DEPARTMENT OF FISH AND WILDLIFE

Tahoe Urban Bear Home Range Analysis and Urban area overlap

Mario Klip

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Introduction

Home range is a ubiquitously used term in wildlife research defined as “the area traversed by the individual in its normal activities of food gathering, mating and caring for its young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered part of the home range” (Burt 1943). Insight into animal home ranges might illuminate intraspecific interactions, mating behavior, and foraging strategies (Powell 2000). The term *home range* was established over 70 years ago, but there still is no standard method for calculating home ranges (Laver and Kelly 2008), or how to account for areas that animals never visit, or do not visit after original discovery (Burt 1943).

Until recently, little effort was spent on understanding how animals perceived their home range, rather home ranges were essentially presented as a map of known animal locations (Powell 2000). Animals do not move randomly across the landscape, but instead use specific areas more than other areas to maximize fitness (Krebs and Davies 1997). To an animal a home range might be part of its cognitive map of its environment that it chooses to keep updated (Powell and Mitchell 2012).

Home range analysis has gradually moved from describing where the animal had been to mechanistic models. These models have allowed for the development of predictions that formed the nexus between animal behavior and movement ecology (Moorcroft et al. 1999, Moorcroft 2012). Animals might be aware of certain areas and choose not to utilize them. In other words their “view” might extend significantly beyond their home range. In this context, an animal might have a different perspective of its home range than the researcher (Powell 2012). GPS technology has allowed for gathering more animal locations per day and associating those locations with additional sensors such as heart rate, temperature, movement (accelerometers) and body cameras (Cagnacci et al. 2010, Walter et al. 2011). These new technologies and data continue to expand the frontiers of modelling and movement ecology and allow for improved understanding of home range and its significance.

Moyer et al. (2007) described various factors affecting bear home range size: habitat carrying capacity and population density, Crooks (2002) addressed human caused factors such as habitat fragmentation and Beckmann (2003a, 2008) identified resource availability such as garbage. Mammals moving into developed areas seeking anthropogenic food sources or following prey have been widely reported; such as increased urban raccoon (*Procyon lotor*) densities in comparison to other habitats (Riley et al. 1998). Red foxes (*Vulpes vulpes*) used derelict houses as dens and reached some of the highest fox distributions in Bristol, United Kingdom. Coyotes (*Canis latrans*) were common in urban areas across North America, where conflict was most severe with coyotes preying upon pets (Grinder and Krausman 2001, Lukasik and Alexander 2012).

Understanding the spatial and temporal implications of large carnivores' habitat usage and urban growth has been a cause for concern, that is, pets are at risk (Torres et al. 1996) due to predators such as mountain lions (*Puma concolo*r). Wildlife in developed settings, and building acceptable solutions with divergent stakeholder values with respect to wildlife, might be one of the most demanding tasks of the wildlife profession (Decker and Chase 1997, Riley et al. 2002).

Black bears are known to frequent urban areas as they are attracted to garbage (Rogers et al. 1974, Herrero 1980, Mccullough 1982, Spencer et al. 2007) and consequently become human food conditioned and habituated to humans (Hopkins et al. 2010). When bears are habituated to people and conditioned to human food, public safety concerns increase (Herrero 2002, Herrero and Higgins 2003). Conflicts involving black bears are increasing in number and significance throughout the western United States (Lackey and Beausoleil 2009). In addition, a survey among wildlife managers in North America found that bear problems are common or increasing according to 82% of the responding wildlife agencies (Spencer et al. 2007). This trend is becoming more evident throughout the Lake Tahoe Basin (hereafter, Basin). Between 2007 and 2011 over than 10,000 bear related requests for service were received by local law enforcement, CDFW, animal control and local non-profit the Bear League (J.M.K. Klip, unpublished data).

The size of the home range might indicate how much space a bear needs, how this area varies across seasons and how this overlaps with urban areas. Overlap of the home range with the urban area was considered to be a good proxy for assessing the importance of this area to bears. This is a key step when trying to understand potential for conflict and mitigation strategies.

Three home range calculating methods were used, Minimum Convex Polygon (MCP) home range analysis is the oldest method and is defined as drawing the smallest polygon which encompassed a given percentage of locations for the animal (Hayne 1949).The approach was characterized by a continued frequent use in wildlife studies (Belant 2002), simple approach, intuitiveness and ease of use (Powell 2000). However, different use intensity regimes of the animal's home range remained obscure. Additionally, the borders of a home range became the focus, whereas the home range boundaries are generally diffuse (Powell and Mitchell 2012). Additionally, home range area increases as the number of points increase and the method is highly sensitive to outliers, increasing the home range size unjustifiably (Powell 2000). Despite its shortcomings, it is still widely used because of its simplicity and ease of interpreting.

Home range estimators which use Kernel Density Estimators (KDE) were first described by Worton (1989). KDE is considered to be one of the best home range estimators (Seaman et al. 1998, Powell 2000, Laver and Kelly 2008). KDE does not take time sequence information into consideration and locations often violate the assumption of independency (Aebischer et al. 1993, Powell 2000). Kernel Density distributions considers the intensity of use in different areas by an animal, whereas MCP calculates the area utilized and does not provide insights into which areas might be of disproportionate importance. Additionally, KDE may have more than one center of activity and the method is not dependent on outlying points (Hemson et al. 2005). KDE estimates the likelihood where a bear can be found. Kernel density provide a utilization distribution that describes the relative amount of time that an animal spent in one place (Seaman and Powell 1996). Using more positions reduces variability when using kernel methods (Arthur and Schwartz 1997). There appears to be no objective method to select a band width (Silverman 1986).

Brownian Bridges Movement Model (BBMM) was selected because GPS locational data are spatially auto-correlated (Kernohan et al. 2001). BBMM is based on the properties of a conditional random walk between successive pairs of locations, dependent on the time between locations. Horne et al. (2007) described the use of BBMM to understand animal movements, specifically to understand home ranges. The BBMM estimates the probability that the animal occurred in an area over the analysis period. While both KDE and BBMM attempt to understand the utilization distribution, KDE assumes and violates temporal independence (Worton 1989). BBMM on the other hand assumes that locations are not independent and specifically incorporates time between locations in the model (Horne et al. 2007).

Three levels of analysis were completed: (1) bear full home ranges were calculated based on MCP, KDE and BBMM including comparison of home range size by method and sex and other published urban and wild home ranges; (2) seasonal home range variation was compared based on sex, season and year based on 50% and 95% KDE method; and (3) home range overlap with urban areas based on sex, season for 50% (core areas) and 95% KDE was analyzed.

Methods

Study Area

This study was conducted in the western portion of the Basin, in El Dorado and Placer Counties, California (Figure 1). The extent for analysis was defined by enclosing all bear locations, with a 500m buffer. One bear utilized habitat in the state of Nevada. The extent for analysis encompassed approximately 850 km^2, consisting of both private and public property. Elevation ranges from 1897m at lake level to 3317m. Vegetation in the Basin (Roth et al. 2004) is dominated by a mixed conifer forest of white fir (*Abies concolor*), Jeffrey pine (*Pinus jeffreyi*), lodgepole pine (*Pinus contorta*), and red fir (*Abies magnifica*). California Wildlife Habitat Relationships (CWHR) plant communities present include montane hardwood, montane hardwood-conifer, riparian, chaparral, wet meadow, and barren (Mayer and Laudenslayer 1988).

Capture Methods

Appropriate trapping locations were selected based on the following criteria: safety, ability to monitor trap, limited opportunity for trap tampering, recent bear activity, and ability to obscure the trap from the road. Appropriate trapping locations were secured through coordination with local businesses, homeowners, and governmental organizations such as California State Parks. Due to the aforementioned process, a systematic or random sampling protocol was not possible. Areas where recent (< 2 weeks) depredation bears were active were not utilized until the offending bear either had been euthanized or until the damage stopped for at least two weeks, indicating that the offending bear had moved to a new area.

Bears were captured using a heavy-duty box trap mounted on a trailer (Figure 2) during the 2013 and 2014 field seasons (May-November). Bears were chemically immobilized using Telazol (Fort Dodge Laboratories Inc., Fort Dodge, IA) following the California Department of Fish and Wildlife (CDFW) Capture and Restraint Manual (Jessup et al. 2001). Preventive measures were taken to prevent infection, and penicillin and Blu-kote® (H.W. Naylor Co. Inc. Morris, N.Y.) were applied to areas where skin perforation had occurred due to the application of ear tags and injections (Table 1). All animal handling procedures were also approved by UC Berkeley’s institutional animal use and care committee (IACUC: R358-0315).

Adult bears were outfitted with Vectronic Iridium Collars (Model GPS PLUS Vectronic Aerospace GmbH Carl-Scheele-Str. 12D-12489 Berlin Germany). Sub-adults were not included in the study because the risk of collar embedment was considered too severe.

Communication via email was received twice daily with the relevant GPS coordinates from each collar deployed. During the first six weeks of deployment, collars were programmed to gather locations every 20 minutes to monitor for mortality. After six weeks, positions were gathered every two hours to conserve battery life. All collars were also equipped with VHF Very High Frequency (VHF) transmitters to facilitate locating on the ground in real time. In addition to remote drop off mechanisms, cotton spacers were bolted on all Vectronic collars (Hellgren et al. 1988, Garshelis and McLaughlin 1995). Cotton spacers degrade over time, and while at unpredictable rates, provided a way for the animal to shed the collar after approximately two years.

All handled bears were permanently marked with an ear tag (Allflex, DFW Airport, TX, 75261) for recognition during future captures or sightings. Bears captured during the hunting season (August - December) were outfitted with an ear tag containing a warning to contact CDFW prior to consuming the animal, due to potential drug residue.

Estimated age classes include: cubs less than one year of age and accompanied by a sow; sub-adults over one year old, unaccompanied by a sow, and weigh between 40 and 100kg; and solitary bears weighing over 100kg were classified as adults. Bears recovered for a minimum of six hours in a quiet location prior to release. The animals had access to clean drinking water upon waking up and recovered without disturbances.

Seasons were defined as follows; Spring: March 16th till June 15th, Summer: June 16th till August 31st, Fall: September 1st till 30th of November 30th , Winter: 1st of December 1st till March 15th. Three sex classes were defined, (1) females, (2) females with cubs and (3) males.
All analysis was completed in ArcGIS 10.2 (ESRI 2015, ArcGIS Desktop, Redlands, CA, Environmental Systems Research Institute) and R (version 3.1.3 R Core Team 2014, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/).

Graphs were made in R using the package GGPLOT2 (Wickham 2009), data manipulations and statistical analyses were done by using the following R packages: PLYR (Wickham 2011), STRINGI (Gagolewski 2015), RESHAPE (Wickham 2007) and doBy (Hojsgaard and Halekoh 2014), LmerTest (Kuznetsova et al. 2015) and lme4 (Bates et al. 2015). Home ranges were calculated in ArcGIS Extension ArcMet (Wall 2014). All data layers downloaded were re-projected from their native projection to WGS-84 UTM Zone 10.

Bears also participated in an Aversive Conditioning (AC) study, with three treatment groups. AC with dogs, dogs and firing less-lethal ammo and control. The effects of AC are not reported here.

Data Cleaning Efforts

Data cleaning included removing locations that were either missing information or were inaccurate. Points that were labelled as “no fix”, “mortality”, as well as any points after and before deployment of the collar were removed. The collars were programmed to take regular data points, but were not always successful, causing some gaps in the data. For example, it was possible that a percentage of the mortality signals and no fix signals during winter months might have been associated with hibernation. This association was not further investigated.

Upon investigating, velocities above 4 km/h speed appeared to be spurious and were removed. All GPS locations (2D and 3D) were preserved for this analysis and no subsampling was performed, because the estimate for a subset may differ from the entire GPS location dataset (Fieberg 2007, Kie et al. 2010). Field error rates were not calculated but Chris Kochanny, (Senior Project Consultant/Wildlife Biologist Vectronic Aerospace, personal communication) reported the following error statistics for a similar collar which collected 38,756 locations: mean deviation of all fixes; 1.77m for the latitude, 1.59 meter for the longitude and 2.25 meter for the height. The Circular Error Probable (CEP) is as follows: better 15 meter > CEP 99.6%, better 10 meter > CEP 98.6%, better 7 meter > CEP 95.6%, better 5 meter > CEP 86.3%. Actual field error rates might differ substantially (D'Eon and Delparte 2005).

Bear 15544 and 13209 were the same bear: this was the only bear that was subsequently outfitted with two collars due to a chance re-capture when original collar was nearing battery depletion. Further analysis treated the two collars independently and data was not pooled, and effectively the two collars were analyzed as if they were on two different animals. Analyses were conducted with and without this bear and no significant patterns could be discerned as a result of not pooling the data.

A longstanding convention typically looks at 95% of the locations since exploratory behavior (5%) might be excluded from the home range assessment (Powell 2000). Core areas were defined as 50% of the locations (Powell 2000, Hemson et al. 2005, Spencer 2012).Where a core area can be defined as the area that is used most intensively (Seaman et al. 1998, Powell 2000). Other percentages were also calculated for comparison purposes. MCP home ranges were calculated at 50, 95, 99 and 100%, while for KDE and BBMM calculations were at 50, 95 and 99%. The percentages refer to the percentage of locations taken into consideration for the calculation of the home range. Seasonal home ranges were calculated, using the 50 and 95% KDE method. No additional data cleaning was performed to prepare the data for seasonal analysis, nor were any steps taken to evenly distribute the GPS locations across seasons.

All home ranges were calculated using ArcMET (Wall 2014). KDE utilized fixed bandwidth smoothing parameter (h) because adaptive bandwidth might overstate the areas used (Seaman et al. 1998). Furthermore, a 30 meter raster and 1.5 meter raster expansion ratio were selected. All other values remained at default.

Within ArcMet, BBMM parameters were set up with a maximum tolerated gap of 72 hours, and a telemetry error standard deviation of 10 meters and integration time-step of 10 minutes. Raster resolution was set at 30 meters and raster expansion ratio at 1.5 meter.

Home range overlap was based on the urban definition as defined as "Combined" (J.M.K. Klip, unpublished data). Combined is a combination of the urban definitions that include "Census", "City Limits", and "eVeg", and was considered to be the most conservative measurement for "urban". Seasonal KDE home ranges at 50% and 95% were utilized to find overlap with urban areas. The home range area that was within the urban polygon was considered overlapping with the urban area. The portion of the home range not overlapping with the urban area was deemed "wild". Overlap was expressed in two percentages, an urban overlap percentage and a wild percentage. Overlap was calculated by dividing the respective area by the total home range area for the animal.

Results

Full Home Range Sizes

Eleven bears were captured: three males, five females and three females with cubs. The number of positions for each bear varied from 567 to 7875. The number of days that these positions were gathered ranged from 61 to 499 days (Table 2). Although the fix schedule for all animals was similar, the total GPS locations gathered differed, even among relatively similar number of days of collar deployment (Table 2). For example, bear 15442 had a collar on for 166 days and collected 4372 positions and bear 15442 was outfitted with a collar for 161 days and collected 706 locations. Causes for these differences included; slipped collars, collar variability and other logistical reasons. The total number of GPS fixes taken into consideration for this analysis was 43,359 locations.

Sex affected home range sizes at all percentages. Statistics here, and hereafter will be presented at 95% unless otherwise specified. Statistics identifying how sex affected home ranges at 50% and 99% can be found in Table 3. At 95% (linear mixed model $F_{2.13.71)} = 7.83$, p > .0.026), so did the home range method used for all percentages, at 95% (linear mixed model $F_{2,19.87}$ =, p > . 0.00001). There were no interactions reported between sex and method linear mixed model $F_{4,19.87}$ =, p > .0.68)

Males reported a larger home range for all methods and percentages (Table 4), except for BBMM at 50%. Home ranges sizes between females and females with cubs were not significantly different for all methods and percentages.

