



# Diverse Movement Patterns of North America's Eastern Box Turtle (*Terrapene carolina carolina* L.). Part 1: Extremes of High and Low Site Fidelity

Susan Seibert<sup>1</sup> and William R. Belzer<sup>2</sup>

<sup>1</sup>AA Forestry and Wildlife Service, Inc., 2270 Raymilton Road, Utica, Pennsylvania 16362, USA (turtltracker@windstream.net)

<sup>2</sup>Eastern Box Turtle Conservation Trust, 304 East Bissell Avenue, Oil City, Pennsylvania 16301, USA (billbelzer@hotmail.com; corresponding author)

Photographs by the authors unless otherwise noted.

Twenty years ago (1993), we started tracking the movements of displaced adult (and, later, headstarted juvenile) Eastern Box Turtles (*Terrapene carolina carolina*) released into two different nature sanctuaries in northwestern Pennsylvania, USA (Belzer 1996, Belzer and Steisslinger 1999, Belzer and Seibert 2009a). Our project strives to discover whether releasing adult and headstarted juvenile turtles might be a practice that could rebuild decimated and extirpated box turtle populations (Belzer 2002, 2008; Belzer and Seibert 2009a). Extant knowledge of the long-term habitat use by box turtles had been developed largely by annual and decennial censuses of several different populations (Stickel 1950, 1978, 1989; Schwartz and Schwartz 1974; Kiestler et al. 1982; Schwartz et al. 1984; Williams and Parker 1987; Hall et al. 1999; Schwartz 2000). Whereas some box turtles in these long-term studies were observed to shift the position of their home ranges, and other (“transient”) individuals arrived in and then passed through an established population’s habitat, high site fidelity within relatively small parcels of habitat was seen to be normative for this species. Stickel (1989) stated that locations of home ranges of adult turtles were generally stable across 29 years, while Schwartz et al. (1984) noted that once a turtle establishes a home range, it becomes so well acquainted with the features of it that gradual successional changes in the vegetation are tolerated and have little influence on home range. Repeat encounters with ultra-centenarian box turtles at their earlier sites after many intervening decades (Graham and Hutchison 1969, Lovewell 1989, National Park Service 2005) also supported the impression that high site fidelity is the norm.

Consequently, we anticipated that once we observed highly consistent habitat use by a released individual over several consecutive years, we would essentially have demar-

cated the adoptive home range for that turtle, and we could remove its radiotransmitter, secure in the assumption that it would continue to use that parcel of habitat indefinitely. Our weekly monitoring of movements across decades, however, has revealed highly distinctive and sudden changes in patterns of habitat use. We now recognize that frequent observations over protracted periods are necessary to disclose the real spectrum of how individuals of this species use habitat. Conclusions about habitat preferences derived from less intensive monitoring can be misleading.

Pooling our movement data for the more than 100 turtles that we have intensively monitored for lengthy periods tends to conceal remarkable differences in habitat use. Each turtle is its own case study. In order to better divulge distinctive details about how different individuals use their habitat,



Adult female Eastern Box Turtle (*Terrapene carolina carolina*) C5; habitat use for C5 is plotted in Fig. 4. Note the early stage of posterior carapace regeneration from fire injury about two years before arriving at our study site.

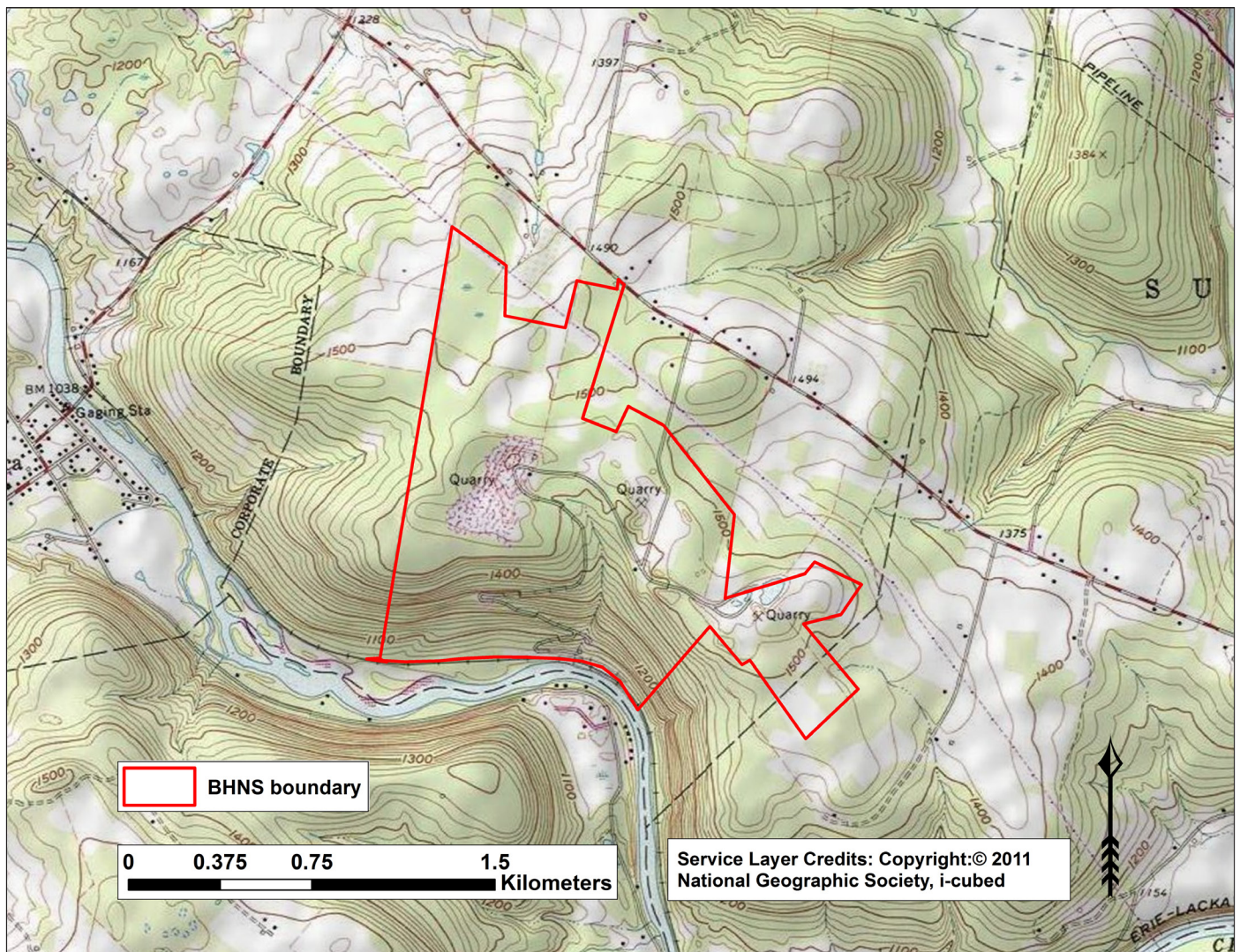
we plan to publish a series of articles in this journal, each of which will examine relatively few turtles. This first installment in the series focuses on the turtles that displayed extremes of very high or very low site fidelity. As the series progresses, types of behavioral variation that are exhibited by other turtles within those extremes will increasingly emerge.

**Study Sites**

We began monitoring turtles in 1993 in the 80-ha forested (mixed mesophytic) sanctuary of the state-owned McKeever Environmental Learning Center (McK) in Mercer County, Pennsylvania. By 1999, we shifted almost all of our field studies to the much larger (200 ha), privately owned Buttermilk Hill Nature Sanctuary (BHNS), located in Venango County, Pennsylvania, only 20 km to the northeast of McK. The larger BHNS site offered the critical advantage of being surrounded by abundant roadless buffer, which more than doubled its 200 ha of safe habitat through which turtles could range. It also offered a more varied habitat than that at McK. In it is a diversity of suc-



Adult female Eastern Box Turtle (*Terrapene carolina carolina*) C21; habitat use for C21 is plotted in Fig. 4.



**Fig. 1.** Topographical view of Buttermilk Hill Nature Sanctuary (BHNS) located in Venango County, Pennsylvania.

cessional woodland stages (mostly deciduous but some coniferous), as well as areas of open meadow, shrubbery, and wetland.

We described the two sites and historical turtle occupancy in Belzer and Seibert (2009a, 2011). Figures 1 and 2 show topo-

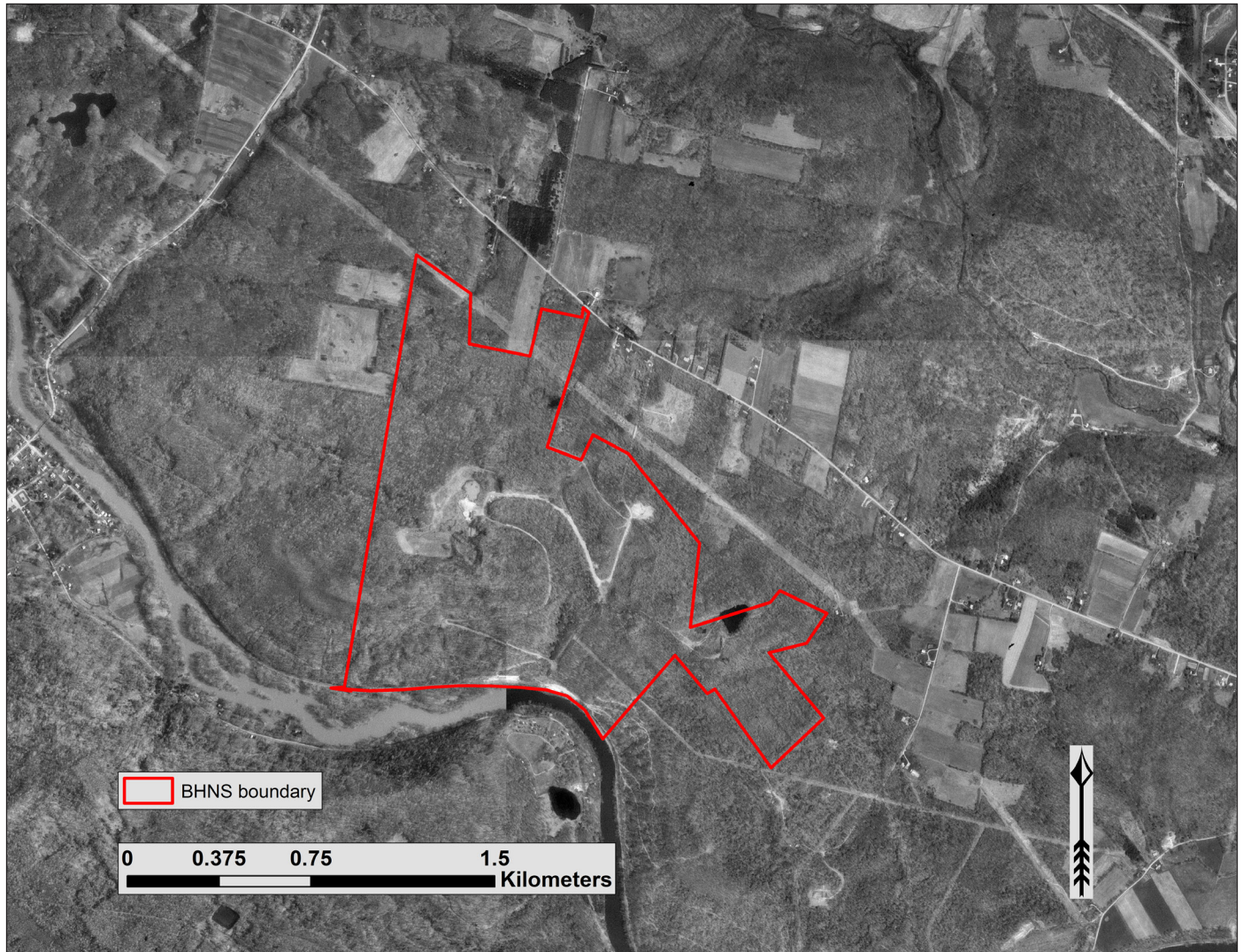


Fig. 2. Aerial view of Buttermilk Hill Nature Sanctuary (BHNS) located in Venango County, Pennsylvania.



Adult male Eastern Box Turtle (*Terrapene carolina carolina*) C9; habitat use for C9 is plotted in Fig. 5.



