Accuracy and location success of an ultralite GPS unit

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Summary

Technological advances in GPS tracking units for wildlife have led to smaller and lighter devices. Increased battery life allows for collection of more locations. Before a new device is used in the field, it is important to evaluate its performance in order to more accurately interpret the raw data collected. Our objective was to determine the accuracy and location success of the G10 Ultralite GPS logger for potential use in a study of wood turtles (*Glyptemys insculpta*).

We conducted stationary and moving tests under a variety of device settings and field conditions. For stationary tests, accuracy was measured by calculating the 50% and 95% circular error probable (CEP) at each test location. The CEP is the radius of a circle centered at the true location which contains either 50% or 90% of locations. We also calculated angular dispersion of each dataset, a measure of the direction and concentration of locations. Moving tests were conducted at two sites where wood turtles occur in order to evaluate the GPS unit performance under expected field conditions.

Location success was ≥ 95% for all tests, including moving tests, indicating strong potential for consistent performance in the field. Location accuracy was not affected by snapshot size, location interval, or canopy cover. The angular dispersion values calculated indicated little bias in any compass direction, although smaller datasets had greater bias. The 95% CEP for most tests was < 40 m, demonstrating feasibility for assessment of wood turtle movements and habitat use. Integrating use of a temperature sensor would allow for better determination of aquatic vs. terrestrial behavior. To increase accuracy of GPS datasets, data should be screened to identify and remove outliers, using prior knowledge of animal movement characteristics.

The high accuracy and location success documented in our tests combined with low power consumption and high storage capacity demonstrates the potential of the G10 Ultralite as an effective animal tracking device.

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Introduction

The use of Global Positioning System (GPS) technology for tracking wildlife has increased dramatically in recent years. The number and type of GPS tracking devices has expanded to include products designed for reptiles, birds, and fish, as well as terrestrial and marine mammals. GPS tracking devices enable increased frequency, accuracy, and precision of locations when compared to previous methods such as VHF radiotelemetry (Rodgers et al. 1996, Hulbert and French 2001, Rodgers 2001, Tomkiewicz et al. 2010). It also allows data to be collected and stored automatically 24 hours a day in all weather conditions (Cagnacci et al. 2010, Tomkiewicz et al. 2010, Bjørneraas et al. 2010). Before deployment it is important to evaluate the accuracy and precision of GPS devices to facilitate correct interpretation of results (Moen et al. 1997, Hulbert and French 2001, D'Eon and Delparte 2005). Possible sources of location error and bias include canopy cover, position, and animal activity level(Moen et al. 1996, 2001, Hulbert and French 2001, Lewis et al. 2007). These sources of error can decrease accuracy (proximity to true location) and precision (proximity of repeated measurements to each other), as well as location success (the percentage of successful locations) (Moen et al. 2001, Rodgers 2001, D'Eon and Delparte 2005). Removing locations with large errors through data screening can increase accuracy and precision of datasets (see Bjørneraas et al. 2010) and allows for better evaluation of animal movements and habitat selection (D'Eon and Delparte 2005, Lewis et al. 2007, Tomkiewicz et al. 2010). Obtaining a large number of locations (high location frequency) can reduce the impact of data loss through data screening.

The main factor limiting location frequency is unit size/weight (Tomkiewicz et al. 2010). When GPS systems were first adapted to use in animal tracking studies, applications were limited by the need for large batteries to operate GPS receivers for a useful amount of time (Cagnacci et al. 2010, Tomkiewicz et al. 2010). Reducing battery size severely limited the operational life and the amount of data that could potentially be collected. Technological advances have led to smaller GPS units and more efficient batteries, however battery size can still limit location frequency, making data collection for some species not feasible (Cagnacci et al. 2010). However, the newest units being manufactured are small enough in size for use on small- and medium-sized animals, and have sufficient battery power and technology to obtain large datasets, and allow for effective data screening.

Our objective was to determine the accuracy and location success of a new GPS logger that can be used on small animals. The GPS logger is small enough to be deployed on wood turtles (*Glyptemys insculpta*), which usually weigh < 1500 g (Brooks et al. 1992, Kaufmann 1995, Arvisais et al. 2002). The wood turtle is at the western edge of its geographic range in Minnesota and although they can be locally abundant, populations have declined throughout the state, leading to designation as a threatened species in Minnesota. Recorded home-range sizes vary widely, with mean size usually <30 ha and some individuals <1 ha (Ross et al. 1991, Kaufmann 1995, Arvisais et al. 2002, Remsberg et al. 2006). Previous research suggests that wood turtles can move up to 1.6 km along riparian corridors, but rarely travel >300 m from the water's edge (Kaufmann 1995, Arvisais et al. 2002, Parren 2013). Relatively small home-range size combined with the low mobility of wood turtles highlight the importance of accurate and precise GPS locations in order to understand habitat use in a heterogeneous landscape.

