent of the number of radiolocations and IAA curves reached an asymptote for all but two individuals, we conclude that our findings accurately portray summer home range size in *P. concinna*. Because of sample size limitations, we were unable to statistically compare sexes but males and females had similar sized home ranges (5.3 and 4.9 ha, respectively). Our home range estimates were larger than that of a population in the New River (1.4 ha; Buhlmann and Vaughan, 1991). Thus, turtles in Round Pond moved shorter distances within a larger home range compared to a riverine population, which moved greater distances within a smaller home range (Buhlmann and Vaughan, 1991).

River cooters (*P. concinna*) were adept at moving through their aquatic environment and capable of routinely making daily movements $\geq$ 500 m. Although we reported one instance of an overland foray between adjacent ponds, it remains unknown how far and frequently *P. concinna* may travel overland. Because we lacked the sample size for statistical inference, further work needs to be conducted using more individuals at Round Pond to conclusively determine if sexual differences exist in either movement or home range area. This work should also encompass the entire activity season to examine seasonal differences in spatial patterns.

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Comparative Efficiency of Different Sampling Techniques to Obtain DNA from Freshwater Turtles

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The advance of polymerase chain reaction (PCR) analysis has had an important impact on molecular ecology by allowing researchers to perform genetic analysis from small quantities of DNA. This modern technique, using non-lethal collection methods, is particularly useful when dealing with threatened species. Though blood sampling represents the predominant methodology for mammals (Sambrook et al., 1989), birds (Seutin et al., 1991), and reptiles (Haskell and Pokras, 1994), blood collection is invasive and can stress the animal and cause injuries. Alternative non-invasive sampling techniques would be beneficial for turtles and other small animals where blood sampling is difficult or potentially harmful.

Numerous tissue collection methods and extraction protocols have been designed to obtain DNA from old, dry, and degraded samples, such as fish scales (Tessier and Bernatchez, 1999), otoliths (Hutchinson et al., 1999), human fingernails (Ricci and Giovannuci Uzielli, 1996), mammal hairs (Goosens et al., 1999), and museum specimens (Ellegren, 1991; Thomas et al., 1990), among others. Re-