Adult female Eastern Box Turtle (*Terrapene carolina carolina*) C42 emerging from brumation; habitat use by C42 is plotted in Fig. 5.

graphical and aerial photographs, respectively, of the BHNS site with an overlay of the sanctuary's approximate boundary.

### Study Populations

All of the turtles in the McK study were displaced adults who had lost their native habitat for various reasons (Belzer and Steisslinger 1999, Belzer and Seibert 2009a). By 1999, six years after the inception of the project, most (86%) of the turtles at the McK site were repeatedly ranging beyond the 80-ha boundary into hazardous areas outside the sanctuary (highways, railroads, cultivated fields, residential areas), and so were evacuated to the much larger BHNS. Eighty hectares proved to be too small a habitat to accommodate the movements of these turtles. The BHNS site, with its much larger buffer zone, would presumably be better at safely accommodating the turtles' movements. Several of the adults at the McK site that had established small, consistent home ranges in unfragmented habitat were left there and their movements are still being monitored. No turtles have been added to the McK site since 1997.

The study population at the BHNS site began with adults evacuated from McK in 1999. It has been steadily augmented with displaced adults donated by licensed Pennsylvania animal rehabilitation centers and veterinarians, and also with half-grown (~250 g), headstarted juveniles, average age 24 months (Belzer and Seibert 2007a), raised from our population's salvaged eggs. Imperiled eggs are not uncommon in our experience. Eggs have been left exposed by females whose injured rear feet were poor at digging proper nests, by heavy rains that washed eggs from completed hillside nests, and by predators that were interrupted in the midst of nest-excavation.

### Telemetry

Each turtle carried a Holohil radiotransmitter (model and attachment methodology detailed in Belzer and Seibert 2009a, 2009b). We used AR8000 receivers (AOR, Ltd.) with an infinitely variable frequency oscillator to detect radio signals and determine exact locations. We located turtles every 2–10 days and recorded their waypoint coordinates with a Garmin® GPS 12™ receiver, downloaded the entries with Waypoint+® software (Brent Hildebrand), and plotted the waypoints on maps of the habitat with Environmental Systems Research Institute (ESRI) ArcGIS® software version 10.1 (additional receiver, GPS, and software details available in Belzer and Seibert 2009a, and at [www.esri.com](http://www.esri.com)).

### Changing Perceptions as a Data Continuum Lengthens

Our impressions of turtle movement patterns that we distilled from years of observation repeatedly changed the longer that our fieldwork continued. By comparing three subsets of our longitudinal data here, we illustrate how perceptions of habitat



Adult male Eastern Box Turtle (*Terrapene carolina carolina*) A10; habitat use by A10 is plotted in Fig. 8.

use derived from relatively short (5–10 yr) periods of observation may prove to be invalid as more years of data accumulate.

Our original subset (OS) of movement data is for 61 turtles (27 adults and 34 juveniles) through the 2007 activity season at the BHNS site. Our extended subset (ES) includes four additional years of data (through season 2011) for those same 61 turtles. Our comprehensive set of data (CD) is for all turtles (49 adults and 59 juveniles) that had used the BHNS habitat for at least one year by the end of 2011.

At the Third Box Turtle Conservation Workshop in Maryland, 2007, we summarized (Belzer and Seibert 2007b) the movements of 37 adults (18 males, 19 females) that had been roaming the McK site for 2–7 years (1993 through 1999). Fifteen of the 18 males (83%) had ranged outside the 80-ha McK sanctuary; 17 of the 19 females (89%) had done likewise.

After 1999, we started to release adult turtles into the larger (200 ha) BHNS habitat. In 2002, we also began to add headstarted juveniles to the BHNS site. By the end of the 2007 field season, 27 adults (16 males, 11 females) and 34 headstarted juveniles (25 males, 9 females) had been using the BHNS habitat for 3–5 years. The BHNS movement data accumulated as of 2007 for these 27 adults and 34 juveniles comprise our OS of waypoints.

The OS tally confirmed the reasonable expectation that the larger BHNS habitat would accommodate the movements of a larger proportion of adults than did the smaller McK habitat. By the end of the 2007 field season, 69% of the 16 adult males, and 36% of the 11 adult females (56% adult mean) had ranged beyond the BHNS perimeter. That total was 30 points lower than the 86% mean departure that we found for adults at the smaller McK site.

Of the 25 male and nine female headstarted juveniles in the OS, 10 males (40%) and one female (11%) ranged beyond the 200-ha BHNS boundary. The lack of juvenile releases at McK precludes a comparison of mean departure level for this age class at McK with that found at BHNS, but a BHNS intra-site comparison from the OS shows a 32% juvenile mean compared to the 56% adult mean. That more restrained movement by our headstarted turtles during their early years was reported at the 2007 Third Box Turtle Conservation Workshop; it also gave us false hope that released juveniles would be more likely than adults to confine their ranges within this larger sanctuary.

When we reassessed the status of the OS turtles by examining the ES, with its additional four years of data for these same 61 turtles, we found that, with more time in the sanctuary, the proportion of adults (as well as of juveniles) ranging outside the BHNS perimeter increased. The ES showed that 70% percent of the OS adults (86% of males, 55% of females) had roamed beyond the 200-ha margin at BHNS. The ES adults' proportion had risen 14 percentage points higher than their 2007 (OS) mark, but was still 16 points below the 86% departure mean for adults at the smaller McK site.

Similarly, in the ES we found that emigration by juveniles increased. Fifty-nine percent of the 34 juveniles (64% of

juvenile males, 33% of juvenile females) had ranged outside the BHNS border at one time or another. Thus, the additional four seasons since 2007 increased their out-migration mark to 27 percentage points above their OS (2007) tally of 32%, but (so far) juvenile dispersal remains somewhat below that for the adults at BHNS.

Each month, more juveniles range beyond the sanctuary boundary, so juvenile dispersal might eventually match the dispersal tendency found among our adults. This level of dispersion is far over our earlier impression that a majority of 2-yr-old headstarted juveniles would develop home ranges enclosed by the BHNS perimeter.

We have begun a study to assess whether soft releases (releasing individuals only after prolonged periods of confinement within the new habitat) will foster better site fidelity. We need to gather many more years of data, but our earliest results do not suggest that for this species an initial confinement (for several years or more) within a sanctuary will greatly improve site fidelity once the turtles are free to roam.

The CD so far suggests that some of the general age and gender patterns in the OS and ES might hold. Using data accumulated to December 2011, the CD pool includes 49 adults and 59 headstarted juveniles that have been in the habitat of the BHNS site for at least one year during the past 11 years. We find that 65% of all adults (72% of 30 males



Adult female Eastern Box Turtle (*Terrapene carolina carolina*) C48 basking atop a ledge of rock; habitat use by C48 is plotted in Fig. 9.

vs. 47% of 19 females) in the CD ranged outside the BHNS boundary. This 72% adult male versus 47% adult female disparity in the CD is similar to the 69% adult male versus 36% adult female disparity found for turtles in the ES tally.

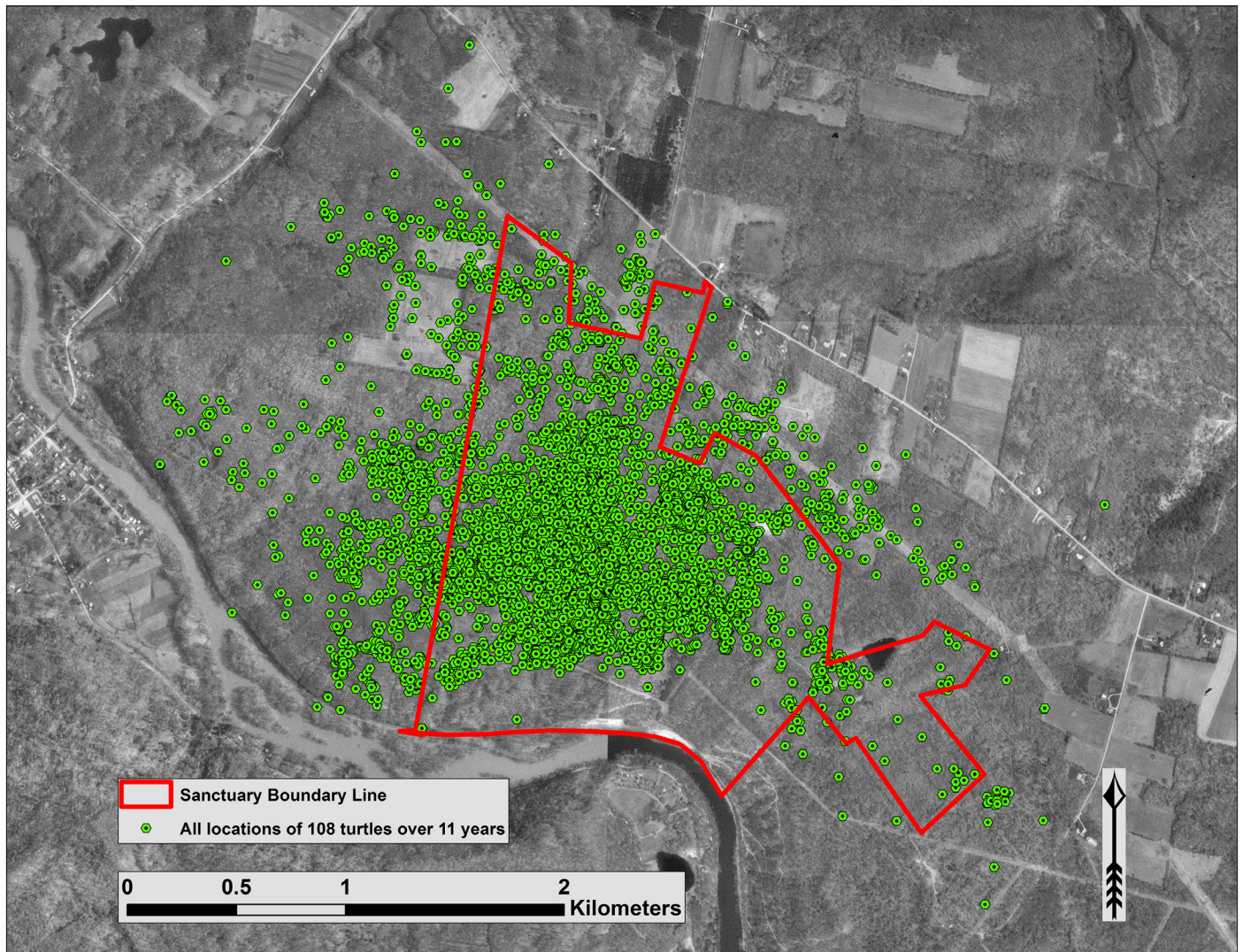
Similarly, for juveniles in the CD, 49% (61% of 36 juvenile males and 30% of 23 juvenile females) have ranged outside the BHNS boundaries at one time or another. The 2011 CD sexual disparity of 31% for juveniles (61% juvenile males vs. 30% juvenile females) is about the same 29%-gap (40% male vs. 11% female) that we saw between male and female juveniles in the smaller 2011 ES tally.

We anticipate that the total proportion of juveniles as well as adults in the CD that ranges beyond the perimeter will increase as the newer turtles inhabit the sanctuary for more years. At this stage, the 2011 CD count (like the 2011 ES count) shows a somewhat lower dispersal tendency among juveniles when compared to adults and among females when compared to males. However, notice that our first seven years

of data gathered at the McK site had given us the very different and conspicuously contradicted expectation that slightly more of the females that we released at BHNS would range outside the sanctuary's boundary than would released males.

#### Estimating Minimum Sanctuary Size

Although the larger BHNS habitat encompassed the movements of a greater proportion of the population than did the smaller McK sanctuary, the 200-ha expanse at BHNS is still far too small to accommodate the population's distribution. Figure 3 shows all recorded locations (13,484 GPS waypoints) for the 108 adult and juvenile turtles that we have tracked at BHNS during the past 11 years. Comparing the sanctuary boundary with the outlying waypoints seen in this cumulative plot shows dispersion across an area larger than 400 ha. Considering that many of the far-ranging individuals reached hazardous areas and had to be retrieved before they ventured farther, their dispersal would have been greater than seen in Fig. 3. Thus, we estimate



**Fig. 3.** All 13,484 locations (green dots) where individuals were found at BHNS during seasons 2001 through 2011. At this scale, numerous proximate waypoints appear as single dots, creating the mistaken impression of far fewer waypoints than the actual total.

that a minimum size for a sanctuary that would envelop this population’s movements is at least 800 ha. Jim Basinger tracked an Eastern Box Turtle (M17) in Virginia, USA for a straight-line trek of over 5.5 km (<http://home.ntelos.net/~jbasi/M17%20Superturtle.html>), and so even an 800-ha sanctuary would not have accommodated the movements by that individual.