BBMM home ranges were smaller than home ranges calculated with MCP or KDE for all percentages, at 95% ($t_{(12.32)} = 8.45$, p<0.00001). MCP generated the largest home ranges for all percentages, at 95% ($t_{(25)} = 5.71$, p< 0.00001), KDE generated home ranges in between BBMM and MCP (Table 5).

The average home range (Table 6) for males (n=3) at 95%, was 77.96 km^2 (±46.80 km^2) for MCP, 77.37 km^2 (±32.77 km^2) for KDE and 34.82 km^2 (±4.57 km^2) for BBMM. For females (n = 5) the average MCP home range at 95% was 17.57 km^2 (±11.21 km^2), for KDE 16.85 km^2 (±10.59 km^2) and 10.17 (±8.92 km^2) for BBMM. Females with cubs (n=4) for MCP at 95%, was 25.70 km^2 (±9.37 km^2), 22.36 km^2 (±7.93 km^2) for MCP, and 14.95 km^2 (±4.70 km^2) for BBMM. Summary home range statistics for individual bears were calculated for all three methods and can be found in Figure 3A-F.

Individual MCP home ranges (Table 7) at 95% varied from 33.30 km^2 to 126.64 km^2 for males, from 3.44 km^2 to 33.10 km^2 for females, and for females with cubs 12.59 km^2 and 33.10 km^2. Male KDE at 95% home ranges reported between 44.55 km^2 and 110.09 km^2, females 5.02 km^2 and 31.66 km^2 and females with cubs 10.96 km^2 and 29.26 km^2. Male BBMM at 95% were between 29.78 km^2 and 38.71 km^2, for females between 0.59 km^2 and 22.66 km^2 and females with cubs between 9.83 km^2 and 19.95 km.

All MCP home ranges were mapped at 100% (Figure 4), home range overlap was observed between animals, and was not further analyzed. Individual MCP home ranges are represented by Figures 5A-L. KDE was represented by Figures 6A-L and BBMM by Figures 7A-L. The BBMM method defined visibly smaller use areas in comparison to MCP and KDE. Additionally, BBMM reported more distinct areas.

Seasonal Home Ranges

Season is not significant at 50% (linear mixed model $F_{3,16.3} = 2.28$, p = 0.12) but is significant at 95% (linear mixed model $F_{3,18.42} = 4.59$, p = 0.014) . At 95% seasonal home ranges are largest in the fall ($t_{19.36}$=43.38, p<0.0001) and smaller in spring ($t_{19.36}$=43.38, p<0.0001) smallest in winter ($t_{-3.22}$=43.38, p=0.0034). Summer and fall were not significantly different in size. Sample size was too small to assess year.

Sex affected the size of the home range at 50% (linear mixed model $F_{3,57.2}$ = 4.43, p = 0.025) and at 95% (linear mixed model $F_{2,23.09}$ = 5.40, p = 0.012). No interaction was found between season and sex, at 50% (linear mixed model $F_{6,50.9}$ = .25, p > .91) and 95% (linear mixed model $F_{3,63.51}$ = .9.16, p <0.0001).

At 50% females with cubs did not report significantly larger home ranges from females for all seasons (Table 8). Males reported a significantly larger home range during the summer and possibly the fall (p=0.0519). Males did not report a significant difference from females during the spring and winter.

At 95% seasonal home ranges female with cub home ranges were not significantly different from females. Male home ranges were significantly larger in the summer and fall. While spring and winter was not significant.

Differences between male, female and females with cub home ranges were most pronounced in the fall of 2014 (Figure 8), females recorded a home range of 28.75 km² (±5.12 km²), females with cubs 24.68 km² (±17.96 km²) and males 102.48 km² (±6.36 km²) (Table 9).

All individual seasonal home ranges were mapped for 50% and 95% and can be found in Figure 9A-L.

Home Range Overlap with urban envelope

Home range overlap was calculated to 50% and 95% seasonal KDE, 95% reported a smaller overlap ($t_{(56.36)}$ = -2.95, p=0.005) Season, sex and year were not significant, nor was the interaction between percentage and season significant.

Direct comparison of means indicated that home range overlap was greater at the core (50% KDE) for the three sex classes during all seasons in comparison to 95% KDE home ranges, except for males and females with cubs during the spring (Figure 10). Females had the greatest percentage overlap with urban areas followed by females with cubs. During the summer and fall females and females with cubs presented a similar high usage pattern of the urban area, with females having the highest usage.

For the core areas urban usage the overlap was highest during the fall for all sexes (males 54% (±44%), females 85% (±18%), and females with cubs 61% (±30%). Overlap was smallest during the spring, for males 29% (±23%) and females with cubs 26% (±3%) and female 64% (±37%) overlap was smallest in summer.

At 95% KDE, females 65% (±30%) and males 36% (±27%) had the highest overlap in spring, females with cubs 53% (±28%) during the summer. Females 53% (±14%) recorded the smallest overlap in the summer, males 26% (±15%) and females with cubs 18% (±18%) recorded the smallest overlap in winter.

Discussion

Full Home Range Sizes

Different home range tools and methods yield different home range sizes (Mitchell 2007, Walter et al. 2011, Fieberg and Börger 2012). This is consistent with findings of this study. Home range estimates between MCP, KDE and BBDM vary significantly. BBMM produced the smallest home ranges when comparing home range sizes at 95%. MCP/BBMM ratios were at 2.23 times for males, 1.72 times for females and 1.85 times for females with cubs. KDE/BBMM ratios were at 2.22 times for males, 1.65 times for females and 1.49 for females with cubs. KDE and MCP were very similar in size and MCP/KDE ratios were 1.007 times for males, 1.04 times for females and 1.15 times for females with cubs.

BBMM home ranges were smaller due to fact that the sampling time was of relatively high resolution and affected the bandwidth and consequently the home range size (Wall et al. 2014). BBMM home ranges were hard to interpret due to the larger number of distinct polygons.

Acknowledging that different methods yield different results is important when utilizing home ranges in follow up analysis, or as a constraint for the placement of random locations. Different home range sizes affect the outcome.

In this study full home ranges from females with cubs did not differ significantly from females. Other studies suggested that interaction between year and breeding status influenced home range size in Florida (Moyer et al. 2007), and in North Carolina resource depressions had a greater effect on home range of lactating females in comparison to breeding females (Mitchell and Powell 2007). Covariates might have different effects geographically, Idaho reported that home ranges for females with cubs and without cubs were similar (Reynolds et al. 1980). Future research should focus on whether small cubs impede mobility the first year and whether greater home ranges were required the second year to sustain yearlings.

Home range sizes for females and for females with cubs were smaller than male home ranges at 95% percent intervals for all three methods. At 95% KDE male home ranges were 4.6 times larger than female home ranges. Similar results are reported in many other studies, in Washington male home ranges were found to be 3.9 times larger than female home ranges (Koehler and Pierce 2003). Across bear species, males typically have larger home ranges, sloth bears (*Melursus ursinus)* (Joshi et al. 1995) and grizzly bear (*Ursus Arctos)* (Mace and Waller 1997).

In this study urban home ranges were expected to be smaller than wild; conspecifics (Ditchkoff et al. 2006). Beckmann and Berger (2003a) reported 70-90% smaller home ranges for urban bears in comparison to their wild counterparts on the Nevada side of the Basin. They reported home range estimates (95% fixed kernel method) for urban interface males to be 52.86 km² (±32.96 km²), for females 55.17 km² (±54.07 km²) and for wild bears, male home range estimates were 519.57 km² (±527.83 km²) and females 172.78 km² (±198.72 km²). Beckman and Berger reported that urban bears were characterized by having close to 100%, or at least 90%, of their locations in urban areas. Even although all bears in this study were captured in urban areas they did not record close to 100% of their locations in urban areas. This study did not include bears captured in wildland settings. The average male home range (at 95% KDE), was 77.37 km² (±32.77 km²) or ~1.46 times larger than the urban home range reported in Nevada. Females reported an average home range of 16.85 km² (±10.59 km²) which equated to 3.2 times smaller than the urban home range size reported in Nevada. Wild bear home ranges, for both sexes, reported in Nevada were much larger than the home ranges found for bears in this study; males reported ~6.7 times smaller and females recorded home ranges ~10.75 times smaller.

In comparison, male urban bear home ranges were smaller in Nevada than reported on the California side of the Basin, females reported the opposite in California and had larger home ranges in comparison to urban bears in Nevada. Female home ranges are larger in Nevada, even although bears in Nevada reportedly spent more time in urban areas. It was expected that home ranges would be larger if bears were not exclusively urban, since the inclusion of wild areas in the home range would increase the total home range area. Counter to expectations, the inclusion of wild areas in California did not increase the home range.

Different results between California and Nevada might be explained by the smaller sample size in this study and different method for gathering locations. Beckmann and Berger gathered locations by fixed wing aircraft with a minimum of 60 annual locations during daylight hours. This study utilized Iridium collars that on average generate a GPS location every two hours, yielding hundreds or thousands of locations. Additionally, even although the Basin population could be considered one contiguous population, habitat differences between California and Nevada exist (Johnson et al. 2015).

It appeared that female urban home ranges might even be smaller than Beckmann and Berger previously reported, even when bears were not strictly urban. A comparison of urban home ranges to wild bears in the adjacent study system would be very valuable. Are bears indeed leaving wild areas in favor of urban areas and do wild bears have home ranges that are 7-9 times larger than urban bear home ranges?

In order to understand whether the reported urban home ranges in this study were small, a comparison to other published results in adjacent areas was made. Placer county, one of the counties including Lake Tahoe, reported wild male home ranges to be 63.6 km² (±51.2 km²) or ~82% of home ranges reported in this study (KDE 95%), and adult females 27.3 km² (±15.9 km²) or ~162% of home ranges reported in this study (KDE 95%) methods in the Placer county study were unreported (Koch 1983). In the Tahoe National Forest (Grenfell and Brody 1986) female home ranges were recorded as 36.4 km² (harmonic mean) which is ~216% of female home range reported in this study compared with KDE. Both, Tahoe National Forest and Placer county bears were wild land bears, and male home ranges in this study were reported larger in the same area and female home ranges much smaller. This pattern was also observed in comparison to the Nevada study. Home ranges for wild land bears in adjacent areas are much more comparable to urban home ranges reported in this study than the wild bears in Nevada, further necessitating a follow up analysis on wild land bears.

Comparison to home ranges outside of the study area' vicinity warrants caution because black bear home ranges vary widely across North America, largely due to habitat quality (Mitchell and Powell 2007, Moyer et al. 2007). However, when comparing to Southern California (Van Stralen 1998), four urban bears were captured and home ranges were estimated at 95% MCP. Male home ranges were 7.4, 22.1 and 28.4 km² and for the single female 5.4 km² was recorded. This study recorded a 95% MCP male home range of 77.96 km² (±46.80) % and females 17.57 km². Southern California male home ranges are between ~9% and ~36% and females ~30% of the home ranges recorded in this study (compared to MCP). The differences reported might be due to the differences in habitat, where bears in Tahoe might have more alternative food sources, consequently relying less on urban habitats (Johnson et al. 2015). Home ranges in the San Bernardino Mountains, male and female annual home ranges were 36.4 km² and 17.1 km² (Novick 1979), or ~47% or ~101% compared to this study. Females reported very similar results and males were at 50% in comparison to this study. Southern California's home ranges were much smaller than what was reported in Nevada, even although habitats are less productive than the California side of the Basin.

When Basin home ranges were compared to home ranges across North America, Basin home ranges do not appear to be consistently 7-9 times smaller than home ranges reported for wild bears reported elsewhere.

For example; Washington state (95% fixed kernel) reported at three different sites were surveyed and males reported, 125.5 km^2 (±47.9 km²), 90.8 (±62.5 km²), 73.5 (±72.9 km²), and for females the reported home ranges were 28.3 km² (± 1 km²), 18.0 km² (±15.2), 25.9 km² (±16.8 km²) (Koehler and Pierce 2003). In Idaho 60 km² (±29 km²) and 105 km² (±39 km²) for both years combined and female 12 (±6 km²) and 18 km² (±5 km²) (Reynolds et al. 1980). In Florida annual home range size were reported for female black bears between 3.8 km² and 126.9 km² and averaged 24.2 km² (±4.59 km²) using 95% KDE and MCP (Moyer et al. 2007). Mean home range size in Manitoba were 464.7 km² (males) and 298.8 km² (females) (95% Harmonic Mean) home ranges (Pacas and Paquet 1994). In Texas mean male home ranges were 97.7 km² (± 35.8 km²) and females 32.1 km² (±4.3 km²), calculated by 95% MCP and 50% kernel estimator from Animal Movement Extension (Onorato et al. 2003). Total home ranges in Pennsylvania were reported 173 km² for males and 41 km² for females, where locations were directly noted on maps (Alt et al. 1980).

Urban bears in this study do not seem to deviate widely from reported wild land home range studies in California and beyond except for Manitoba, Pennsylvania and Nevada. More research is needed to compare urban home ranges to wild home ranges within the same study system while utilizing the same methods for calculating home range. More research is warranted to understand how urban bears vary their use of the landscape. Nevada home ranges are unique in which they report wild home ranges of over 500 km² for males and 172 km² for females. Larger wild home ranges could not be located in the published literature.

Seasonal Home Ranges

The core size of the home range appears to be stable (no significant differences) across the various seasons. While not quantified, cores do appear to spatially shift across (Figures 9A-L) the landscape during the various seasons. Future research should address whether shifting cores are relevant when assessing potential for human-bear conflict and habitat requirements during each season.

Female and male home ranges were not significantly different at both 50% and 95% in both spring and winter. Small winter home range sizes were most likely due to limited movement during hibernation. The results for spring suggest that males might stay close to females potentially coming into estrus (Rogers 1987). Larger home ranges during the fall may be explained by hyperphagia, where male bears appear to have spent more time in wild areas foraging. Much larger male in comparison to female home ranges in the fall and lower male home range overlap (Figure 10) may suggest that males utilize wild lands more extensively than females and potentially generate less conflict during the fall. Other studies suggested that hyperphagia during the fall period may actually lead to increased human-wildlife conflict (Dolson 2010, Baruch-Mordo et al. 2014).

During the 2014 fall period (Table 9), male home ranges were 3.72 and 4.33 times larger than females and females with cubs. The smallest ratios were reporting during the fall of 2013 where male home ranges were 1.59 and 1.75 times greater than females and females with cubs respectively. Male/female ratios represented between 6.3 (summer 2014) to 22.98 (spring of 2015), and for males/females with cubs the ratios were between 2.65 (spring 2014) and 54.48 (spring 2015).

Follow up analysis should investigate the covariates such as snowfall, daily temperatures, food availability that might be responsible for the seasonal and annual differences reported.

Home Range Overlap with urban envelope

Higher home range overlap with the urban envelopes at the 50% versus 95% suggests that urban areas were disproportionately important to bears in this study. On the other hand, total home range size may not always be affected by concentrated food availability, but may lead reduced utilization levels, in large parts of the home range. For example; home ranges in Washington State did not reduce when supplemental feeding, to protect Douglas firs (*Pseudotsuga menziesii*), took place, likely due to conspecific strife. However, bear concentrations around the feeder were reported (Fersterer et al. 2001).

Male overlap (at 50% and 95%) with the urban envelope is lower in comparison to females and females with cubs (Figure 10). Understanding overlap with the urban envelope is important because seasonal, sex specific inter-annual variation might provide insights into resource partitioning. Male overlap with core areas is highest in spring compared to other seasons while females with cubs record a lower overlap during this season in comparison to other seasons. Spring home range size does not statistically differ between males and females for both 50% and 95% without a clear physiological rationale (e.g. winter hibernation leading to small home ranges for all sexes). The spring coincides with the mating season potentially bringing males into urban areas in pursuit of resident females. Male bears might actively exclude females with cubs from urban areas, due to threat of infanticide (Ben-David et al. 2004). Consequently females may utilize the urban area less during the spring.

