FINE-SCALED MOVEMENTS AND HABITAT USE OF BLACK BEARS IN SOUTH CENTRAL LOUISIANA

A Thesis

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ABSTRACT

Animal movements are related to many parameters of interest such as the search for food and other life requisites. Several measures, including home range, have been used to quantify and describe animal movement. However, fine-scaled movements of mammals have received less attention even though they are more directly related to energy expended for locating resources and provide information on how a home range is used.

I tracked radiotagged female black bears (*Ursus americanus*) from two geographically separate populations in the Atchafalaya River Basin in south central Louisiana: the Coastal population at the southern extent and the Inland population at the northern extent. During tracking sessions, 2 technicians and myself measured azimuths from telemetry stations to radio-collared bears and test transmitters at 5-minute intervals for an average of 5.1 hours. I used these data to estimate 39 travel paths for 15 individual bears tracked from 1 to 7 times. Randomization tests indicated that telemetry precision was sufficient to detect fine-scaled bear movements.

Movement path turning angles, measured relative to the previous direction of travel, and net displacement of individuals through time indicated that bears concentrated their movements (net displacement <72m) approximately 50% of the time, suggesting that they were utilizing a concentrated or patchily distributed resource. I failed to detect any differences in measures of fractal dimension, a scaling relation providing an index of path tortuosity or “wiggliness”, among bears in different reproductive conditions, study areas, or seasons. Bear, hour relative to sunset, reproductive condition, and season influenced the fall movement rates of bears. The effects of reproductive condition and time of day were not consistent across bears, and the effect of time of day was not consistent across reproductive conditions.

Movement extent, or area traversed during an average tracking session, was similar between study areas, but Coastal females used a larger percentage of their home range. These data suggest life requisites are more compactly distributed in the Coastal area. Despite the difference in the distribution of bear resources between Coastal and Inland suggested by these data, I failed to detect any habitat preferences or avoidance of anthropogenic features such as roads and agricultural fields in either study area using movement path location data.

CHAPTER I: FEMALE BLACK BEAR MOVEMENT PATHS

BACKGROUND AND MOTIVATION

Movement behavior of animals may relate to their ability to disperse, population dynamics, and gene flow (Jones 1977, Johnson et al. 1992) and is influenced by animal size, foraging strategy and the distribution of resources within the landscape (Swihart et al. 1988). Because of potential relationships between movement and other biologically significant parameters, an understanding of animal movement patterns is critical to understanding the ecology of a species.

One measure of movement is home range. Home range has been defined as the area an animal traverses to obtain food, mates, and care for young (Burt 1943). It is generally estimated by the utilization distribution of animal locations through some specified period (e.g., annual or seasonal) as calculated under the assumption of a bivariate normal distribution or using kernel estimators (White and Garrott 1990). This measure of movement has received much attention and has been estimated for many species, including the American black bear (*Ursus americanus*; Lindzey and Meslow 1977, Novick and Stewart 1982, Hellgren and Vaughan 1990, Smith and Pelton 1990, Wagner 1995). Home range measures describe large-scale movement behaviors of animals. However, movement patterns apparent at large scales may not be representative of those at finer scales (With 1994). To understand the behavioral processes influencing fine-scaled movement patterns (e.g., hourly, daily), studies of movement at spatial scales finer in resolution than those needed to describe home range are necessary.

I studied the fine-scaled movements of individuals from 2 disjoint populations of Louisiana black bears (*U. a. luteolus*) in the Atchafalaya River Basin of south central

Louisiana to describe how bears move through these habitats and to discern scales at which bears may view their habitats. A second objective was to use movement paths to examine habitat use in relation to anthropomorphic features in the landscape. Because of gross habitat differences between areas occupied by the 2 study populations and differences in home range sizes (Wagner 1995), I predicted that movement paths would differ between study areas.

STUDY AREA

I studied bears located in 2 areas of south central Louisiana that I will refer to as Inland (approx. 460 km^2 in size) and Coastal (approx. 570 km^2 in size; Figure 1). Inland was located primarily within the Morganza Spillway, a floodway developed by the U.S. Army Corps of Engineers to release floodwaters of the Mississippi River into the Atchafalaya Basin. Forested habitats within the floodway were primarily bottomland hardwood stands managed for timber production. Agricultural fields within the Spillway were located adjacent to the levees and Louisiana Highway 10, which bisected the Spillway near its northern extent. Seasonal flooding occurred throughout the Inland area, but was not severe during the term of this study. Large areas of slightly higher elevation were dry throughout winter, and flooded areas were generally <0.5 m deep.

The Coastal area consisted of small bottomland hardwood stands, baldcypress-water tupelo swamps (*Taxoduim distichum – Nyssa aquatica*), and coastal marshes that varied along salinity gradients ranging from fresh to saline (U.S. Army Corps of Engineers 1974). Wetland scrub habitats occurred in the transition zone between swamp and marsh. Bottomland hardwood stands were restricted to the borders of sugarcane fields protected from flooding by levees, and along spoil areas near waterways.

Coastal habitats were highly interspersed and most contained open water, sloughs, bayous, and canals influenced by tidal fluctuations (Chabreck 1970). The Coastal area also contained 4 salt domes, characterized by upland cover types, rising >30 m above surrounding deltaic plains (Evans et al. 1983). Most of the land area, excluding the salt domes and areas protected by levees, was flooded throughout most of the year. The water table was generally <0.2 m above the surface. Drier sites in the swamp and scrub habitats generally were those areas surrounding isolated groups of trees. Nyland and Pace (1997) provided detailed habitat descriptions including the relative value of the main habitats to bears.

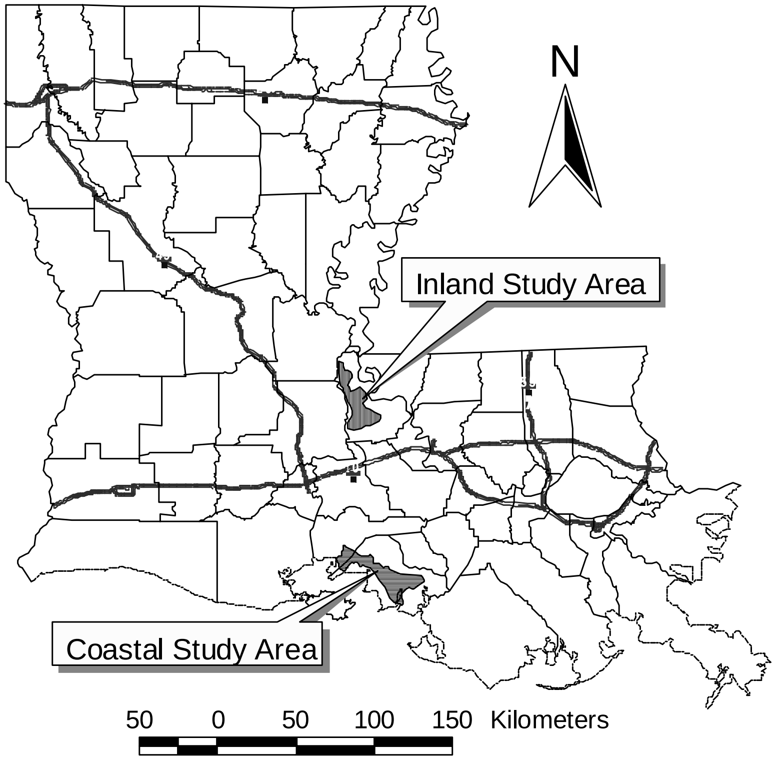

Figure 1. Study areas in south central Louisiana**.**

METHODS

Field Methods

Together with others, I trapped Coastal and Inland black bears during May–August of 1995–96. We used Aldrich foot snares or culvert traps following the methods detailed in Johnson and Pelton (1980). Bears were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride (5.5 mg/kg), and uniquely marked with ear tags and a lip tattoo. We extracted a first premolar for age estimation using cementum annuli techniques (Matson Laboratories, Milltown, Montana, USA) and attached breakaway radio collars with leather spacing material to animals $\geq$ 1 year-of-age (Advanced Telemetry Systems, Isanti, Minnesota, USA).

To estimate bear movement paths, 2 technicians and I tracked tagged bears in both study areas during October–December 1995 and September–December 1996. We used stationary and mobile telemetry system configurations, both with 4-element twin-yagi antenna systems (Fig. 2) and a null-peak combiner box (AVM Instrument Co., Livermore, California, USA). Stationary towers consisted of the antenna array mounted on a telescoping television antenna mast with a compass rose and pointer to determine azimuths. The masts were set in the ground approximately 1m and secured with guy wires. I used a hand-held sighting compass to determine the direction of stationary systems relative to true north. Truck- or boat-mounted (mobile) units were similar in design, but electronic compass engines (KVH Industries, Middletown, Rhode Island, USA) were used to determine azimuths. We used handheld two-way radios to coordinate activities during tracking sessions and mobile units were free to move to improve reception or tower configuration (White and Garrott 1990).

Figure 2. Robert Wagner operating truck-mounted twin yagi antenna system with electronic compass engine used to track black bears in south central Louisiana (1995–96).

Fall activity patterns of bears in the study populations were bimodal with peaks occurring near sunrise and sunset (Wagner et al. 2002). Because it was easier to set up tracking equipment during daylight ours, I conducted intensive tracking sessions near or including sunset. During all tracking sessions, each operator recorded azimuths to the same, randomly selected, target bear and test transmitter every 5 minutes. I told the other operators that the test transmitter was a radio-tagged bear to limit the influence of operator "evaluation apprehension" (Mills and Knowlton 1989). Azimuths to test transmitters were used to calibrate antenna systems and estimate bearing precision.

I determined the location of test transmitters, and tracking units using a global positioning system receiver (GPS; Magellan Systems Corp., San Dimas, California, USA). To increase precision, I collected at least 2 location estimates>12 hrs apart, each based on an average of 32 uncorrected position fixes, at each test transmitter and tracking unit location. I averaged the location estimates, weighting each by its standard deviation. Experience led me to believe that this procedure produced locations to within 20m of ground truth despite the effects of selective availability.

Azimuth Processing and Location Estimation

Because instruments used to measure azimuths were only approximately aligned to magnetic north, I used azimuths to test transmitters to calculate an adjustment factor that was applied to azimuths to bears and determine azimuth precision. The difference between each observed azimuth to the test transmitter and the "true" azimuth, calculated using the global positioning system estimates of tower and test transmitter locations, was a result of the bias in the telemetry system and a random error term (Lee et al. 1985). The averaged differences between observed and truth for each tower provided an adjustment factor for azimuths to bears (White 1985). The adjustment factor was also used as a check for drift and bias in the antenna systems.

I estimated bear locations by triangulation using Lenth's maximum likelihood estimator (Lenth 1981) and a moving window approach (Pace 2000). Because location estimates gathered close in time (e.g., 5-minute intervals) should not be independent, but highly correlated, azimuths collected at adjacent time intervals may be pooled to improve location precision (Pace 2000). Pooling azimuths improves location precision by reducing the effects of random error or "white noise", and spurious azimuths. I selected a 10-minute moving window in which azimuths were pooled to estimate bear locations. For example, azimuths collected at 4:00, 4:05, and 4:10 were used to estimate the bear's location at 4:05. Similarly, the azimuths collected at 4:05, 4:10, and 4:15 were used to estimate the bear's location at 4:10, and so on. The temporally ordered set of estimated bear locations collected during a tracking session was my estimate of the animal's movement path with each pair of sequential locations termed a move.

Telemetry Precision

I used the standard deviation of azimuths to test transmitters as the measure of azimuth precision. I tested for differences in azimuth precision among observers and between telemetry system configurations (compass rose vs. electronic compass) within observers using mixed model ANOVA (proc mixed; SAS Institute, Inc. 1997). I tested several potential models of azimuth precision selected *a priori*, some of which included distance and squared distance of the telemetry station from the test transmitter as covariates. I used Akaike's Information Criterion (AIC; Akaike 1973) with small sample correction (AIC_c; Burnham and Anderson 1998) to select the most parsimonious model. The use of an information criterion for model selection allows for testing a suite of models and therefore is less constraining than hypothesis testing (Burnham and Anderson 1998).

Telemetry observations on test transmitters provided data to determine expected detectable displacement of animals. I estimated test transmitter locations using the same methods as for bears, and determined the distance between triangulated location estimates and the transmitter location established using GPS. I took the median error distance as the minimum bear movement detectable by the system.

To determine if the telemetry was of sufficient precision to delineate a movement path, I tested for independence of the estimated locations using the methods of Solow

(1989). I treated each location within a movement path as an observation. Within a movement path, $n!$ permutations of the n locations were possible and, if the locations were independent, each permutation had a probability of $1/n!$ of being observed. I calculated Schoener's ratio, the ratio of the mean squared distance between successive observations in a movement path and the mean squared distance from the center of activity or centroid of all path locations (Schoener 1981), for all movement paths. I estimated the distribution of the Schoener's ratio for each path by calculating the ratio for 1000 randomly selected permutations of each movement path. I tested for independence of path locations by comparing the Schoener's ratio of the observed path against the derived distribution (Solow 1989). If the observed movement path locations were independent, then the order in which they were recorded would be irrelevant and they would not likely represent a path.

To test the procedure, I estimated test transmitter locations using azimuths recorded during tracking sessions. I processed azimuths to test transmitters using the same protocol as for estimating bear locations and performed the same randomization test. I expected azimuths to test transmitters would not represent a path (i.e., the order in which they were recorded would be irrelevant).

Bear Movement Paths

I classified bear movement paths according to the study area, season, and reproductive condition of the bear tracked. Reproductive classes were solitary, with young, and unknown. I defined fall as the months of September and October, and winter as November and December, when some bears may have been preparing to enter winter dens (Hightower et al. *in press*).

The basic measurements of movement paths were turning angles, measured relative to the previous direction of travel, and move lengths or straight-line distances between consecutive location estimates. To test whether distributions of turning angles were similar among paths, I examined frequency plots. I also tested for autocorrelations in the turning angles by categorizing them as right (R) or left (L) turns and testing for differences in angle pairs (RL, LR, RR, LL) using a chi-squared test (α=0.05; Zalucki and Kitching 1982). I used average move length by hour relative to sunset, with sunset being time 0, to index movement rate because samples were not uniformly distributed across hours. Move lengths calculated from consecutive location estimates > 5 minutes apart were excluded from all analyses of movement rate. I tested for differences in movement rate by bear, hour relative to sunset, season, and reproductive condition using mixed model ANOVA with tracking sessions considered random and repeated measures on hours within bears. I selected the most parsimonious model using AIC_c. I examined model fit by plotting the predicted against the observed movement rate, and model residuals against predicted values and quartiles of the normal distribution.

To estimate the area used by bears during tracking sessions, I derived the 100% minimum convex polygon (MCP) for each bear movement path using the Animal Movement extension (Hooge and Eichenlaub 1997) for ArcView (Earth Resources Systems, Inc., Redlands, California, USA). I used the average annual MCP home range estimates for Coastal and Inland bears from Wagner (1995) to calculate the percentage of home range covered by movement path MCP’s as a measure of movement extent.

To characterize the tortuosity or “wiggliness” of movement paths, I calculated the overall fractal dimension (fractal D) of each path. Fractal D is a scaling relation that is proportional to the degree of convolution in planar curves (Bascompte and Vila 1997). At the extremes, a straight line has a fractal D of 1 and movement so convoluted that it fills a defined plane has a fractal D of 2 (Turchin 1996). I estimated fractal D for bear movement paths using the program FRACTAL (Nams 1996) and a modification of the dividers method that produces one measure of fractal D over a range of scales. Dividers, similar to a geometric compass, consist of 2 straight arms joined by a common hinge. By changing the angle between the arms, one may change the distance between the arm endpoints opposite the hinge. The program measured the length of each path by "walking a set of dividers" of size *n* over the path and counting the number of steps required to reach the end of the path. I repeated this process 1000 times, each time starting at a random location within the path. I averaged those 1000 measurements and repeated the entire process using 15 larger sets of dividers (i.e., measurement scales). I restricted the range of scales from the median distance error between triangulated test transmitter locations and those established using GPS to 100m to ensure an adequate number of steps at larger divider sizes (Dicke and Burrough 1988). Fractal D was estimated from the slope of a linear model fit to $\log_e$ path length versus $\log_e$ divider size (Nams 1996). I used the finding that $\log_e$-transformed values of fractal D are approximately normally distributed (Bascompte and Vila 1997) and tested for differences in overall fractal D of movement paths among bears, seasons, and reproductive conditions using ANOVA. Because the number of moves within a path represented time tracked, I included number of moves as a covariate in one suite of models. I considered bear, reproductive condition, hour relative to sunset, season, and bear by hour, bear by reproductive condition, and hour by reproductive condition interactions (the largest model) through only bear as possible explanatory models *a priori,* and I used AIC to select the best model (Table 1).

Fractal D measured across a movement path provided a measure of path tortuosity, but not a test of the hypothesis that the path was fractal or self-similar at all scales measured. To be considered fractal, the smaller segments of a fractal movement path would be statistically similar to a reduced-scale image of the whole (Mandelbrot 1967). To determine if bear movement paths were fractal (i.e., self-similar at all scales measured), I calculated fractal D for each movement path at 15 scales ranging from the median test transmitter distance error to 100m using the VFractal estimator (Nams 1996). Dividers are walked across the path at varying scales similar to the measurement of overall fractal D, but fractal D is estimated for each scale. VFractal estimates fractal D for each pair of consecutive moves along the path using the mean cosine of the turning angles between successive pairs of moves and the mean net or straight-line distance between consecutive move endpoints using equations from Nams (1996, p. 291):

$$D = \frac{\log_e(2)}{\log_e\left(\frac{Net}{s}\right)}, \tag{1}$$

$$\text{If } (\phi \leq 89^\circ) \text{ then } D = \frac{\phi}{1 + \log_2(\cos\phi + 1)}, \text{ else } D = 2 \tag{2}$$

where, *Net* is the mean net distance between the endpoints of successive moves, *s* is the divider size, ϕ is the turning angle, and cos ϕ is the mean cosine of all turning angles.

I averaged the estimates of equation 1 across move pairs within each movement path at each scale measured between the median test transmitter distance error and 100m.

I did likewise for equation 2. To estimate fractal D for each scale of interest, I averaged the mean values of equation 1 and equation 2 for each movement path (Nams 1996).

I used the correlation of the cosines of consecutive turning angles (measured clockwise relative to the prior direction of travel), to estimate scales at which bear movements differed qualitatively. If a bear movement path is measured at scales below habitat patch size, then the correlation in the turning angles between successive moves are positive because tortuous within-patch path segments and straighter between-patch path segments would likely be followed by like segments (Nams 1995). At scales near patch size the correlations are negative because segments within patches are likely followed by path segments outside of patches. Correlations are approximately zero above patch size.

Using methods similar to the Vfractal, I estimated the correlation of the cosines between successive moves at a range of scales (30m–100m) using the program FRACTAL. As part of the output, 95% confidence intervals were generated around the estimated correlations.

To describe the within path movement patterns of bears, I examined plots of the net distance or straight-line distance moved between the beginning point of the path and all subsequent points. Also, I calculated the difference in net distance moved between time t_i and time t_{i+2}. If the difference between t_i and time t_{i+2}, and t_{i+3} and t_{i+5} were both less than the mean scale at which I detected the first significant correlations in the cosines of the turning angles then I considered the bear movements at time t_{i+5} to be concentrated or “within patch movements”. Otherwise, I considered bear movements directed. I modeled the percentage of movement paths that represented concentrated movement using mixed model ANOVA and I used AIC_c to select the most parsimonious model.

RESULTS

Telemetry Precision

Distances between test transmitters and telemetry stations ranged from 0.06 km to 3.7 km. Overall azimuth precision was 2.1° and was not different among observers ($F_{11,141}$=1.34, P=0.21) or within observers between telemetry systems with electronic compasses or a compass rose ($F_{4,141}$=1.11. P=0.35). Distance and squared distance of the telemetry station from the test transmitters did not improve model fit, therefore neither was included in the final model. The distribution of distance errors of estimated and GPS-established test transmitter locations was skewed, as expected, with a mean of 97m, median of 28m, and 90% of estimates <98m (Fig. 3).

I found no evidence that the ordering locations mattered for pseudo paths ($P>0.05$, for all paths), which indicated that there were no movement path attributes, such as spatial correlation, imputed into presumably independent locations by my selection of a moving window approach to estimate locations. Estimated locations within bear movement paths were not independent ($P<0.001$, for all paths), indicating that the order in which the locations were recorded was important and suggesting telemetry precision was sufficient to delineate bear movement paths.

Bear Movement Paths

I attempted a total of 81 tracking sessions during September–December 1995–96. Due to poor weather conditions, equipment failure, human error, and inability to locate radiotagged animals, I was successful in only 48 attempts. Nine of the 48 tracking sessions resulted in <20 locations and were not considered. The average length of successful tracking sessions was 5.1 hours (range, 2.1-7.3 hrs).