Methods

GPS Unit Testing

We conducted stationary and moving tests of a prototype version of the G10 Ultralite GPS unit manufactured by Advanced Telemetry Systems, Inc. (ATS), Isanti, MN, in June 2014. This unit weighs approximately 11 g (without housing or other attachment hardware). It records GPS locations using “snapshot technology,” where positional data are recorded for a short length of time (milliseconds), and are then processed into locations later when the unit is connected to a computer. These short “snapshots” reduce battery use and eliminate on-board processing which reduces unit weight (Tomkiewicz et al. 2010). The GPS logger must be recovered from the animal to calculate locations (i.e. it is non-transmitting).

Prior to each test, the location interval (time between sequential locations) and snapshot size (the time allowed to record the raw data) were programmed onto the unit. All previous locations were cleared from the unit prior to the next test. Location intervals tested were 10 s, 30 s, 1 m, and 20 m. Snapshot sizes tested were 64, 256, and 512 ms.

For each test, the programmed GPS unit was secured to a high visibility container (Fig. 1). We placed the entire unit on an even surface at each stationary test site for between 1 – 12 hr. All test sites were located in and around Duluth, Minnesota. Test sites were classified as either “open” or “closed” canopy (Fig. 2). Following each testing period, the GPS unit was removed and connected to a computer to calculate locations.

Figure 1. Configuration of setup for field testing of the G10 Ultralite GPS logger. The G10 Ultralite unit (unhoused) was placed in a sealed Ziploc® bag and secured to a handheld seed spreader with duct tape for ease of transportation and visibility. A Garmin ® Etrex 30 was secured adjacent to the G10 (right) during moving tests to provide a reference track.

Moving tests were conducted by carrying the G10 Ultralite GPS unit by hand (Fig. 1) in areas where wood turtles occur (i.e. forested areas near rivers). The G10 Ultralite was programmed to record locations every 1 minute, with a 512ms snapshot size. During field testing, a Garmin® Etrex 30 handheld GPS receiver was secured adjacent to the G10 Ultralite (Fig. 1). The Garmin® Etrex was programmed to record a track with a 30 second location interval. The G10 Ultralite locations were then compared to the reference locations taken by the Garmin® Etrex.

Figure 2. Photographs showing test sites C, D, and E used for stationary tests of the G10 Ultralite GPS logger. Sites A and B (not pictured) were both located in the Natural Resources Research Institue (NRRI) parking lot in Duluth, MN and were classified as “open.” Site C, was classified as “open” and sites D and E were classified as “closed” canopy.

Data Analysis

We converted the GPS locations from each test from latitude/longitude coordinates to Universal Transverse Mercator (UTM) using the NAD1983 datum in Corpscon 6.0.1. The mean of locations at a single test site was considered the true location for that test (Moen et al. 1997). The x- and y-error (hereafter dx and dy) were calculated as the difference between the x- or y-coordinate for a single GPS location and the true location. We then used the Pythagorean Theorem to calculate the error (distance in meters from each GPS location to the true location).

We calculated the radius of the 50% and 95% circular error probable (CEP) using the percentile method, in which the 50% CEP is the radius of a circle centered at the true location which contains 50% of the GPS locations (Moen et al. 1997, D’Eon and Delparte 2005, Lewis et al. 2007). We also calculated the direction ($\bar{a}_j$) and magnitude (r_j) of angular dispersion for each dataset (j), and then the grand mean direction ($\bar{a}$) and magnitude (r) for all tests using the equations presented by Zar (1984). The magnitude of angular dispersion, r, is a measure of concentration of the angles, and is a value between zero and one (i.e. high r value represents high concentration and therefore high bias).

We screened datasets by removing all GPS locations located outside the original 95% CEP to create a screened dataset. CEP radii were then recalculated using the screened dataset. This was done to demonstrate the effectiveness of data screening. Screening of turtle datasets would need to incorporate knowledge of turtle ecology to determine appropriate criteria for location removal (Bjørneraas et al. 2010).

Results

Stationary Field Testing

We conducted 14 stationary tests from 5-19 June 2014. One test was removed from further analysis due to very low location success (~20%). Because other tests were so consistent, we do not know the cause of this low success rate. Success rate was high for all other tests, and did not appear to be affected by snapshot size, location interval, or canopy cover (Table 1).