During the fall time period fewer adult males were captured without a change in capture effort in comparison to the spring period. During the study period more adult females were trapped than adult male bears. When considering the total trapped population, sub-adult captures represented almost all males. Sex ratios of urban bears were previously reported skewed to male bears (Hellgren and Vaughan 1987, Beckmann and Berger 2003a). Skewed sex distributions were only the case when sub-adults were included. Reduced urban overlap for male bears might explain why mature males were captured less frequently and were underrepresented (3 out of 11) in the sample size. Males had larger home ranges, and the urban area consequently represented a smaller percentage of their home range, reducing the chance of a bear encountering a trap in the urban area. Noyce et al. (2001) found that bears are more likely to be trapped when spending >50% of time in an area. Future research should focus on male bears and how land utilization changes as they mature, where young bears seem to be heavily dependent on urban areas and appeared to use wild lands more as they mature.

Management Implications

The size of a home range and amount of overlap between bears would allow for an extrapolation of density, possibly extended across the study area. Habitat was relatively homogenous in the study area, with the exception of the availability of anthropogenic food sources.

Currently the Department estimated a population of 300-350 bears on the California side of the Basin (Jason Holley, Senior Environmental Scientist - CDFW; personal communication). Calculating home range density and their overlap might provide a quick and crude approach to test this number. If for example the average home range for a female bear is 15 km², with a reasonable home range tolerated overlap of 40% (Powell 1986, Oli et al. 2002) then in a 850 km² study area approximately 79 females could be expected. Male home ranges are estimated conservatively with an overlap of less 15% and could be higher (Lindzey and Meslow 1977, Horner and Powell 1990) with an average home range of 73 km² this would yield 14 mature males. The total would then be: 79 females+ 14 males = 93 adult animals, without taking cubs or sub adults into consideration.

Density estimates from adjacent areas were applied to the Basin, and might provide insights in the area's population. Estimates widely differed. A Placer County study reported 1 bear per 3.5 km² (Koch 1983), which would yield approximately 242 individuals for an 850 km² study area. Tulare County's density at 0.48 bear per km² would result in 408 bears for the study area. Both estimates are 30 years old and the bear population likely grew during this period. Beckmann and Berger (Beckmann and Berger 2003b) found densities in Nevada of 3.2 bears per 100 km² for wild bears and urban interface bears of 120 per 100 km². The Combined urban area comprises of 161 km², which is ~20% of the study area. Yielding a population estimate of 204 urban bears and 22 wild bears, resulting in an estimate of 226 bears in the study area.

Future research should also focus on generating a contrast to wild bears, a rapid decline in density in wild areas has been recorded in comparison to historical and urban density numbers (Beckmann and Berger 2003a). Understanding the total population of bears in the Basin area in both urban and wild settings would allow for better management decisions, and would provide insight into whether bears are vacating wild lands in favor of anthropogenic edges. Additionally the relative proportion of adult to sub adult bears should be estimated. Both may provide insights into whether urban areas are a source or a sink.

Stochastic events affect forage availability; less profitable natural environments might lead to greater dependency on urban areas. While not investigated, one current stochastic event, drought, likely impacts bears adversely, reducing home ranges and possibly increasing home range overlap (Baruch-Mordo et al. 2014). Smaller home ranges and more time in urban areas potentially yields more human/bear conflict. Understanding the effects of drought on hibernation, fecundity and habitat use are important when attempting to model conflict risk.

Seasonal home ranges are the starting point in understanding which areas are important to bears. Management might also utilize re-visitation rates to understand sources of anthropogenic food. Re-visitation would elucidate small areas, such as concentrated anthropogenic resources that are of disproportionate importance to bears. This might allow for more proactive management response in the abatement of bear attractants. The T-LoCoH (Time Local Convex Hull) method calculates re-visitation rates (Lyons 2014). This method combined with ground proofing might provide management insights into where bears are likely able to obtain anthropogenic food sources and proactively plan appropriate management responses.

An initiative to share data and allow for comparison based on source data rather than archived static home ranges would be beneficial (Börger et al. 2006). Additionally, sampling and estimation methods should be standardized to facilitate direct comparisons (Fieberg and Börger 2012). KDE is highly dependent on the selected value of the bandwidth (h) and can create very different home range estimates as a result (Hemson et al. 2005) bandwidth values often were unreported. Movebank might be an example where source data could be shared with other researchers to make more astute comparisons based on source data (https://www.movebank.org/).

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APPENDIX 1

List of Tables

Drug	Dose	Route	When administered
Tiletamine-Zolazepam (Telazol)	2.2 mg/lb	IM	At time of capture
Penicillin	1.0cc per 200 lbs of weight	IM	During capture episode
Blu-kote® wound dressing	Small amount admin to dart site	TOPLY	During capture episode

Table 1: Drugs Used; this table identifies the drugs utilized during the anesthesia of black bears. Telazol is used to anesthetize the other drugs are intended as preventative care.

BEARID	SEX	Total positions	on	off	number of days
13205	Female	4749	5/15/2014	11/21/2014	190
13206	Male	4552	5/23/2014	4/1/2015	313
13207	Female w Cubs	4293	5/24/2014	4/2/2015	313
13208	Female	1047	11/7/2013	4/4/2014	148
13209	Female	3367	8/5/2013	3/6/2014	213
13210	Female w Cubs	7875	10/22/2013	3/5/2015	499
13211	Male	567	11/15/2013	1/15/2014	61
13212	Female w Cubs	4541	9/28/2013	3/3/2014	156
15441	Male	5078	6/14/2014	3/5/2015	264
15442	Female	4372	6/14/2014	11/27/2014	166
15544	Female	2212	9/7/2014	3/24/2015	198
15448	Female	706	9/7/2014	2/15/2015	161

Table 2: Capture details for all bears; captured bears categorized by sex, number of collar deployment days, dates between which positions were collected and total number of positions utilized for analyses.

SEX					METHOD				SEX*METHOD			
%	DF	DF	F	P	DF	DF	F	P	DF	DF	F	P
50	2	13.771	4.6546	0.02856	2	20.351	16.1074	6.41E-05	4	20.351	0.1495	0.96108
95	2	13.71	4.8291	0.02585	2	19.867	16.2011	6.71E-05	4	19.867	0.5897	0.674
99	2	13.522	4.7325	0.02585	2	19.823	12.704	6.71E-05	4	19.823	0.6401	0.674

Table 3: Effect of sex, method and interaction on home range 50%, 95% and 99%.

	Female				Female with Cubs				Male			
	t	df	p	intercept	t	df	p	Δ to Female	t	df	p	Δ to Female
MCP-50	2.963	10	0.0142	1.2142	0.893	10	**0.3927**	0.5787	2.655	10	0.0241	1.8846
MCP-95	9.061		3.89E-06	2.6263	1.21		**0.254**	0.5545	3.168		0.01	1.5904
MCP-99	9.126		3.65E-06	2.7171	1.34		**0.21**	0.6306	3.143		0.0105	1.621
KDE-50	3.391		0.00687	0.9517	0.77		**0.45895**	0.3418	3.726		0.0039	1.8109
KDE-95	10.77		8.05E-07	2.6284	1.076		**0.3071**	0.4155	3.912		0.0029	1.6541
KDE-99	11.89		3.18E-07	3.0251	1.166		**0.2707**	0.4688	3.747		0.0038	1.6506
BBMM-50	-0.7	10	**0.4979**	-0.368	0.948	10	**0.3655**	0.7833	1.973	10	**0.077**	1.7859
BBMM-95	4.724		0.000811	1.8221	1.383		**0.19673**	0.8435	2.578		0.0275	1.722
BBMM-99	6.504		6.86E-05	2.3345	1.48		**0.1697**	0.8398	2.778		0.0195	1.7274

Table 4: Comparison by methods, percentage and sex. Females with cubs do not differ significantly from females. Males differ significantly from females. Males are significantly different except for BBMM at 50%.
Δ refers to difference to intercept.

	BBMM				KDE				MCP			
Percentage	t	df	p	intercept/Δ	t	df	p	intercept/Δ	t	df	p	intercept/Δ
50%	0.75	15.48	4.68E-01	0.26	4.77	24.90	6.87E-05	1.19	0.75	24.90	1.87E-06	1.54
95%	8.45	12.32	1.79E-06	2.45	5.49	24.97	1.07E-05	0.66	5.70	24.97	6.13E-06	0.68
99%	10.25	11.87	3.02E-07	2.96	5.71	24.98	5.99E-06	0.56	3.00	24.98	0.006	0.29

Table 5: full home ranges comparison at BBMM. BBMM is smallest in comparison to all other methods, where MCP is the largest home range estimation method for all percentages except at 95%, where KDE is larger than MCP. Differences (Δ) are to the intercept (BBMM) and data was grouped by percentage.

MEAN				MAX			MIN			Standard Deviation		
SEX %	MCP	KDE	BBMM	MCP	KDE	BBMM	MCP	KDE	BBMM	MCP	KDE	BBMM
F-50	4.72	3.4	1.64	11.35	7.81	4.4	0.78	0.88	0.05	3.92	2.63	1.92
F-95	17.57	16.85	10.17	33.1	31.66	22.66	3.44	5.02	0.59	11.21	10.59	8.92
F-99	19.99	25.47	15.86	42.96	45.34	32.99	3.5	7.1	1.17	14.24	16.54	12.86
F-100	21.81	N/A	N/A	46.31	N/A	N/A	3.51	N/A	N/A	15.04	N/A	N/A
FwC-50	8.68	3.87	2.05	22.4	5.68	4.4	2.34	2.16	0.48	9.23	1.47	1.71
FwC-95	25.7	22.36	14.95	33.1	29.26	19.95	12.59	10.96	9.83	9.37	7.93	4.7
FwC-99	30.81	35.24	24.81	42.96	45.34	30.61	15	16.77	14.84	12.99	12.92	7.03
FwC-100	37.19	N/A	N/A	59.48	N/A	N/A	17.07	N/A	N/A	19.25	N/A	N/A
M-50	34.82	17.8	4.17	78.95	27.08	4.96	7.78	8.02	3.56	38.54	9.54	0.72
M-95	77.96	77.37	34.82	126.64	110.09	38.71	33.3	44.55	29.78	46.8	32.77	4.57
M-99	84.05	114.94	59.03	128.67	160.89	68.35	43.78	64.07	44.94	42.61	48.6	12.41
M-100	126.33	N/A	N/A	198.28	N/A	N/A	48.18	N/A	N/A	75.24	N/A	N/A

Table 6: Full home range size statistics for all by sex (F: Female, FwC: Females with Cubs, M: Males) and percentage. The number following indicated the percentage points included in the calculation. All home range sizes were in square kilometer.

	50%			95%			99%			100%
Bear ID	MCP	KDE	BBMM	MCP	KDE	BBMM	MCP	KDE	BBMM	MCP
13205(F)	2.34	2.16	2.13	12.59	10.96	9.83	15.00	16.77	14.84	17.07
13206(M)	78.95	27.08	4.00	126.64	110.09	38.71	128.67	160.89	68.35	132.53
13207(FwC)	4.86	4.19	4.40	33.10	25.34	19.95	42.96	45.34	30.61	46.31
13208(F)	0.78	0.88	0.05	3.44	5.02	0.59	3.50	7.10	1.17	3.51
13209(F)	2.19	1.53	0.31	13.15	10.04	5.44	13.99	14.84	9.66	15.35
13210(FwC)	5.12	3.44	1.18	31.76	23.86	17.75	39.78	36.10	28.68	59.48
13211(M)	7.78	8.02	4.96	33.30	44.55	29.78	43.78	64.07	44.94	48.18
13212(FwC)	22.40	5.68	0.48	25.34	29.26	12.28	25.51	42.76	25.09	25.91
15441(M)	17.74	18.32	3.56	73.94	77.46	35.96	79.68	119.88	63.79	198.28
15442(F)	6.92	4.44	0.71	21.60	20.53	6.47	23.83	29.01	11.14	24.71
15444(F)	2.24	1.55	0.59	8.36	8.51	5.92	9.03	12.53	9.56	12.03

15448(F)	11.35	7.81	3.78	25.78	31.66	22.66	26.60	43.97	32.99	28.93

Table 7: Individual home ranges calculated with MCP, KDE and BBMM; F: Females, FwC: Females with Cubs, M: Males. Individual home ranges showed similar pattern as the aggregated home ranges by sex, while BBMM computed typically the smallest home ranges while MCP and KDE provide a more similar home range size. All home range sizes in square kilometer.

	Spring				Summer			
50%								
	t	**df**	**p**	**interc./Δ to F**	**t**	**df**	**p**	**interc./Δ to F**
Female	21.131	9.916	1.42E-09	15.0406	57.861	13.629	< 2e-16	15.7368
Females with Cu	-0.176	10.565	**0.863**	-0.2559	-1.739	15.796	**0.10155**	-1.0555
Male	0.34	9.009	**0.742**	0.3715	4.012	13.629	0.00135	1.5431
95%								
Female	25.63	11.217	2.60E-11	16.22536	62.679	13.539	< 2e-16	17.139
Females with Cu	0.024	11.885	**0.982**	0.03245	-0.86	14.837	**0.40335**	-0.5127
Male	0.642	9.988	**0.535**	0.64917	4.222	13.539	0.000916	1.6325
	Fall				Winter			
50%								
	t	**df**	**p**	**interc./Δ to F**	**t**	**df**	**p**	**interc./Δ to F**
Female	31.372	18.03	<2e-16	15.0713	10.934	8.962	1.75E-06	12.911
Females with Cu	0.129	17.949	**0.8985**	0.1293	0.352	8.962	**0.733**	1.018
Male	2.079	18.341	**0.0519**	1.5044	0.89	8.194	**0.399**	1.424
95%								
Female	40.15	20.232	< 2e-16	16.4483	12.816	12	2.32E-08	14.24
Females with Cu	0.347	19.996	**0.73208**	0.3171	0.545	12	**0.596**	1.285
Male	3.146	20.501	0.00498	2.0449	0.902	12	**0.385**	1.475

Table 8: Seasonal significance based on sex. Males and females with cubs were compared to females. Bold numbers indicate associations that are not significant. Females with cubs did not differ significant from females. Neither did males at 50% in the spring, fall and winter and at 95% males were not significantly different from females in the spring and winter. Δ refers to differences to intercept (females).

Sex - Season - Year	MEAN	MAX	MIN	Std. Dev.
FEMALE FALL 2013	4.74	8.36	1.12	5.12
FEMALE FALL 2014	28.75	45.21	9.87	14.51
FEMALE SPRING 2014	2.69	6.56	0.01	3.43
FEMALE SPRING 2015	5.36	8.46	2.26	4.38
FEMALE SUMMER 2013	7.61	12.41	2.80	6.79
FEMALE SUMMER 2014	15.74	19.69	11.78	5.59
FEMALE WINTER 2014	0.62	1.05	0.19	0.61
FEMALE WINTER 2015	5.66	12.95	0.01	6.63
FEMALE_CUBS FALL 2013	26.20	30.22	22.17	5.69
FEMALE_CUBS FALL 2014	24.68	45.21	11.89	17.96
FEMALE_CUBS SPRING 2014	11.12	32.68	1.18	14.54
FEMALE_CUBS SPRING 2015	2.26	2.26	2.26	NA
FEMALE_CUBS SUMMER 2013	2.80	2.80	2.80	NA
FEMALE_CUBS SUMMER 2014	16.13	25.96	10.64	8.53
FEMALE_CUBS WINTER 2014	5.58	6.31	4.84	1.04
FEMALE_CUBS WINTER 2015	6.48	12.95	0.00	9.16
MALE FALL 2013	45.84	45.84	45.84	0.00
MALE FALL 2014	106.98	111.47	102.48	6.36
MALE SPRING 2014	29.42	56.29	2.55	38.00
MALE SPRING 2015	123.13	123.13	123.13	NA
MALE SUMMER 2014	99.25	126.11	72.39	37.98
MALE WINTER 2014	26.97	26.97	26.97	NA
MALE WINTER 2015	42.04	65.60	18.49	33.31

Table 9: Seasonal home range statistics based on 95% KDE for sex, season and year.