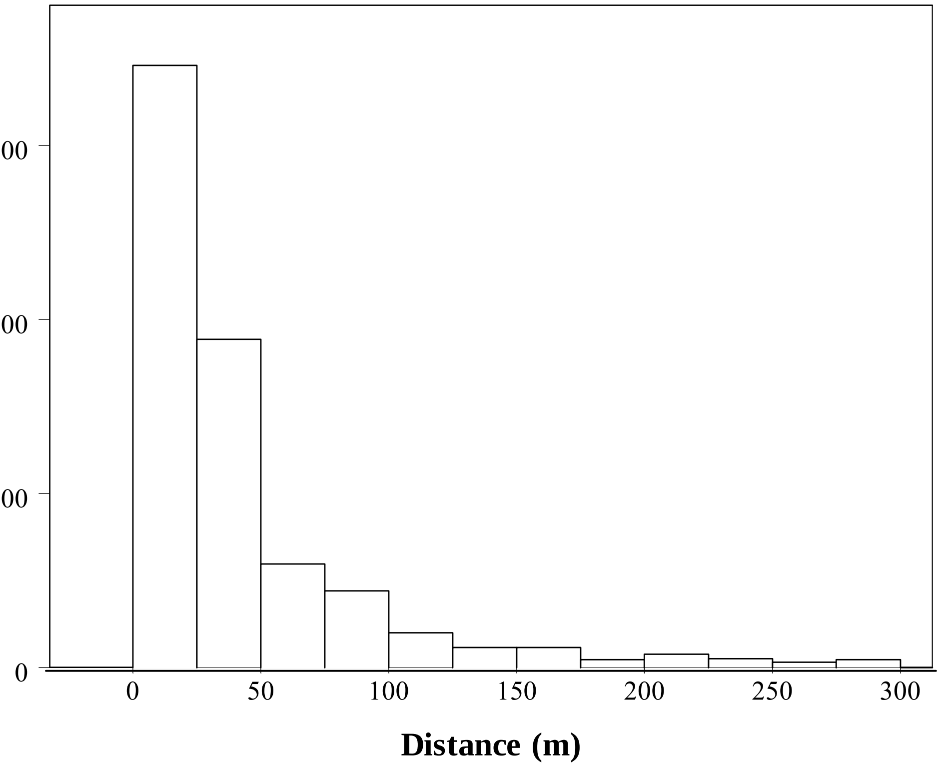

Figure 3. Error distance of triangulated test transmitter locations from positions estimated using a global positioning system receiver (1995–96). Estimated locations were calculated using Lenth’s MLE and a moving window approach that included all azimuth-station pairs measured during a 15-minute interval (n ranged from 3 to 9).

I constructed a total of 39 bear movement paths by following the movements of 15 individual bears from 1 to 7 times for a contiguous period near or including sunset (Appendix A) and 39 pseudo paths from azimuths to test transmitters. Estimated bear movement paths varied in length from 0.39 km to 8.8 km, whereas estimated pseudo paths ranged from 0.06km to 2.00km.

Turning Angles - No consistent pattern was evident in the distribution of turning angles within bears, seasons, or reproductive classes. Some turning angle distributions were bimodal while others were bell-shaped (Fig. 4). Because of the bimodal nature of the turning angle distributions for most travel paths, I did not calculate any measure of central tendency. Most turning angle distributions peaked near 0° and 180° (27 of 39) with the dominant angle being 180° in some paths and 0° in others, indicating a tendency to either continue moving in the same direction or reverse direction.

Despite the tendencies suggested by turning angle distributions, I detected no first order serial correlation in turning angles across sessions within bears (χ^2_1 tests, $P>0.05$). Therefore, I pooled turning angles across bears and sessions within treatment groups and tested for first order correlations in the turning angles. No first order autocorrelations in the turning angles were detected for 10 of 11 treatment groups. Serial correlations in the turning angles of Coastal females with young ($\chi^2=6.131$, 1 df, $P=0.013$) indicated that they were more likely to turn right or left following a like turn.

Movement Rate - The distribution of move lengths within movement paths was highly skewed, with most <100 m. The movement rate averaged across all movement paths was 0.64 ± 0.05km/hr versus 0.53 ± 0.35km/hr for stationary test transmitters. The hourly movement rates of bears, indexed by mean distance moved between consecutive locations taken 5 minutes apart, was variable among bears (Fig. 5) and among sessions within bears. The most parsimonious model of bear movement rate included bear, hour relative to sunset, reproductive condition, season, and bear by reproductive condition, bear by hour, and hour by reproductive condition interactions (Table 1).

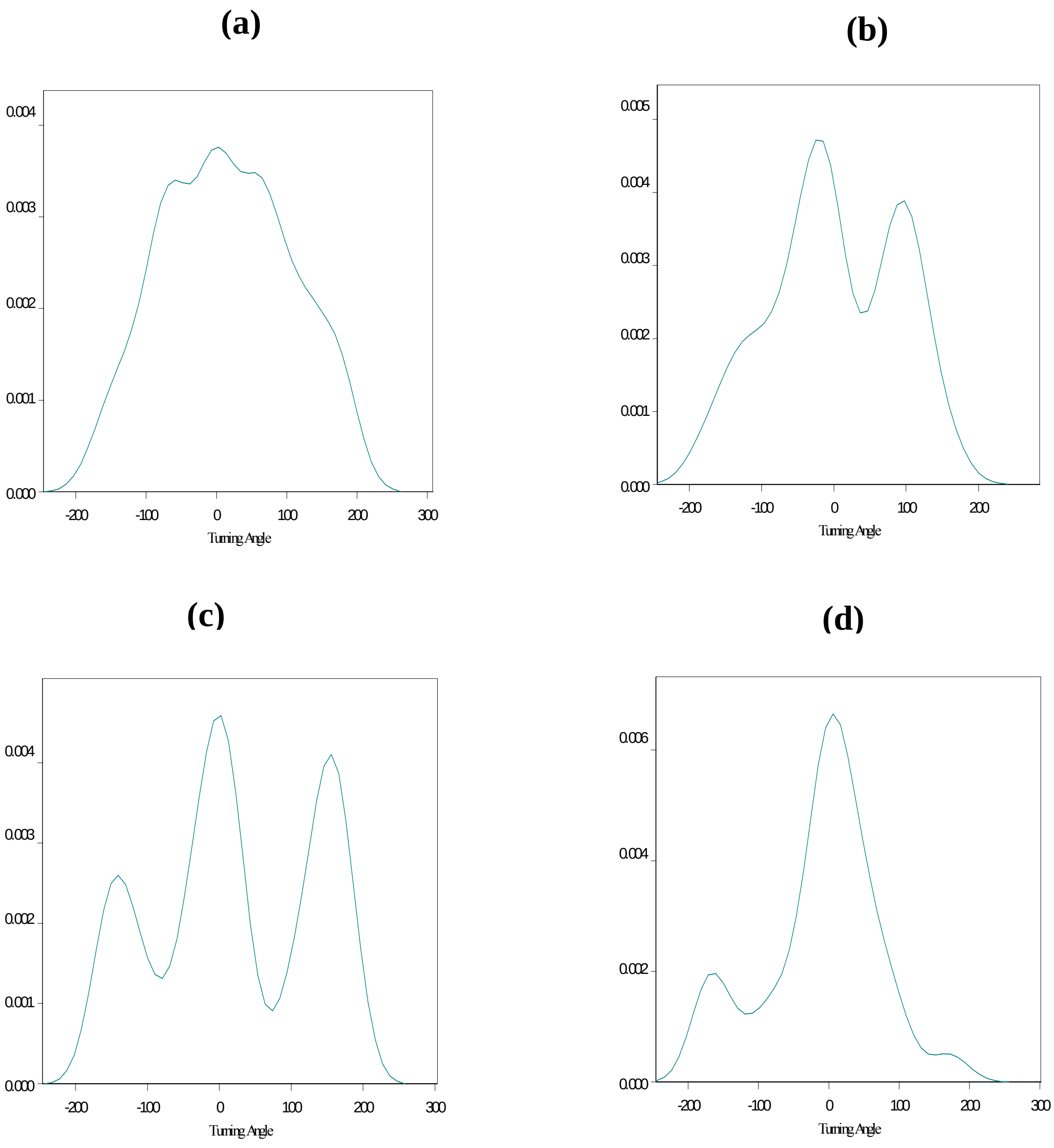

Figure 4. Bell-shaped (a) and multimodal (b-d) turning angle distributions (modulo 180°) from estimated movement paths of 4 tracking sessions of female black bears in south central Louisiana during 1995–96. Note that the above graphs represent smoothed approximations of the turning angle distributions and erroneously exceed ± 180°.

Table 1. Number of model parameters (k), model deviance, model weights (w_i) and cumulative model weight ($\sum w_i$) of *a priori* models of female black bear movement rate ranked using small sample corrected AIC (AIC_c).

Model	k	Deviance	AIC	AIC_c	ΔAIC_c	w_i	$\sum w_i$
Bear, Hour, ReproCond., Season, Bear*Hour, Bear*ReproCond., Hour*ReproCond.	9	2088.60	2106.60	2112.81	0.00	0.92	0.95
Bear, Hour, ReproCond., Season, Bear*Hour, Bear*ReproCond.	8	2097.00	2113.00	2117.80	4.99	0.08	1
Bear, ReproCond., Season, Bear*ReproCond., Bear*Season, ReproCond.*Season	6	2221.30	2233.30	2235.93	123.12	0	1
Bear, Hour, ReproCond., Bear*ReproCond.	6	2227.80	2239.80	2242.43	129.62	0	1
Bear, ReproCond., Bear*ReproCond.	5	2236.00	2246.00	2247.82	135.01	0	1
Bear	3	2245.50	2251.50	2252.19	139.38	0	1

Within bears, hourly movement rates were larger during fall than winter. Two bears were tracked that were with yearlings in one year of the study and solitary the other; they provided my only comparison of movement rate between reproductive conditions. Their movement rates were larger when with yearlings than when solitary.

Movement Extent - Wagner (1995) reported mean annual 100% MCP home ranges of $15.3km^2$ and $32.7km^2$ for Coastal and Inland bears, respectively. The percentage of average annual 100% MCP home range accounted for by 100% minimum convex polygons of female black bear travel paths was, on average, lower for Inland bears than Coastal bears, 0.7% (n=23) and 1.8% (n=15), respectively (Fig. 6). One travel path of a Coastal solitary female accounted for 8.6% of the average home range and was almost 2.5 times larger than the next largest travel path MCP. Removal of this observation resulted in an average percentage of 100% MCP home range accounted for by Coastal bear travel paths of 1.33%, which was approximately twice as large as for Inland bears.

Despite the disparity in the percentage of home range area used (Fig. 6), movement extent was similar between areas (Fig. 7).

Fractal D **-** Path-level measures of fractal D ranged from 1.09-1.98. The cumulative weight of 3 of 12 a priori models of path-level fractal D was 97% (Table 2). The data were insufficient to distinguish between the top 2 models that included the number of moves and number of moves squared, respectively, as covariates, suggesting that the time an animal was tracked influenced path-level fractal D. The top 2 models also suggested that bear, bear reproductive condition, season, and bear by reproductive condition and bear by season interactions influenced path tortuosity as measured by overall fractal D (Fig. 8).

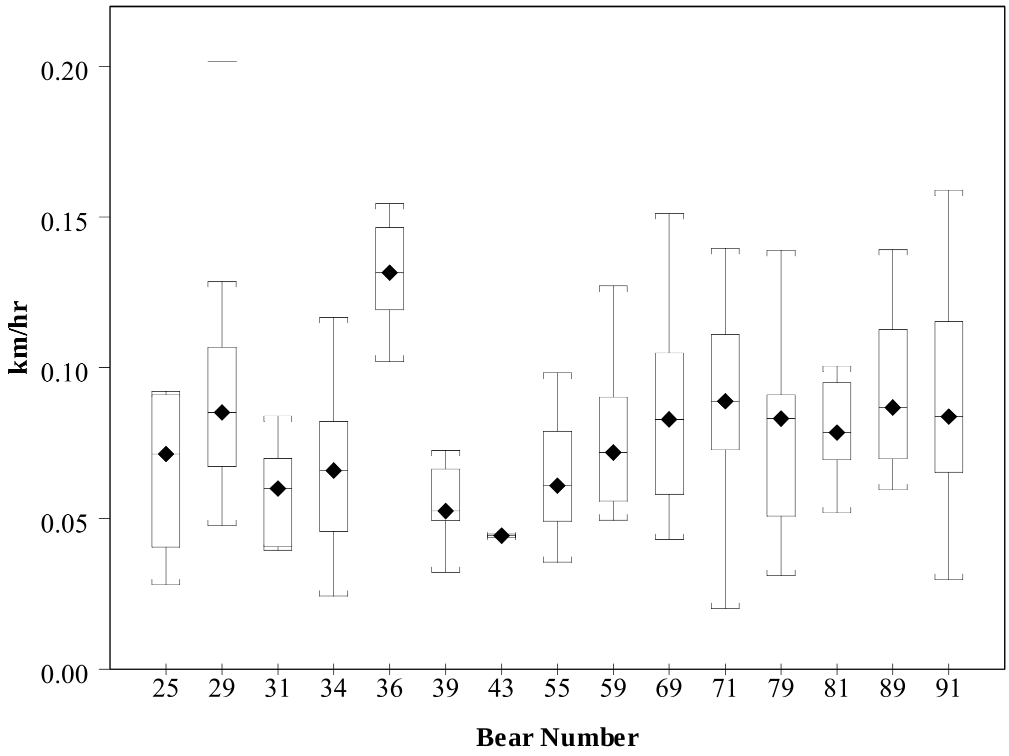

Figure 5. Distribution of fall/winter black bear movement rates (km/hr) in south central Louisiana (1995–96), by bear, with median (◆).

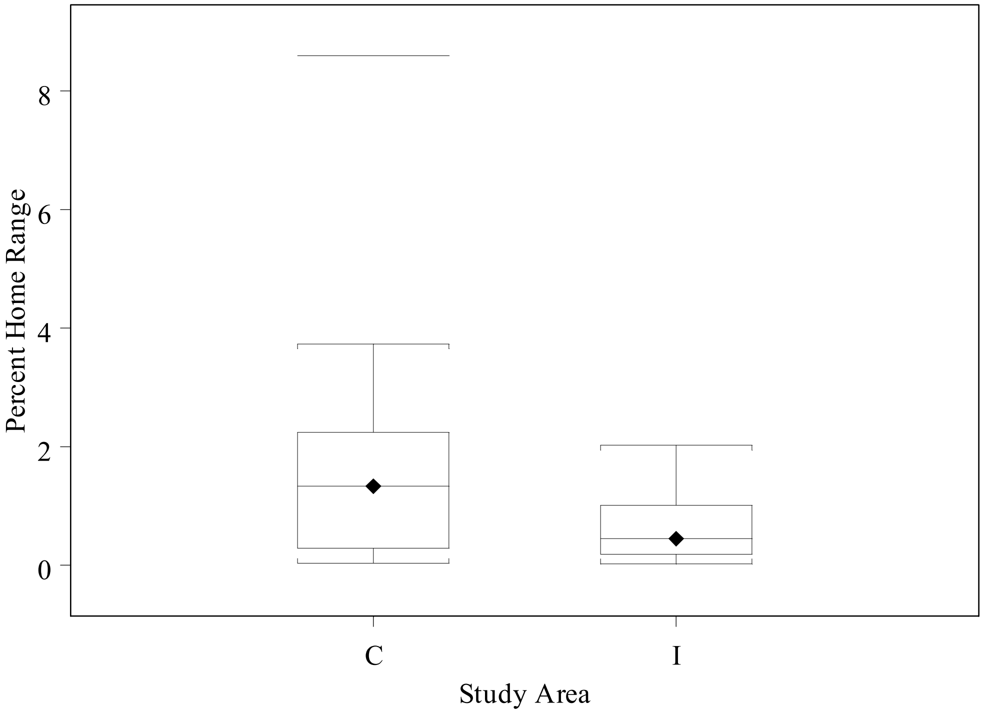

Figure 6. MCP area of female black bear travel paths (1995–96) in terms of percentage of average annual MCP home ranges from Wagner (1995) for Coastal (C) and Inland (I) female bears (median ◆).

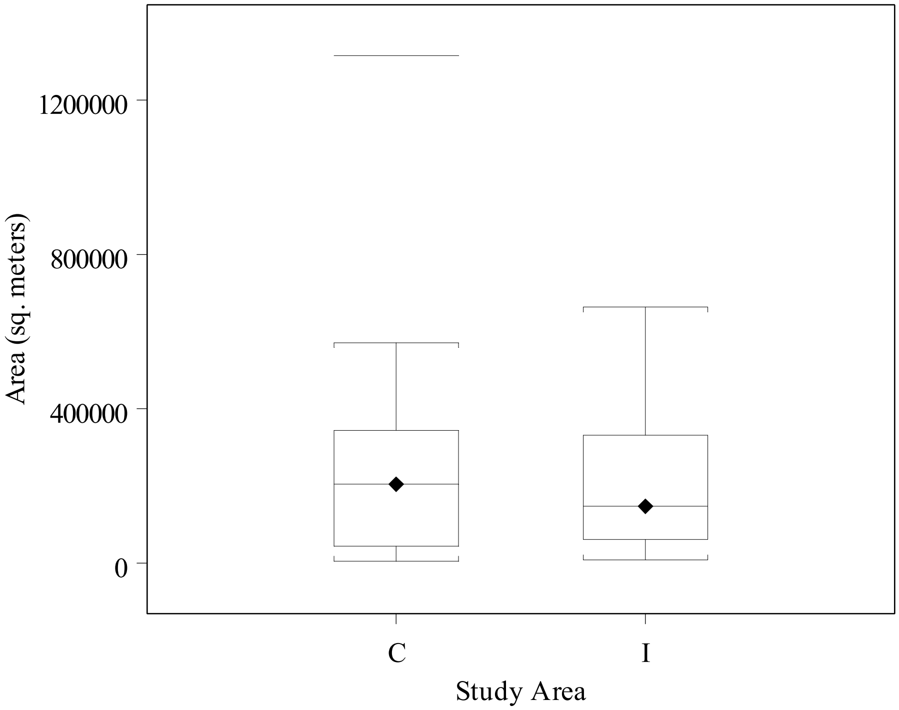

Figure 7. MCP area of female black bear travel paths in south central Louisiana (1995–96; median ◆).

Table 2. Number of model parameters (k), model deviance, model weights (w_i) and cumulative model weight ($\sum w_i$) of *a priori* models of overall fractal D of female black bear movement paths ranked using small sample corrected AIC (AIC$_c$). Three of 12 models received a weight $\geq$10 and are given.

Model	k	Deviance	AIC	AIC$_c$	ΔAIC$_c$	w_i	$\sum w_i$
Bear, ReproCond., Season, Bear* Season, Bear*ReproCond., #Moves^2	8	-90.70	-74.70	-69.90	0.00	0.50	0.50
Bear, ReproCond., Season, Bear* Season, Bear*ReproCond., #Moves	8	-90.10	-74.10	-69.30	0.60	0.37	0.87
Bear, ReproCond., Season, Bear* Season, Bear*ReproCond., #Moves, #Moves^2	9	-90.90	-72.90	-66.69	3.21	0.10	0.97

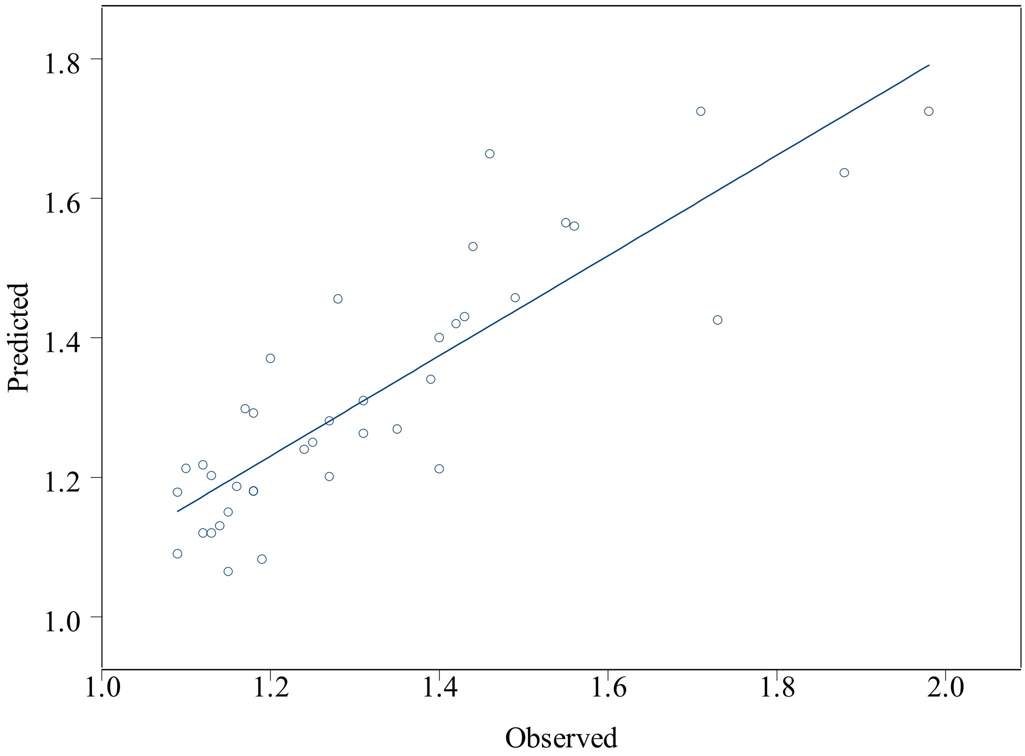

Figure 8. Observed versus best model predicted overall fractal D, selected using AIC$_c$, for female black bear movement paths (n=39) in south central Louisiana (1995–96).