**Extremes in Habitat Use**

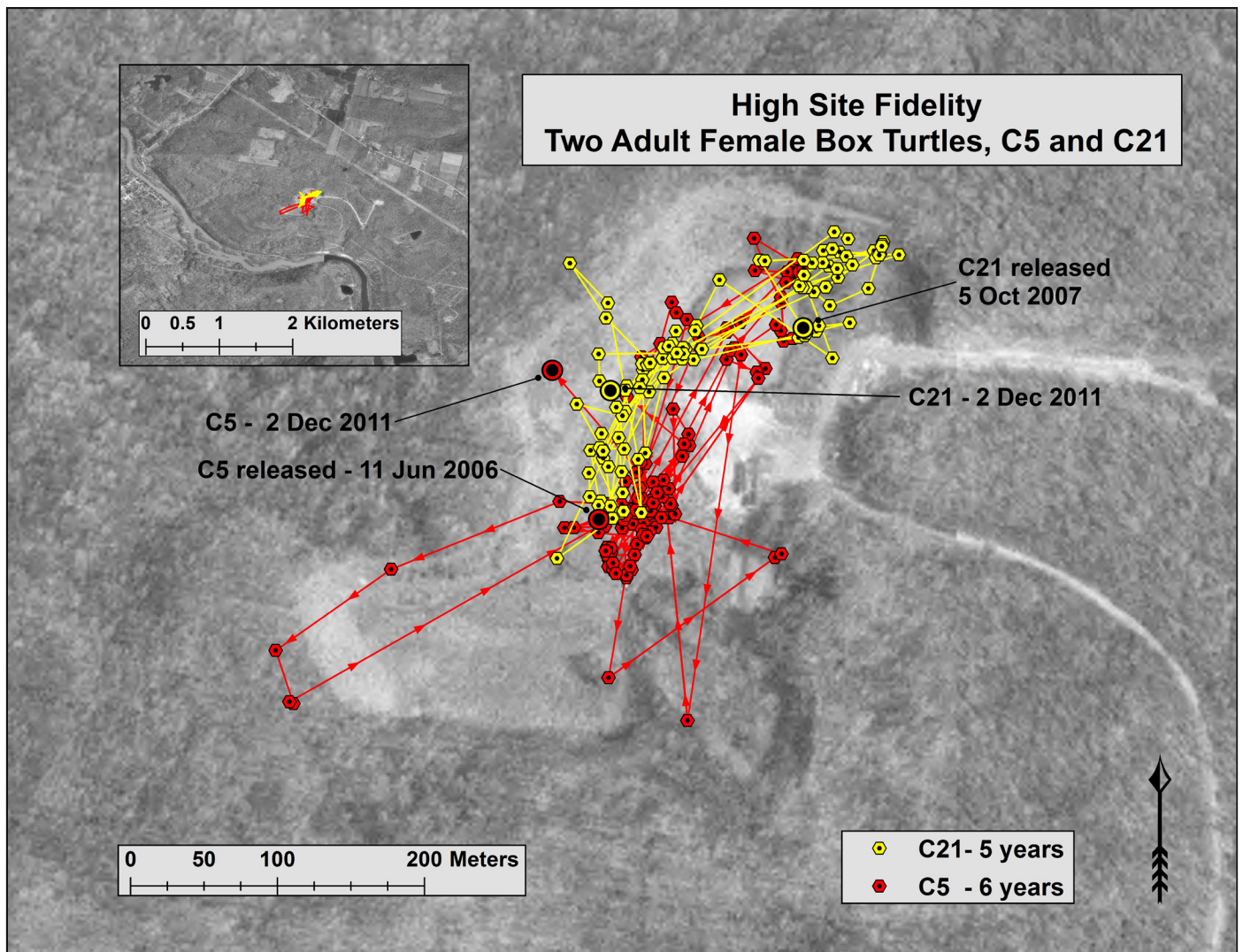
Despite the accruing body of longitudinal data that has expanded our insight into box turtle habitat use, we see too much individual variation to be able to use it to formulate generalizations about what movement patterns or ranges can be expected from any given turtle. A number of released individuals immediately ranged outside the sanctuary. Others quickly settled into small areas and either remained there, moved off after a few years to adopt another confined home range, or else continued their emigration until they left the sanctuary. We see turtles that move through habitats in the sanctuary that a few cohorts had adopted, and continue on to

settle into a different environmental type, suggesting individualized habitat preferences. A few of the farthest-ranging émigrés returned years later. Several turtles have engaged in wide, repetitive circuits spanning months or years. Movement-pattern disparity like that might explain why Williams and Parker (1987) failed to find “a substantial proportion” of their study subjects in the habitat more than once, despite the decades-long duration of their mark-recapture census.

To begin our disclosure of such disparate predilections, this first paper presents those turtles that have exhibited extreme ends of the movement spectrum: Individuals that have (to date) never ventured far from a patch of habitat that each selected soon after release 4–9 years previously versus individuals that relatively quickly ranged so far beyond the sanctuary buffer that they reached hazardous areas and had to be retrieved.

**High Site Fidelity Displayed by Some Adults**

Figure 4 shows the high site fidelity exhibited by two adult females (C5 and C21) during their entire (5 years for C21,



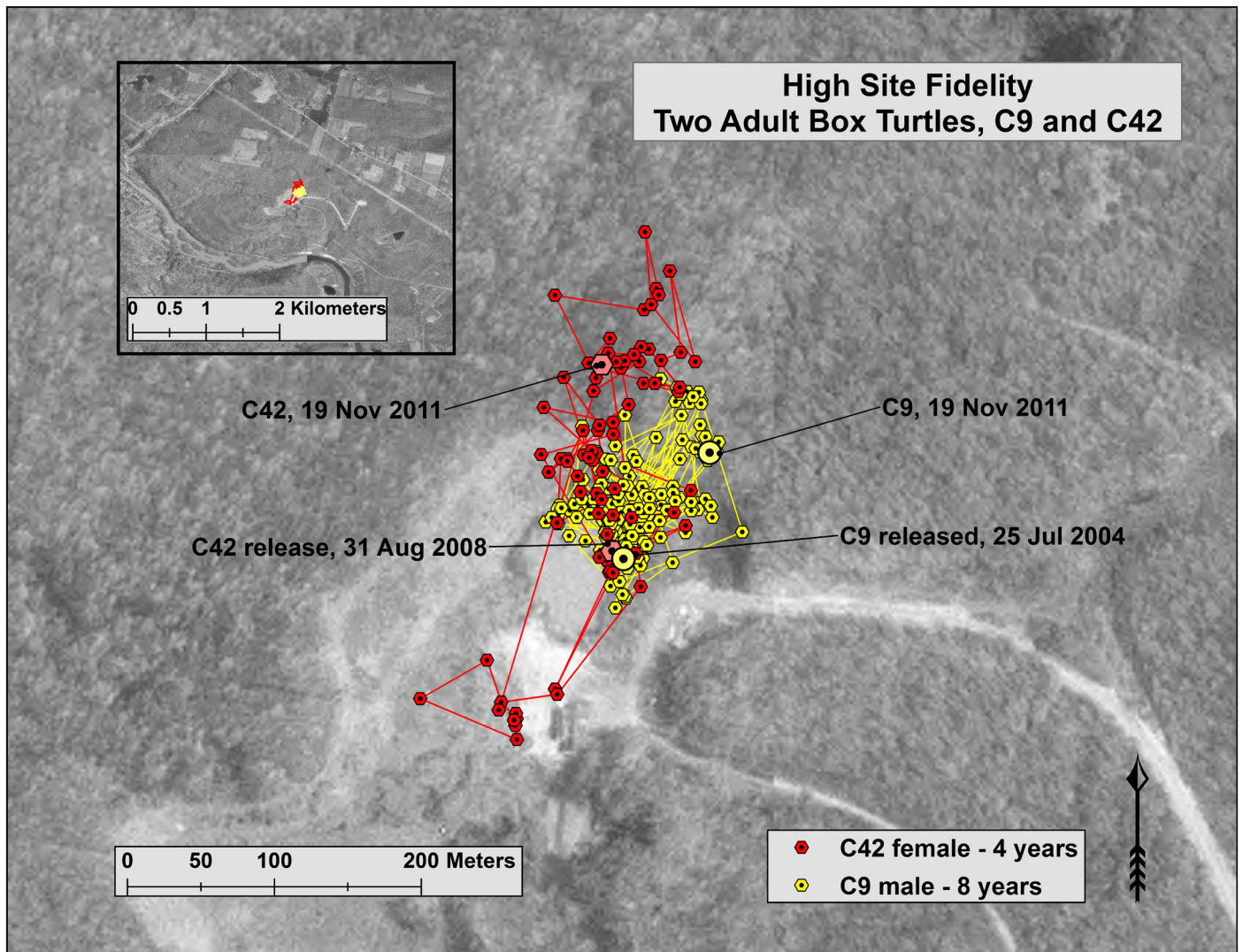
**Fig. 4.** Red lines mark sequential connections between 139 waypoints collected during the first six seasons (2006 through 2011) for adult female C5. Yellow lines mark sequential connections between 105 waypoints collected during the first five seasons (2007 through 2011) for adult female C21.

6 years for C5) residency at BHNS. Figure 5 shows the high site fidelity displayed by an adult male (C9) and an adult female (C42) during their entire (7 years for the male, four years for the female) residency at BHNS. Note that in all maps in this paper a number of proximate waypoints can appear as only one point in the Arc View plot; captions for each map list the actual number of waypoints used to make the map.

The habitat fidelity seen for the adults in Figs. 4 and 5 conforms to what the detailed movements mapped by Stickel (1950) for Eastern Box Turtles in Maryland had originally led us to expect. The site fidelity demonstrated by these four individuals is high, but notice that the preferred type of habitat among them is not uniform. Figure 6 is a photograph of the open, swampy sedge meadow frequented by the two females (C21 and C5) in Fig. 4. The photograph in Fig. 7 shows the nearby forest-pond ecotone used by the male and female (C9 and C42) in Fig. 5. The varied habitat choices that we see

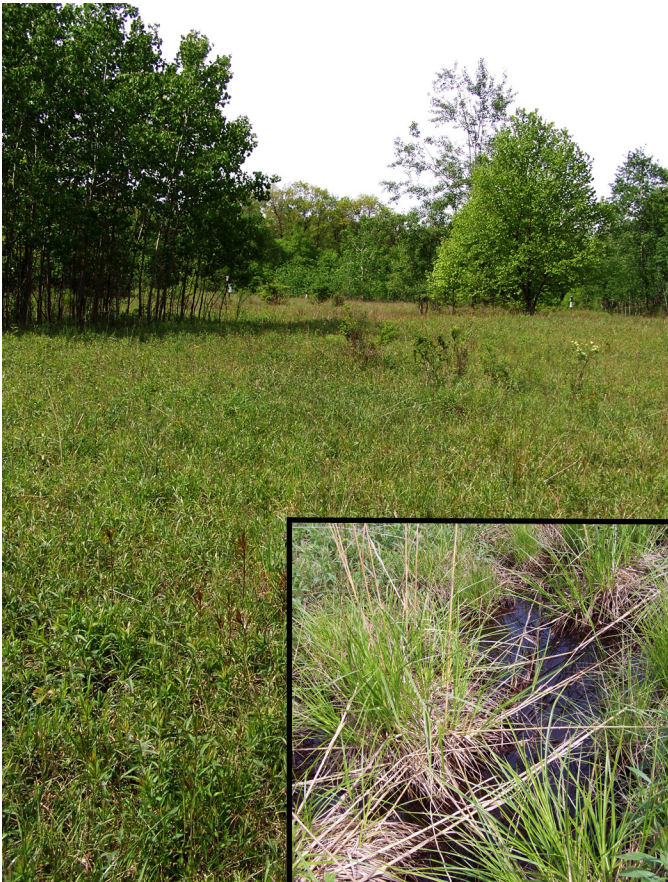


Adult male Eastern Box Turtle (*Terrapene carolina carolina*) D23; habitat use by D23 is plotted in Fig. 10.