List of Figures

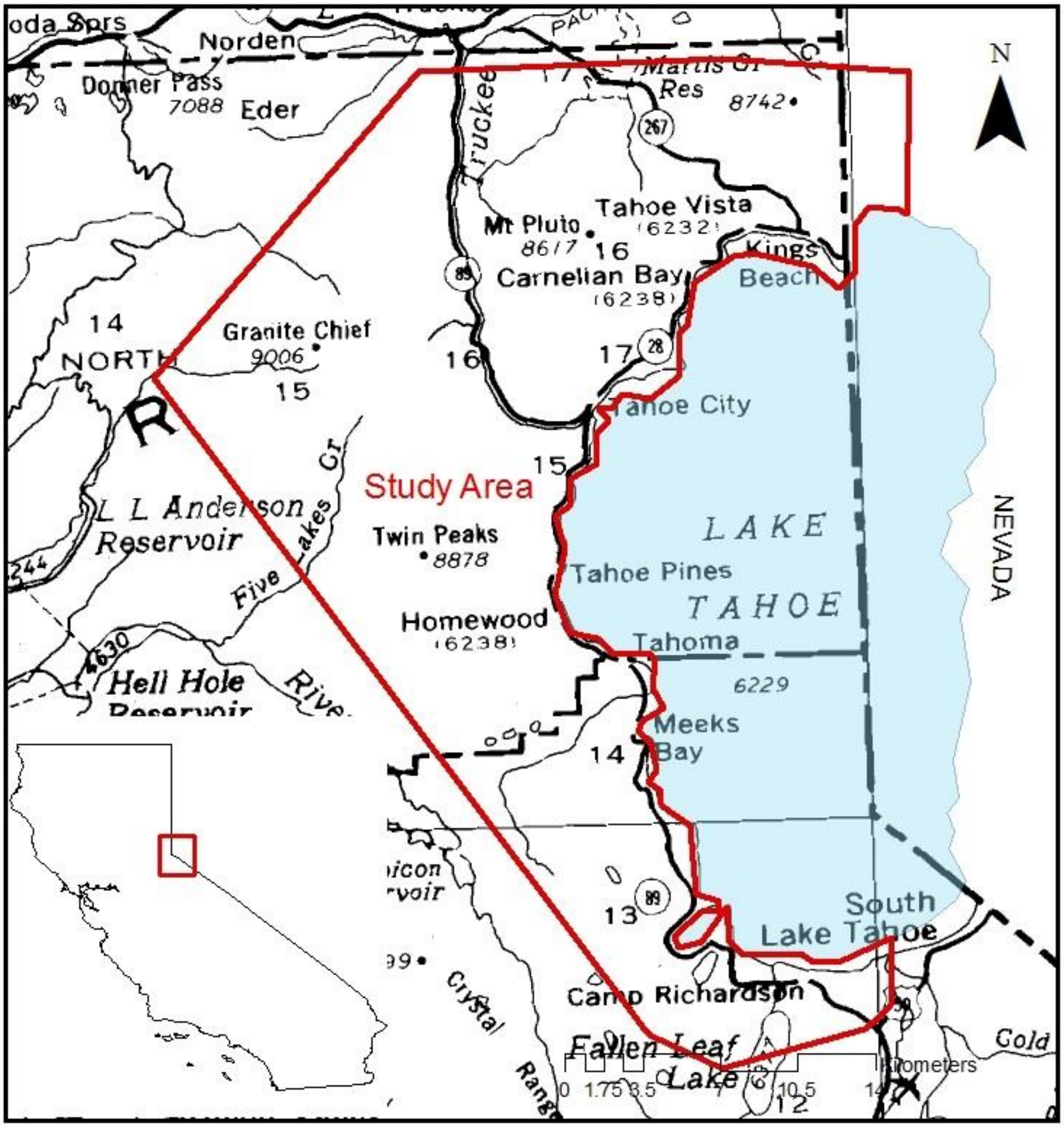


Figure 1: Study Area; Western side of Lake Tahoe in California, and adjoining areas. A small area at the Northern portion of the lake around Kings Beach crossed into Nevada.

Figure 2: Bear Trap; trap is set by opening the back, luring bears in with bait, when the bear pulls on bait bag attached to a cable running through the conduit and work the trigger. The round portholes on all sides provide access by jab stick.

Figures 3A thru F - Individual home range statistics based on MCP, KDE and BBMM

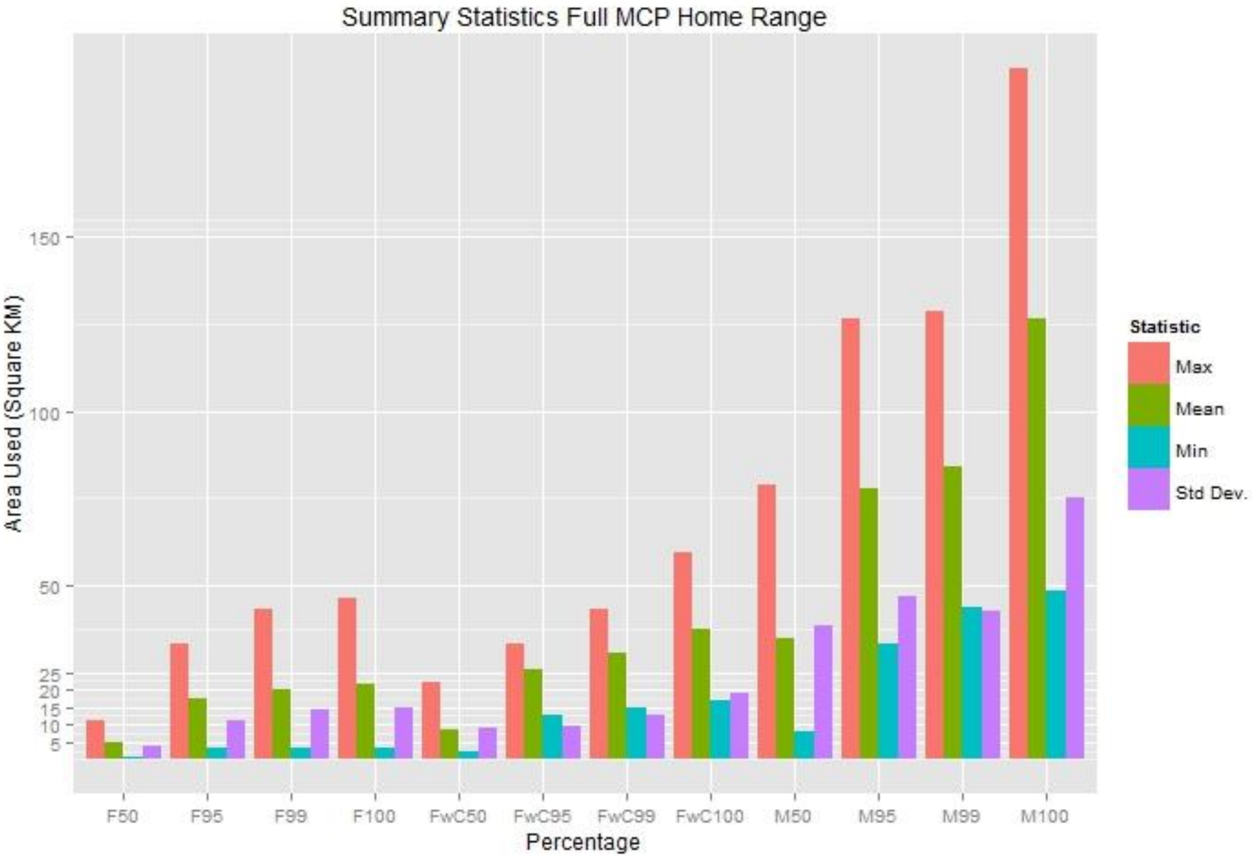


Figure 3A: Summary statistics MCP full home range by sex and percentage (50, 95, 99, 100%), maximum and minimum value, mean and the standard deviation. Females (F) and females with cubs (FwC) had the smallest home range whereas males (M) had the largest home range at all percentages compared.

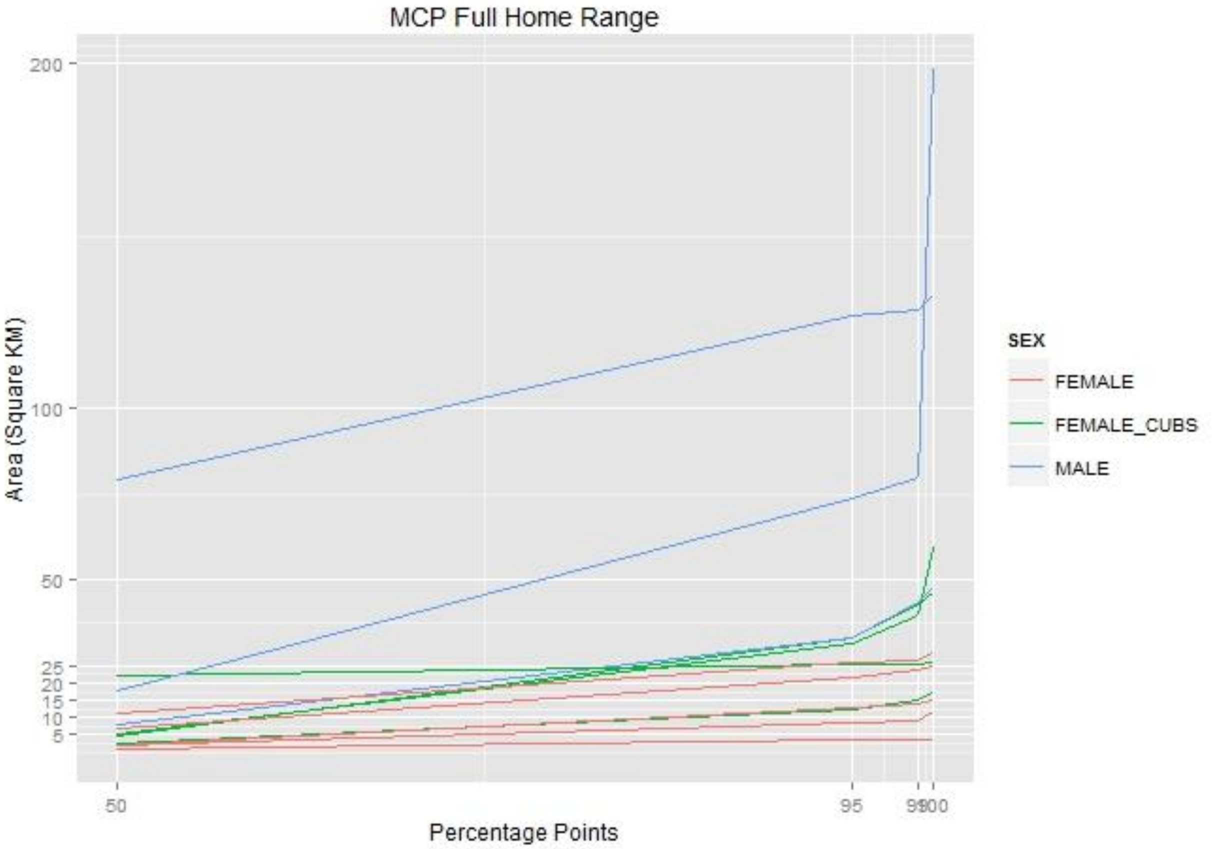


Figure 3B: Summary MCP graph full home range by sex, a steep increase in slope when increasing the number of locations might be indicative of the impact outliers have on the total home range area.

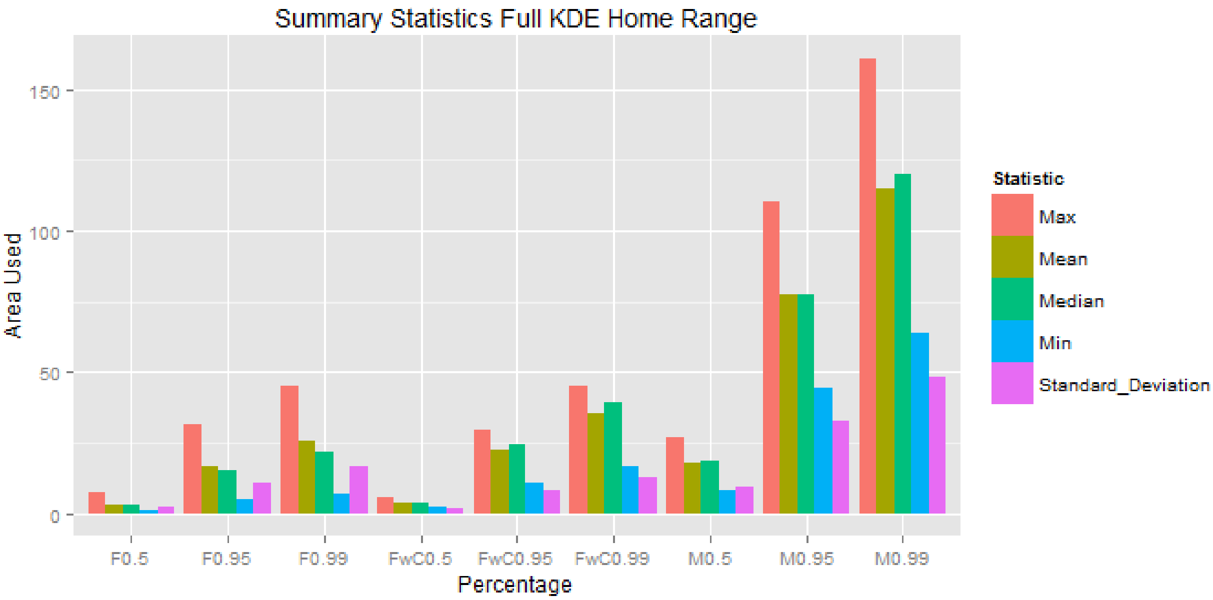


Figure 3C: Summary statistics KDE full home range by sex and percentage (50, 95, 99, 100%), maximum and minimum value, mean and the standard deviation. Females (F) and females with cubs (FwC) had the smallest home range whereas males (M) had the largest home range at all percentages compared.