Black bear movement paths were not statistically self-similar (i.e., fractal). Fractal D was not constant across spatial scales (i.e., divider sizes), but in many cases increased with measurement scale. Although the assumption of constant fractal D across scales, required for extrapolation of movement characteristics recorded at fine scales (Turchin 1996), was violated, my goal was only to measure path tortuosity over the range of scales given. Therefore, I did not consider violation of this assumption important for the test of tortuosity (With et al. 1999).

Correlations between cosines of the turning angle between successive moves provided evidence that, qualitatively, bears moved differently at different scales. I observed ≥1 significant correlations in 27 of 39 movement paths (Table 3). The majority of significant correlations were negative (81%), indicating that small angles were followed by large angles when the path was viewed at those scales. No relationship was evident between the time an animal was tracked and the number of significant correlations observed.

Table 3. Mean scale (± SE) at which the first through seventh significant correlations in the cosines of the turning angles were observed in black bear movement paths in south central Louisiana (1995–96).

Correlation	**Mean Scale (m)**	**#Paths**
1	60.63(19.22)	27
2	72.35(22.27)	20
3	82.07(31.81)	14
4	92.20(62.44)	5
5	97.00(76.00)	3
6	106.00(93.00)	3
7	112.00(256.00)	2

The scales at which I observed the first, second, and third correlations in the cosines of path turning angles were somewhat similar among movement paths (Fig. 9).

Low precision in estimated scales at which the fourth through seventh significant correlations in the cosines of the turning angles occurred was low because of low sample sizes.

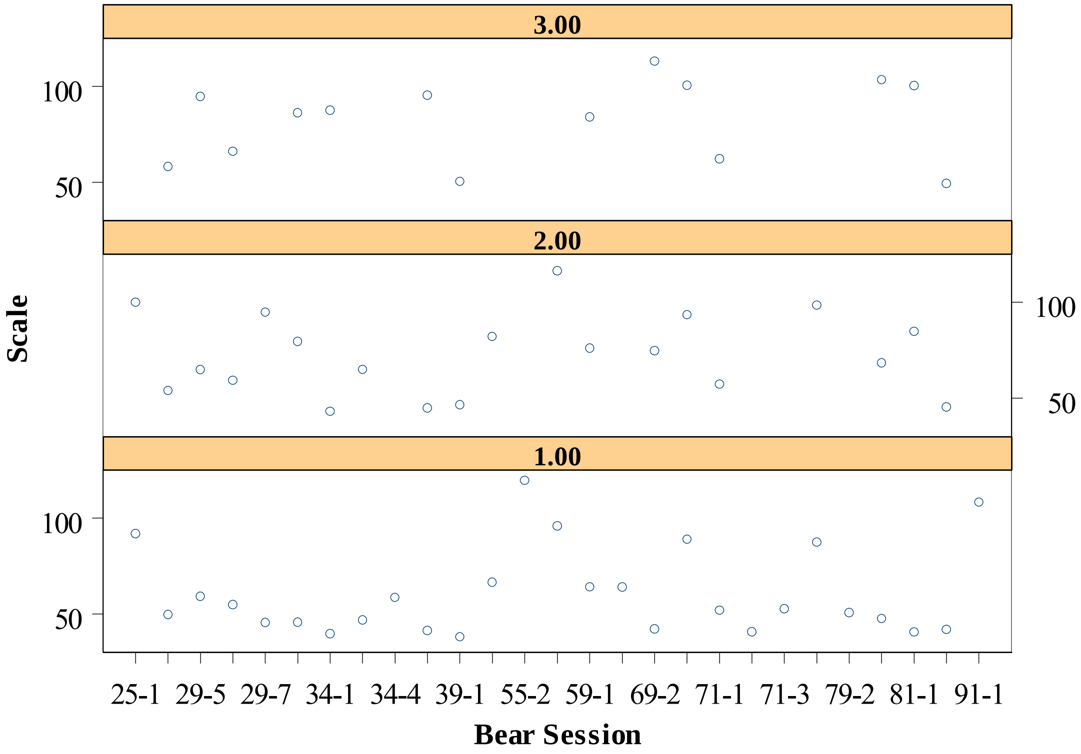

Figure 9. Scales at which the first, second, and third significant correlations were observed in the cosines of the turning angles of black bear movement paths in south central Louisiana (1995-96).

Net Distance - Net distance moved or the difference between the beginning point and subsequent points in bear movement paths varied among bears and sessions within bears (Appendix C). Because the average scales at which the first, second, and third significant correlations in the cosines of the turning angles occurred were similar, suggesting that these correlations represent the same break in the continuum of habitat scales perceived by bears, I selected the second (72m) as my cut-off to classify movement based on net displacement. Based on this criterion, I found movement in most paths consisted of concentrated movement, separated by bouts of directed movement. However, the percentage of paths accounted for by each movement strategy varied (Table 4). The mean percentage of paths characterized by concentrated and directed movement across bear-seasons was 50.8% and 49.2%, respectively, with a common standard error of 4.4%.

Table 4. Mean percentage of female black bear travel paths characterized by concentrated movement, by bear and season.

				Mean Pct.		
Bear#	**Season**	**N**	**Total Hours**	**Concentrated**	**Directed**	**SE**
25	Fall	1	3.1	50.00	50.00	
29	Fall	3	10.6	35.63	64.36	7.97
29	Winter	4	20.3	51.05	48.94	9.67
31	Fall	1	4.8	84.61	15.38	
34	Fall	2	12.5	40.33	59.66	16.42
34	Winter	3	17.7	85.30	14.69	3.66
36	Winter	1	5.2	18.33	81.66	
39	Fall	1	5.4	92.59	7.40	
43	Fall	1	2.1	63.15	36.84	
55	Fall	3	15.4	64.11	35.88	11.38
55	Winter	1	5.8	53.33	46.66	
59	Winter	2	11.6	57.50	42.50	17.50
69	Fall	3	17.8	43.59	56.40	15.74
71	Fall	4	20.3	36.59	63.40	7.93
71	Winter	1	6.3	53.42	46.57	
79	Fall	3	13.6	53.01	46.98	16.93
81	Fall	1	6.1	29.03	70.96	
89	Winter	2	11.2	35.00	64.99	12.05
91	Fall	1	4.9	24.44	75.55	
91	Winter	1	5.8	45.00	55.00	

I tested 6 *a priori* models of the percentage of bear travel paths accounted for by concentrated movement. Bear, season, and bear reproductive status were all important predictors of bear movement pattern (Table 5), and the selected model fit the data reasonably well (Fig. 10).

Table 5. Number of model parameters (k), model deviance, model weights (w_i) and cumulative model weight ($\sum w_i$) of *a priori* models of the percentage of concentrated movement within female black bear travel paths, ranked by small sample corrected AIC (AIC_c).

Model	k	Deviance	AIC	AICc	ΔAICc	w_i	$\sum w_i$
Bear, ReproCond., Season, Bear*Season, Bear*ReproCond.	7	310.10	324.10	327.71	0.00	0.45	0.45
Bear, ReproCond., Season, Bear*ReproCond.	6	313.90	325.90	328.53	0.81	0.30	0.75
Bear, ReproCond., Season, Bear*Season	6	316.10	328.10	330.73	3.01	0.10	0.86
Bear, ReproCond., Season	5	319.40	329.40	331.22	3.51	0.08	0.93
Bear, ReproCond., Season, Season*ReproCond., Bear*Season	7	315.00	329.00	332.61	4.90	0.04	0.97
Bear, ReproCond., ReproCond., Season*ReproCond.	6	318.70	330.70	333.33	5.61	0.03	1.00

DISCUSSION

Female black bears in the 2 study areas reduced their movement rate during winter, as expected. Wagner (1995) also noted smaller movements in winter in these two bear populations. A larger movement rate by females with young, however, was not expected. I caution interpretation of this result as it was based on a sample size of 2, but it suggests more study on the differences in fine-scaled spatial utilization between bears in differing reproductive conditions is warranted.

Short-term tracking data (e.g., movement path data) combined with annual home range data, suggest that Coastal bears can acquire life requisites within smaller areas than Inland bears. Movement extent (i.e., the amount of ground traversed) was similar among bears between areas, during 4-6 hour evening tracking sessions, but Coastal bears used a larger portion of the home range reported by Wagner (1995). Coastal bears were able to procure sufficient resources on an annual basis in a smaller area than Inland bears required, but needed to cover similar amounts of ground to meet their daily needs.

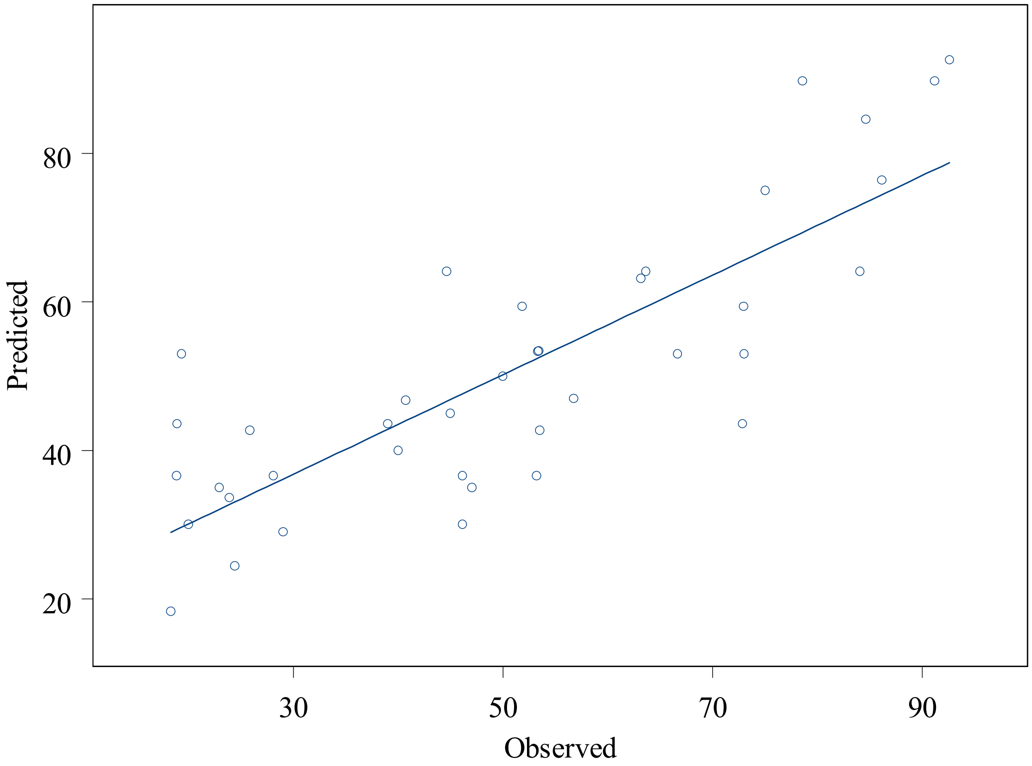

Figure 10. Predicted versus observed % of female black bear movement paths (n=39) in south central Louisiana (1995–96) with concentrated movement.

The majority of Coastal and Inland bear movement paths were a sequence of turns and accelerations that resulted in little displacement, suggesting intensive use of habitat patches. Bears tended to continue moving in the same direction or reverse direction however, a lack of serial correlation in the turning angle distributions of all but one treatment group indicated that there was no predictable pattern to their turning behavior. With almost equal probabilities of continuing in the same direction or reversing direction, the displacement of individuals through time was relatively small. In most paths where a short-term increase in net displacement with time was evident, a comparable decrease was observed, leading to a small net displacement between the beginning and ending points of the path. Thus, in the majority of paths, the bear's movements were either highly concentrated or patterned in a circular fashion resulting in a return to the area near the start of the path.

Within path movements also suggested that bears were using habitat patches. Based on my classification of net displacement, bears, on average, moved in a directed manner for brief periods and then confined their movements to a small area before moving directionally again, as would be expected if resources were patchily distributed. Estimates of overall path fractal D were below the expectation of purely random (i.e., Brownian) movement, suggesting at least periodic directionality. Correlations of the cosines of movement path turning angles also suggested that tracked bears used habitat patches at ≤ 7 scales. However, contrary to my hypothesis of larger patch sizes in the Inland area, there were no differences apparent between study areas in the scales at which bears viewed their habitats. Upon inspection, the travel paths that I sampled for Inland bears failed to capture the among-patch movements (e.g., among forest blocks separated by large agricultural areas) that seemed evident in annual home range data examined by Wagner (1995). This may have been due to the infrequency of patch to patch moves, time of day when between patch movements were made, or time of year when between patch movements were made, relative to the timing of my sampling.

The activities of tracked bears during tracking sessions were unknown. However, the turning behavior and low net displacement suggests that the bears were searching for resources within restricted areas. During fall and winter, oak mast, an important fall food resource of black bears in the eastern U.S. (Landers et al. 1979, Clark et al. 1987, Hellgren and Vaughan 1988) and within my study areas, occurred in high concentrations in groves of oak trees. Bears may have been feeding in these groves or utilizing some other concentrated resource.

Because of the great variability within and among bears, I included bears in my models of path-level fractal D, which precluded me from directly testing for the influence of study area (bears nested within study areas). Although I could not directly test my hypothesis of lower path-level fractal D for Inland bears, analyses of net distance traveled and turning angle distributions did not support it. The variability among bears within areas appeared to be as great as between areas.

Black bears in south central Louisiana may use a number of movement strategies. Movement paths recorded on individuals were varied, but seemed to represent within and between patch movements. Based on the observed Fractal D values, they were not moving completely randomly, but were not overtly directed. It seemed that they moved "randomly with direction" and that the correlation in movement direction was not constant, but occasional. If the scale at which bear resources are distributed within the landscape were known, then paths could potentially be more precisely dissected into within and between patch movements and a clear set of rules governing their movement defined.

CHAPTER II: FEMALE BLACK BEAR HABITAT USE AND RESPONSE TO ANTHROPOMORPHIC FEATURES

BACKGROUND AND MOTIVATION

One of the objectives in most autecological studies is to determine habitats and habitat characteristics most important or limiting to the species. Knowledge of habitat preferences is critical to formulating appropriate management plans. Studies of seasonal black bear habitat use, as well as the distribution of bear food resources within habitats (Nyland and Pace 1997), have been completed for some areas in the southeastern U.S. (Hellgren et al. 1991), including Louisiana (Nyland 1995).

However, locations in seasonal habitat use studies are generally gathered $\geq$24 hours apart and may fail to capture habitat use during periods when bears are active. Finer-scaled descriptions of habitats used by bears during movement bouts, such as the movement path data that I recorded, incorporate time spent within each habitat during a movement bout into analyses of habitat use. I evaluated female black bear habitat use using intensive tracking data to determine if habitat use differed between the Inland and Coastal populations and if bears use or avoidance of anthropomorphic features in the landscape.

METHODS

I modified a version of the Louisiana GAP map, a land use/land cover GIS coverage, as the habitat map for my analysis (Hartley et al. 2000). The Louisiana GAP map was developed using Landsat 5 Thematic Mapper satellite imagery collected between 29 November 1992 and 7 March 1993, botanical surveys, color infrared aerial photography, and existing coastal Louisiana habitat maps produced by the U.S. Fish and

Wildlife Service's National Wetlands Inventory. I selected this coverage for my analysis because the vegetation layer was readily available in electronic form (raster format) and the delineated vegetation types were loosely analogous to habitats identified by Nyland and Pace (1997; Table 6).

Table 6. Estimated hectares and percent of study area within each Louisiana GAP land use/land cover type, and roads and trails in the Coastal and Inland study areas in south central Louisiana.

	Coastal		**Inland**	
Land use/Land cover	**Hectares**	**Percent of Study Area**	**Hectares**	**Percent of Study Area**
Fresh Marsh	37997.2	14.2	0.0	0.0
Intermediate Marsh	1089.3	0.4	0.0	0.0
Wetland Forest-Deciduous	35203.4	13.1	23511.7	47.8
Wetland Forest-Mixed	499.7	0.2	0.0	0.0
Upland Forest-Deciduous	329.0	0.1	0.0	0.0
Upland Forest-Evergreen	1.3	<1.0	0.0	0.0
Upland Forest-Mixed	1114.4	0.4	0.0	0.0
Wetland Scrub/Shrub-Deciduous	4924.9	1.8	51.4	<1.0
Wetland Scrub/Shrub-Evergreen	19.4	<1.0	0.0	0.0
Wetland Scrub/Shrub-Mixed	69.0	<1.0	219.0	<1.0
Agriculture-Cropland-Grassland	20909.7	7.8	20445.9	41.5
Vegetated Urban	2880.1	1.1	0.0	0.0
Non-vegetated Urban	40.1	<1.0	0.0	0.0
Wetland Barren	53.1	<1.0	0.0	0.0
Upland Barren	9.1	<1.0	0.0	0.0
Water	162737.8	60.7	3843.6	7.8
Woods Trail	0.0	0.0	600.1	1.2
Road	162.1	0.1	545.2	1.1

Anthropomorphic features identified in the map included agriculture fields and urban areas. To include roads and trails as part of my habitat map, I overlaid onto the GAP map a coverage of buffered roads and trails based on a digital line graph file of roads and trails digitized from USGS 1:100,000 topographic quadrangles by the

Louisiana Department of Environmental Quality and made available through the Louisiana Oil Spill Contingency Plan Map CD issued in 1996. I buffered roads by 50m and trails by 25m. Because of small sample sizes (i.e., 39 movement paths), I reduced the number of vegetative classes considered in the analysis of habitat use by reclassifying the 3-wetland forest types (wetland forest – deciduous and wetland forest - mixed) into one category, wetland forest. I reclassified upland forest and wetland scrub/shrub habitats in a like manner. I also reclassified fresh, brackish, and intermediate marshes into marsh. After map reclassification, a total of 6 and 4 habitat types in the Coastal and Inland areas, respectively, were considered (Figs. 11, 12). All anthropomorphic features outlined above were treated as habitat types in the analysis.

I estimated bear locations by triangulating azimuths obtained during radio tracking sessions using a 10-minute moving window as described in Chapter I. Estimating habitat use from these locations required consideration of the measurement or triangulation error (Samuel and Kenow 1992). If the bear's true location were in a different habitat than the estimated location then estimates of habitat use could be biased. To account for measurement error in animal locations, I used the program SUBSAMPL (Kenow et al. 2001) to calculate the 95% confidence ellipse around each estimated animal location using the overall bearing standard deviation described in Chapter I (2.09) and the maximum likelihood procedures of Lenth (1981). To estimate habitat use, I used SUBSAMPL to generate a random subsample of 100 locations within the confidence ellipse of each location estimate from a bivariate normal distribution constructed from the variance-covariance matrix of the confidence ellipse (Kenow et al. 2001). Habitat use for each estimated bear location was the number of subsample points/location/habitat type. I excluded subsample points in water. Hence, the number of subsample points per location estimate was <100 in some cases. To estimate habitat availability, I buffered the subsample points within each movement path by the 90th percentile distance moved between location estimates taken 5 minutes apart. Because of differences in bear movement rates, I calculated the 90th percentile distance within bears for buffer generation (range 26m–278m). I scaled the buffer to reflect the time elapsed between locations. For example, if the mean 5-minute move distance was 88 m then the buffer distance for consecutive position estimates 10 minutes apart would be 176 m, and at 15 minutes apart 264 m. Using ArcView® (Environmental Systems Research Institute, Inc., Redlands, California, USA), I merged the subsample point buffers within bear location estimates and estimated habitat availability by determining the percentage of each habitat type within the merged buffer (Fig. 13). Portions of buffers over water were excluded from calculations of available habitat.

I ranked habitats used and available for each estimated bear location and summed the ranks within movement paths. I used within path sums and the program PREFER (Pankraz, C., Northern Prairie Science Center, Jamestown, North Dakota, USA, http://www.npwrc.usgs.gov/resource/tools/software/prefer.htm, Accessed 23 March 2002) to calculate habitat preference for each study area separately using Johnson's method (Johnson 1980; alpha=0.10). I made pairwise comparisons between habitats with the Waller-Duncan multiple comparison procedure (k=100, alpha≈0.05). I selected Johnson's method to examine habitat preference because repeated observations on individual animals are not required to be independent and the method is relatively insensitive to imprecise estimates of habitat availability (Alldredge and Ratti 1992).