**Fig. 5.** Yellow lines mark sequential connections between 177 waypoints collected during the first eight seasons (2004 through 2011) for adult male C9. Red lines mark sequential connections between 83 waypoints during the first four seasons (2008 through 2011) for adult female C42.





**Fig. 6.** Sedge swamp habitat used by some of the population's adult and juvenile box turtles. Inset in lower right corner is an enlarged view to show temporary stands of water that periodically pool among the sedges.



Adult male Eastern Box Turtle (*Terrapene carolina carolina*) C26 in copulation with a headstarted female; habitat use by C26 is plotted in Fig. 11. Photograph by R. McGarrity.



**Fig. 7.** Some of the population's box turtles use this ecotone encompassing a seasonal pond and deciduous woodland. This site is approximately 200 m from the sedge swamp pictured in Fig. 6.



Headstarted male Eastern Box Turtle (*Terrapene carolina carolina*) D29; habitat use by D29 is plotted in Fig. 12.

from individual to individual echo the varied habitats previously seen from population to population of this species (e.g., river floodplain in Stickle 1950; upland, partially virgin forest in Williams and Parker 1987).

#### Low Site Fidelity Among Some Adults

In contrast to the adults above, other adults in our population exhibited poor site fidelity following their release. Figure 8 shows the movements of an adult male (A10) that took

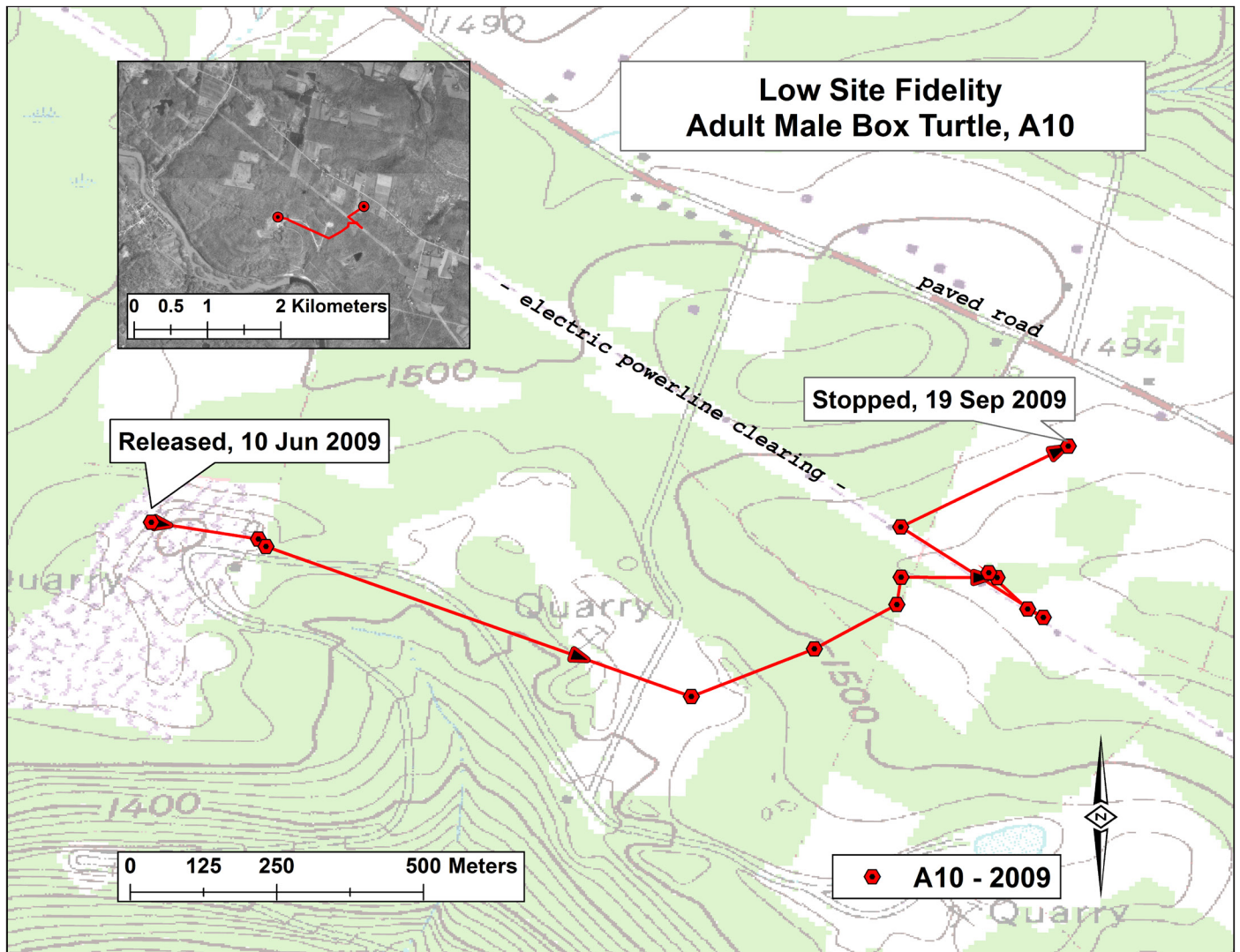


Fig. 8. Red lines mark connections between 13 waypoints collected for adult male A10 from his release on 10 June 2009 until he reached the hazard of a paved road outside the sanctuary in late September 2009.

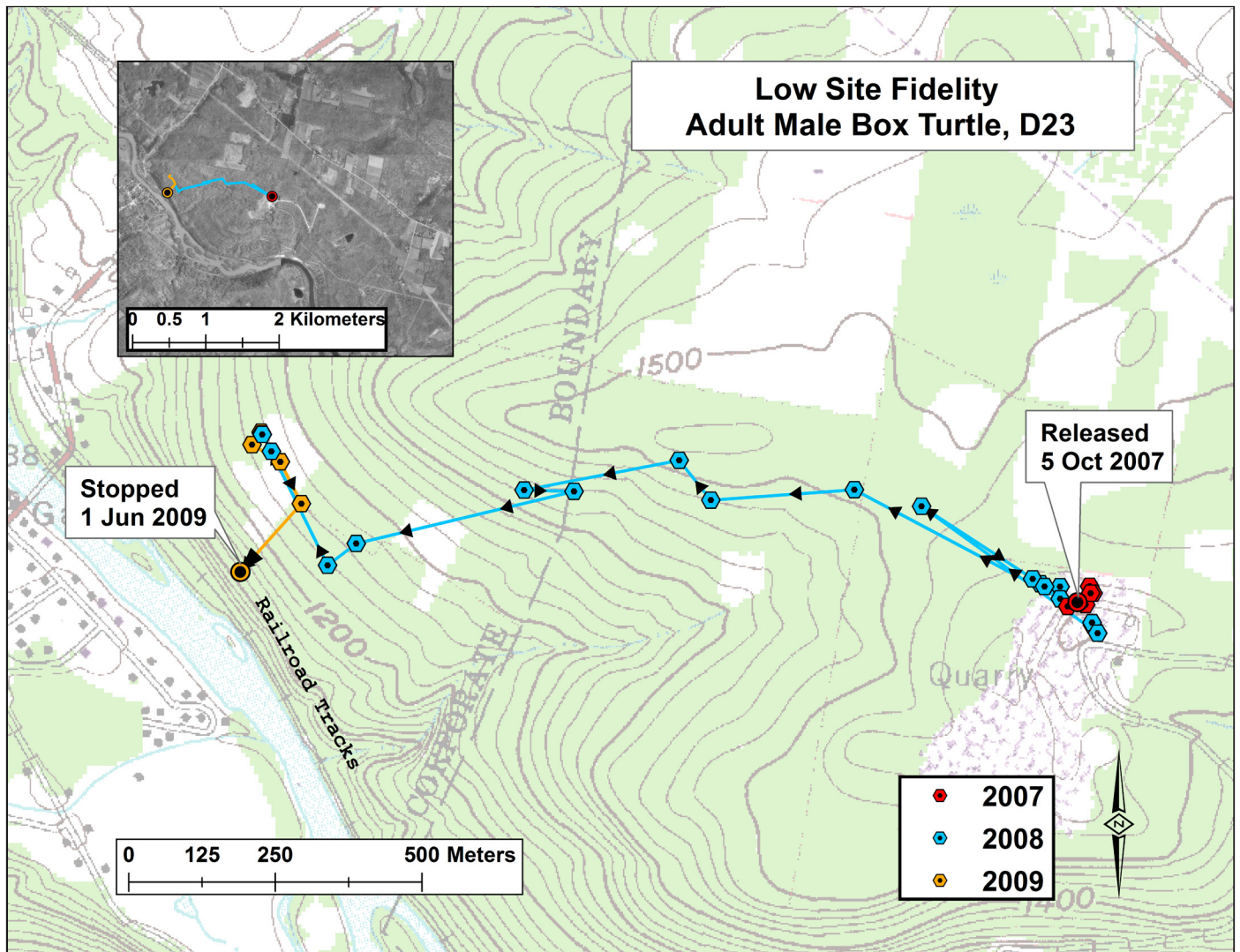


Headstarted male Eastern Box Turtle (*Terrapene carolina carolina*) D14; habitat use is plotted in Fig. 14.



Headstarted male Eastern Box Turtle (*Terrapene carolina carolina*) D37; habitat use by D37 is plotted in Fig. 19.





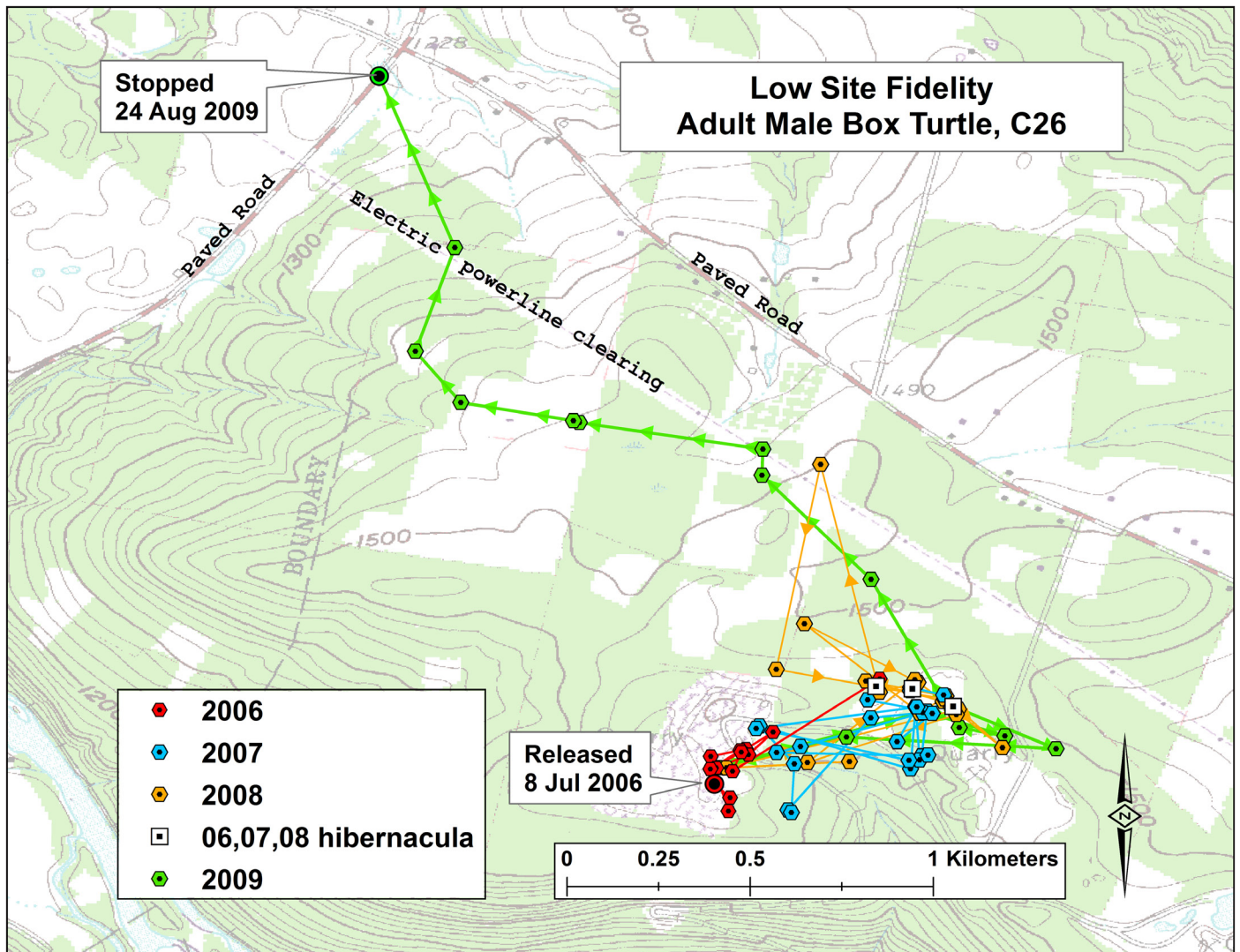
**Fig. 10.** Map lines mark connections between 32 waypoints collected for adult male D23 from his release on 5 October 2007 until he reached the hazard of a railroad track in June 2009. Red = 2007 (six waypoints during one activity-month); blue = 2008 (21 waypoints during the full activity season of six months); gold = 2009 (five waypoints during one activity-month).