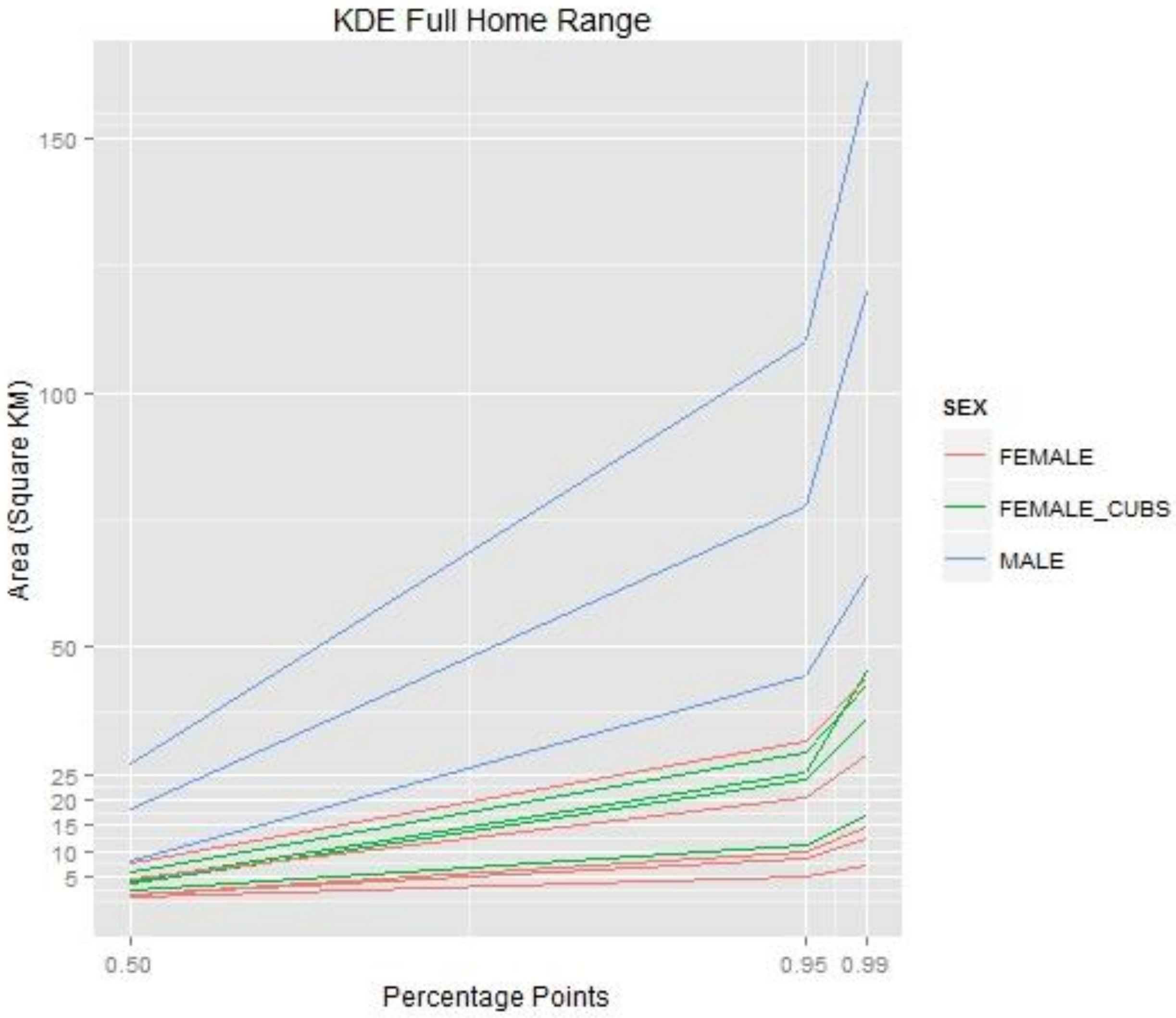


Figure 3D: Summary KDE graph full home range by sex, slope increases between 0.95 and 0.99, this might be indicative that more locations should be included in the calculation of the areas.

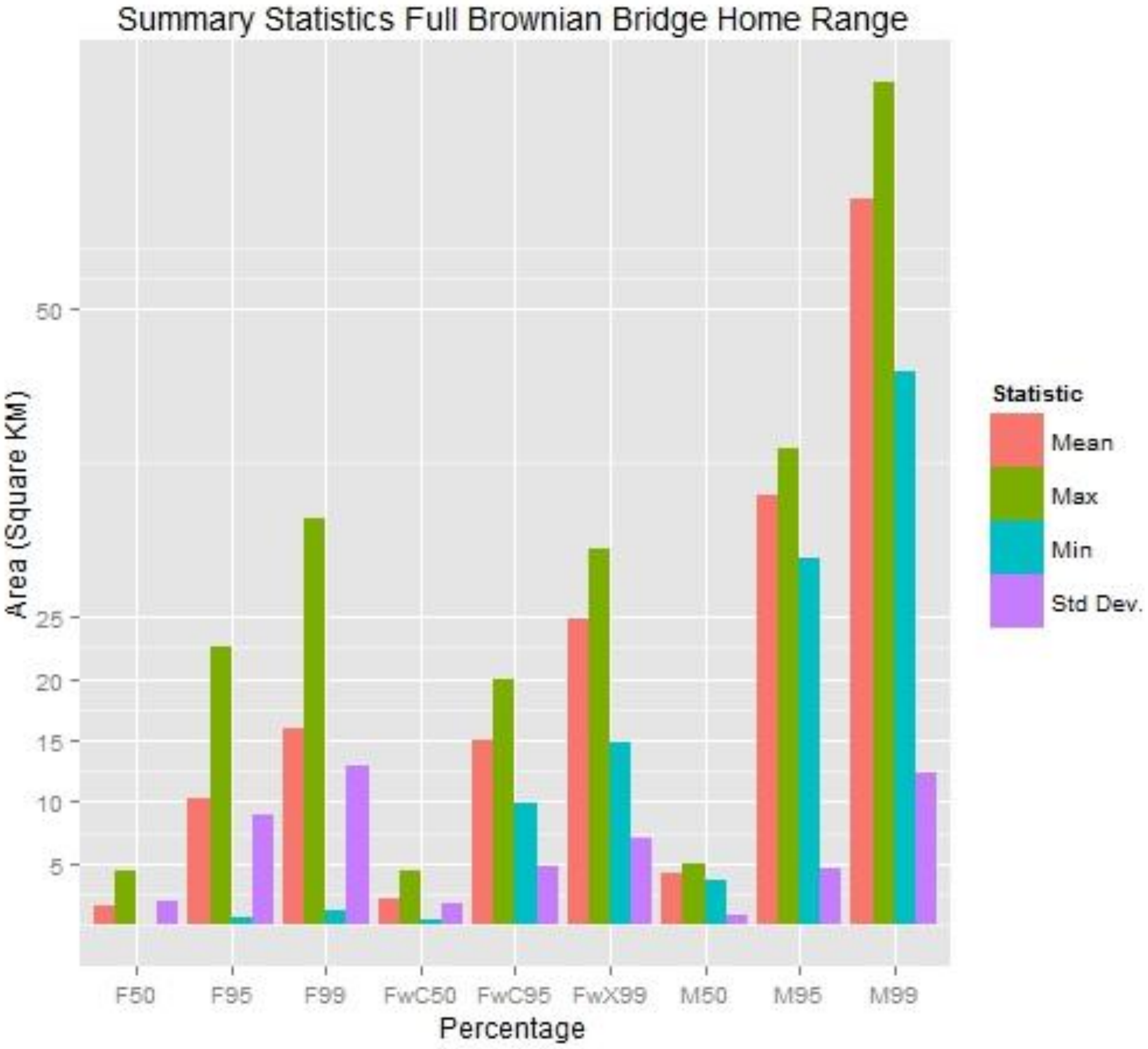


Figure 3E: Summary statistics BBMM full home range by sex and percentage (50, 95, 99, 100%), maximum and minimum value, mean and the standard deviation. Females (F) and females with cubs (FwC) had the smallest home range whereas males (M) had the largest home range at all percentages compared.

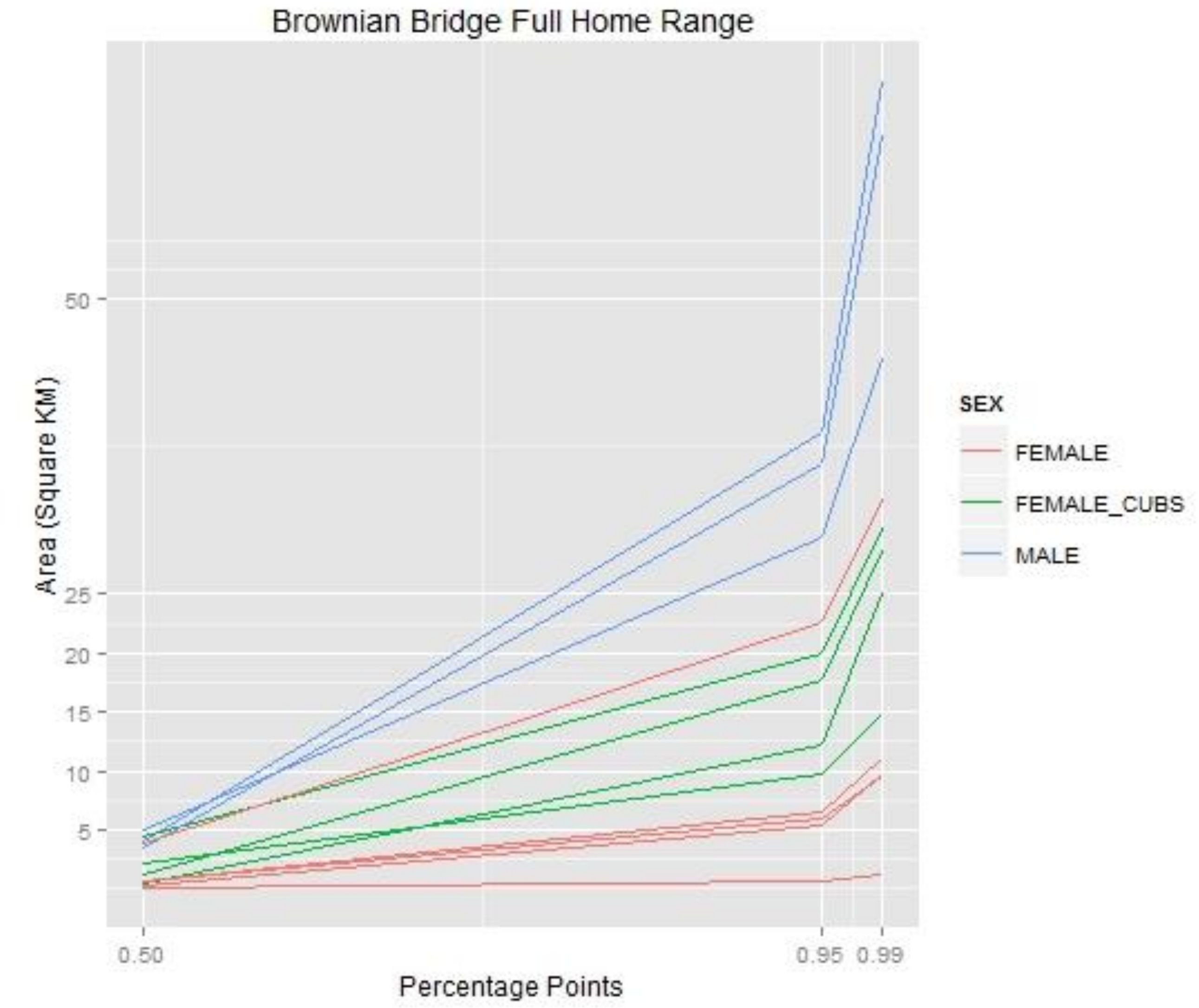
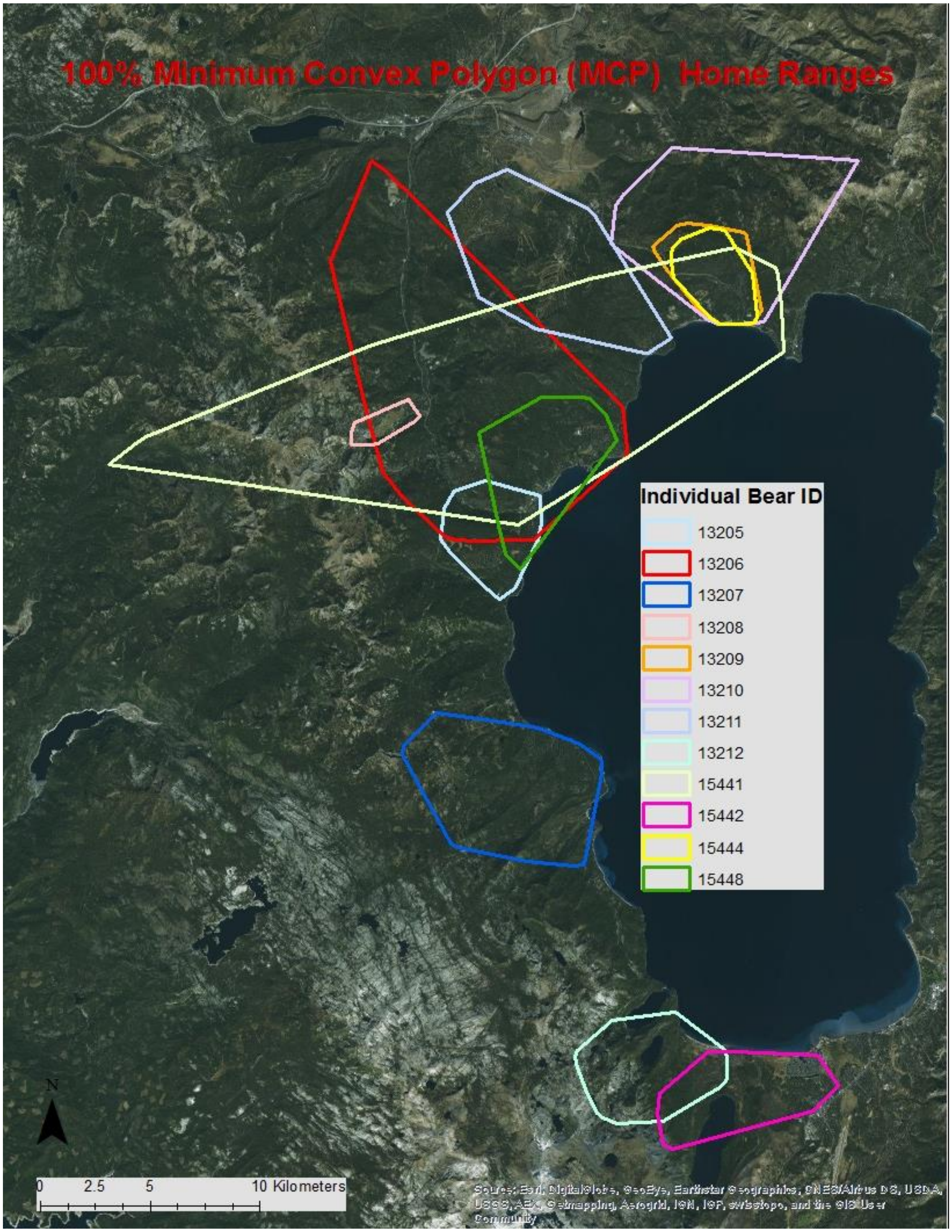


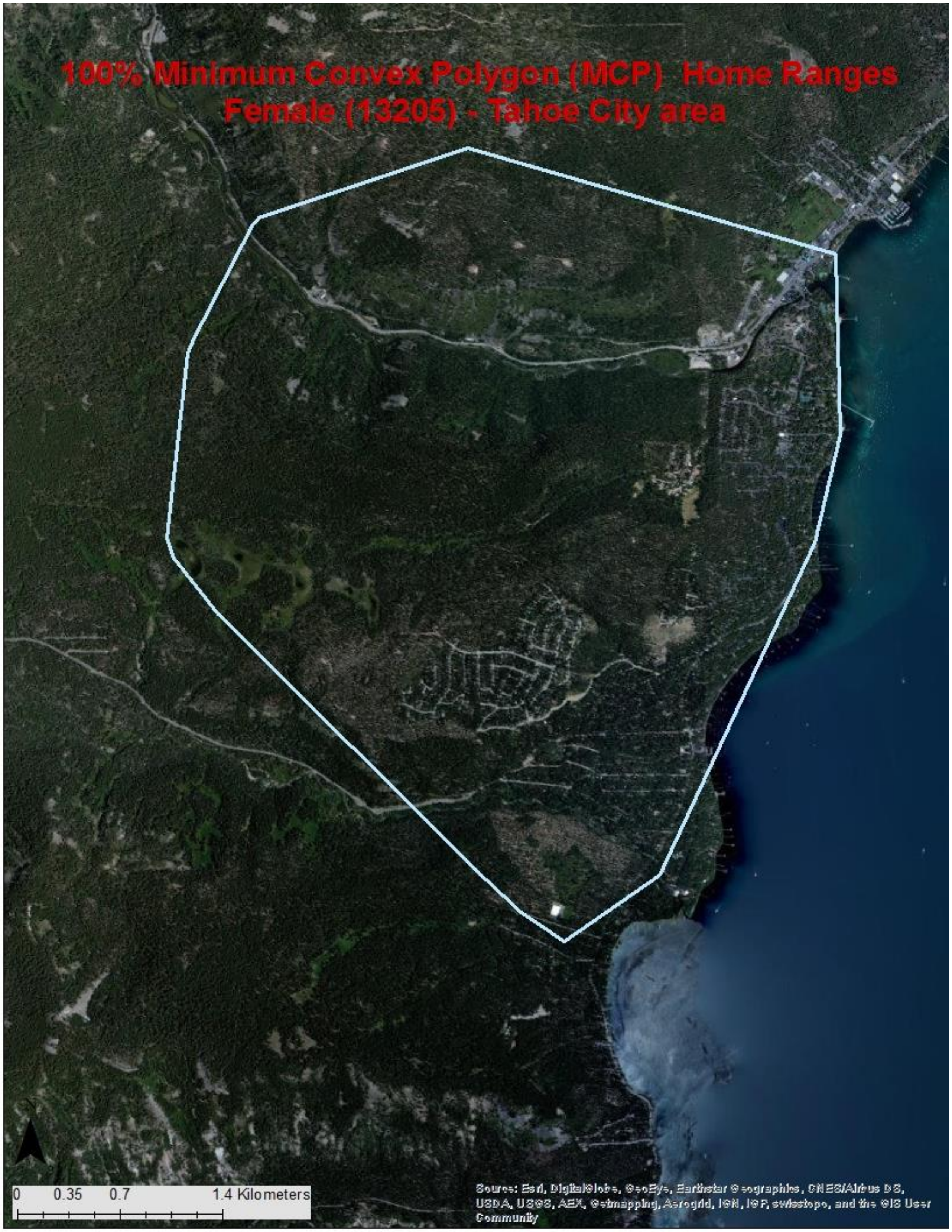
Figure 3F: Summary BBMM graph full home range by sex, a steep increase in slope when increasing the number of locations might be indicative of the impact outliers have on the total home range area. Slope change appeared to be strongest for males.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4: The total home range by bear in the study area, at 100% MCP; It is acknowledged that a 100% MCP overstated the actual area of usage.