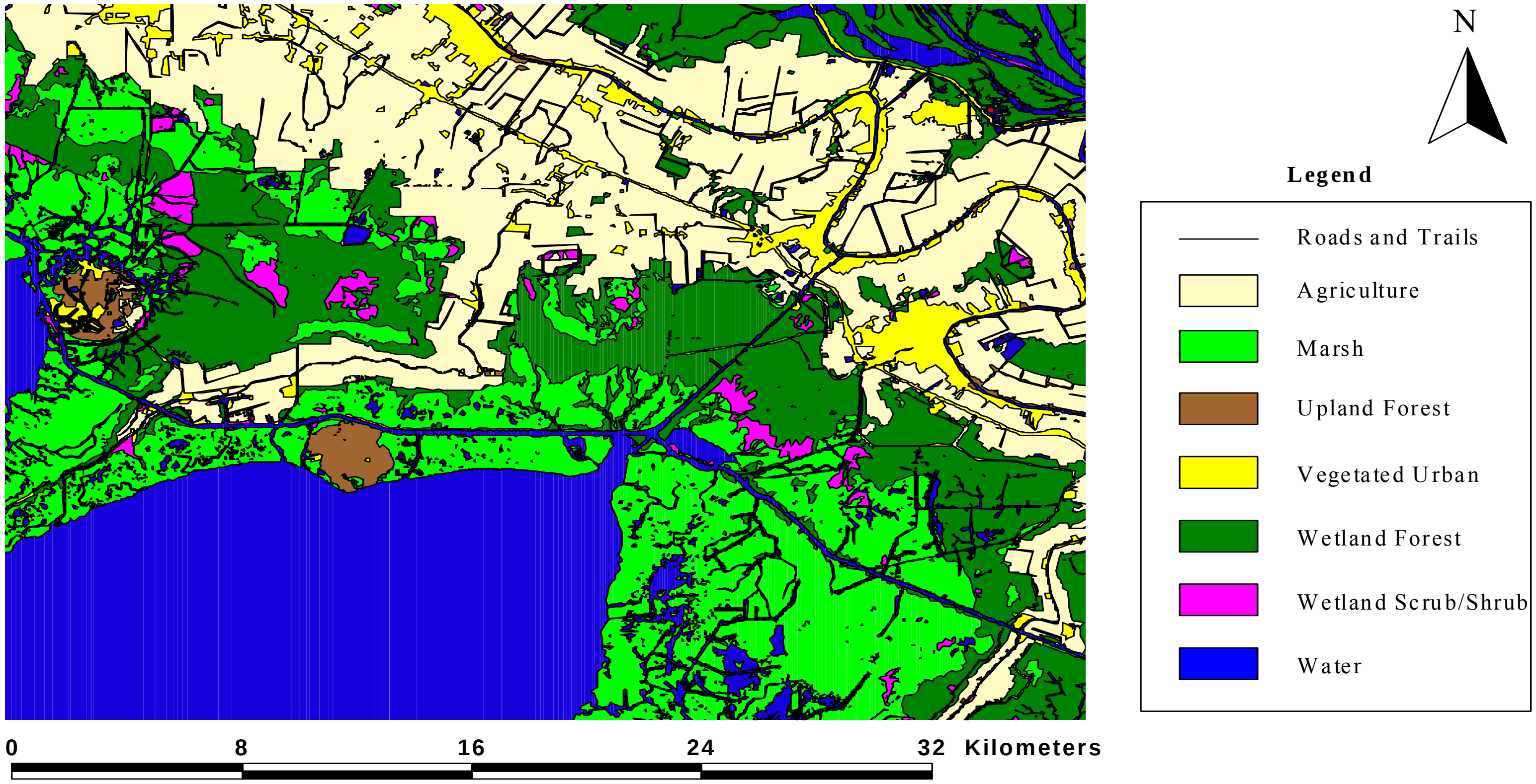

Figure 11. Coastal land use/land cover from the Louisiana GAP map (Hartley et al. 2000) aggregated into marsh, upland forest, wetland forest, and wetland scrub/shrub habitats. Patches of wetland barren, upland barren, and non-vegetated urban were too small to be observed at the map scale and, thus, were excluded from the map legend.

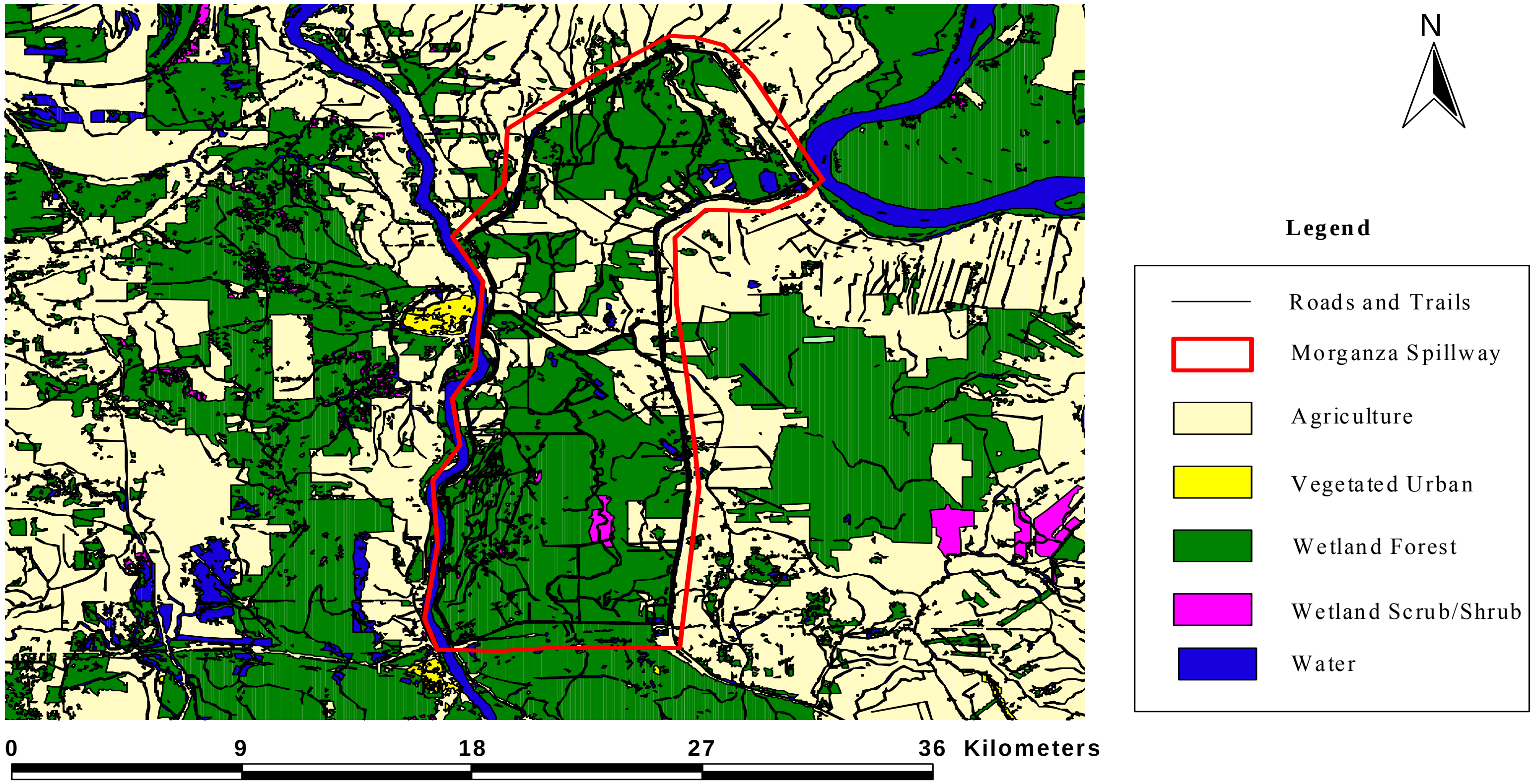

Figure 12. Inland study area land use/land cover from the Louisiana GAP map (Hartley et al. 2000) with wetland scrub/shrub habitats aggregated.

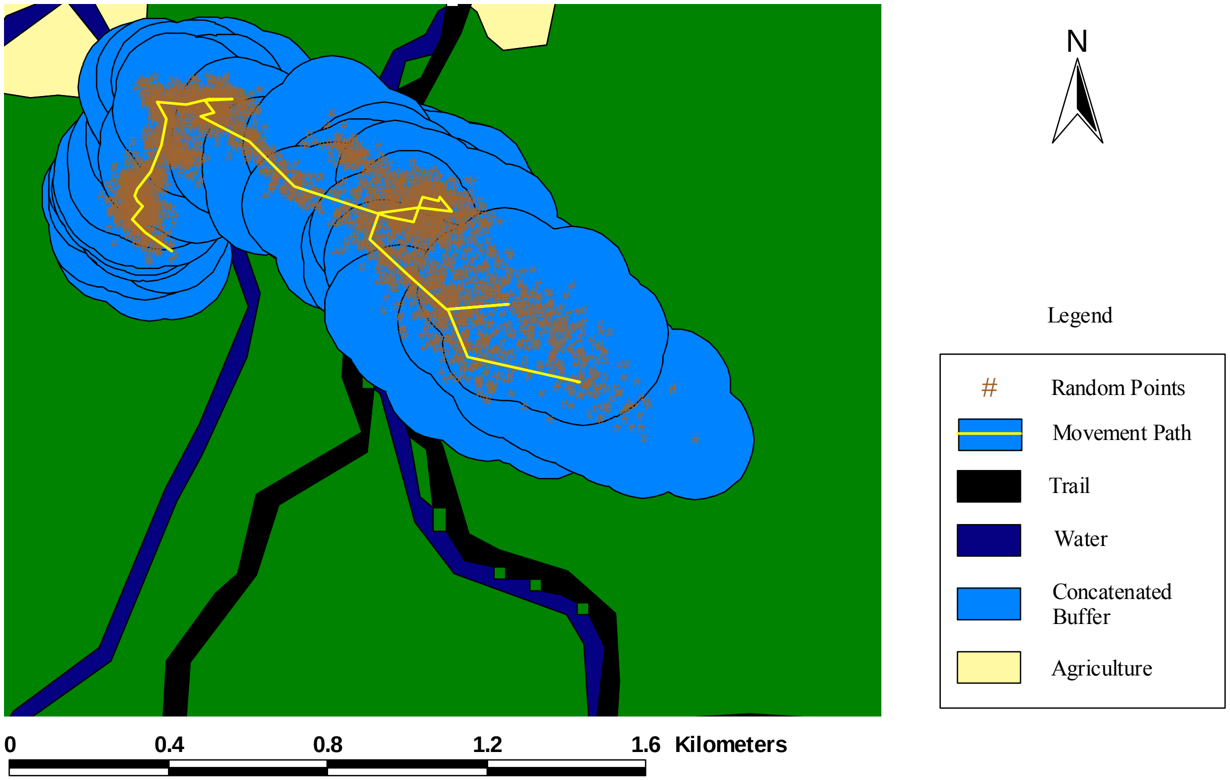

Figure 13. Black bear movement path recorded in south central Louisiana (1995–96) with 100 random subsample points and concatenated subsample point buffers.

RESULTS

No statistically significant habitat preferences were detected in the Inland ($F_{4,17}$=1.83, P=0.17) or Coastal ($F_{8,6}$=1.33, P>0.25) areas. I detected no avoidance of anthropomorphic features by bears in either study area. Due to small sample sizes, the power of these tests was low and caution should be used interpreting these results.

DISCUSSION

I failed to detect habitat preferences for female bears in the Inland or Coastal area, suggesting that all available habitats were used in proportion to availability. I also failed to detect avoidance of or attraction to trails and roads by study bears in either area. However, my habitat map was coarse and bears may have been selecting habitats at scales below the resolution of the mapped habitats.

Coastal bears on Weeks Island, a salt dome near the western edge of the populations known range where most tracking sessions in the area were conducted, had an active salt mine, yet bears frequently entered the mine complex during tracking sessions. Dumpsters containing food waste were available to bears at the site. According to my tracking data, Inland bears frequently used areas surrounding roads and trails. However, the roads within the Inland study area were gravel and traffic volume was generally low throughout the year, excluding logging operations, which resulted in high intensity, concentrated use of areas. In all cases, traffic on those roads was nearly absent during tracking sessions.

The roads most closely associated with bear locations were on top of the guide levee’s surrounding the Morganza Spillway. Most bear tracking in the Inland area took place from the levee’s, but I had the ability to track bears throughout the spillway.

Tracking from levees did not limit my sample to animals near levees. Human use of the study area was highest during the seasons considered in this study, which coincided with the squirrel and white-tailed deer hunting seasons. These results suggest that even at peak use of the area, bears continued to use habitats adjacent to roads and trails, but not coincident with humans.

My results are consistent with the findings of Carr and Pelton (1984) and Hellgren et al. (1991) for an unhunted bear population in Tennessee and Virginia-North Carolina, respectively, and Unsworth et al. (1989) for a hunted population in Idaho. They found that bears used roads and trails for foraging and as travel corridors. Although study animals used habitats adjacent to roads and trails, the timing of the tracking sessions may have influenced my results. At least one-half of most tracking sessions occurred after dark when bears may use roads and trails with a low probability of encountering traffic. Although I detected no avoidance of roads by bears, major roads were a hazard for bears in the Coastal area. Between 1992 and 2000, 17 of 49 (35%) recorded bear deaths in the Coastal area were attributed to vehicular collisions (Pace et al. 2000).

I failed to detect preference or avoidance of agricultural fields by bears in either study area. I observed evidence of bear use (e.g., tracks and scat) of agricultural fields in both study areas during summer and in the Coastal area during fall and winter. Most of the Inland crops (primarily corn during this study) were harvested before the beginning of my field season, but the primary crop in the Coastal area, sugarcane, was available. Nyland (1995) detected a preference for agricultural fields by bears in the Coastal area during fall. Small sample sizes and reduced the power of my tests of habitat use and may have resulted in my failure to detect a preference for agricultural fields during fall in the Coastal area.

Based on intensive radio tracking data, bears in south central Louisiana did not show habitat preferences, nor did they show an aversion to anthropomorphic features within the landscape in fall. In fact, the movements of bears during evening hours seemed uninfluenced by the diurnal activities of humans. Because of the potential for bear-human conflicts near anthropomorphic features, further research on bear use of these areas is warranted.

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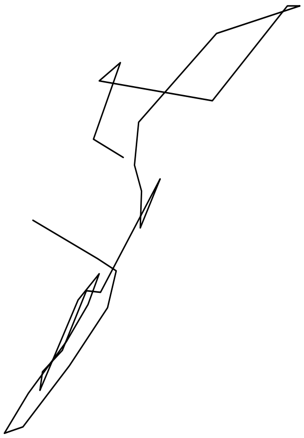
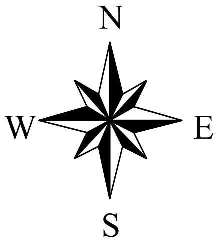
APPENDIX A: FEMALE BLACK BEAR MOVEMENT PATHS

Figures of female black bear movement paths on the following pages were grouped according to the scale at which path detail was still visible. Because of the variability in length and area covered of movement paths, I did not plot them all at the same scale. I used scales: 1:3300, 1:7000, 1:11850, 1:15500, and 1:21225.

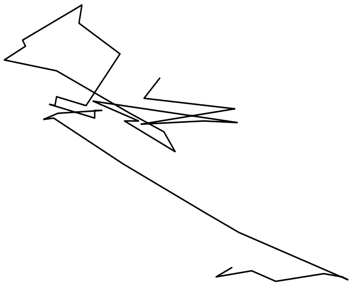
29-1



Condition: Solitary
Season: Fall 1995
Study Area: Inland
Duration: 2.5hrs
Speed: 0.46km/hr
Fractal D: 1.08

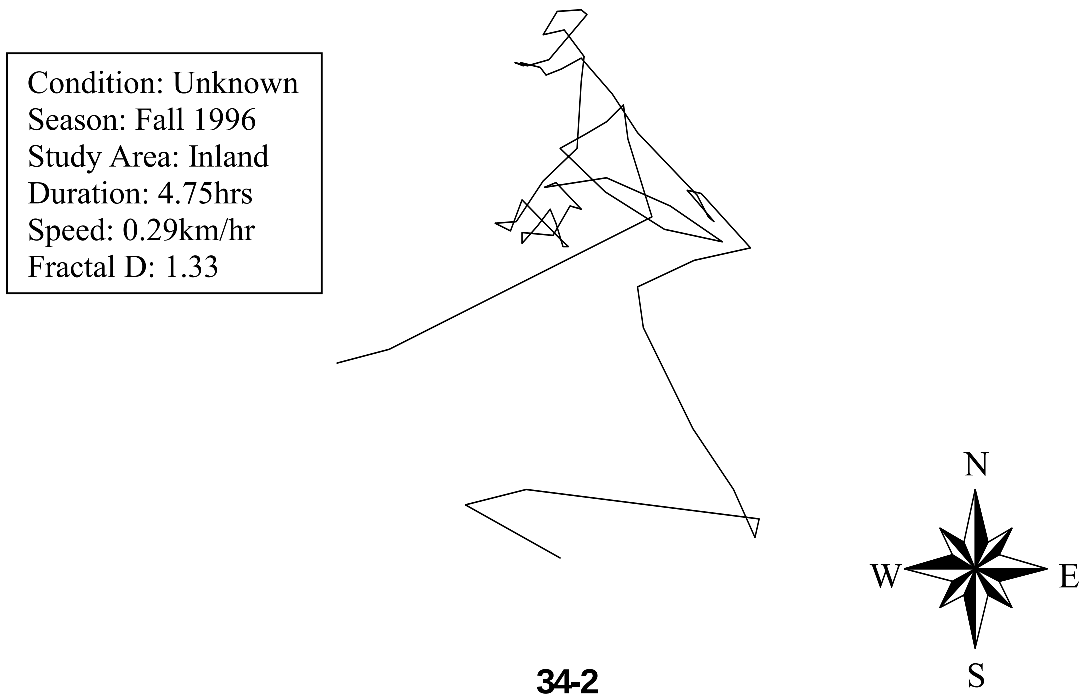


29-3



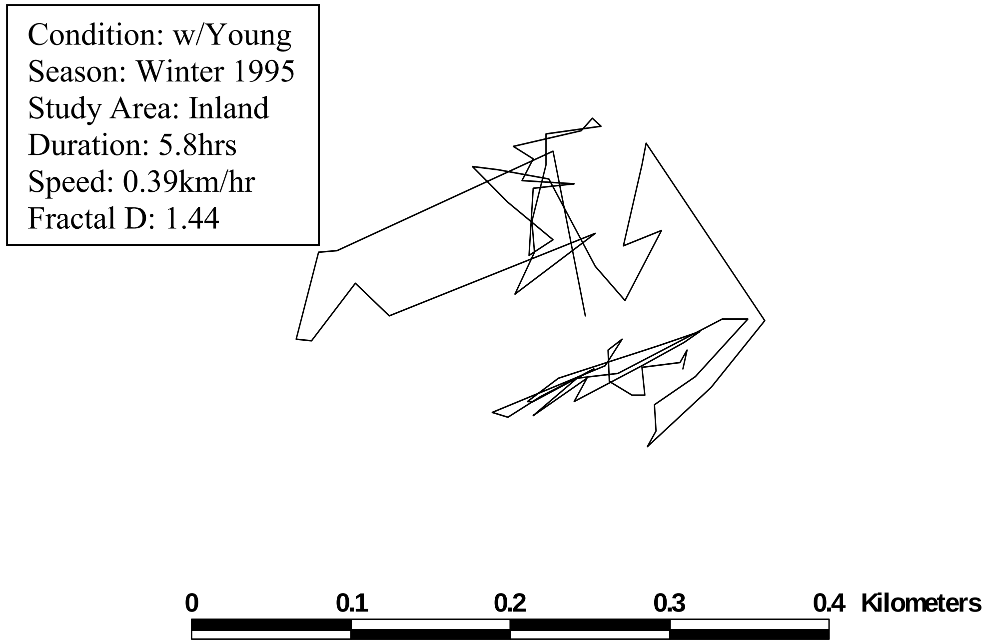
Condition: Solitary
Season: Winter 1995
Study Area: Inland
Duration: 5.8hrs
Speed: 0.30km/hr
Fractal D: 1.48