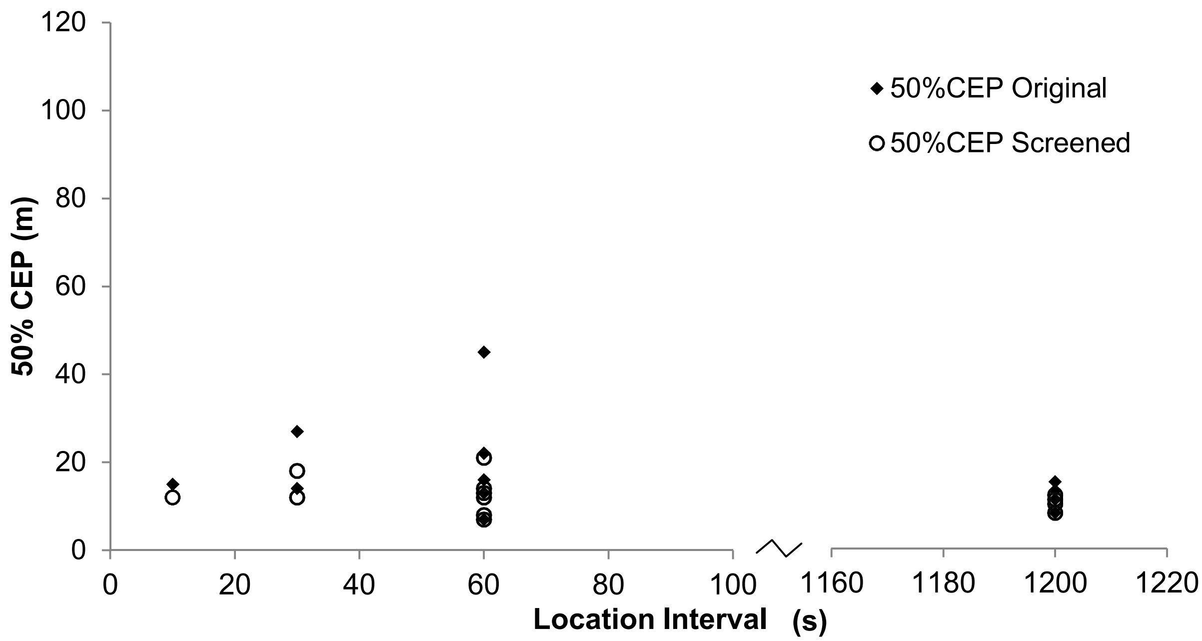
Table 1. GPS unit performance including location success (%) for various settings during stationary testing done in and around Duluth, MN with the G10 Ultralite GPS unit. SV stands for space vehicle, and mean SVs is the number of GPS satellites used to calculate a location.

Snapshot Size (ms)	Location Interval	Test Site	Canopy	Location Attempts	Success (%)	Mean SVs used
64	1 min	B	Open	86	99	8.1
256	1 min	A	Open	74	96	10.3
256	1 min	C	Open	776	97	7.5
256	1 min	B	Open	235	97	7.5
256	20 min	C	Open	28	96	8.1
256	20 min	C	Open	10	100	8.6
256	10 seconds	D	Closed	1282	99	7.8
256	20 min	D	Closed	16	100	10.1
256	20 min	D	Closed	20	100	9.4
512	30 seconds	E	Closed	757	96	7.2
512	30 seconds	D	Closed	297	99	7.6
512	1 min	D	Closed	234	99	10.1
512	1 min	E	Closed	578	97	7.1

Location accuracy also did not appear to be affected by snapshot size, location interval, or canopy cover (Table 2; Fig. 3). Screening datasets by removing locations with large errors increased accuracy (Fig. 4). Mean ± S.E. 50% CEP was 11.4 ± 5.6 m for open canopy tests, and 12.7 ± 2.6 m for closed canopy tests. With the screened dataset, 50% CEP was 10.5 ± 5.1 m for open canopy and 11.9 ± 2.2 m for closed canopy. The 95% CEP were more greatly affected by dataset screening. Open canopy sites averaged 36.8 ± 24.9 m, and closed canopy sites averaged 37.5 ± 16.9 m. Screened datasets averaged 26.9 ± 18.3 m and 28.7 ± 9.8 m for open and closed canopy, respectively.

Angular dispersion was slightly biased overall in a NNE direction (18.4°), although the magnitude of angular dispersion (r) was very low indicating that the angles were fairly evenly dispersed (Table 3). An overall r value of 0 would mean that the angles were distributed exactly uniformly. The magnitude of angular dispersion (r) was greater in tests with longer location intervals, most likely because these tests also had the fewest number of locations. The screened datasets had similar angular dispersion values to the original datasets (Table 3).

Figure 3. Plot of 50% (top) and 95% (bottom) circular error probable (CEP) radius for original and screened datasets vs. location interval for all stationary tests of the G10 Ultralite GPS logger.