Figures 5A thru L - Individual Home Ranges based on MCP



100% Minimum Convex Polygon (MCP) Home Ranges
Female (13205) - Tahoe City area

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5A: Individual home range based on MCP method.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5B: Individual home range based on MCP method.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5C: Individual home range based on MCP method.

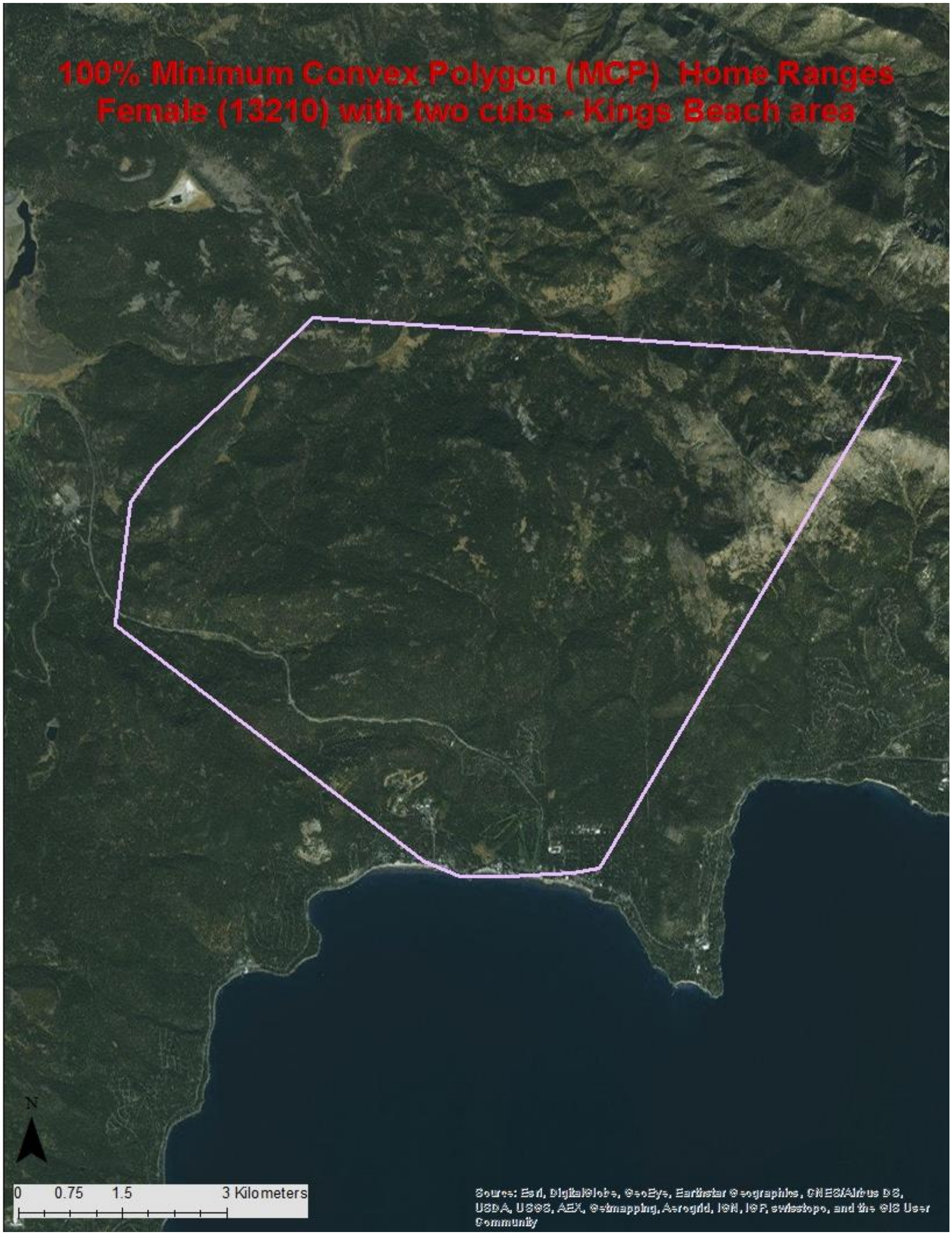
100% Minimum Convex Polygon (MCP) Home Ranges
Female (13208) - Squaw Valley area

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5D: Individual home range based on MCP method.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5E: Individual home range based on MCP method.

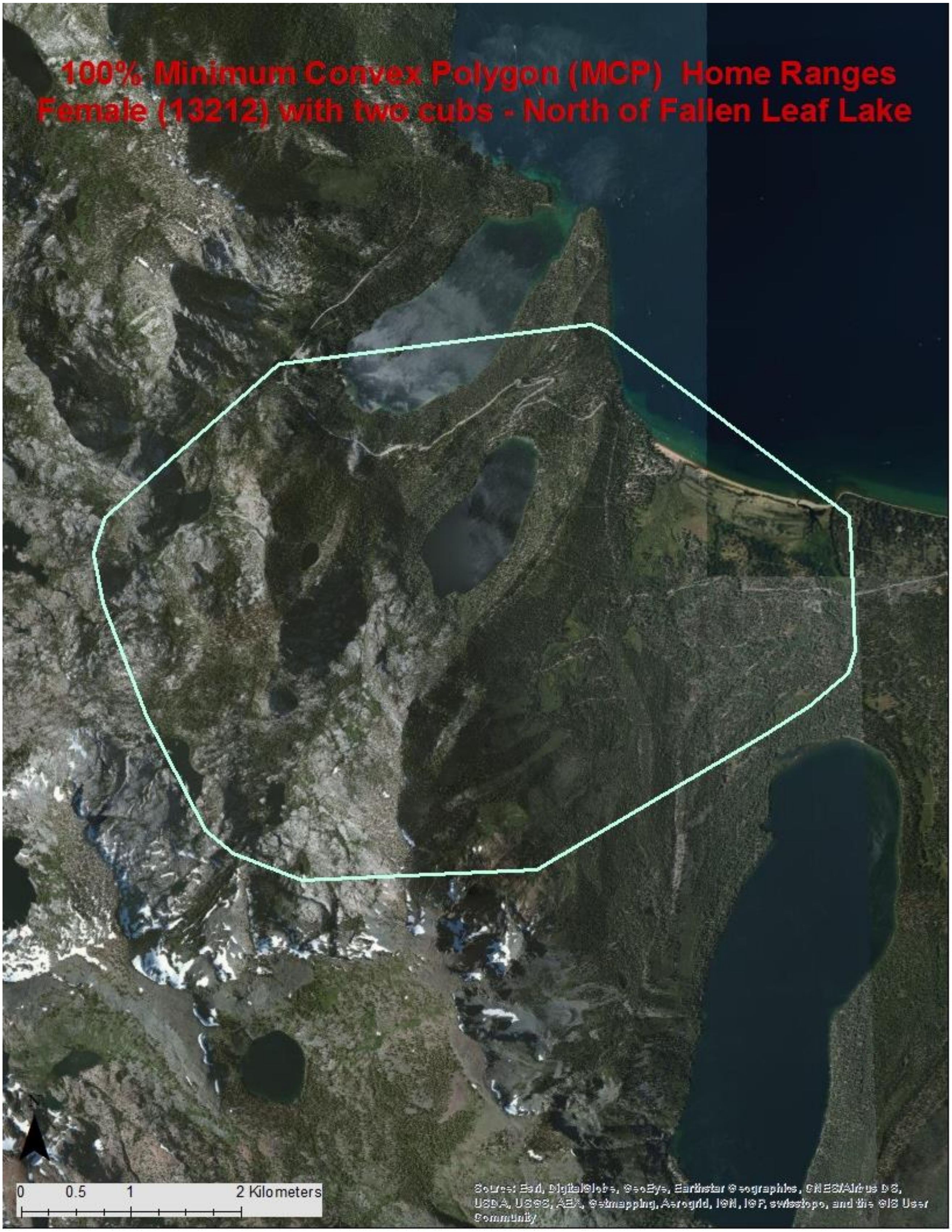


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5F: Individual home range based on MCP method.

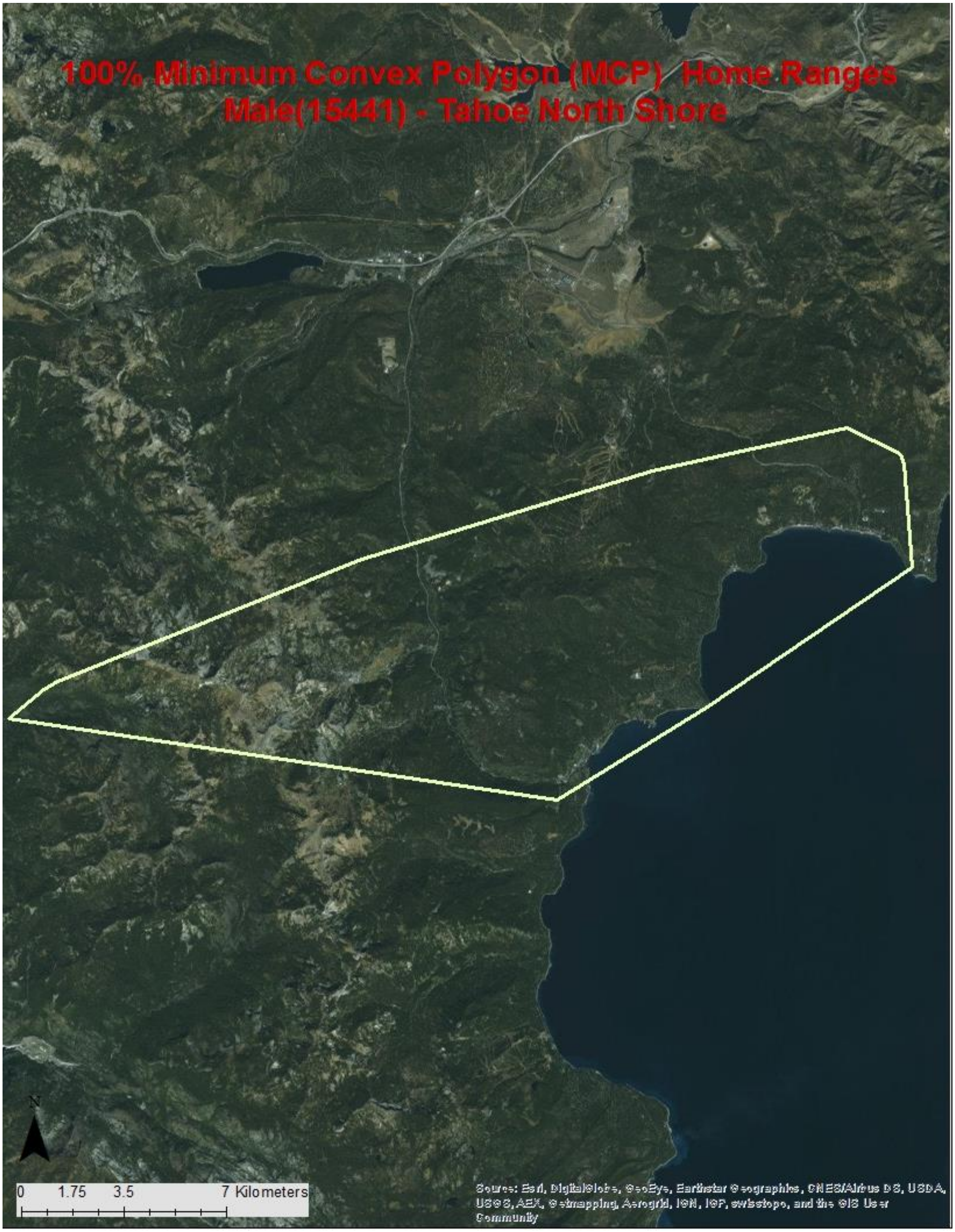
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5G: Individual home range based on MCP method.


100% Minimum Convex Polygon (MCP) Home Ranges
Female (13212) with two cubs - North of Fallen Leaf Lake

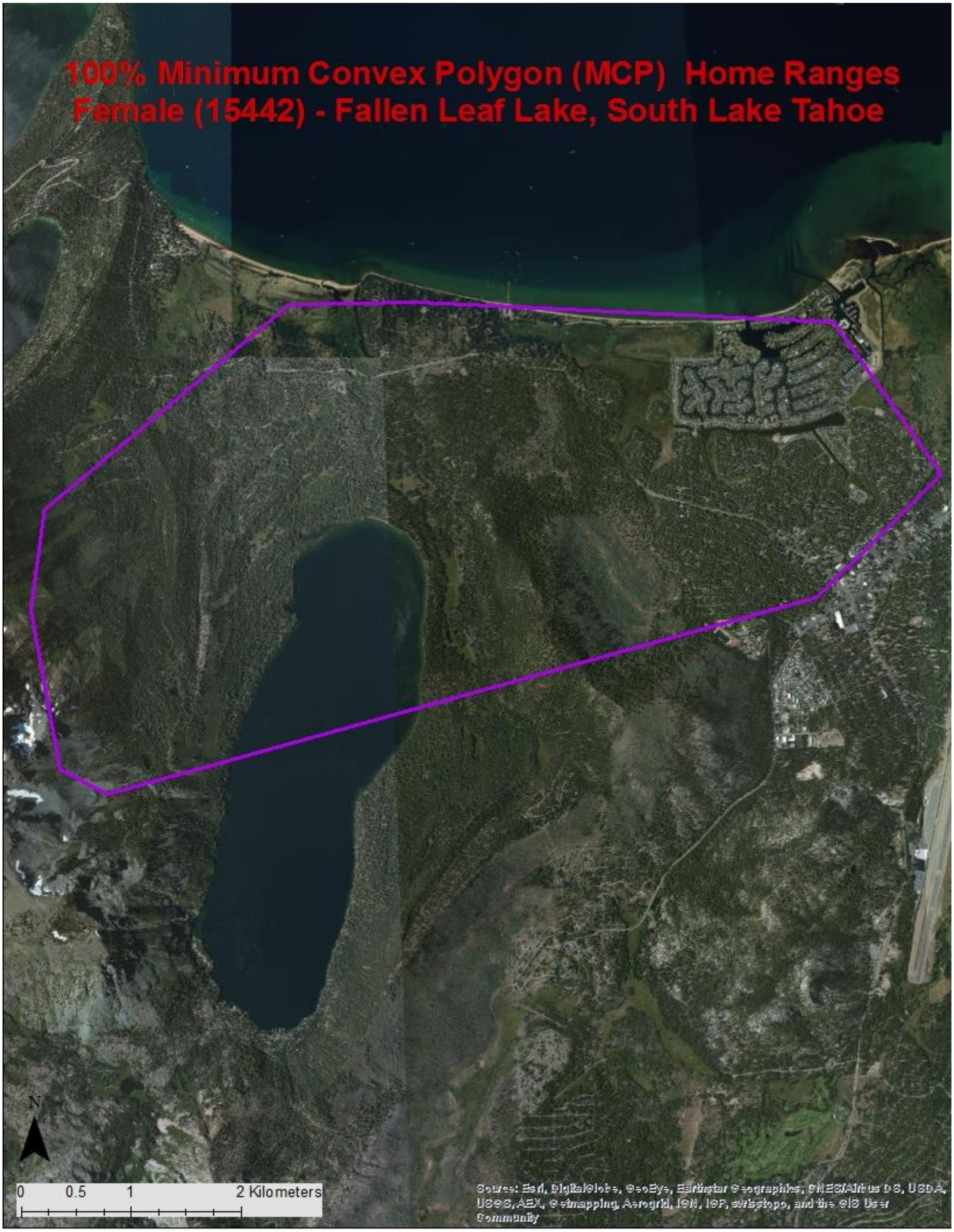
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5H: Individual home range based on MCP method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5I: Individual home range based on MCP method.