31-1

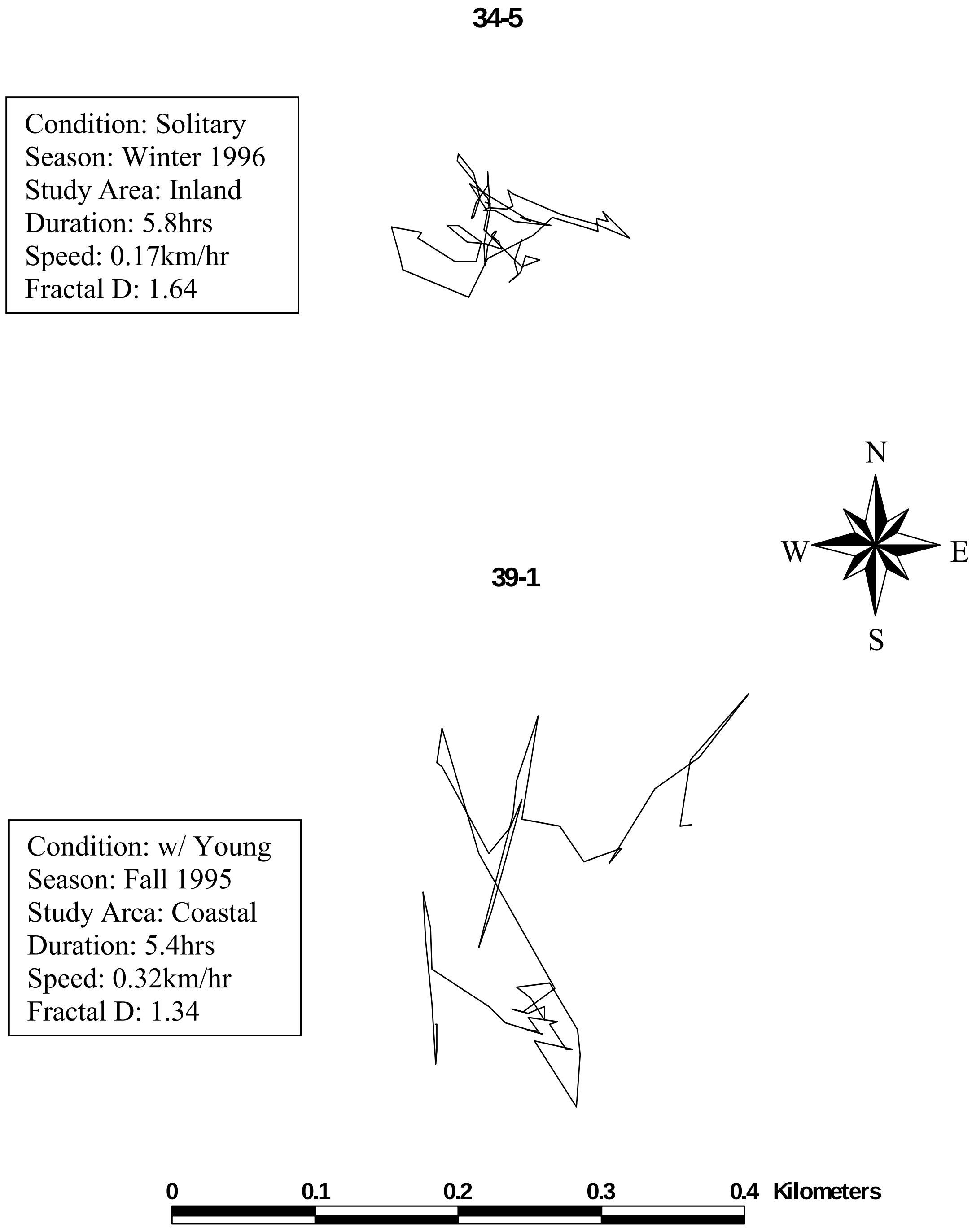


Condition: Unknown
Season: Fall 1996
Study Area: Inland
Duration: 4.75hrs
Speed: 0.29km/hr
Fractal D: 1.33

34-2



Condition: w/Young
Season: Winter 1995
Study Area: Inland
Duration: 5.8hrs
Speed: 0.39km/hr
Fractal D: 1.44

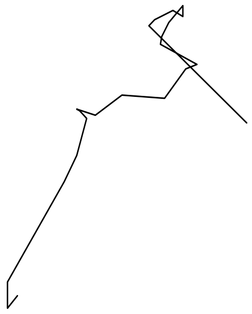


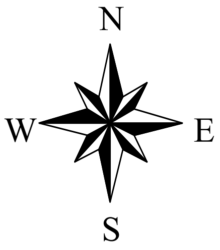
Condition: Solitary
Season: Winter 1996
Study Area: Inland
Duration: 5.8hrs
Speed: 0.17km/hr
Fractal D: 1.64

Condition: w/ Young
Season: Fall 1995
Study Area: Coastal
Duration: 5.4hrs
Speed: 0.32km/hr
Fractal D: 1.34

43-1

Condition: Solitary
Season: Fall 1996
Study Area: Coastal
Duration: 2.1hrs
Speed: 0.20km/hr
Fractal D: 1.18

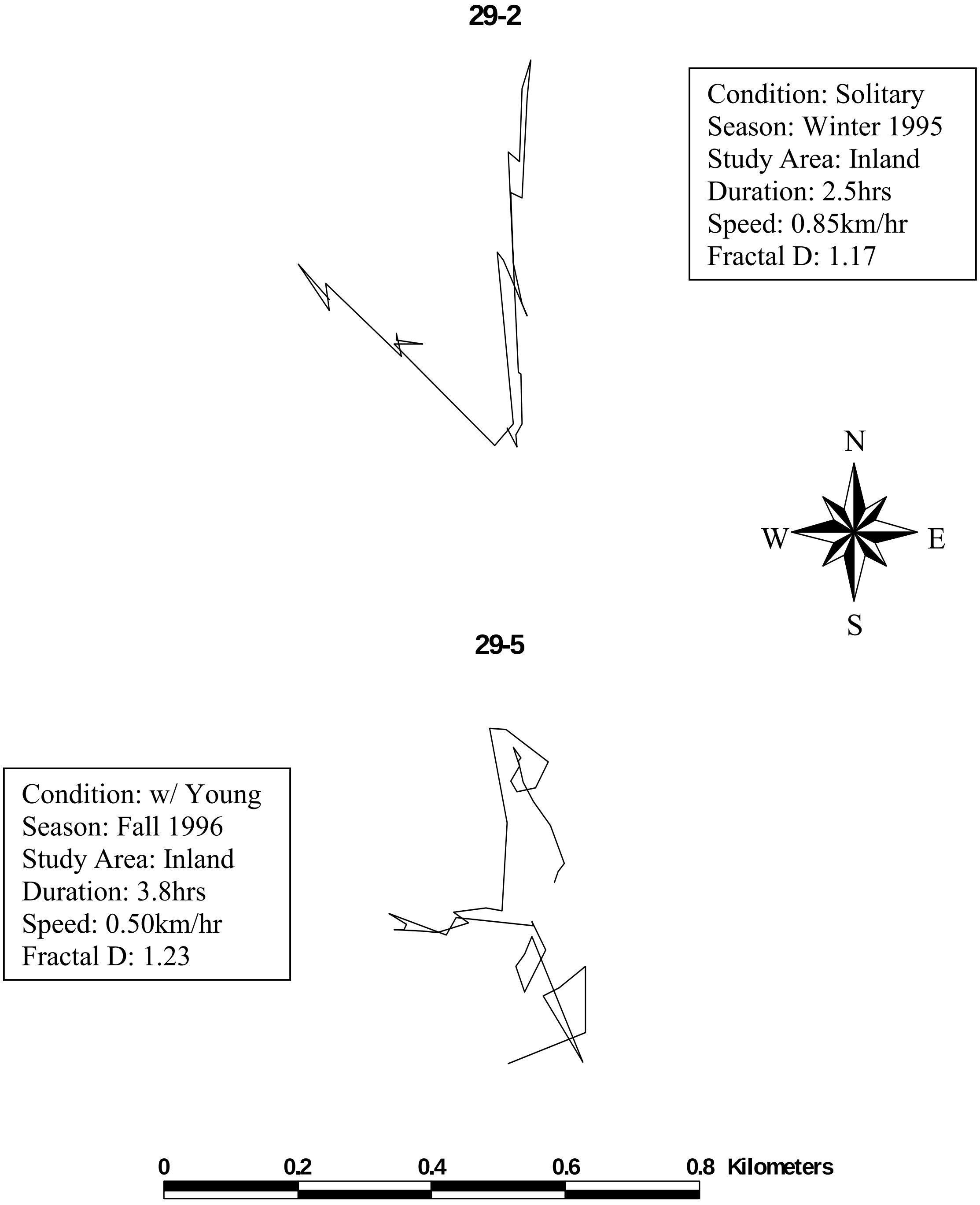




55-3

Condition: Unknown
Season: Fall 1996
Study Area: Coastal
Duration: 5.9hrs
Speed: 0.20km/hr
Fractal D: 1.69

Movement paths plotted at scale 1:7000.

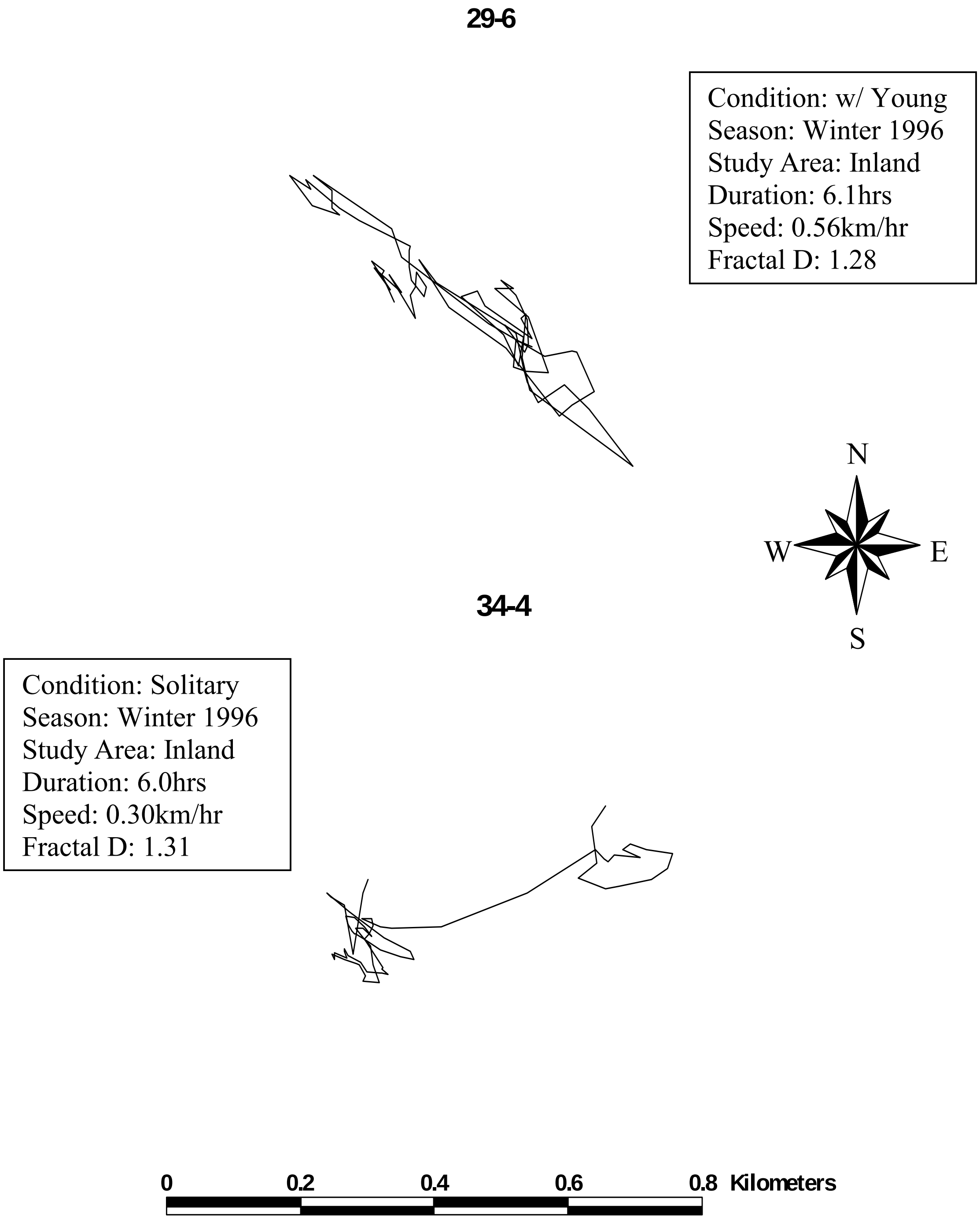


29-2

Condition: Solitary
Season: Winter 1995
Study Area: Inland
Duration: 2.5hrs
Speed: 0.85km/hr
Fractal D: 1.17

29-5

Condition: w/ Young
Season: Fall 1996
Study Area: Inland
Duration: 3.8hrs
Speed: 0.50km/hr
Fractal D: 1.23



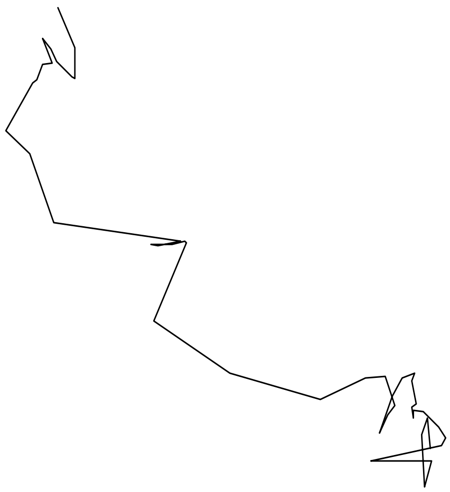
29-6

Condition: w/ Young
Season: Winter 1996
Study Area: Inland
Duration: 6.1hrs
Speed: 0.56km/hr
Fractal D: 1.28

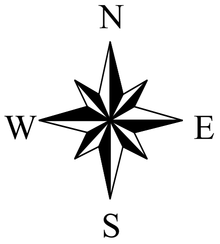
34-4

Condition: Solitary
Season: Winter 1996
Study Area: Inland
Duration: 6.0hrs
Speed: 0.30km/hr
Fractal D: 1.31

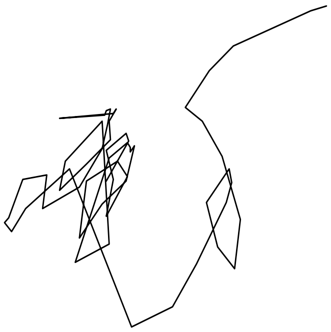
55-2



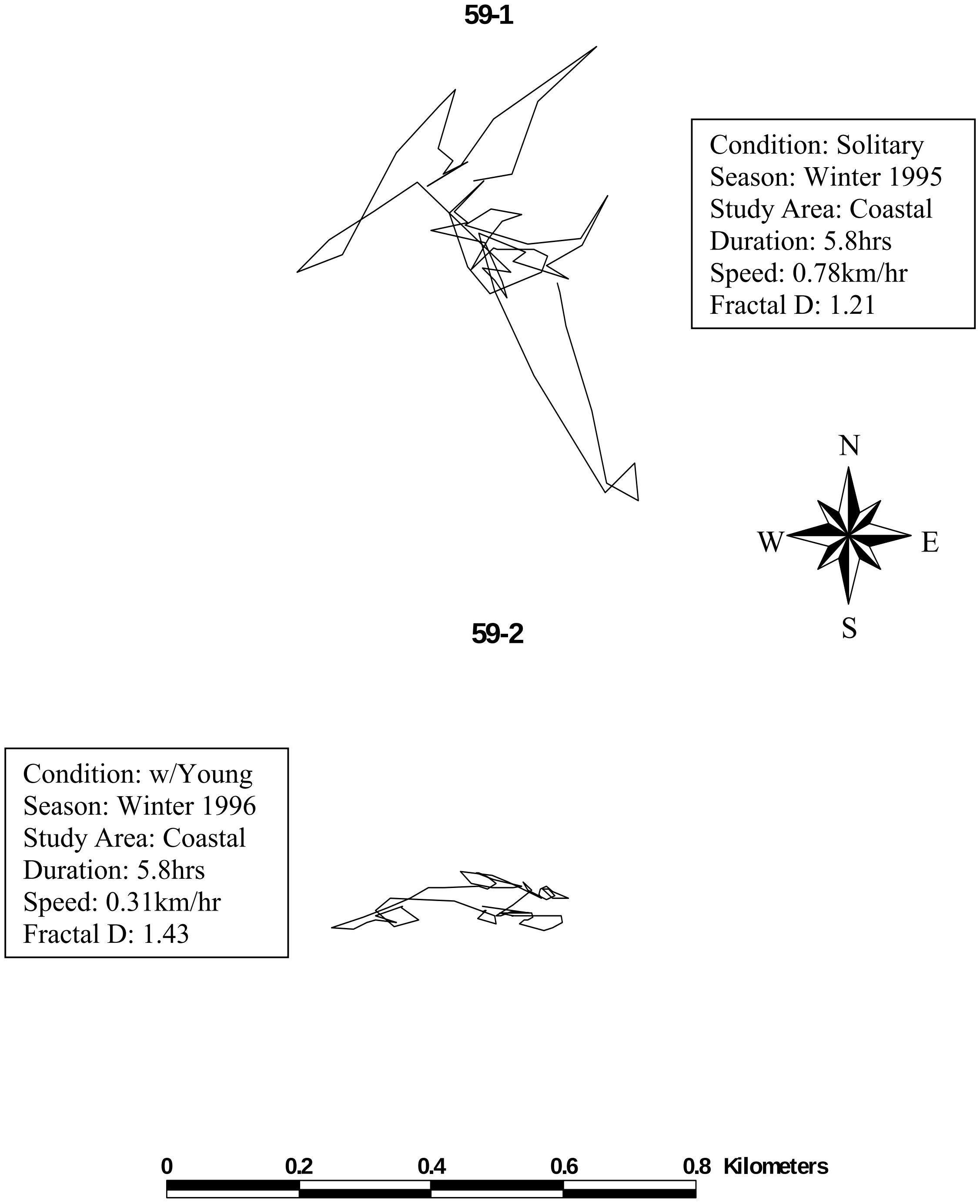
Condition: Unknown
Season: Fall 1996
Study Area: Coastal
Duration: 4.0hrs
Speed: 0.42km/hr
Fractal D: 1.24



55-4



Condition: Unknown
Season: Fall 1996
Study Area: Coastal
Duration: 5.5hrs
Speed: 0.46km/hr
Fractal D: 1.31

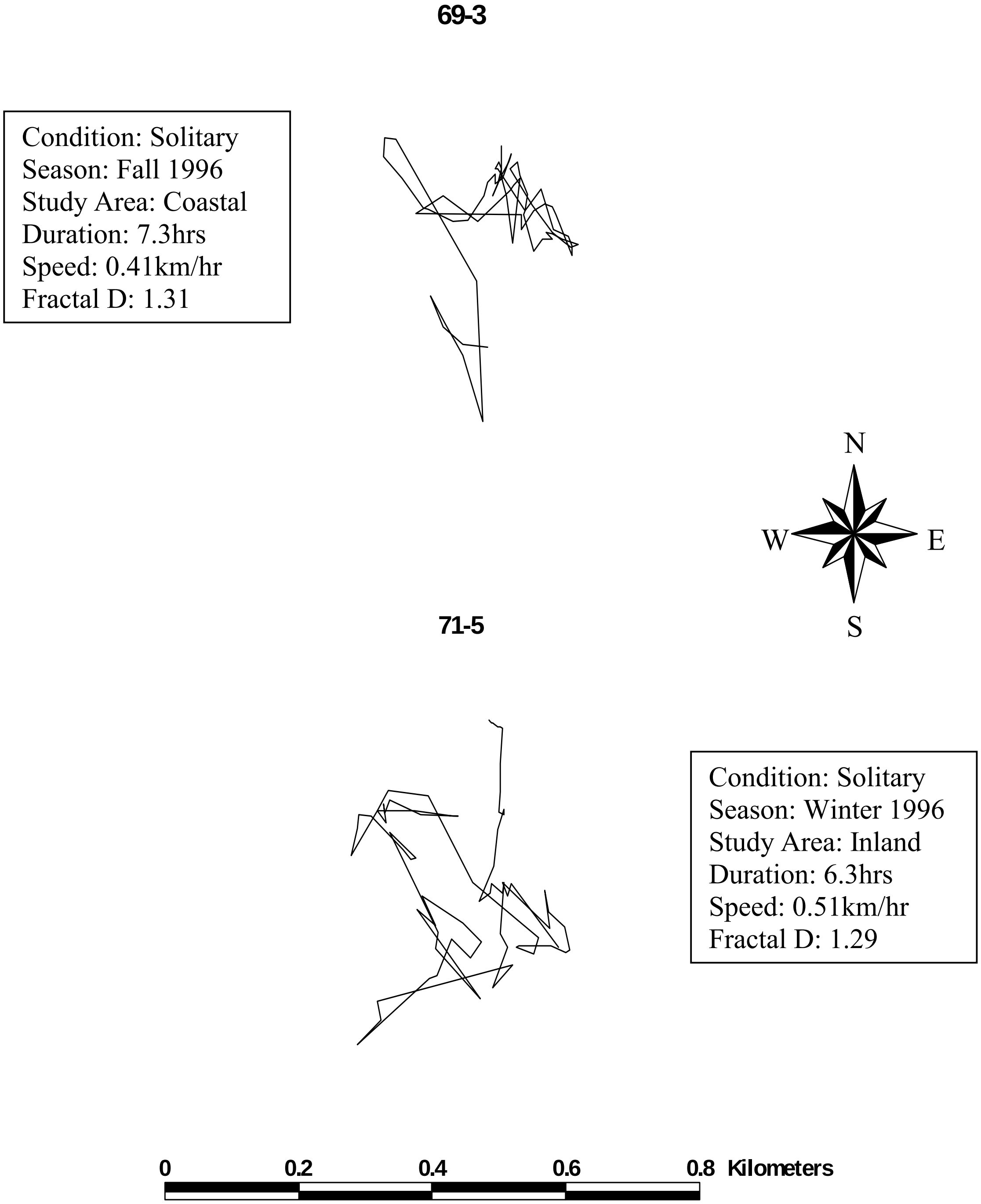


59-1

Condition: Solitary
Season: Winter 1995
Study Area: Coastal
Duration: 5.8hrs
Speed: 0.78km/hr
Fractal D: 1.21

59-2

Condition: w/Young
Season: Winter 1996
Study Area: Coastal
Duration: 5.8hrs
Speed: 0.31km/hr
Fractal D: 1.43