Headstarted male Eastern Box Turtle (*Terrapene carolina carolina*) D49; habitat use by D49 is plotted in Fig. 21.



Headstarted male Eastern Box Turtle (*Terrapene carolina carolina*) E18; habitat use by E18 is plotted in Fig. 22.



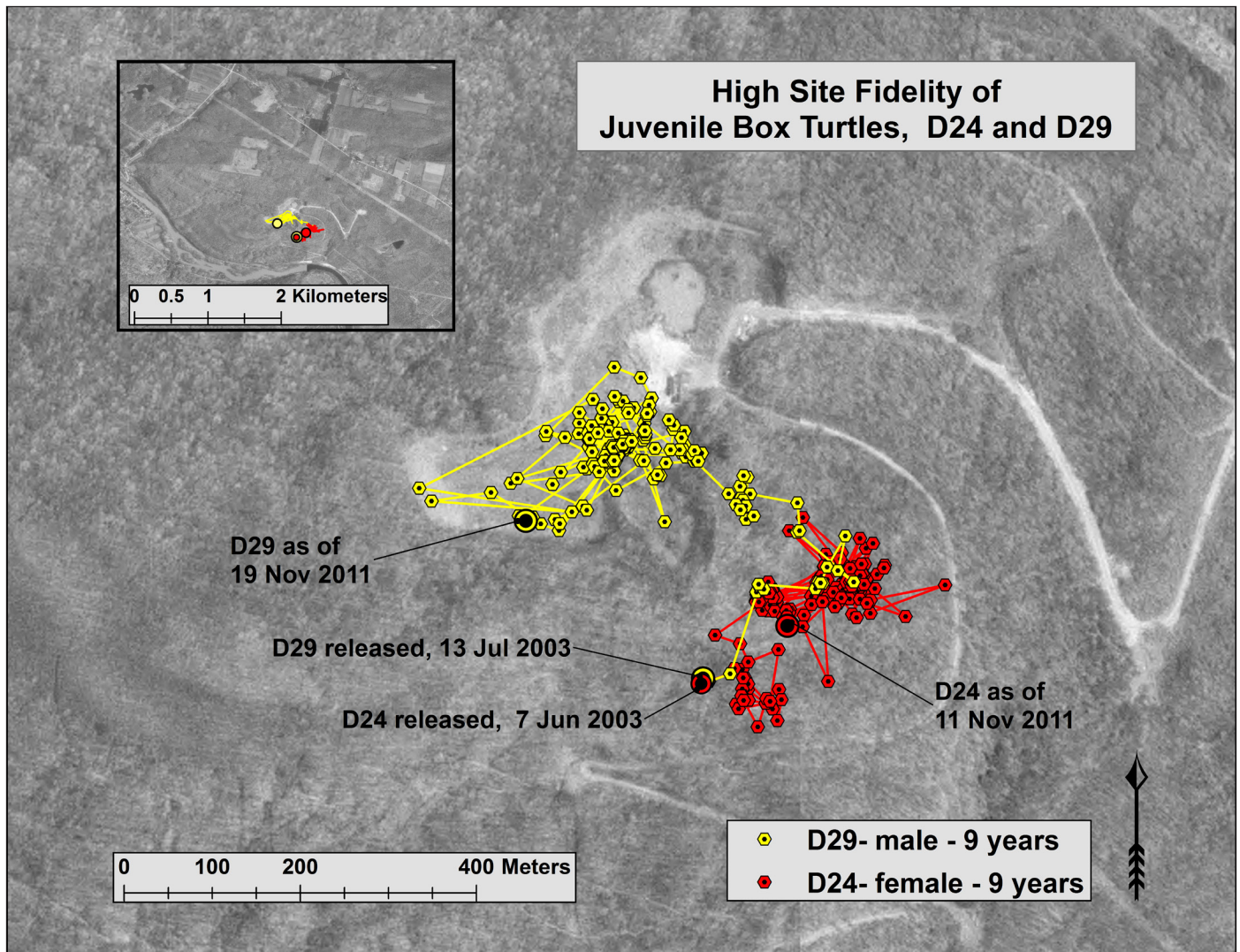
**Fig. 11.** Map lines mark connections between 78 waypoints collected for adult male C26, from his release on 8 July 2006 until he reached the hazard of a paved road 2 km away in late August 2009. Red = 2006 (22 waypoints during the full 7-month activity season); blue = 2007 (19 waypoints during the full 5.5-month activity season); gold = 2008 (22 waypoints during the full 6-month activity season); green = 2009 (15 waypoints during three activity-months). White squares = all three hibernation sites close to each other, leading to our mistaken expectation of long term site fidelity from this male.



Headstarted female Eastern Box Turtle (*Terrapene carolina carolina*) E26; habitat use by E26 is plotted in Fig. 23.



Headstarted female Eastern Box Turtle (*Terrapene carolina carolina*) E27; habitat use by E27 is plotted in Fig. 24.



**Fig. 12.** Red lines mark connections between 196 waypoints collected during the first nine seasons (2003 through 2011) for headstarted juvenile female D24. D24 release body weight at age 34 mo (end of hatch-to-release headstart period) = 248 g. Yellow lines mark connections between 197 waypoints during the first nine seasons (2003 through 2011) for head-started juvenile male D29. D29 release body weight at age 32 mo (end of hatch-to-release headstart period) = 224 g.

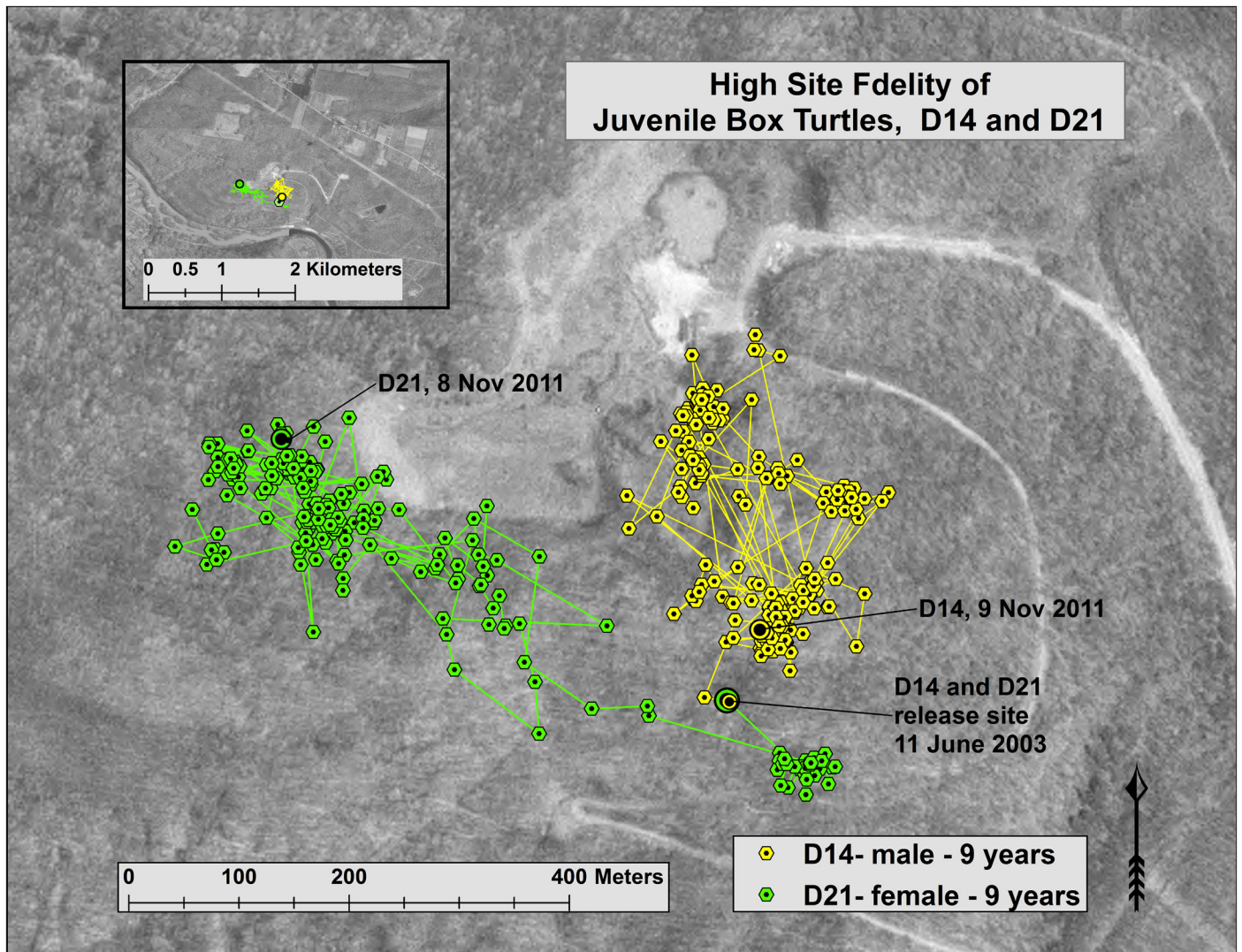
### High Site Fidelity Among Some Headstarted Juveniles

When we began to release headstarted juveniles at BHNS, we had hoped that such 2-yr old, half-grown turtles (Belzer and Seibert 2007a), exposed to no previous natural habitat, would be more inclined to exhibit high site fidelity than did the adults at BHNS. Some juveniles did. Figures 12, 13, and 14 show six juveniles (3 females and 3 males) that have never moved out of their respective, small home ranges during the 8 to 9 years following their release. In each case, the juvenile settled into its chosen home habitat within 4 or 5 weeks after release. Although the stability of habitat use for these six juveniles is high, differences exist between the types of habitat each chose to occupy (as we have seen for adults).

The male (D29; yellow waypoints) in Fig. 12 has used the open, swampy sedge meadow (previously illustrated in Fig. 6) during the nine years since his release in July 2003.



**Fig. 13.** View of the open woodland area used by headstarted juvenile female D24 during her first nine seasons at the BHNS sanctuary. Habitat use by D24 is mapped in Fig. 12.