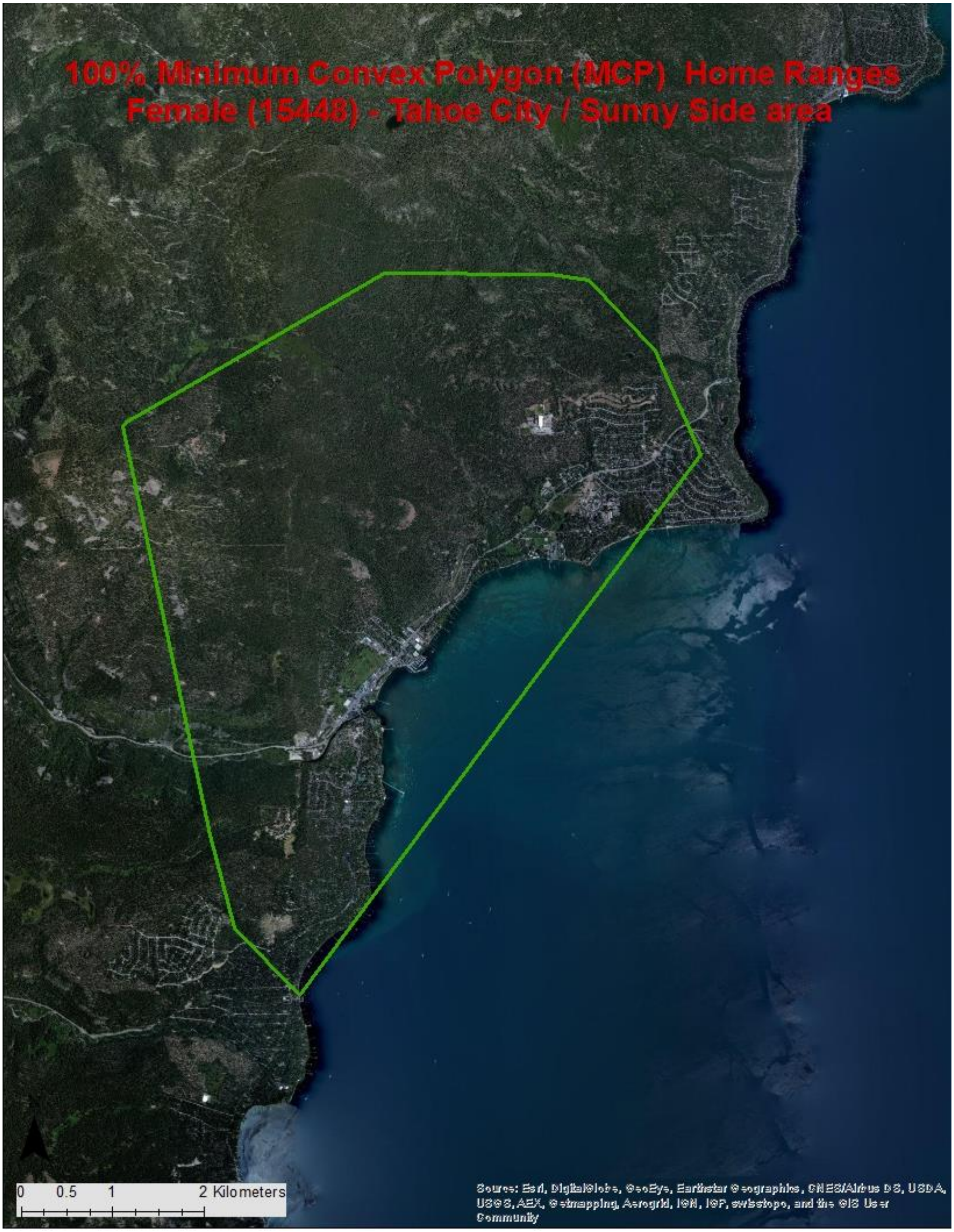


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5J: Individual home range based on MCP method.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

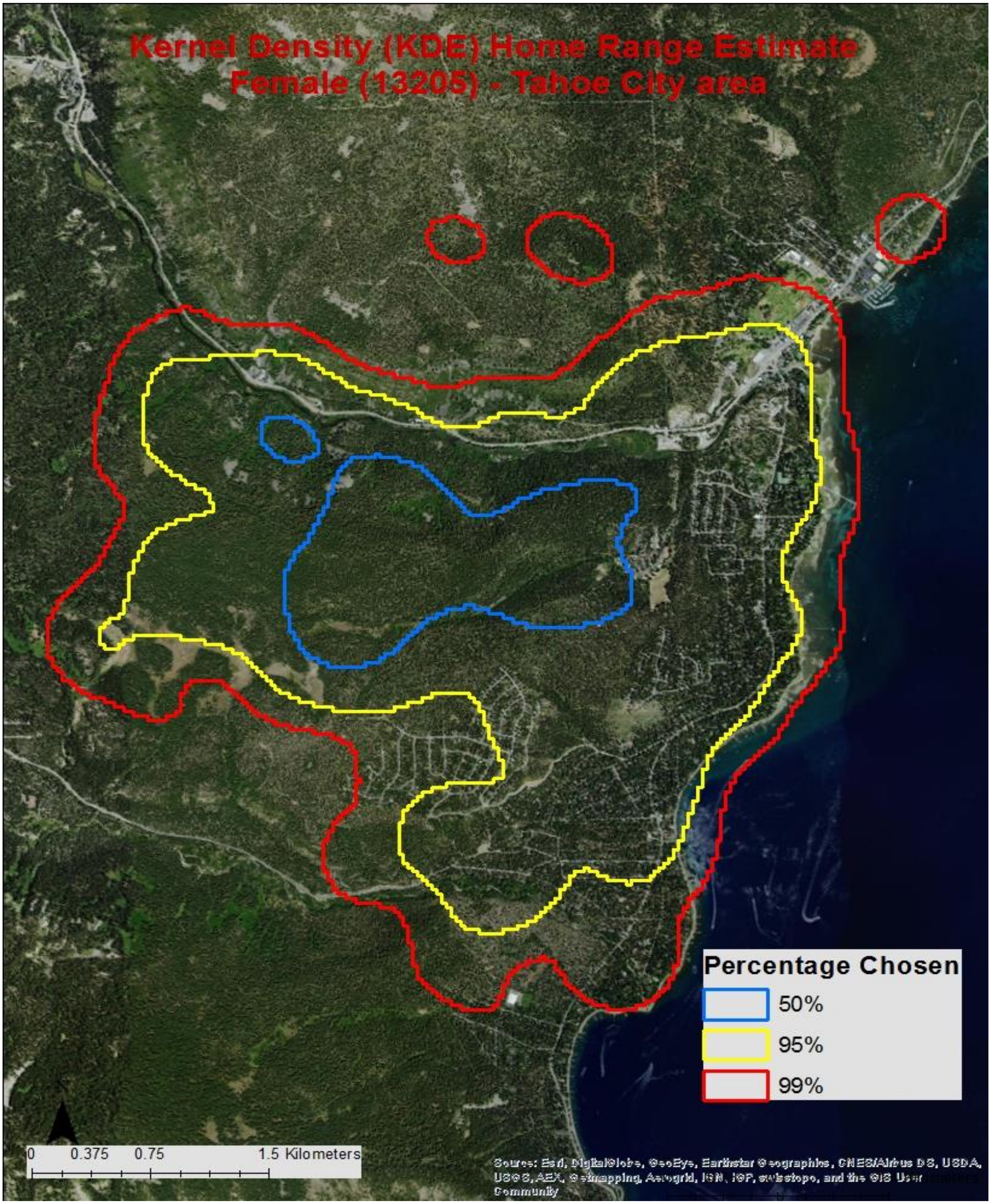
Figure 5K: Individual home range based on MCP method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

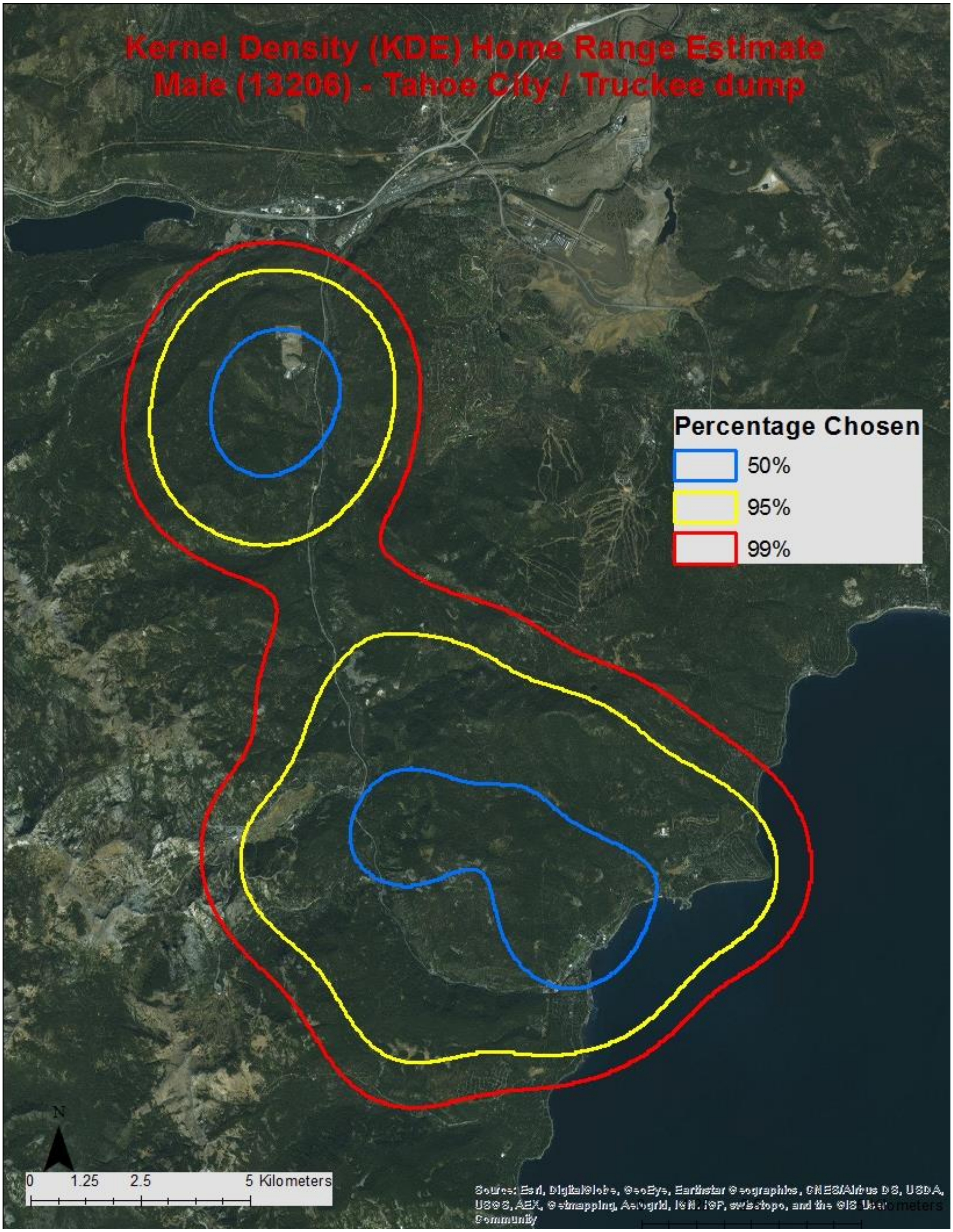
Figure 5L: Individual home range based on MCP method.

Figures 6 A thru L - Individual Home Ranges based on KDE



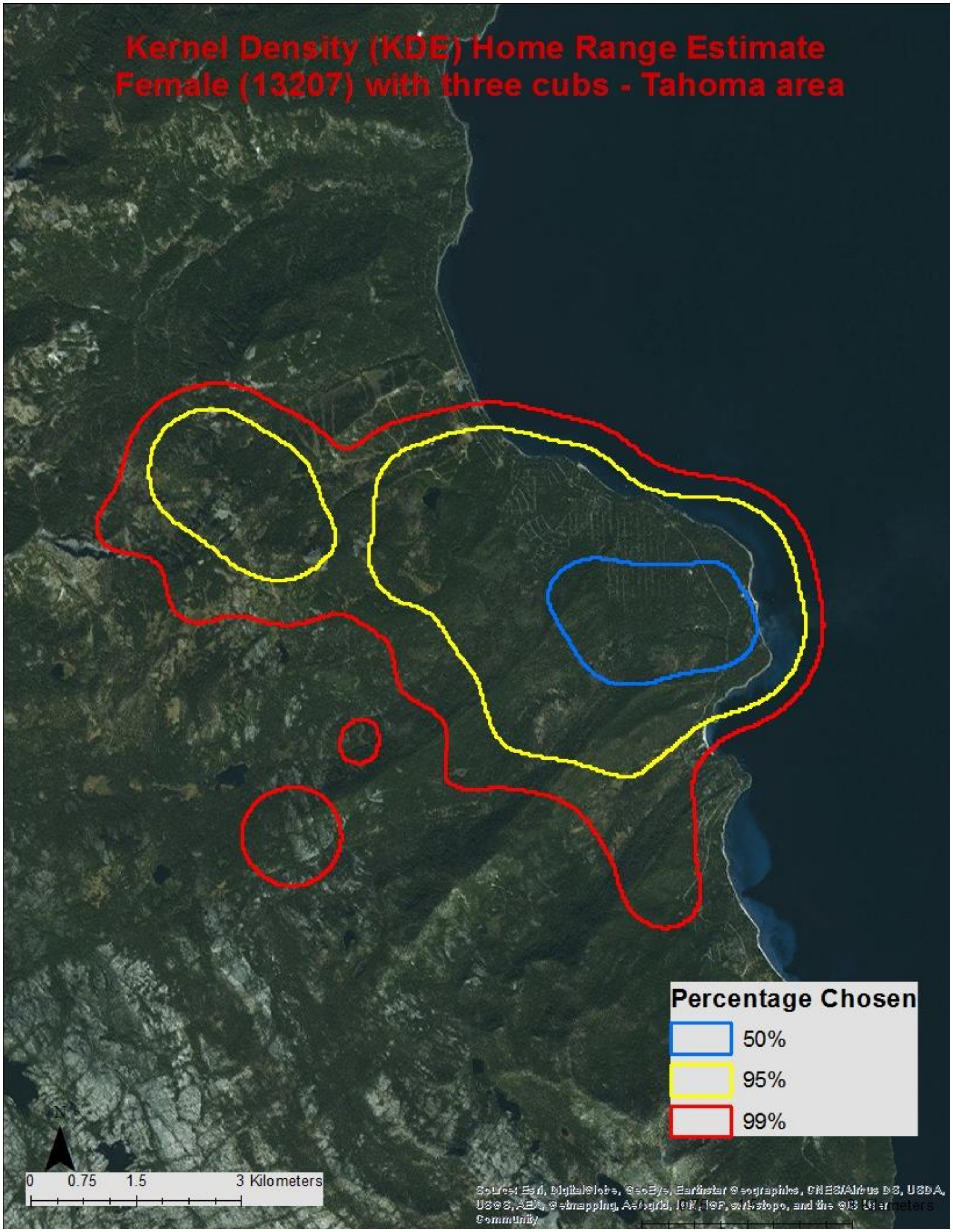
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6A: Individual home range based on KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6B: Individual home range based on KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6C: Individual home range based on KDE method.