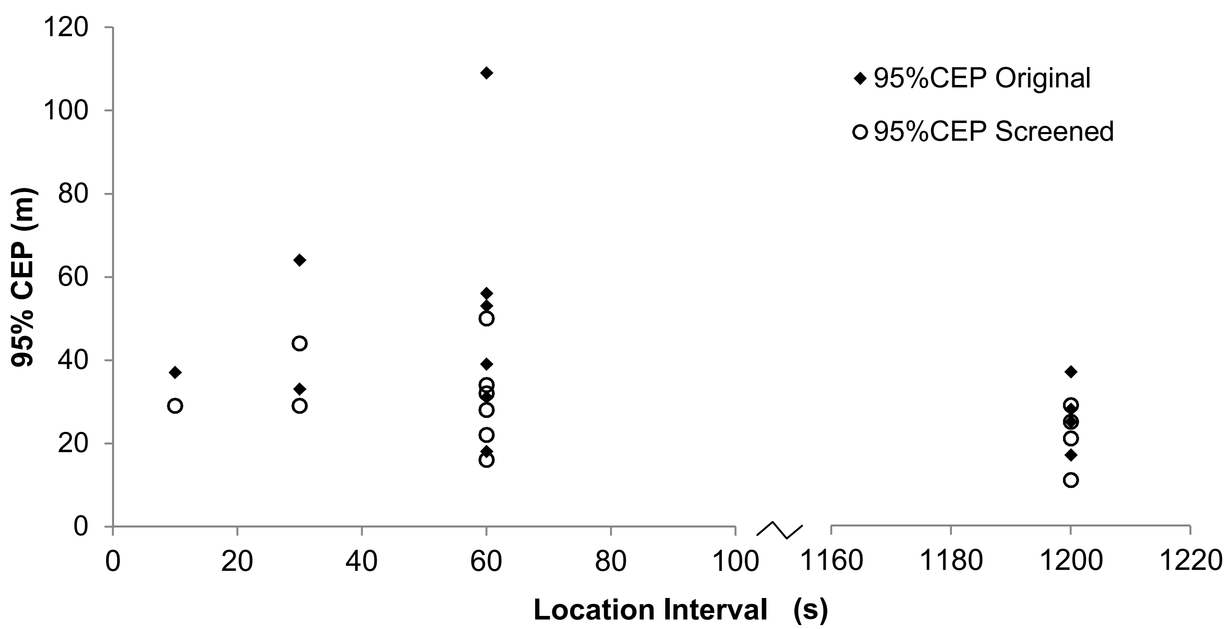


Table 2. 50% and 95% circular error probable (CEP) calculated from full and screened datasets during stationary testing done in and around Duluth, MN with the G10 Ultralite GPS unit.

				Full Dataset		Screened Dataset	
Snapshot Size (ms)	Location Interval	Test Site	Canopy Cover	50% CEP (m)	95% CEP (m)	50% CEP (m)	95% CEP (m)
64	1 min	B	Open	22	56	14	34
256	1 min	A	Open	7	18	7	16
256	1 min	C	Open	22	53	13	32
256	1 min	B	Open	13	31	8	22
256	20 min	C	Open	15	37	12	29
256	20 min	C	Open	8	17	8	11
256	10 seconds	D	Closed	15	37	12	29
256	20 min	D	Closed	13	25	11	21
256	20 min	D	Closed	11	28	10	25
512	30 seconds	E	Closed	73	176	23	55
512	30 seconds	D	Closed	14	33	12	29
512	1 min	D	Closed	16	39	12	28
512	1 min	E	Closed	45	109	21	50
Average:				17.5	42.1	12.2	28.5

Figure 4. Maps showing locations taken by the G10 Ultralite GPS logger during stationary testing at closed canopy sites with location interval 30 s and snapshot size 512 ms. The red circles indicate the 50% (inner) and 95% (outer) CEP. Each dataset was screened by removing locations outside the original 95% CEP and then CEPs recalculated – shown on the right. Additional examples of the effect of screening can be found in Appendix 1.