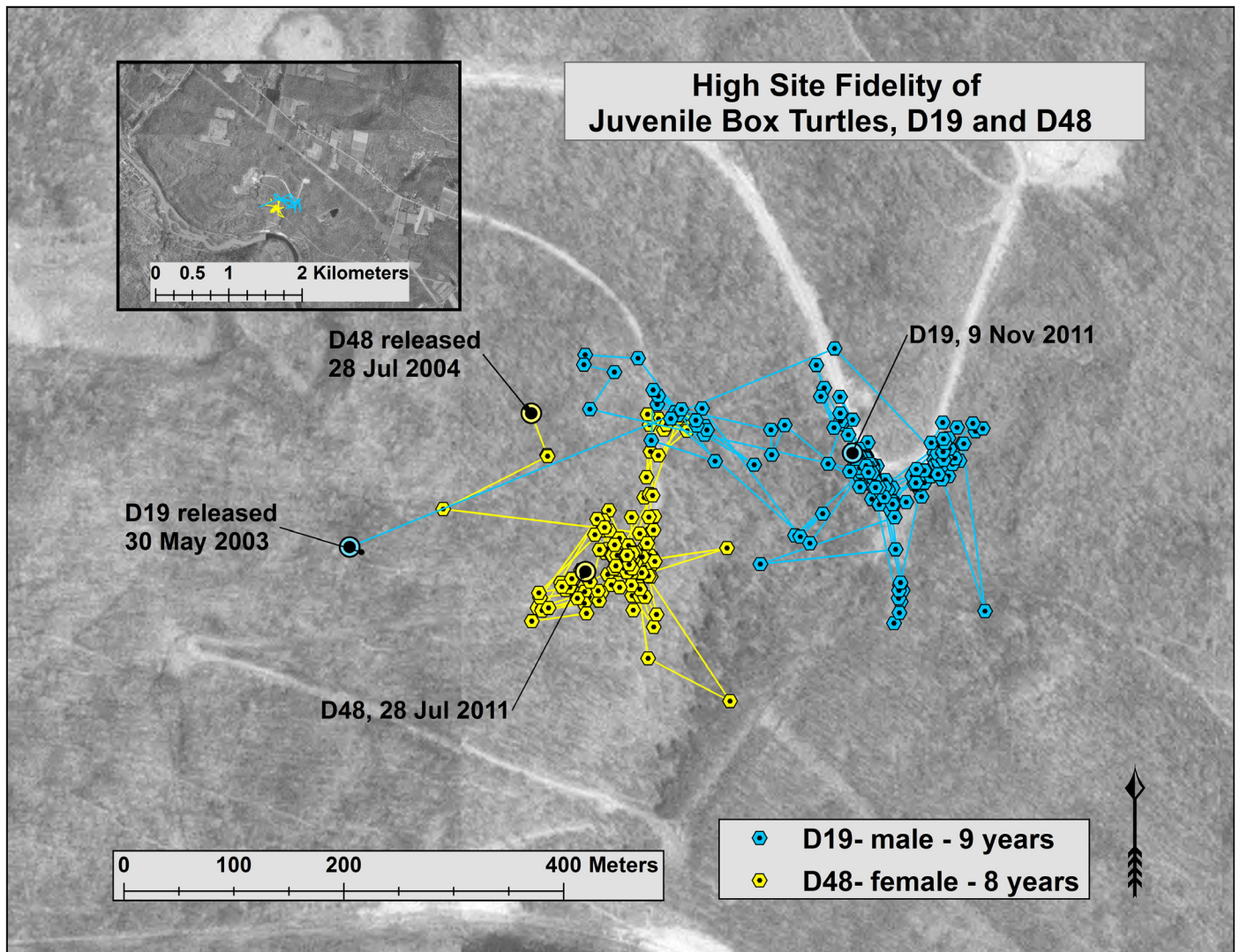
**Fig. 14.** Yellow lines mark connections between 172 waypoints during the first nine seasons (2003 through 2011) for headstarted juvenile male D14. D14 release body weight at age 27 mo (end of hatch-to-release headstart period) = 226 g. Green lines mark connections between 187 waypoints collected during the first nine seasons (2003 through 2011) for headstarted juvenile female D21. D21 release body weight at age 26 mo (end of hatch-to-release headstart period) = 250 g.

The female (D24; red waypoints) in Fig. 12 has used nearby open woodland during the nine years since her release in June 2003. Figure 13 shows the open woods used by D24. During the nine years since his release in June 2003, the male (D14; yellow waypoints) seen in Fig. 14 has ranged back and forth between the sedge meadow and broken woodland (illustrated in Figs. 6 and 13, respectively) that was used more selectively by the juveniles in Fig. 12. The female in Fig 14 (D21; green waypoints) has used neither of those habitats, but chose to reside in more dense woods on the far side of a nearby ridge during the nine years since her release in June 2003. Figure 15 shows the dense woods used by D21.

Figure 16 shows the 9-year home range for a juvenile male (D19; blue waypoints) since his release in May 2003, and the 8-year home range for a juvenile female (D48; yellow waypoints) since her release in July 2004. Although both juveniles adopted ecotones between a dirt road and wood-



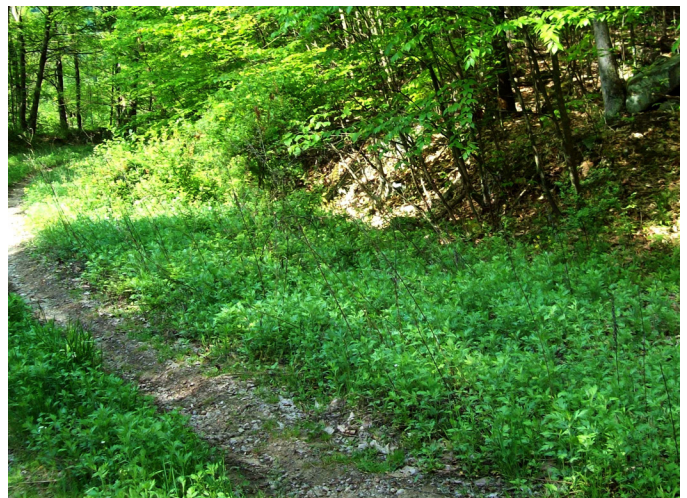
**Fig. 15.** View of the dense woodland area used by headstarted juvenile female D21 during her first nine seasons at the BHNS sanctuary. Habitat use by D21 is mapped in Fig. 14.



**Fig. 16.** Blue lines mark connections between 168 waypoints collected during the first nine seasons (2003 through 2011) for headstarted juvenile female D19. D19 release body weight at age 27 mo (end of hatch-to-release headstart period) = 230 g. Yellow lines mark connections between 142 waypoints during the first eight seasons (2003 through 2011) for headstarted juvenile male D48. D48 release body weight at age 27 months (end of hatch-to-release headstart period) = 237 g.



**Fig. 17.** View of the ecotone between woodland and dirt road used by headstarted juvenile male D19 during his first nine seasons at the BHNS sanctuary. Habitat use by D19 is mapped in Fig. 16.



**Fig. 18.** View of the ecotone between woodland and dirt road used by headstarted juvenile female D48 during her first eight seasons at the BHNS sanctuary. Habitat use by D48 is mapped in Fig. 16.



land, they settled along different dirt roads. Figure 17 shows the road-edge used by D19; Figure 18 shows the road-edge used by D48, about 350 m across a valley to the west of D19.

**Low Site Fidelity**

**Among Some Headstarted Juveniles**

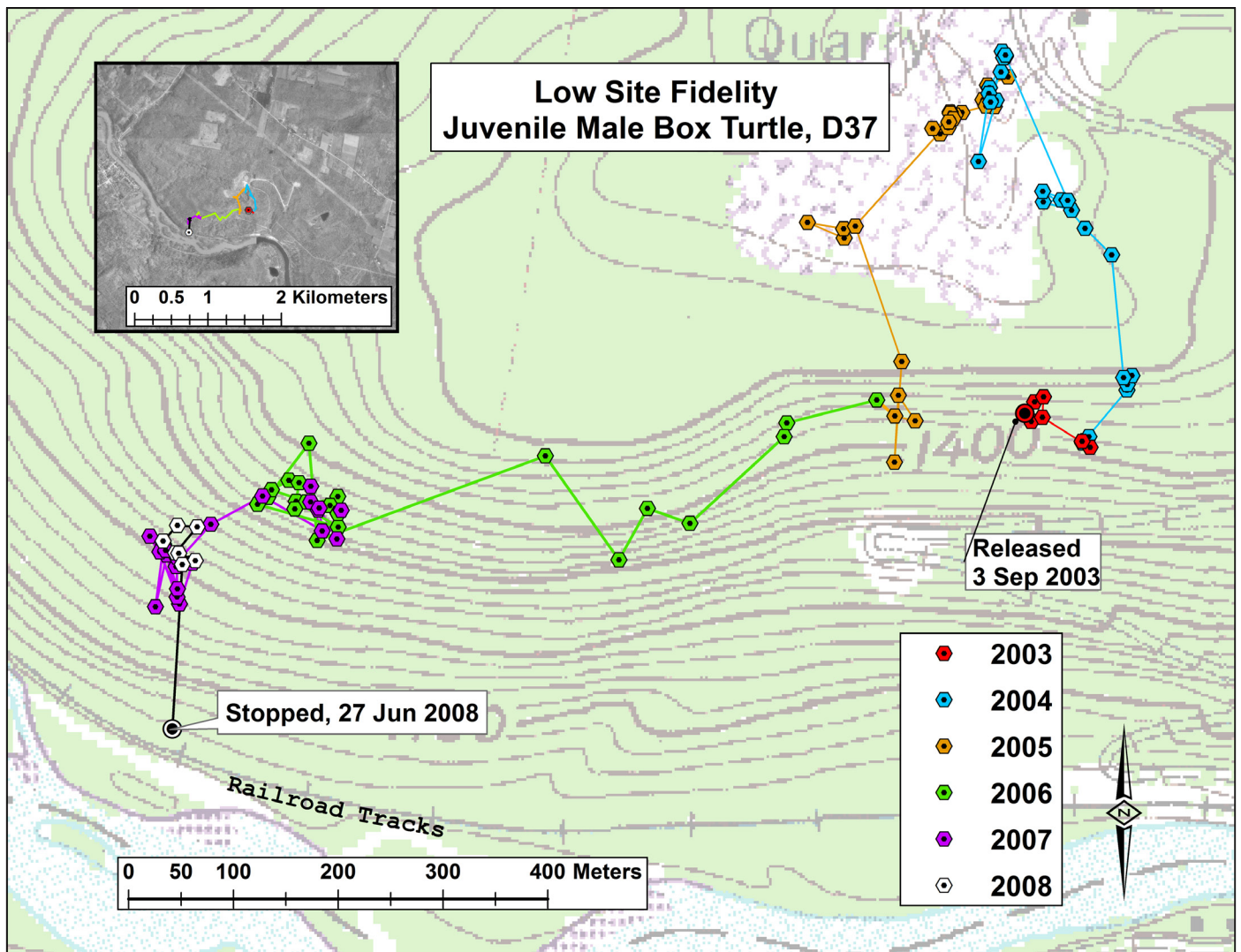
As with the adults (whose movements were portrayed in Figs. 8, 9, 10, and 11), some juveniles in our population are at the far end of the movement spectrum, displaying no apparent inclination to adopt a circumscribed home range. Soon after release, these individuals began a steady out-migration that eventually brought them to a hazardous area outside the sanctuary buffer, requiring their retrieval.