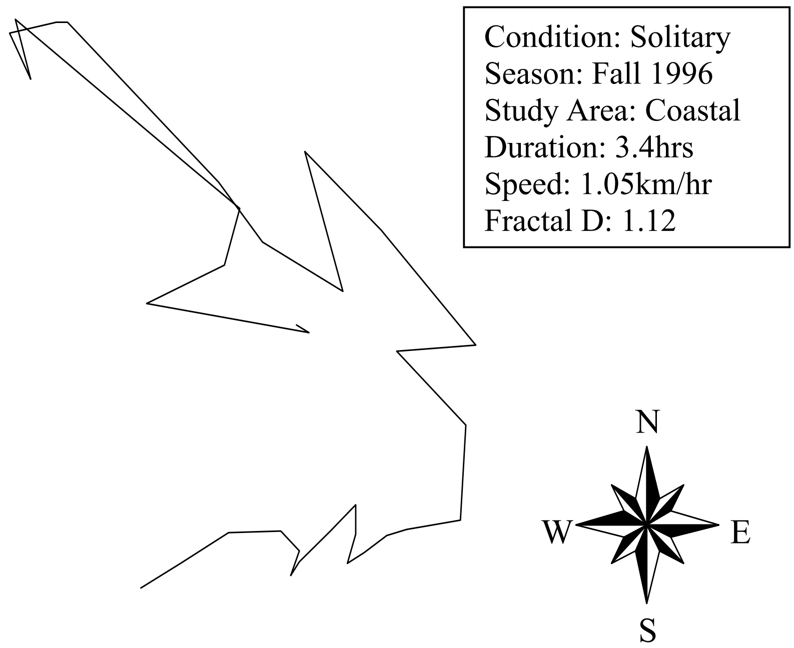
69-3

Condition: Solitary
Season: Fall 1996
Study Area: Coastal
Duration: 7.3hrs
Speed: 0.41km/hr
Fractal D: 1.31

71-5

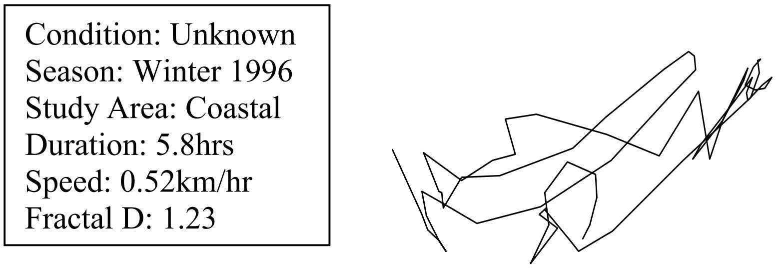
Condition: Solitary
Season: Winter 1996
Study Area: Inland
Duration: 6.3hrs
Speed: 0.51km/hr
Fractal D: 1.29

79-1



Condition: Solitary
Season: Fall 1996
Study Area: Coastal
Duration: 3.4hrs
Speed: 1.05km/hr
Fractal D: 1.12

89-1

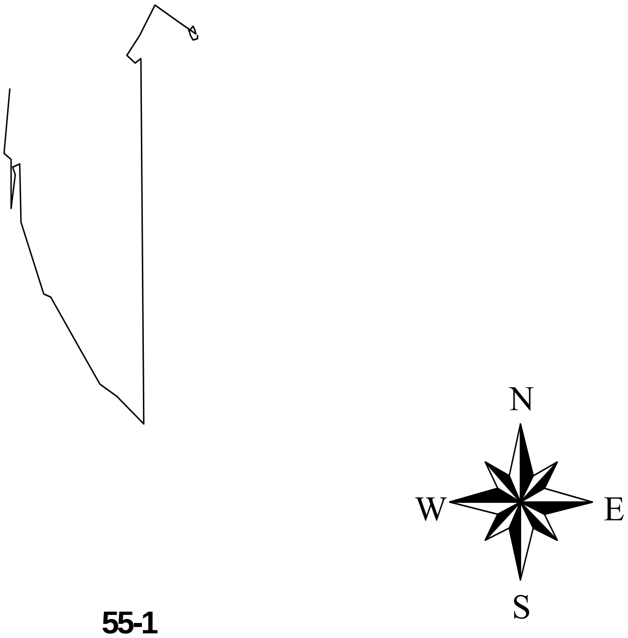


Condition: Unknown
Season: Winter 1996
Study Area: Coastal
Duration: 5.8hrs
Speed: 0.52km/hr
Fractal D: 1.23

Movement paths plotted at scale 1:11,850

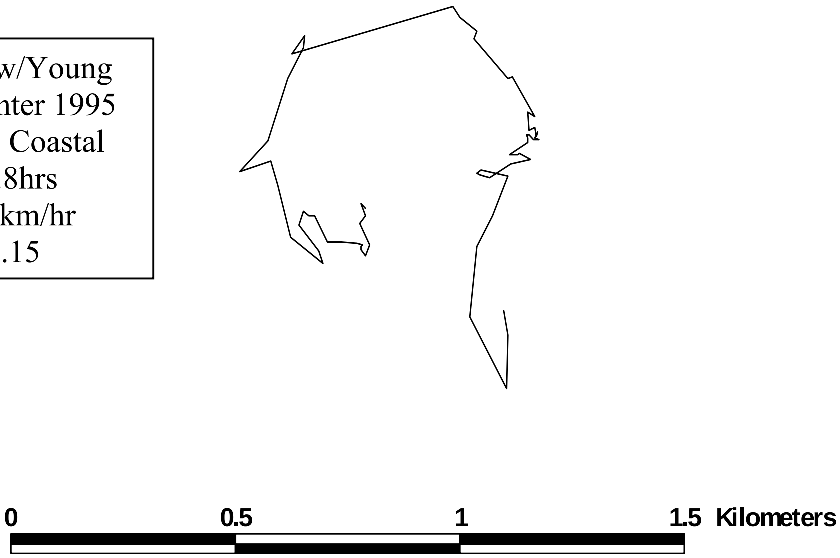
55-1

Condition: Solitary
Season: Fall 1995
Study Area: Inland
Duration: 3.1hrs
Speed: 0.47km/hr
Fractal D: 1.08



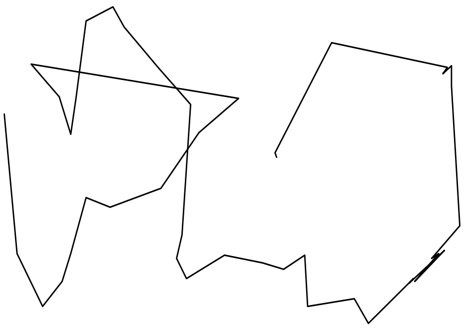
55-1

Condition: w/Young
Season: Winter 1995
Study Area: Coastal
Duration: 5.8hrs
Speed: 0.50km/hr
Fractal D: 1.15



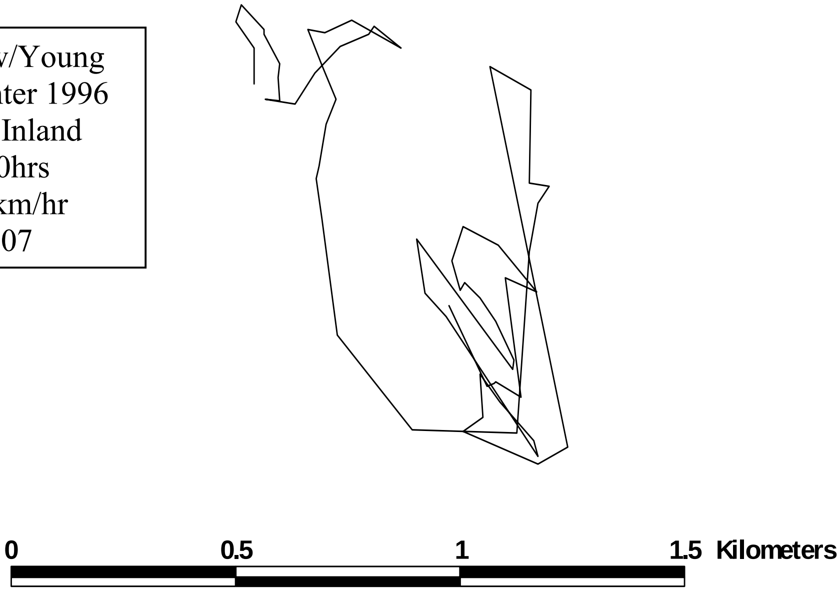
29-4

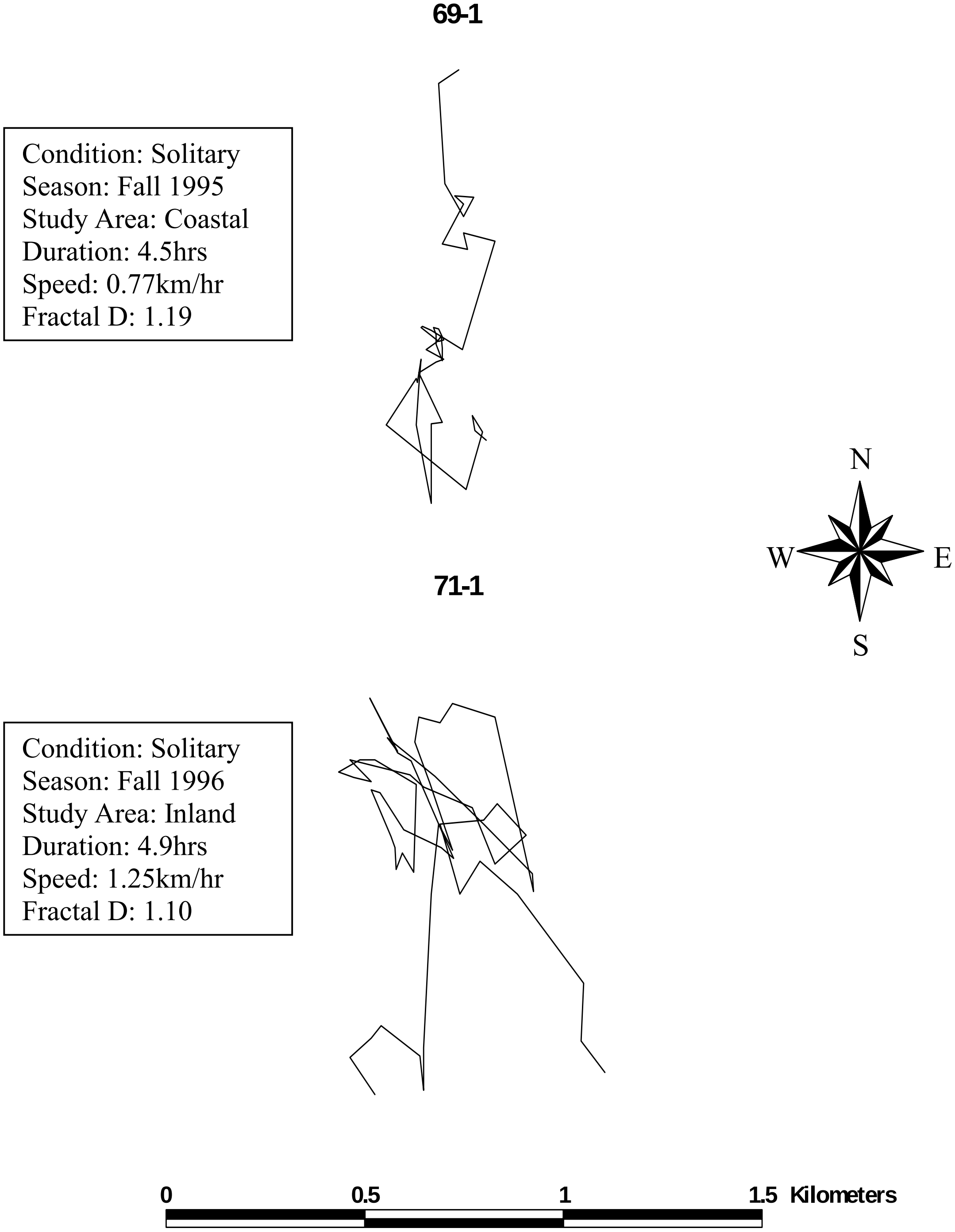
Condition: w/Young
Season: Fall 1996
Study Area: Inland
Duration: 5.8hrs
Speed: 1.10km/hr
Fractal D: 1.07



29-7

Condition: w/Young
Season: Winter 1996
Study Area: Inland
Duration: 6.0hrs
Speed: 1.12km/hr
Fractal D: 1.07



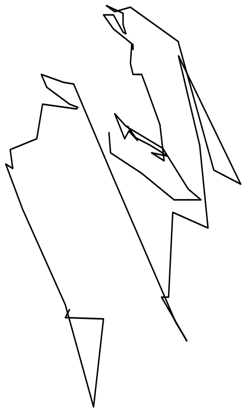


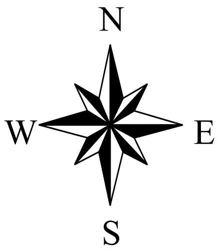
Condition: Solitary
Season: Fall 1995
Study Area: Coastal
Duration: 4.5hrs
Speed: 0.77km/hr
Fractal D: 1.19

Condition: Solitary
Season: Fall 1996
Study Area: Inland
Duration: 4.9hrs
Speed: 1.25km/hr
Fractal D: 1.10

71-3

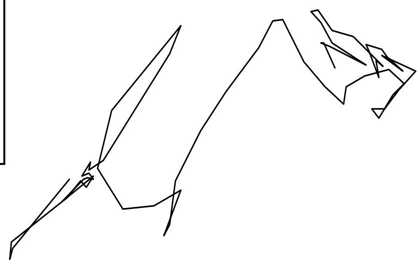
Condition: Solitary
Season: Fall 1996
Study Area: Inland
Duration: 6.2hrs
Speed: 0.78km/hr
Fractal D: 1.14



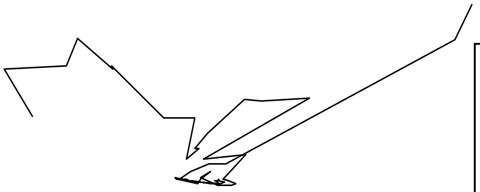


71-4

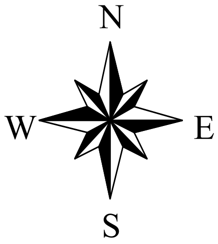
Condition: Solitary
Season: Fall 1996
Study Area: Inland
Duration: 6.3hrs
Speed: 0.68km/hr
Fractal D: 1.21



79-2

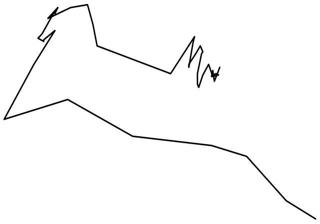


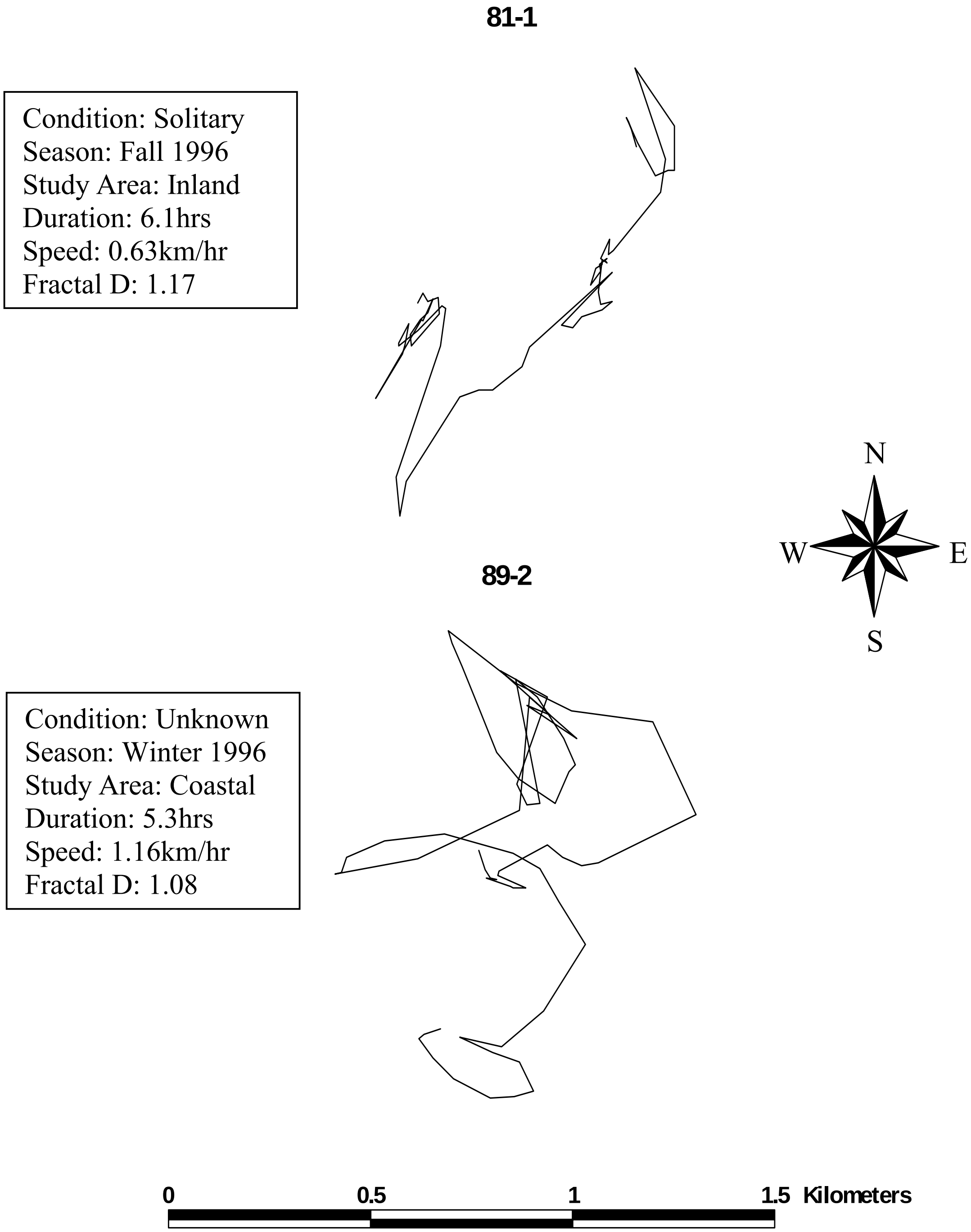
Condition: Solitary
Season: Fall 1996
Study Area: Coastal
Duration: 6.6hrs
Speed: 0.40km/hr
Fractal D: 1.14



79-3

Condition: Solitary
Season: Fall 1996
Study Area: Coastal
Duration: 3.6hrs
Speed: 0.54km/hr
Fractal D: 1.13





81-1

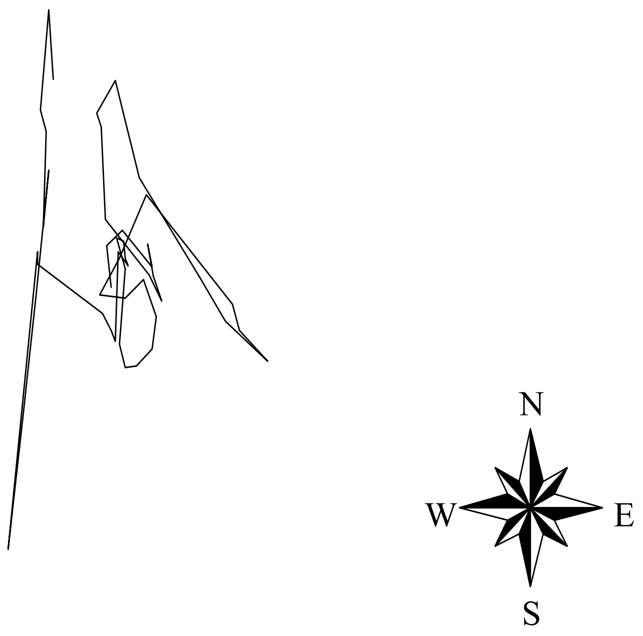
Condition: Solitary
Season: Fall 1996
Study Area: Inland
Duration: 6.1hrs
Speed: 0.63km/hr
Fractal D: 1.17

89-2

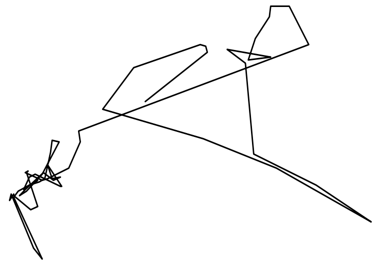
Condition: Unknown
Season: Winter 1996
Study Area: Coastal
Duration: 5.3hrs
Speed: 1.16km/hr
Fractal D: 1.08

91-1

Condition: Solitary
Season: Fall 1996
Study Area: Inland
Duration: 4.9hrs
Speed: 1.21km/hr
Fractal D: 1.12