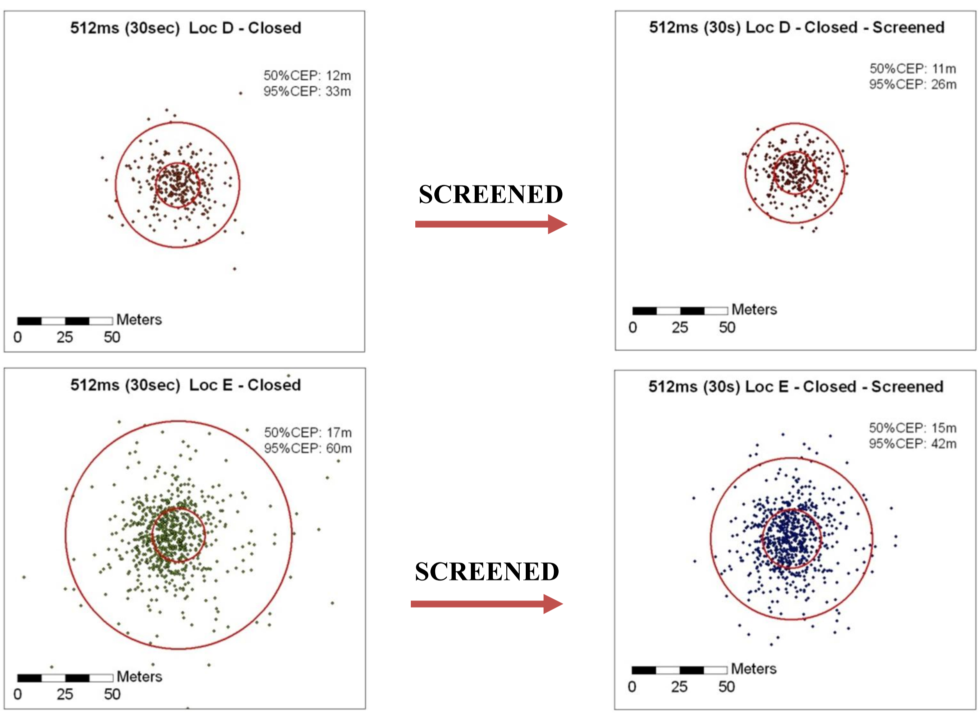


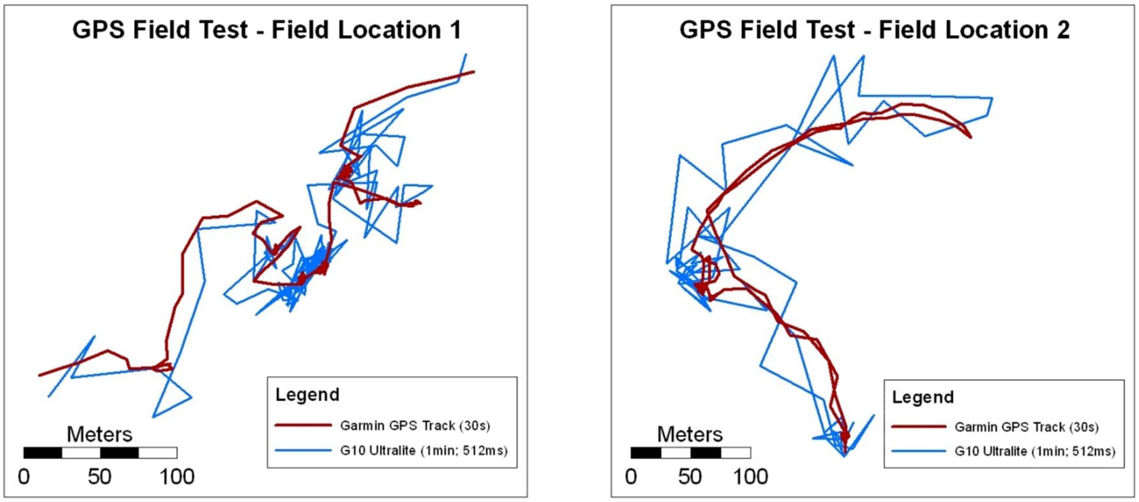
Table 3. Mean angle ($\bar{a}$) and magnitude (r) of angular dispersion for each stationary test of the G10 Ultralite GPS unit. The grand mean for all tests combined is presented at the bottom.

				Full Dataset		Screened Dataset	
Snapshot Size (ms)	Location Interval	Test Site	Canopy Cover	Mean angle, $\bar{a}$ (degrees)	Magnitude (r)	Mean angle, $\bar{a}$ (degrees)	Magnitude (r)
64	1 min	B	Open	42.7	0.03	58.8	0.04
256	1 min	A	Open	330.1	0.16	331.0	0.15
256	1 min	C	Open	16.6	0.05	49.6	0.01
256	1 min	B	Open	318.6	0.12	338.5	0.05
256	20 min	C	Open	59.9	0.09	12.2	0.13
256	20 min	C	Open	298.4	0.16	322.8	0.25
256	10 seconds	D	Closed	297.2	0.06	292.5	0.05
256	20 min	D	Closed	48.2	0.29	67.2	0.37
256	20 min	D	Closed	47.6	0.32	48.5	0.25
512	30 seconds	E	Closed	15.1	0.15	60.8	0.03
512	30 seconds	D	Closed	27.2	0.04	45.8	0.05
512	1 min	D	Closed	64.5	0.14	65.8	0.04
512	1 min	E	Closed	2.5	0.05	79.4	0.02
		GRAND MEAN:		**18.4**	**0.09**	**26.9**	**0.08**

Moving Field Testing

We conducted moving tests at two locations on 11 June 2014, which we will refer to as Field Locations 1 and 2 because wood turtles are a threatened species in Minnesota. Location success was high in both moving field tests (98.7% at Field Location1 and 100% at Field Location 2). Average location difference between the G10 Ultralite and Garmin® Etrex was 14.6 ± 10.0m at Field Location 1, and 24.4 ± 14.6m at Field Location 2 (Fig. 5). Part of the difference in locations between the two units is that the G10 Ultralite GPS logger locations lagged 9 seconds behind the Garmin® at Field Location 1 and 5 seconds behind at Field Location 2.

Figure 5. Recorded GPS tracks during field testing of the G10 Ultralite GPS logger. The Garmin® track shown in red was used as a reference for the G10 Ultralite track (shown in blue).