Figures 19, 20, 21, and 22 show the movements of four such male juveniles (D37, D47, D49, and E18, respectively). Figures 23 and 24 show the movements by two such female juveniles (E26 and E27, respectively). Note that these far-

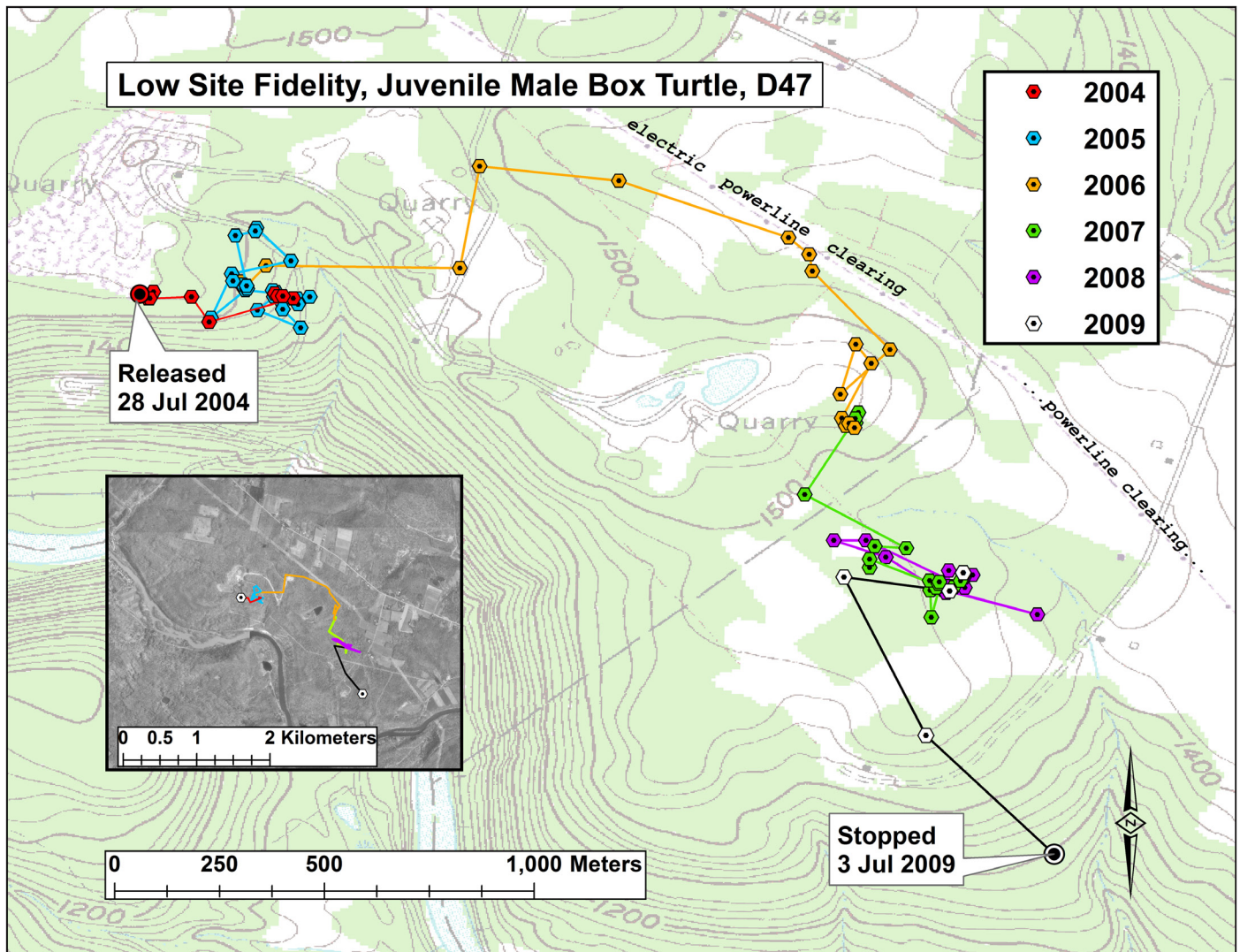
ranging juveniles generally took more years to reach remote areas than did most of the far-ranging adults.

**Discussion**

The turtles chosen for this first paper exhibited simple extremes in site fidelity. Much more complicated patterns of habitat use abound in the population. How any of our released box turtles used its habitat was unpredictable, and some changed their conduct after years of consistency. The remarkable behavioral diversity in this species can easily go unrecognized without decades of careful observation. We will reinforce that point in future installments of this series with examples of very different and more complex patterns of habitat use. However, even the few examples in this first paper may be sufficient to forewarn fieldworkers of pitfalls inherent in anticipating population ranges based on relatively few individuals or few years of data.



**Fig. 19.** Map lines mark connections between 108 waypoints collected for juvenile headstarted male D37 from his release on 3 September 2003 until he reached the hazard of a railroad track at the end of June 2008. Red = late-season 2003, two activity-months; blue = 2004 full 5-month activity season; gold = 2005 full 5.5-month activity season; green = 2006 full 5.5-month activity season; purple = 2007 full 5.5-month activity season; black lines (between white squares) = early 2008, two activity-months. D37 release body weight at age 14 mo (end of hatch-to-release headstart period) = 280 g.

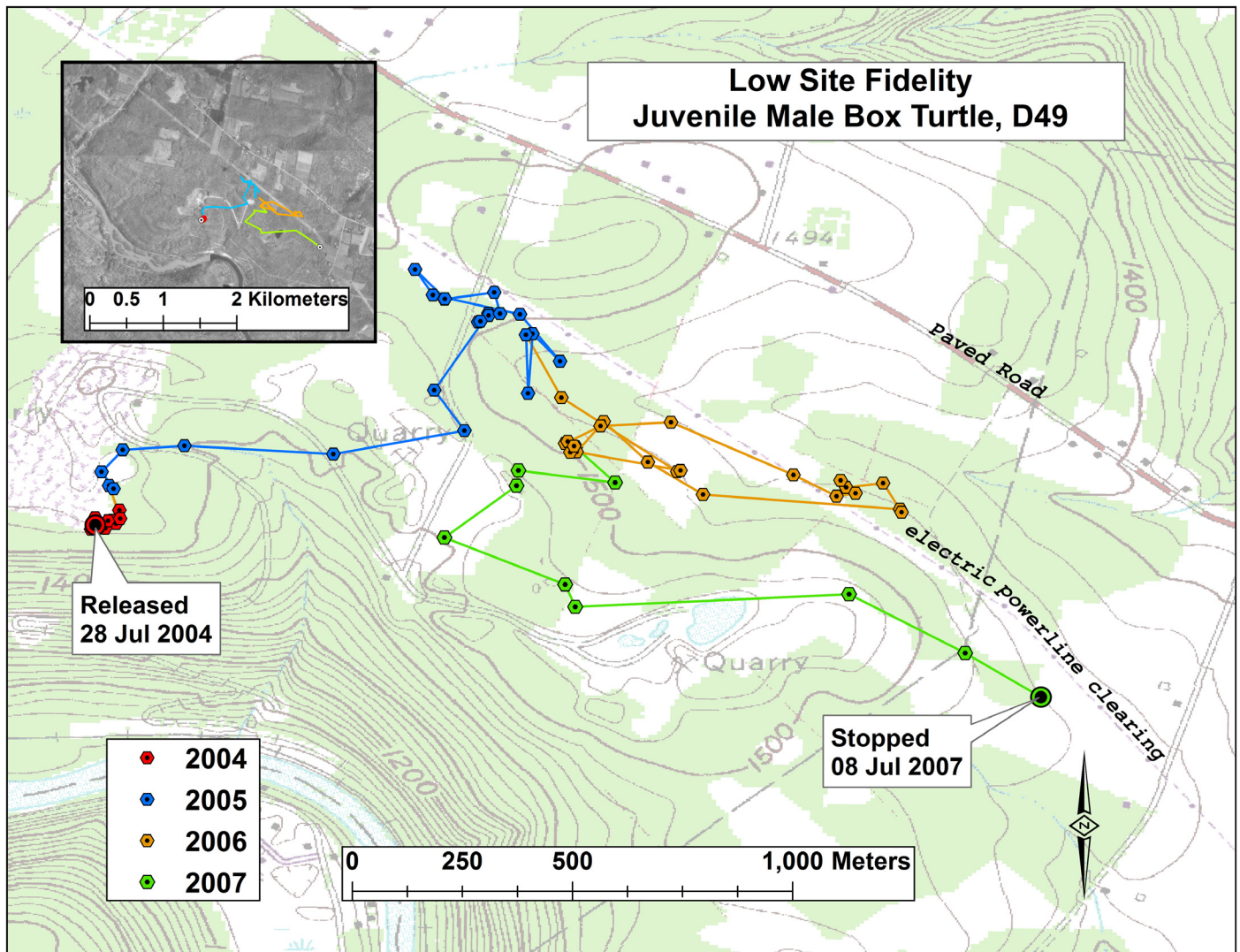


**Fig. 20.** Map lines mark connections between 96 waypoints collected for juvenile headstarted male D47 from his release on 28 July 2004 until he reached the hazard of a summer cottage area near French Creek 2.5 km away in early July 2009. Red = late-season 2004, two activity-months; blue = 2005 full 5.5-month activity season; gold = 2006 full 5-month activity season; green = 2007 full 5-month activity season; purple = 2008 full 5-month activity season; black = early 2009, two activity-months. D47 release body weight at age 27 mo (end of hatch-to-release headstart period) = 266 g.

The idiosyncratic peregrinations among our turtles do not seem to be an artifact of translocation. Our multiple-year tracking (unpublished) of three native male box turtles at McK and BHNS, and Nazdrowicz's (2003) study of movements in several native Delaware (USA) populations of this species found range changes and immigration/emigration individualities resembling those for our translocated adults and habitat-naïve juveniles. Jim Basinger has posted detailed, multi-year movement maps, and terrain information for native Eastern Box Turtles in the Blue Ridge Bioregion of Virginia, USA (<http://home.ntelos.net/~jbasi/boxturtle.html>). His accumulating data and remarkably instructive maps reveal a behavioral diversity among native turtles that is very similar to that seen in our population. One of his turtle's maps is essentially a straight-line trek of over 5 km; some maps show rather settled home ranges; another turtle's map

shows settled but disparate home ranges occupied at different times of year.

Our ongoing field observations increasingly reveal the distinctness of movement patterns displayed by individuals of this species, rendering prospects for describing a generalized habitat type and activity patterns within it for *Terrapene carolina carolina* more and more tenuous. Dodd (2001) noted that the types of habitat used by box turtles can vary by season, weather, and age of the individual turtle, but a reader could infer from his conspectus that, under similar circumstances, the turtles in a population would be expected to behave similarly; we do not see that. Rather, our findings amplify Dodd's (2001) caveat that: "It is easy to fall into the trap of saying that 'box turtles inhabit this or that type of habitat.'" Each of the turtles that we have tracked has exhibited its own distinctive movement pattern and habitat preference.



**Fig. 21.** Map lines mark connections between 64 waypoints collected for juvenile headstarted male D49 from his release on 28 July 2004 until he reached the hazard of a working farm 2 km away in early July 2007. Red = late-season 2004, three activity-months; blue = 2005 full 5.5-month activity season; gold = 2006 full 5.5-month activity season; green = early 2007, two activity-months. D49 release body weight at age 27 mo (end of hatch-to-release headstart period) = 261 g.

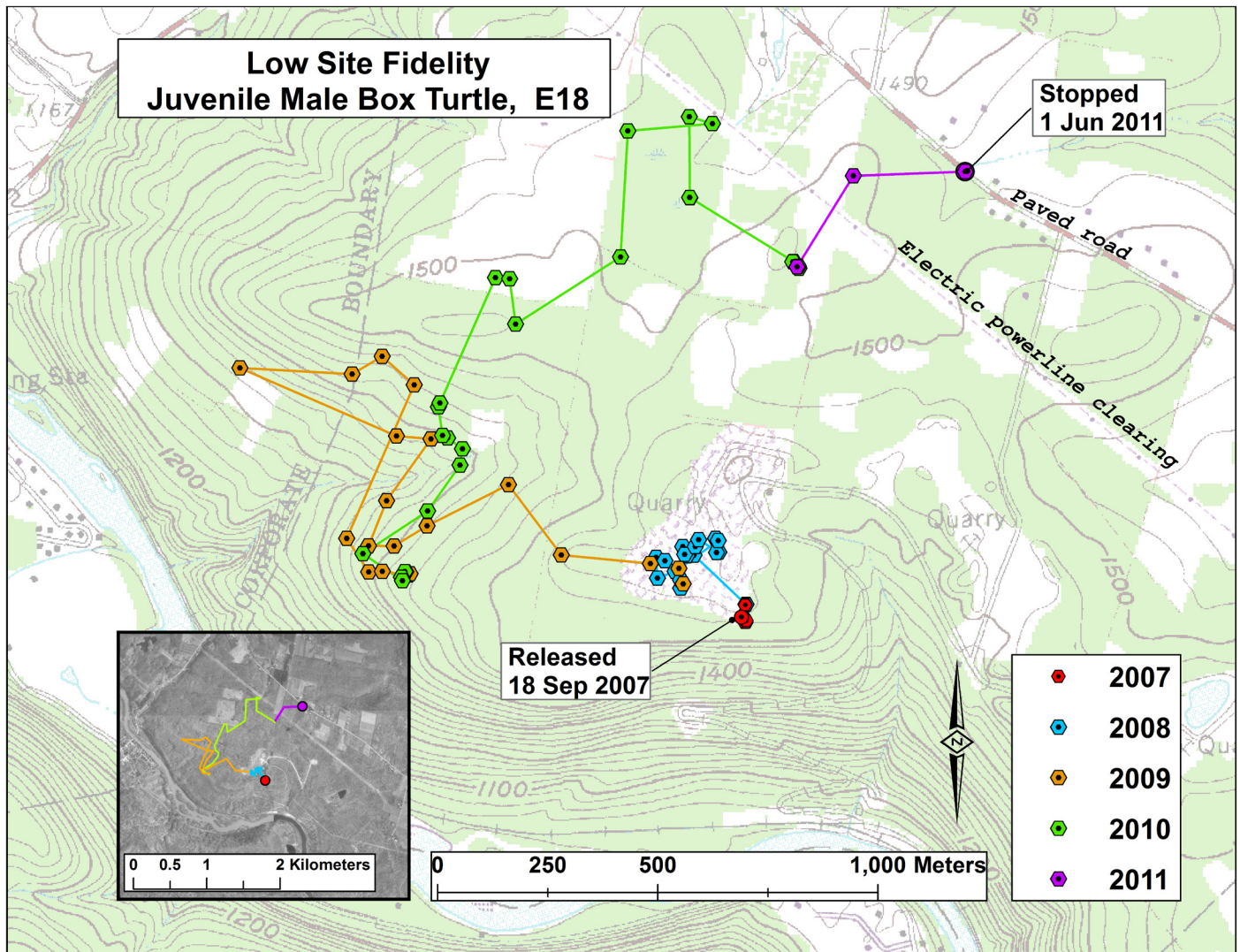
### Acknowledgements

We are deeply grateful to the owners of the Buttermilk Hill Nature Sanctuary for their ongoing permission and patience for these long-term studies on their property. Without their aegis, we would never have gained the insights on habitat use that are beginning to emerge. Our open-ended studies are enabled by a special research permit issued in 1993 by the Pennsylvania Fish and Boat Commission (PFBC). We provide the PFBC with annual updates on our fieldwork in compliance with the permit. We also complied with Guidelines (<http://www.asih.org/files/hacc-final.pdf>) for the Use of Live Reptiles in Field Research (ASIH, HR, and SSAR).