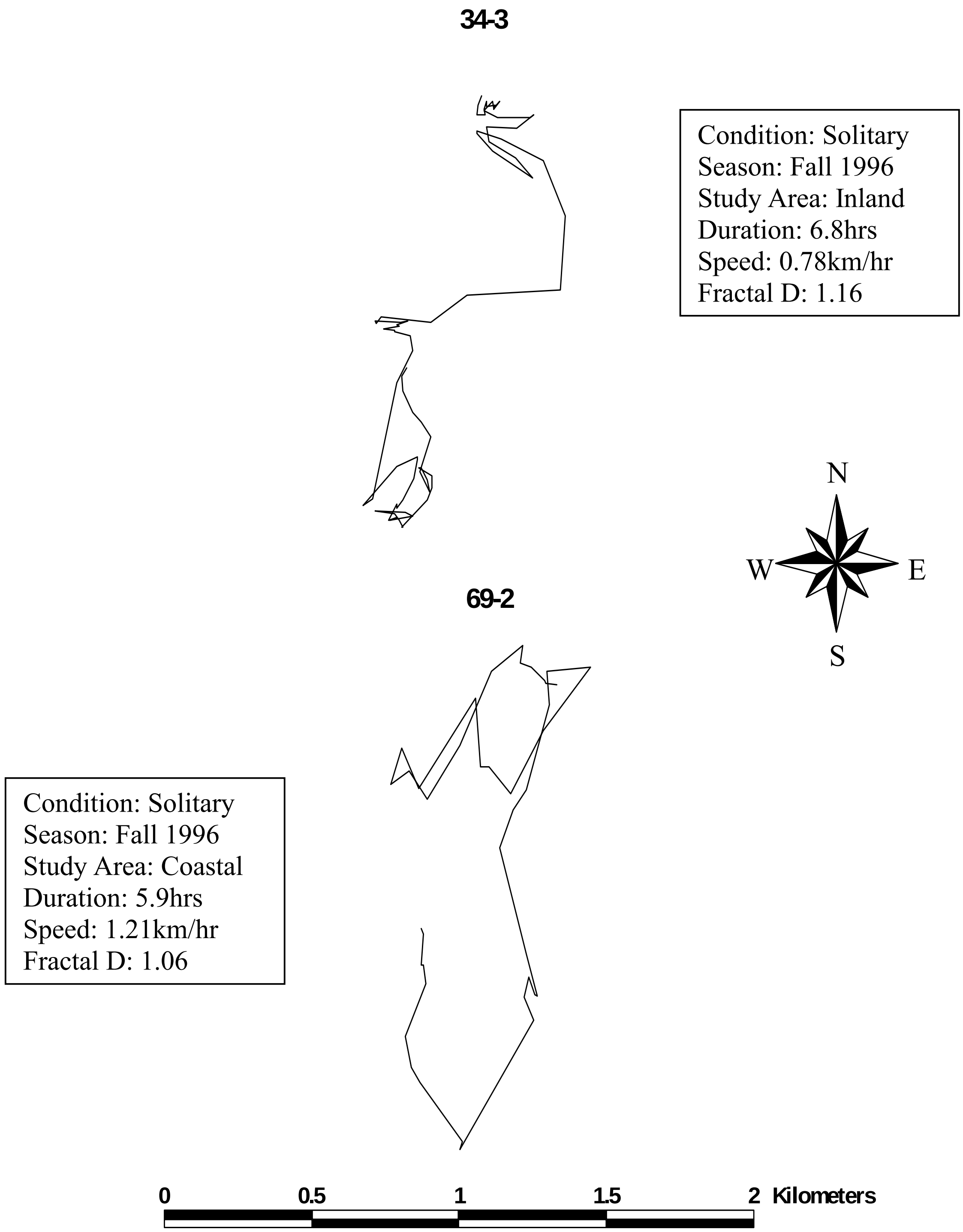


91-2



Condition: Solitary
Season: Winter 1996
Study Area: Inland
Duration: 5.8hrs
Speed: 0.61km/hr
Fractal D: 1.16

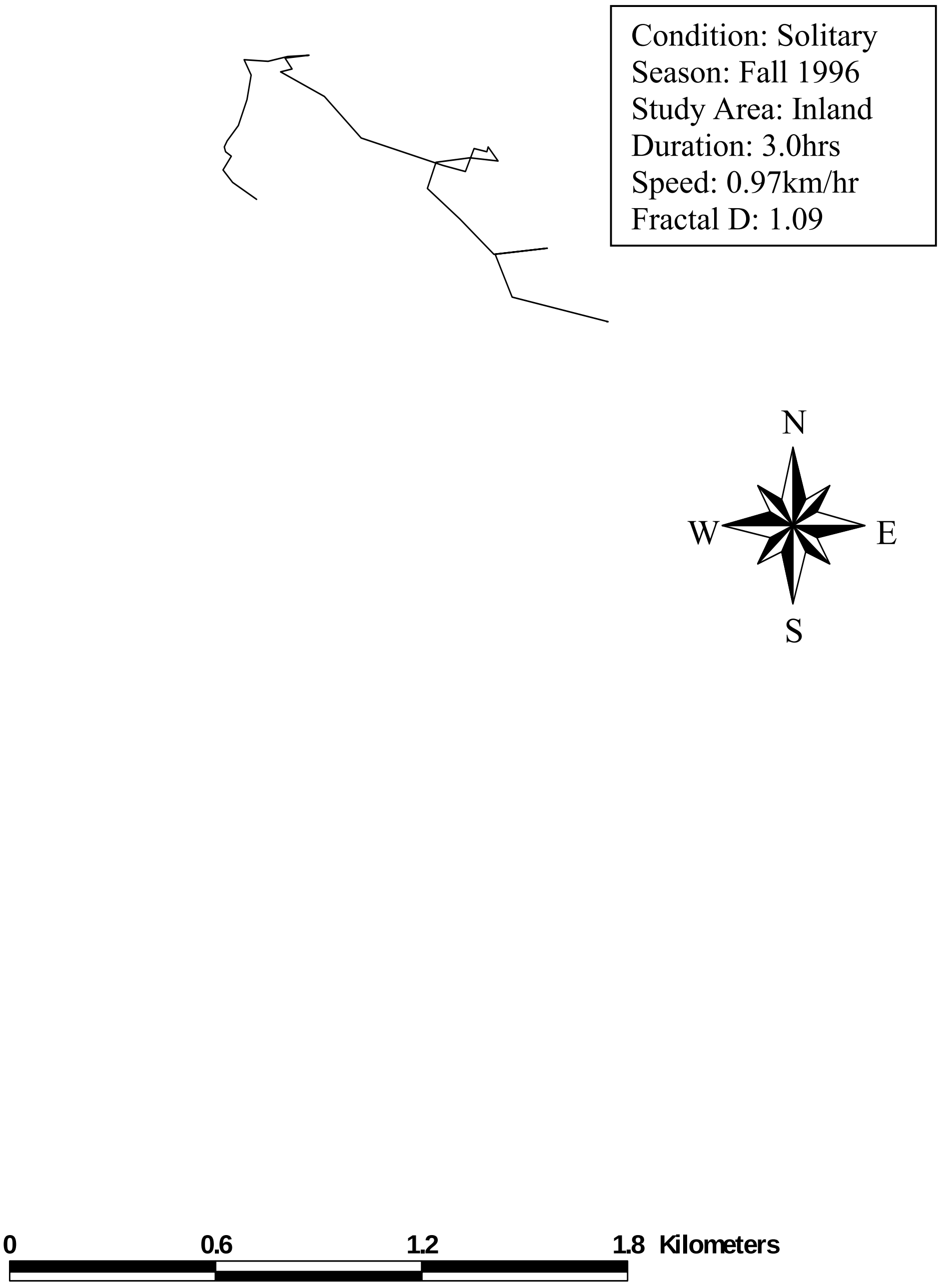
Movement paths plotted at scale 1:15,500



Condition: Solitary
Season: Fall 1996
Study Area: Inland
Duration: 6.8hrs
Speed: 0.78km/hr
Fractal D: 1.16

Condition: Solitary
Season: Fall 1996
Study Area: Coastal
Duration: 5.9hrs
Speed: 1.21km/hr
Fractal D: 1.06

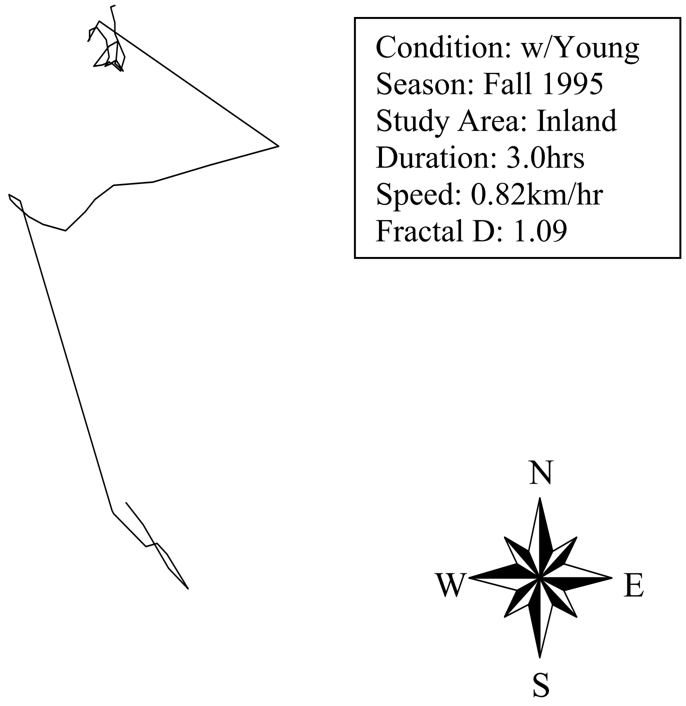
71-2



Condition: Solitary
Season: Fall 1996
Study Area: Inland
Duration: 3.0hrs
Speed: 0.97km/hr
Fractal D: 1.09

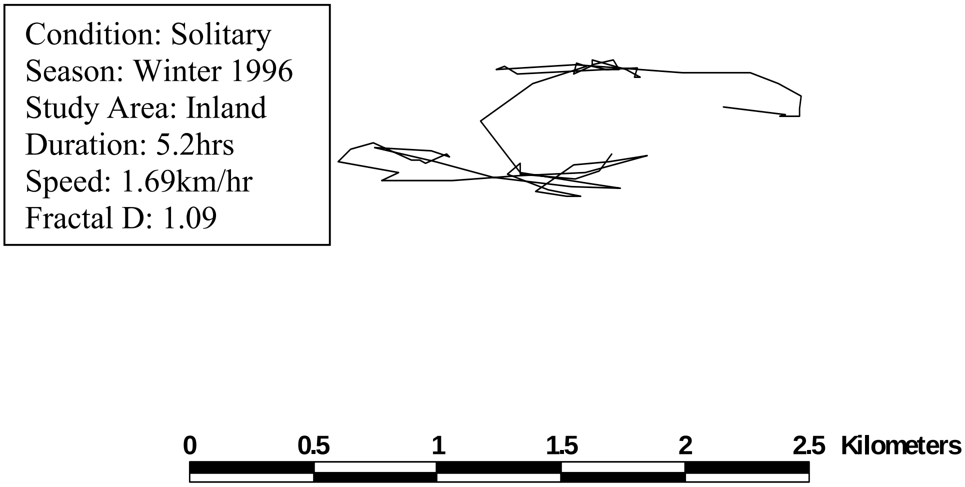
Movement paths plotted at scale 1:21,500

34-1



Condition: w/Young
Season: Fall 1995
Study Area: Inland
Duration: 3.0hrs
Speed: 0.82km/hr
Fractal D: 1.09

36-1

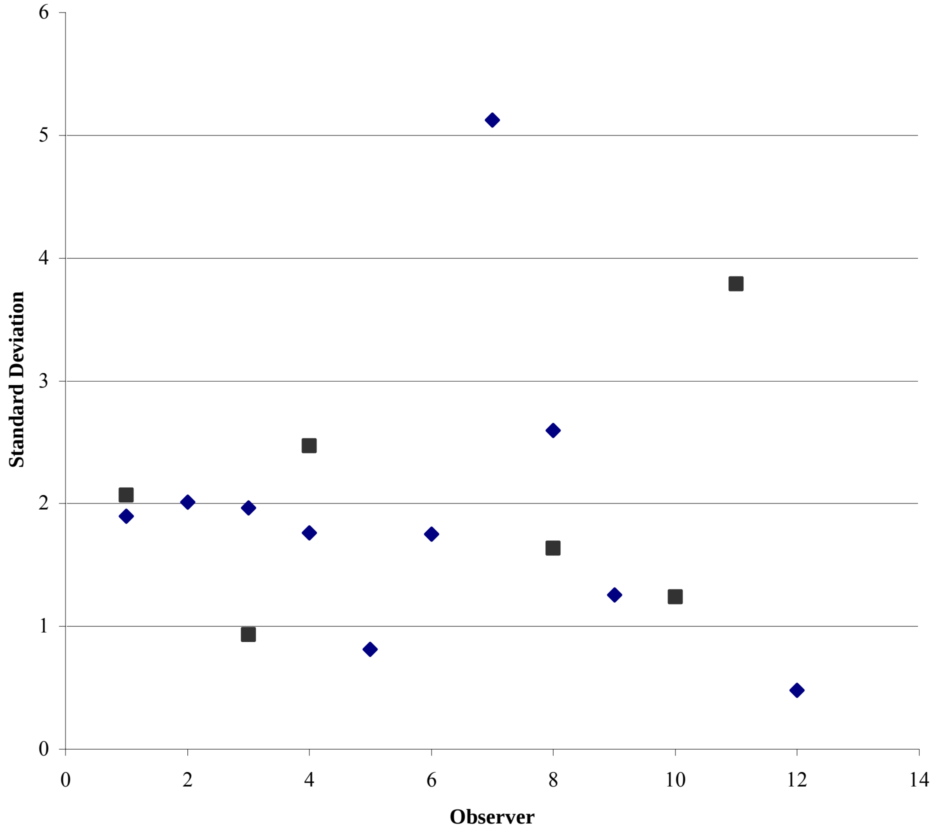


Condition: Solitary
Season: Winter 1996
Study Area: Inland
Duration: 5.2hrs
Speed: 1.69km/hr
Fractal D: 1.09

APPENDIX B: TELEMETRY PRECISION BY OBSERVER AND COMPASS TYPE

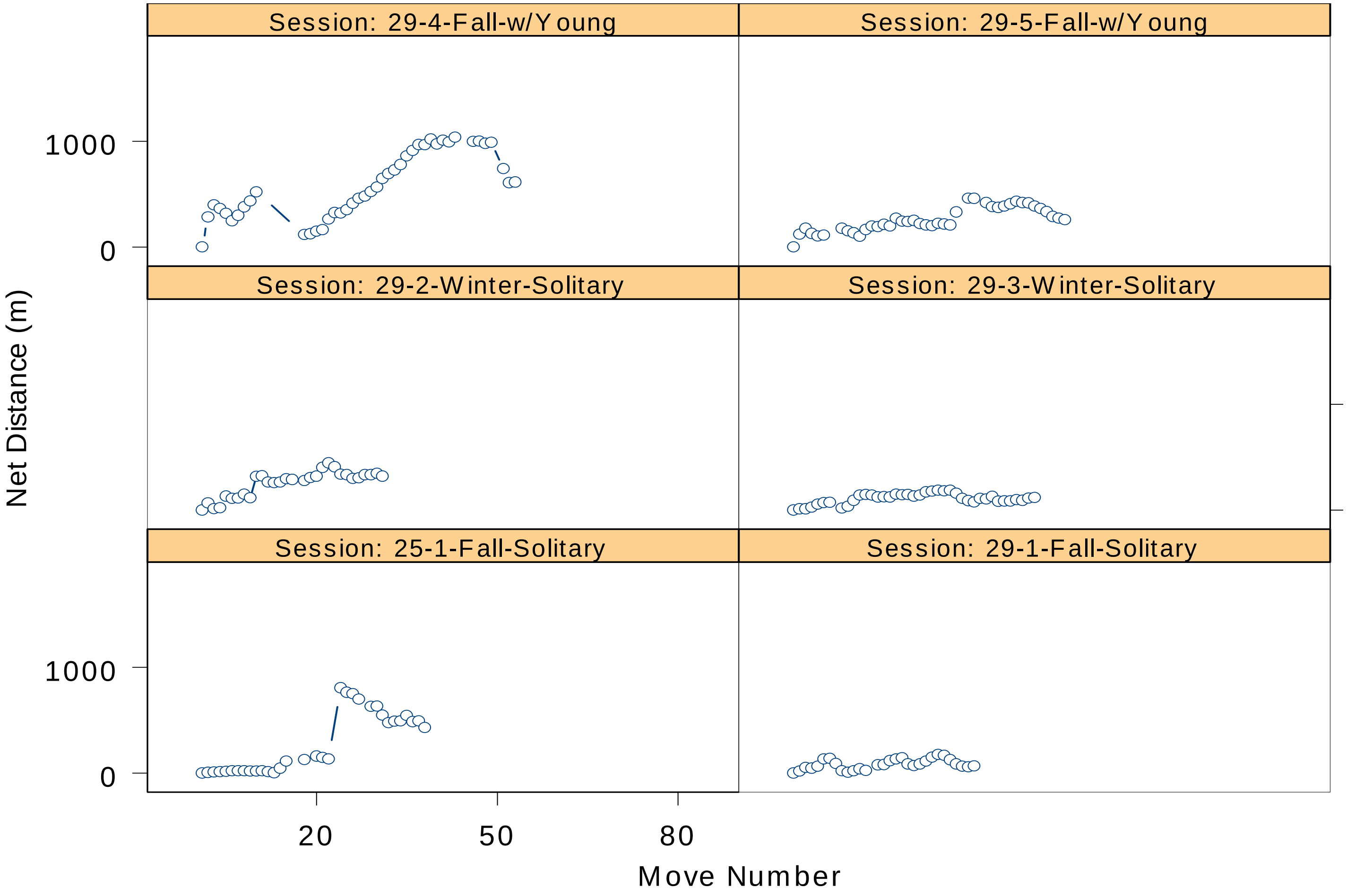
Mean and standard error of standard deviations of azimuths to test transmitters by observer and compass type (1995–96).

	Compass Rose			**Electronic Compass**		
Observer	N	Mean	SE	N	Mean	SE
1	3	1.90	0.63	56	2.07	0.17
2	2	2.01	0.58	0		
3	1	1.96		6	0.93	0.14
4	14	1.76	0.34	26	2.47	0.32
5	2	0.81	0.13	0		
6	3	1.75	0.29	0		
7	2	5.12	0.88	0		
8	20	2.60	0.69	13	1.64	0.35
9	2	1.25	0.08	0		
10	0			1	1.24	0.08
11	0			5	3.79	1.08
12	1	0.48		0		
Total	50			107		

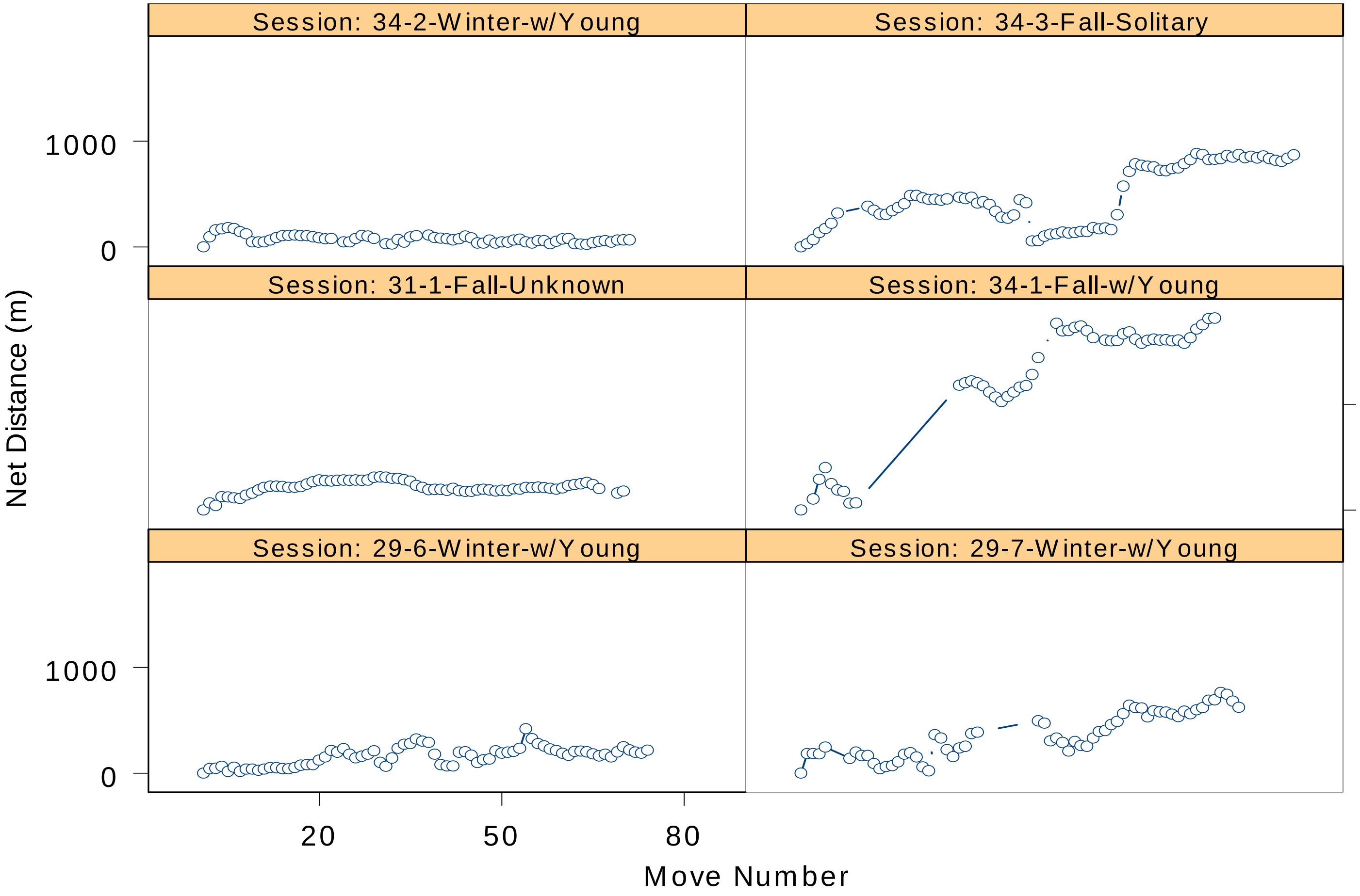


Plot of mean standard deviations by observer and telemetry system type (■ electronic compass, ♦ compass rose).