Discussion

Overall performance of the G10 Ultralite GPS logger suggests that it will provide sufficient data to assess movements and habitat use of small animals such as wood turtles. Location accuracy as measured by the 95% CEP was often within 40 m for full datasets and within 30 m for screened datasets, which suggests proficiency for determining daily and seasonal movements of turtles as this error will not be biologically significant. Our findings are comparable to accuracy values reported by Recio *et al.* (39.5 m; 2011) and Glasby and Yarnell (13.5 m; 2013) for similarly sized units. Although riparian corridors can be narrower than our expected accuracy distance, using a temperature sensor in combination with the GPS logger could make it possible to determine when a turtle enters and exits the water.

Data screening should prove useful for increasing the accuracy of location data. Many methods have been proposed to remove erroneous locations, including evaluating DOP values (Moen et al. 1996, Lewis et al. 2007). Bjørneraas *et al.* (2010) suggested incorporating knowledge of the focal species movement characteristics to identify location errors and limit data loss. A simple step in this process is to set an error threshold between locations, which incorporates the maximum possible distance traveled during a single location interval (Bjørneraas et al. 2010). GPS outliers would likely be easy to identify and remove using this method for small animals with low mobility such as wood turtles, if the location interval is sufficiently short. Increasing the location frequency (and thereby shortening the location interval) above what is necessary to collect relevant data will provide robust datasets for data screening. New GPS units with more efficient technology and increased battery life will facilitate collection of these larger, more accurate datasets.

Location success averaged only around 70% during the early years of GPS use in wildlife tracking (Rodgers et al. 1996, Rodgers 2001); but has increased to 90-100% in most recently published studies (e.g. Recio et al. 2011, Glasby and Yarnell 2013). This is consistent with the G10 Ultralite location success in our study of 97.6% overall.

One of the 14 stationary tests we performed did have location success of only 20%, but the cause of this error was unclear and it did not occur in any further tests, including those conducted at the same location. If we could have downloaded the raw snapshot data stored in the G10 unit it may have been possible to determine why location success was low. It may have been that ephemeris data was not available for the server. A simultaneous test with multiple G10 units would have identified this as a potential service outage.

High location success under all testing conditions established feasibility of the G10 Ultralite for a variety of study designs. The high accuracy levels we recorded also show potential to answer ecological questions on many scales. Our results combined with low power consumption and high storage capacity demonstrates the potential of the G10 Ultralite as an effective animal tracking device.

Acknowledgements

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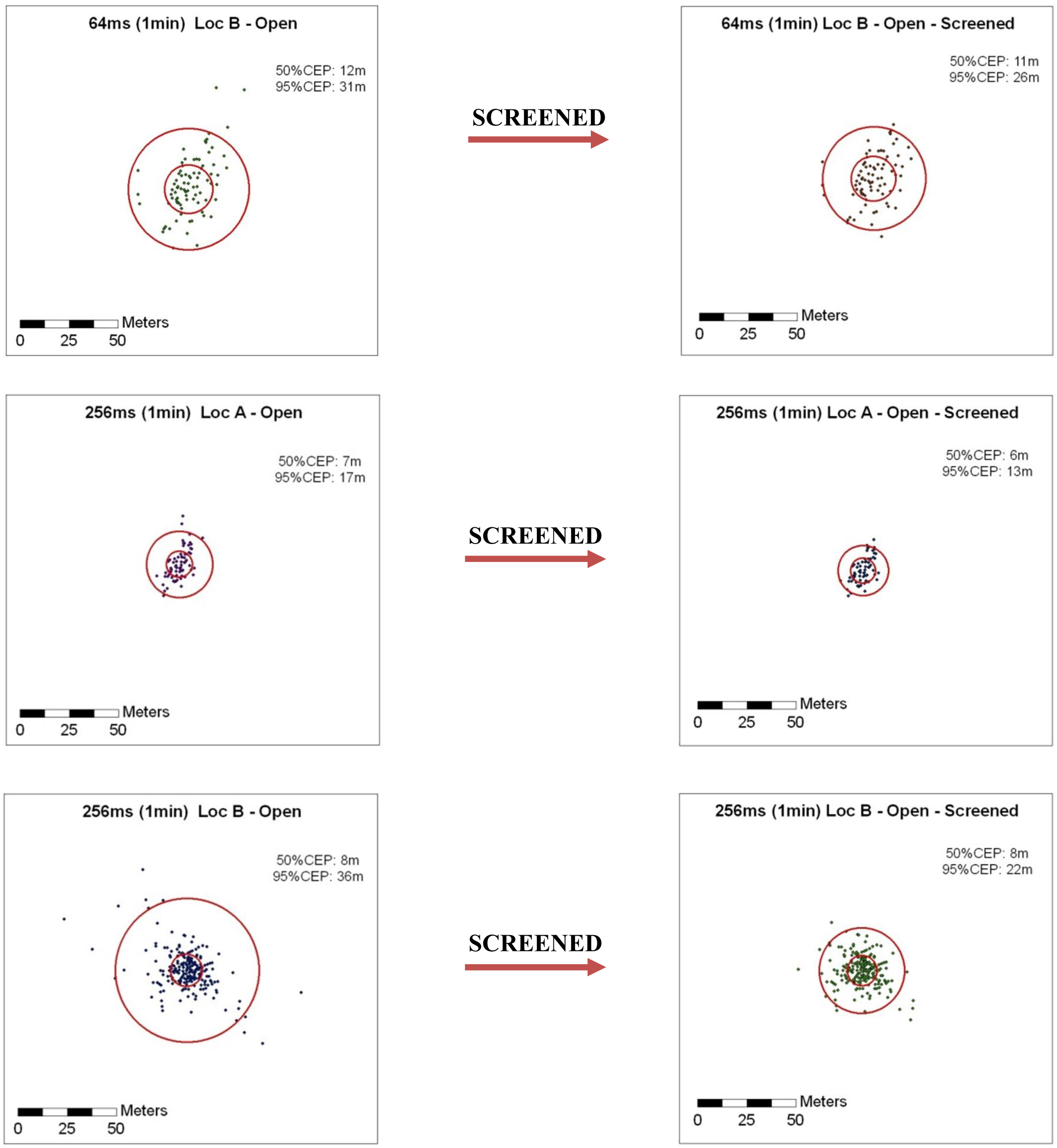
Appendix 1. Maps of Test Locations and CEP boundaries