In 2000, the Pennsylvania Department of Conservation and Natural Resources (DCNR) and Pennsylvania State University's GIS Department provided us with Environmental Systems Research Institute (ESRI) ArcView®

version 3.1 software and instruction in its use. ArcGIS® version 10.1 software was awarded to SS in January 2011 by an ESRI *Conservation Program (ECP)* grant.

The Bartramian Chapter of the Audubon Society, the Bebko family at the Pittsburgh Cat Clinic/Hospital, Fred Hillan, Jude Holdsworth and her associates at Cocksackie Antiques, Edward Pencoske, Hannah Toombs, and a Fall 2003 release-time stipend granted to WRB by Clarion University of Pennsylvania provided important financial support for our work. Veterinary diagnostics and treatment for afflicted turtles and donations of displaced turtles that could not be returned to their native habitat were provided by Wildlife Works, Inc. (Youngwood, Pennsylvania, USA) and by Centre Wildlife Care (Port Matilda, Pennsylvania, USA). Kathy Michell of the New York Center for Turtle Rehabilitation and Conservation gave us important veterinary and field advice.



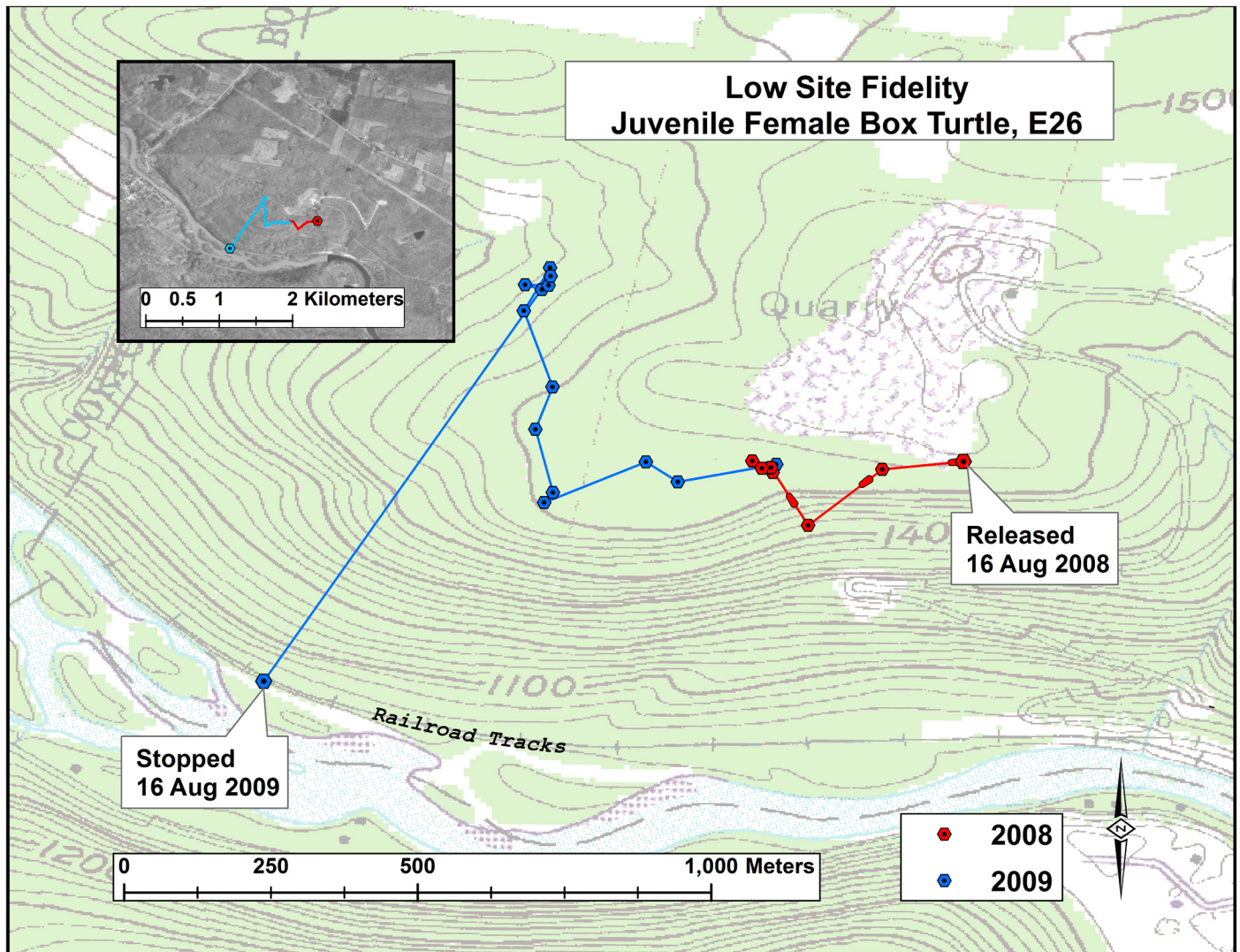
**Fig. 22.** Map lines mark connections between 77 waypoints collected for juvenile headstarted male E18 from his release on 18 September 2007 until he reached the hazard of a paved road in early June 2011. Red = late-season 2007, two activity-months; blue = 2008 full 5-month activity season; gold = 2009 full 6-month activity season; green = 2010 full 6.5-month activity season; purple = early 2011, one activity-month. E18 release body weight at age 26 mo (end of hatch-to-release headstart period) = 341 g.

Ben Atkinson, Chris Hammond, Ryan McGarrity, and the late Frank Weiss volunteered valuable field assistance at various points during the past two decades. We also are indebted to many other volunteers for their dedicated and intensive labor in headstarting hatchlings from our salvaged eggs. Space constraints prevent naming them all, but we do wish to name those who headstarted the 12 juveniles specifically featured in this article. They are Sandy Blystone, Jeneen Gahr, Karen Kovalchick, Jeff McFadden, Tim Parish, Alex Petridis, Gil Pielin, Ted Scarlet, Jane Schwartz, Jenny Shape, and Vincent Spina.

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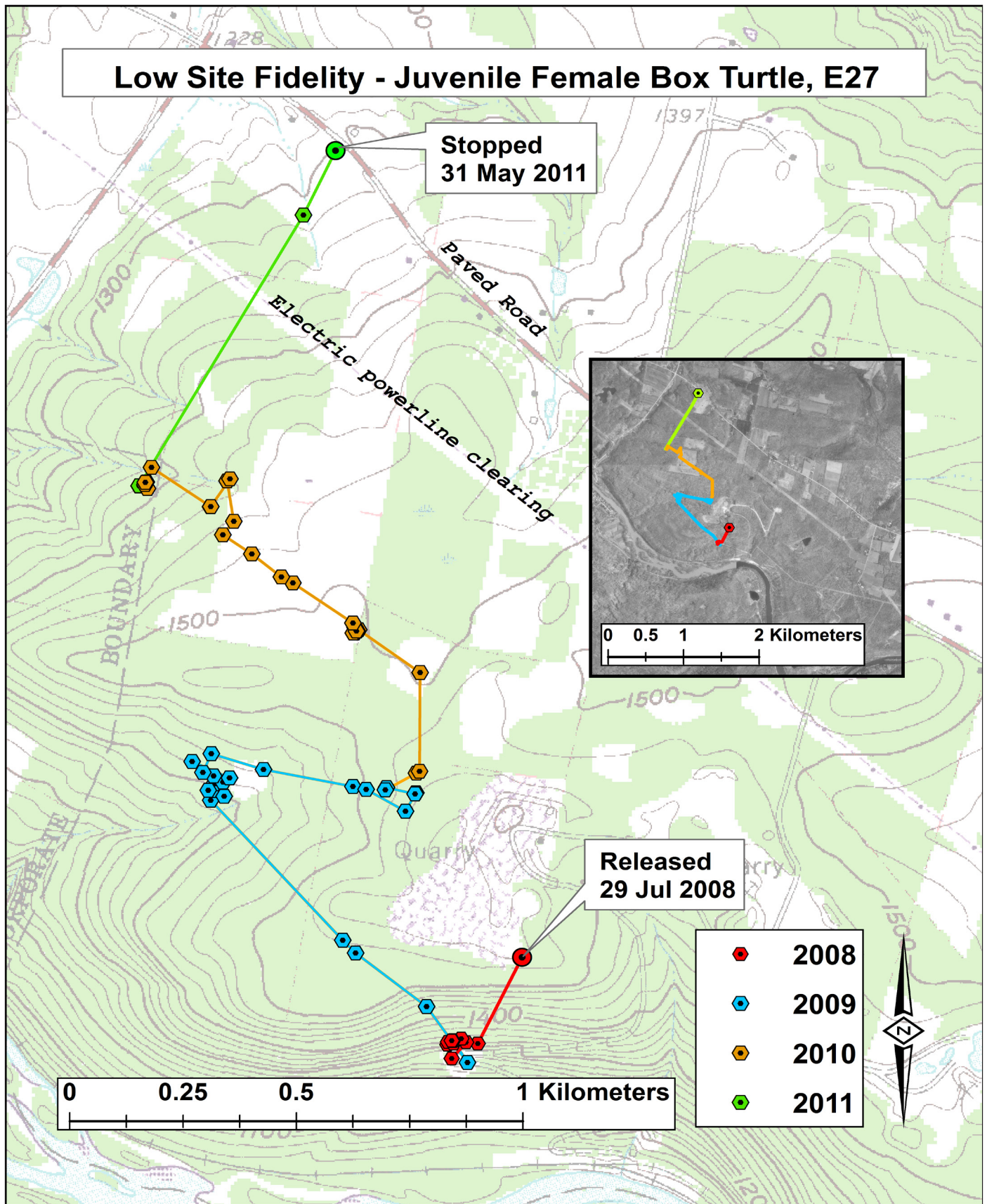
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**Fig. 23.** Map lines mark connections between 23 waypoints collected for juvenile headstarted female E26 from her release on 16 August 2008 until she reached the hazard of a railroad track in mid-August 2009. Red = late-season 2008, 2.5 activity-months; blue = early 2009, 3.5 activity-months. E26 release body weight at age 13 mo (end of hatch-to-release headstart period) = 265 g.

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**Fig. 24.** Map lines mark connections between 64 waypoints collected for juvenile headstarted female E27 from her release on 29 July 2008 until she reached the hazard of a paved road and a working farm 2 km away at the end of May 2011. Red = late-season 2008, three activity-months; blue = 2009 full 7-month activity season; gold = 2010 full 6-month activity season; green = early season 2011, one activity-month. E27 release body weight at age 24 mo (end of hatch-to-release headstart period) = 320 g.