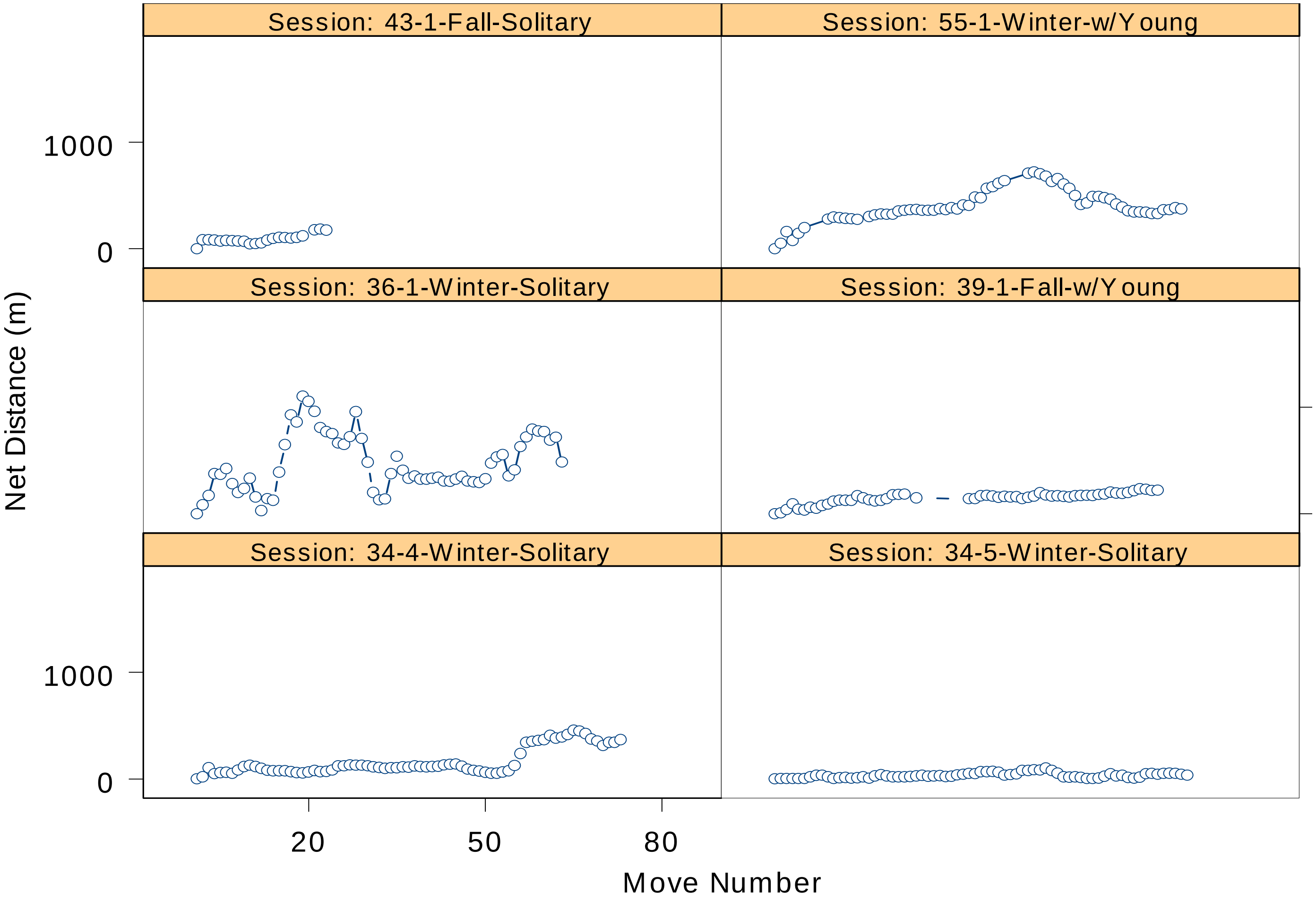
APPENDIX C: FEMALE BLACK BEAR NET DISPLACEMENT



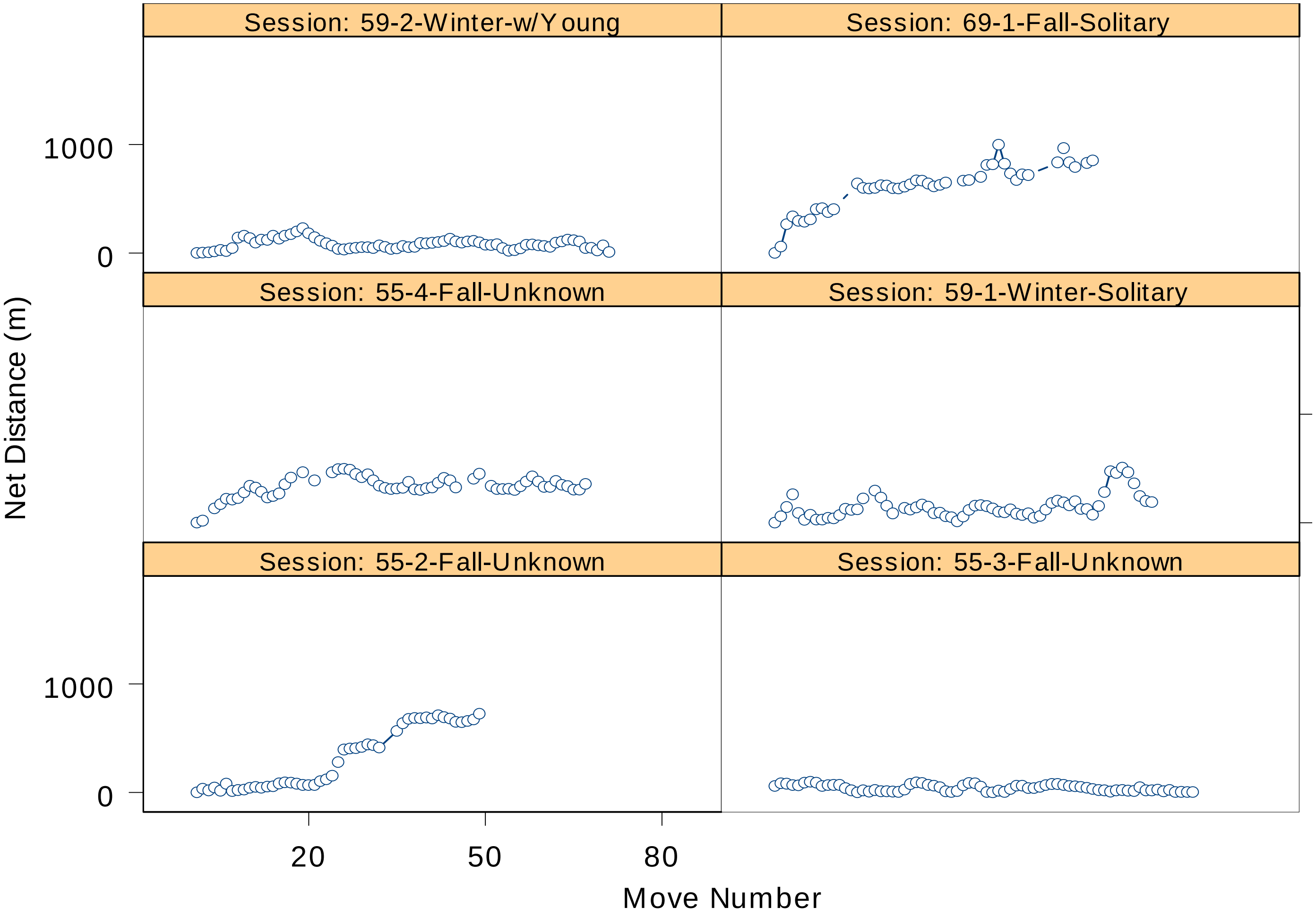
Net displacement of female black bears from the starting point of travel paths recorded in south central Louisiana during fall and winter (1995–96). Session numbers are bear number – session recorded on bear – season – reproductive condition.



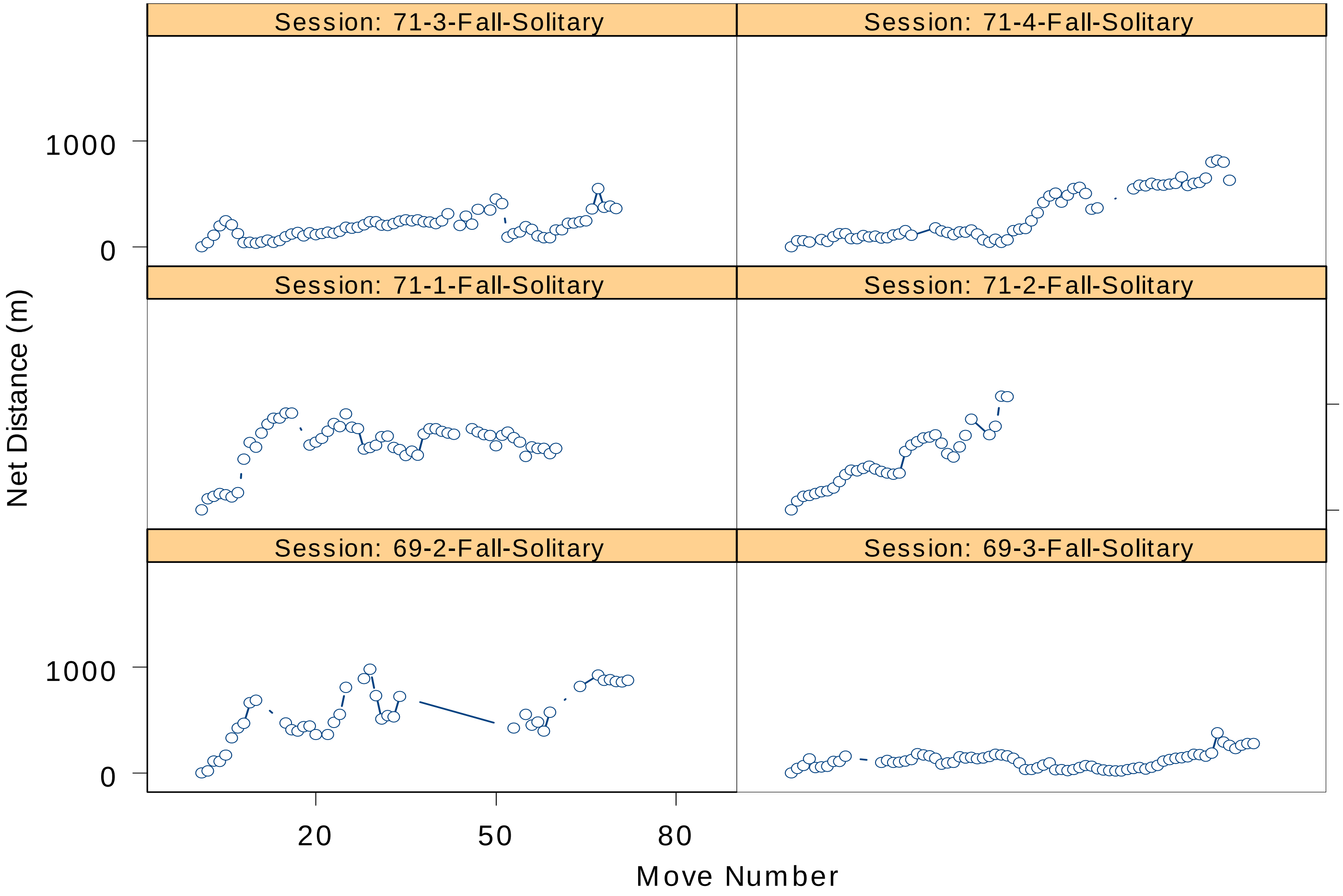
Net displacement of female black bears from the starting point of travel paths recorded in south central Louisiana during fall and winter (1995–96). Session numbers are bear number – session recorded on bear – season – reproductive condition.



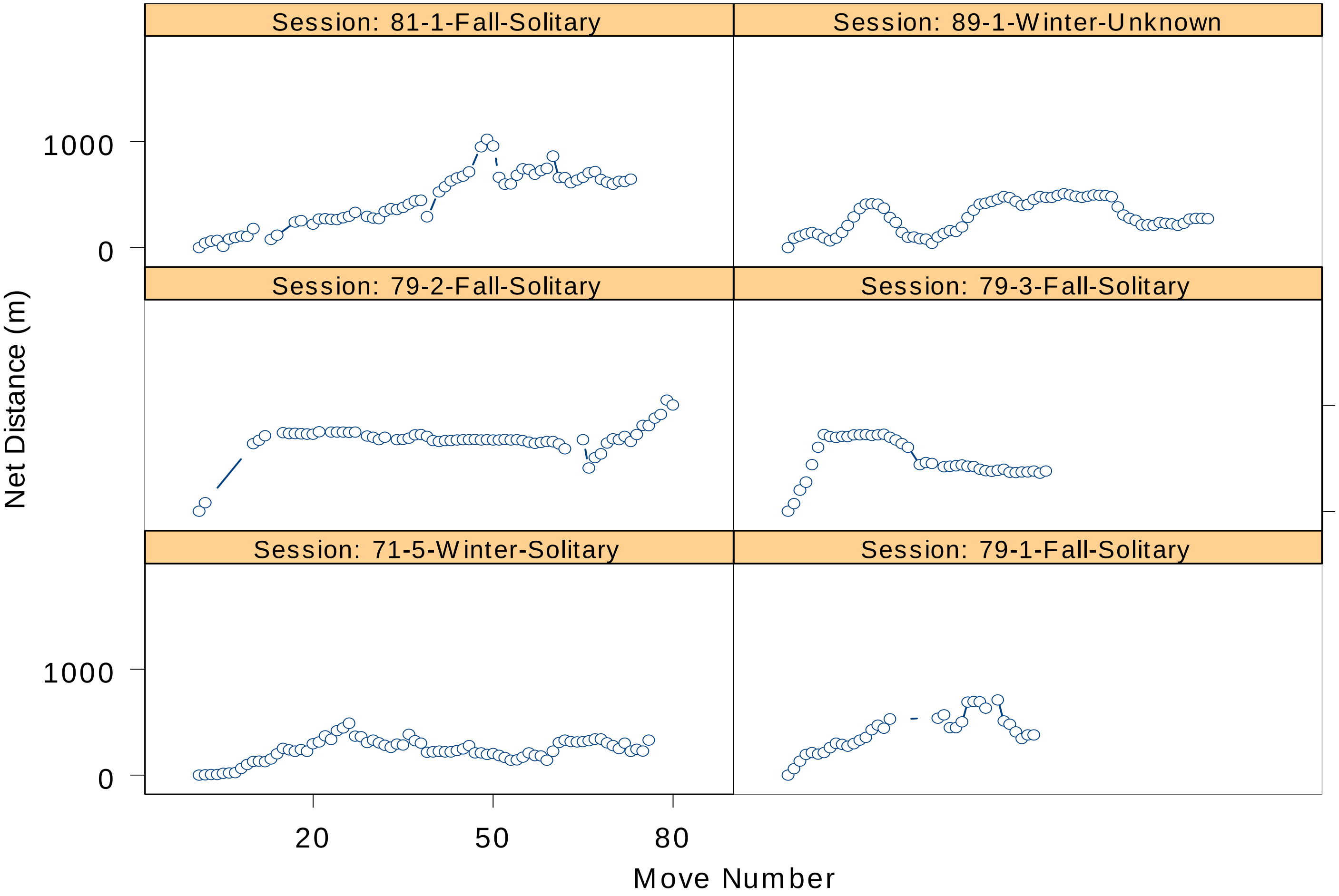
Net displacement of female black bears from the starting point of travel paths recorded in south central Louisiana during fall and winter (1995–96). Session numbers are bear number – session recorded on bear – season – reproductive condition.



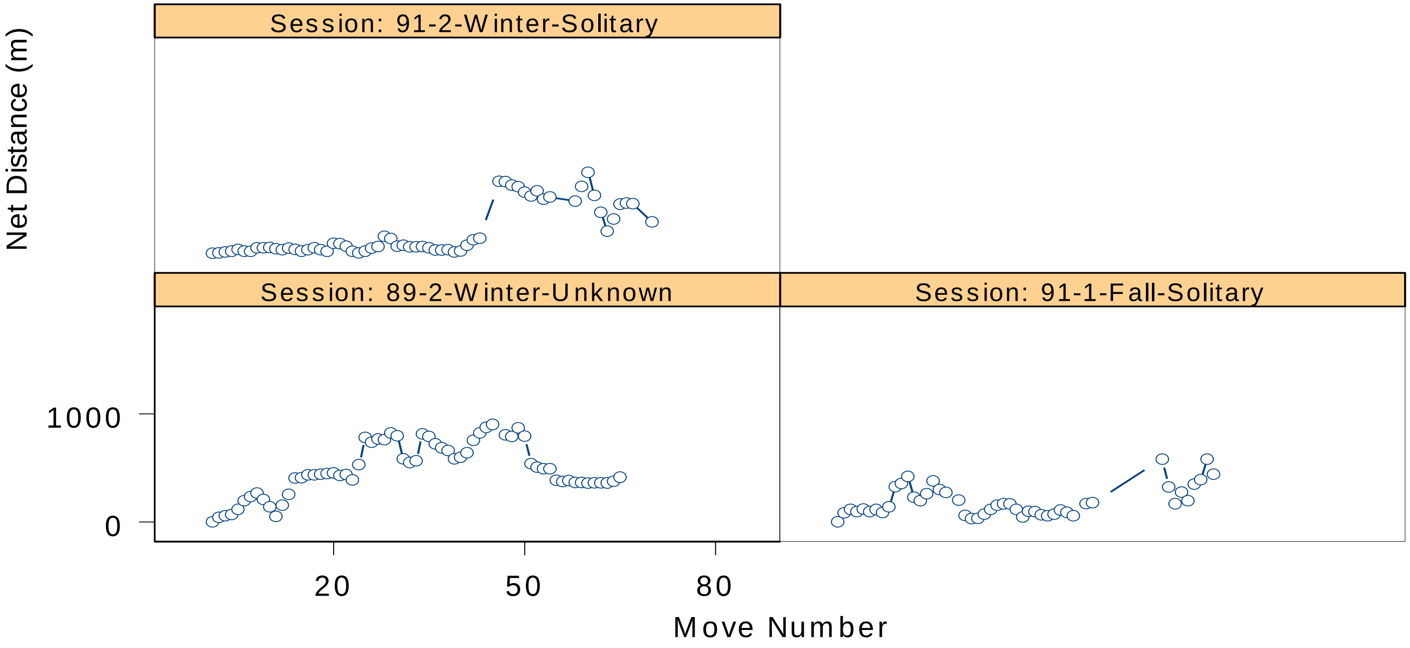
Net displacement of female black bears from the starting point of travel paths recorded in south central Louisiana during fall and winter (1995–96). Session numbers are bear number – session recorded on bear – season – reproductive condition.



Net displacement of female black bears from the starting point of travel paths recorded in south central Louisiana during fall and winter (1995–96). Session numbers are bear number – session recorded on bear – season – reproductive condition.



Net displacement of female black bears from the starting point of travel paths recorded in south central Louisiana during fall and winter (1995–96). Session numbers are bear number – session recorded on bear – season – reproductive condition.



Net displacement of female black bears from the starting point of travel paths recorded in south central Louisiana during fall and winter (1995–96). Session numbers are bear number – session recorded on bear – season – reproductive condition.

VITA

Dwayne Allen Hightower was born September 13, 1972, in Lake Charles, Louisiana. He is the son of Ms. Martha Lynn White and Mr. James Allen Hightower. He graduated from Sam Houston High School in Moss Bluff, Louisiana, in 1990 and McNeese State University in 1994 with a Bachelor of Science degree in wildlife management. He was accepted into the Graduate School of Louisiana State University in 1994. After completion of his thesis field research in 1996, he accepted a Research Associate position in the School of Forestry, Wildlife, and Fisheries to supervise the field research for the Louisiana State University Black Bear Project. He remained in that position until the departure of his advisor, Dr. Richard M. Pace, III, in 2000. Mr. Hightower is currently employed as a staff ecologist with Quantitative Ecological Services, Inc. Mr. Hightower has co-authored 2 published manuscripts stemming from his work with black bears at Louisiana State University.