For all maps, the snapshot size (ms), location interval (seconds or minutes), and canopy cover (open or closed) are identified in the title. The red circles indicate the 50% (inner) and 95% (outer) CEP for each test. Each dataset was screened by removing locations outside the original 95%CEP and then CEPs recalculated – shown on the right.



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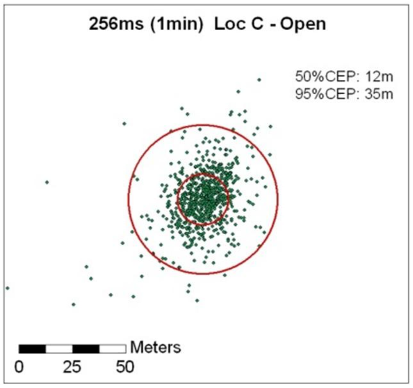

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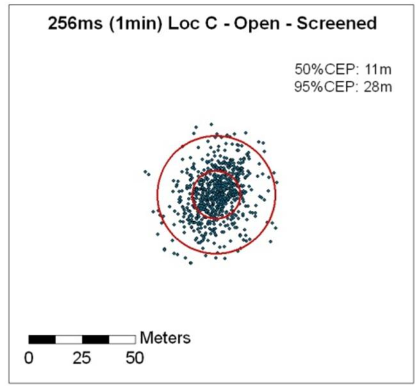

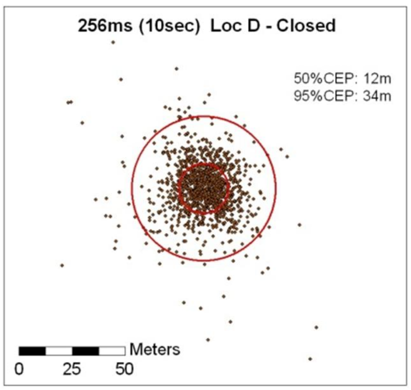

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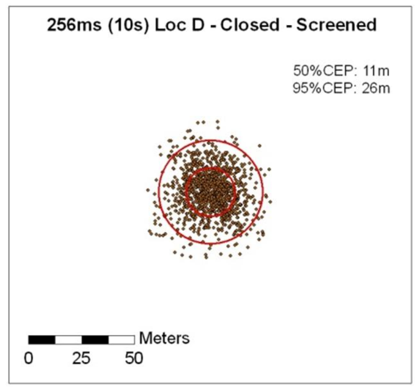

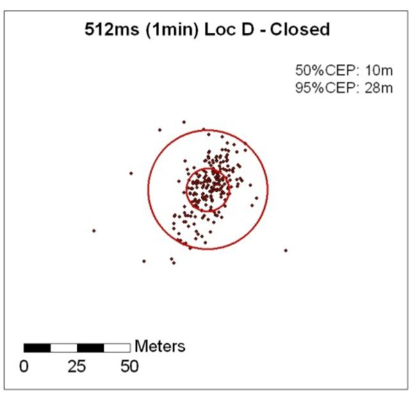

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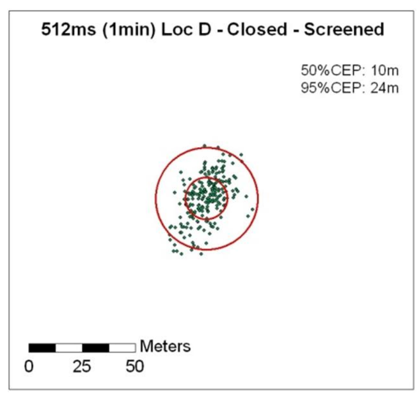

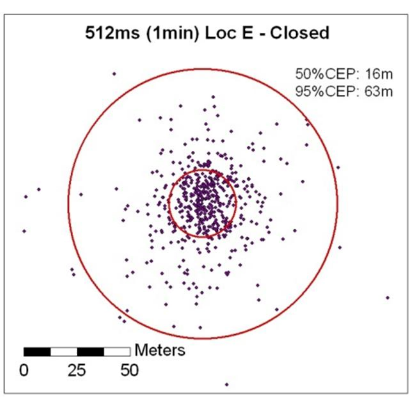

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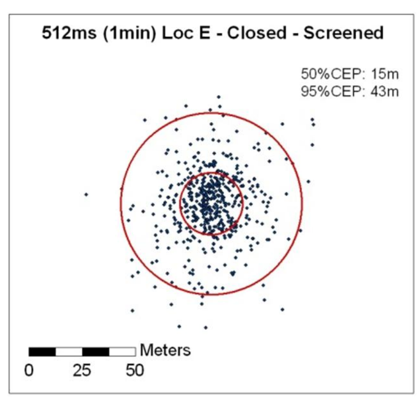

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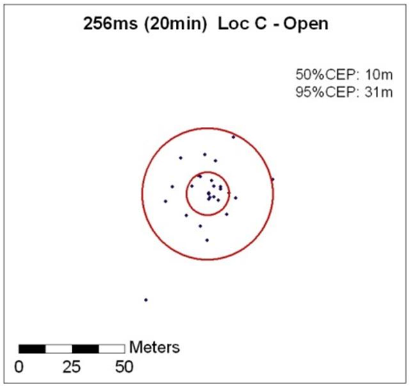

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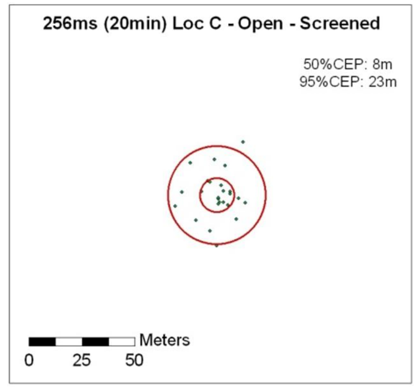

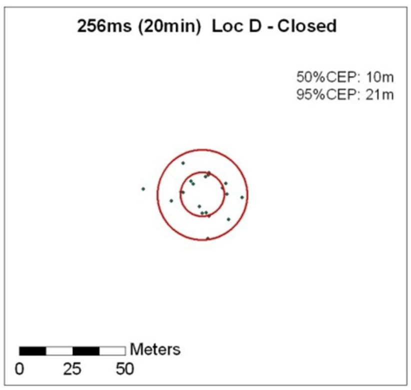

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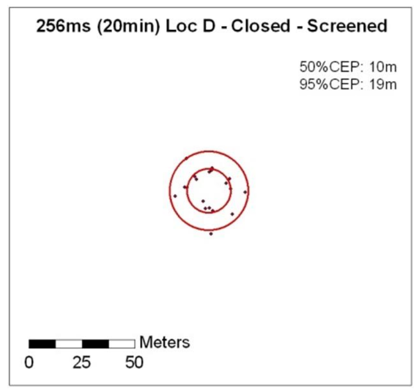

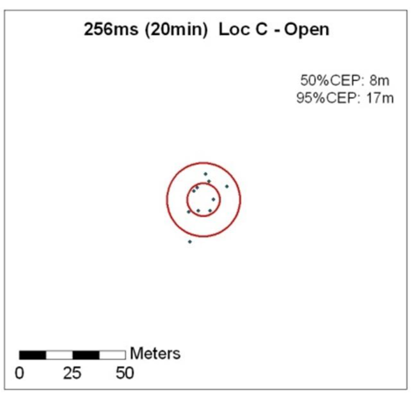

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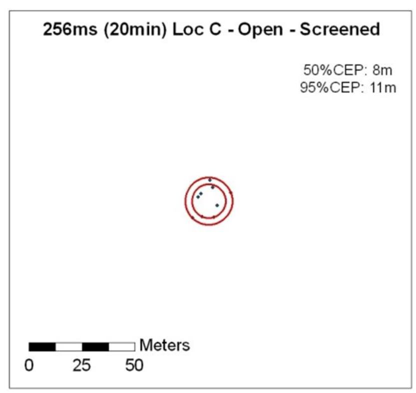

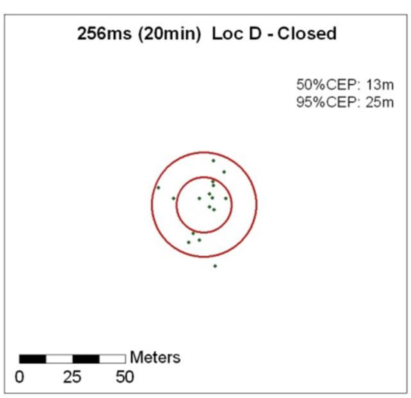

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