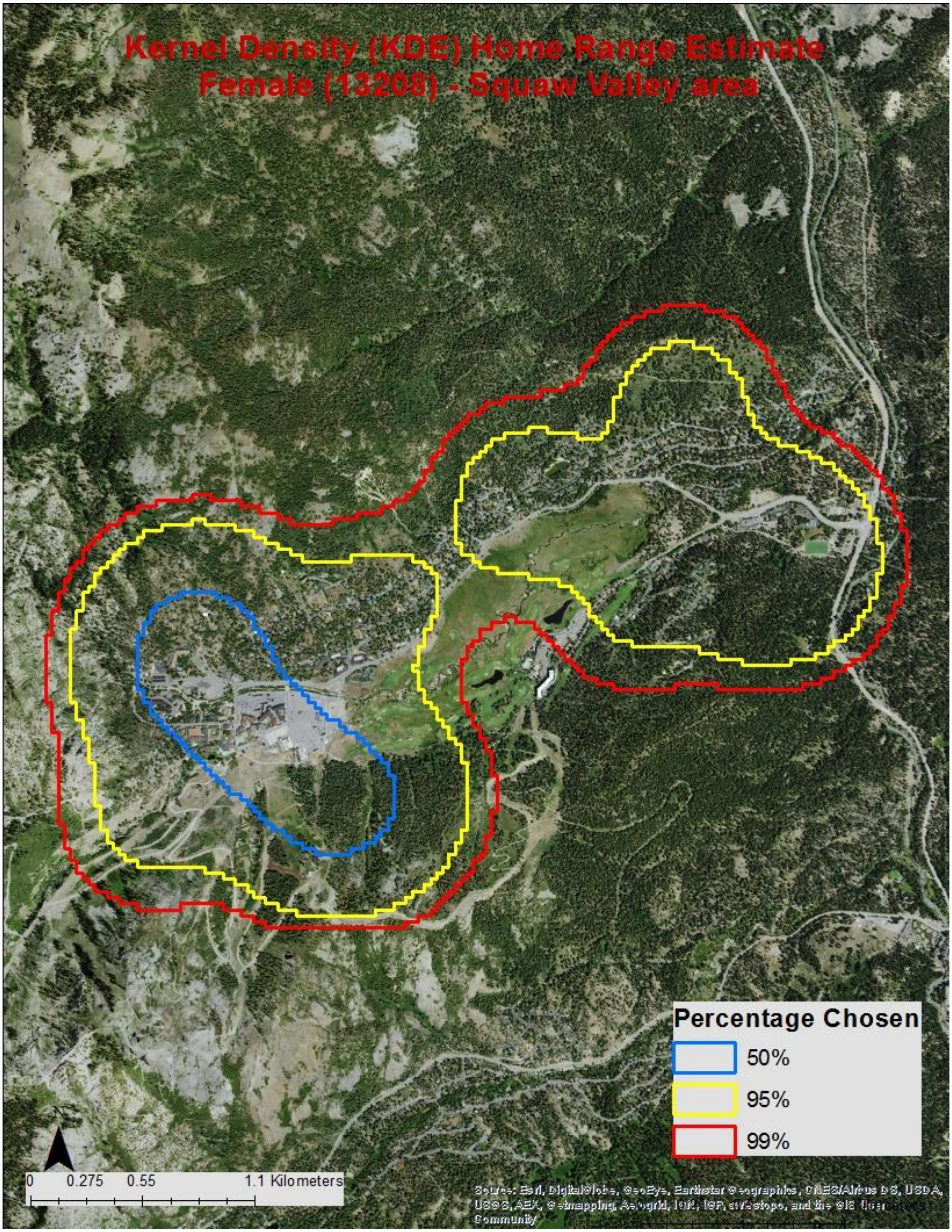
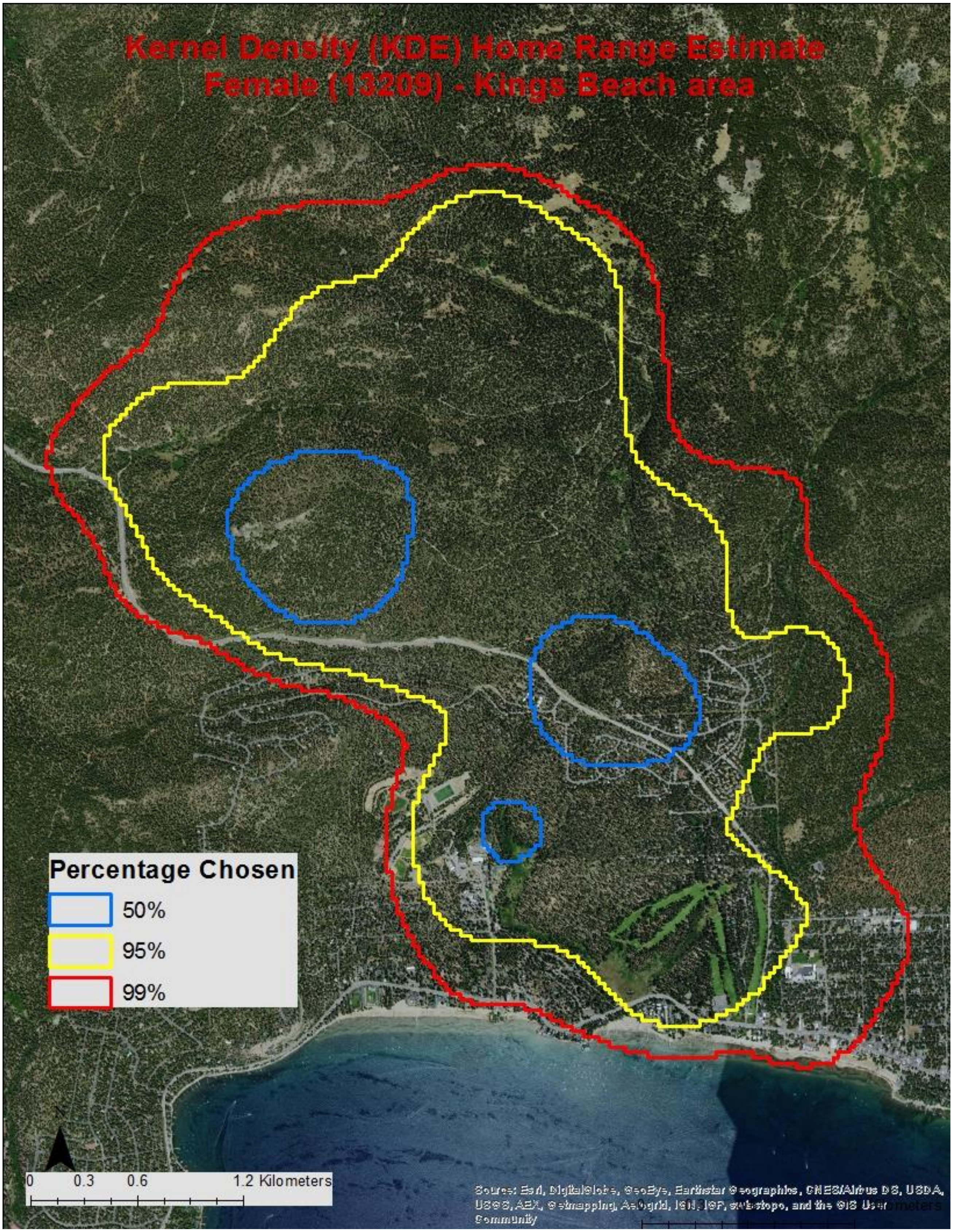
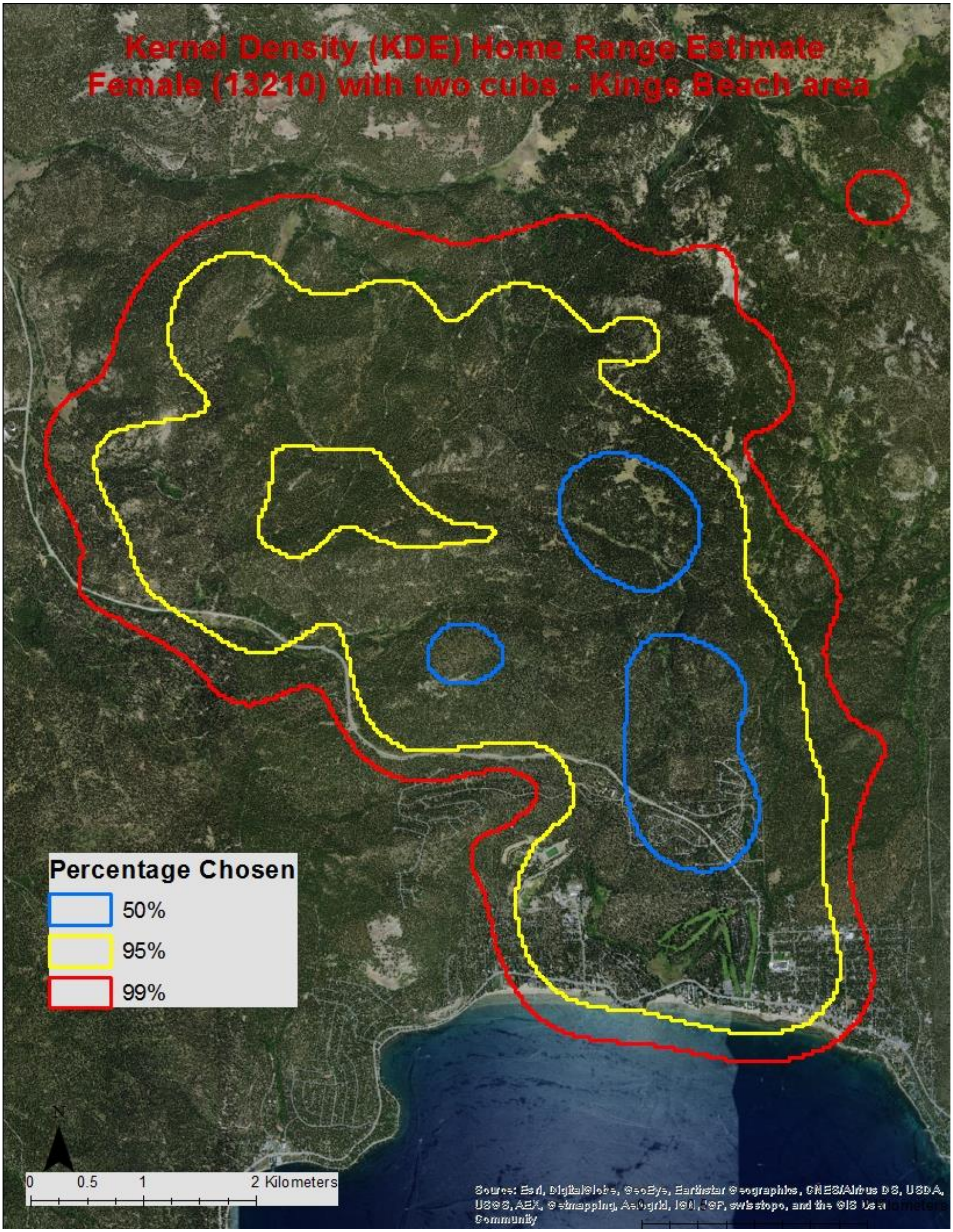


Figure 6D: Individual home range based on KDE method.



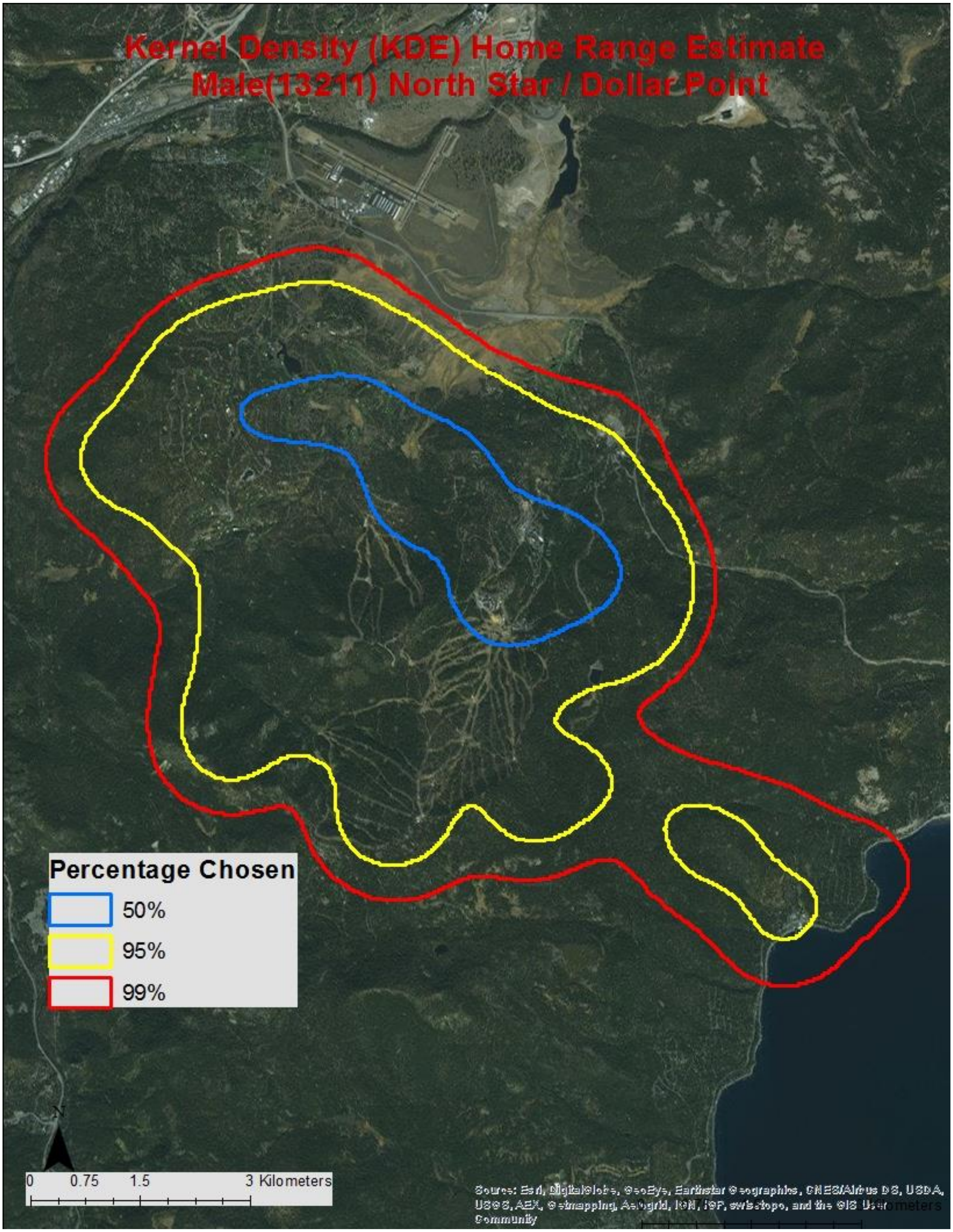
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6E: Individual home range based on KDE method.



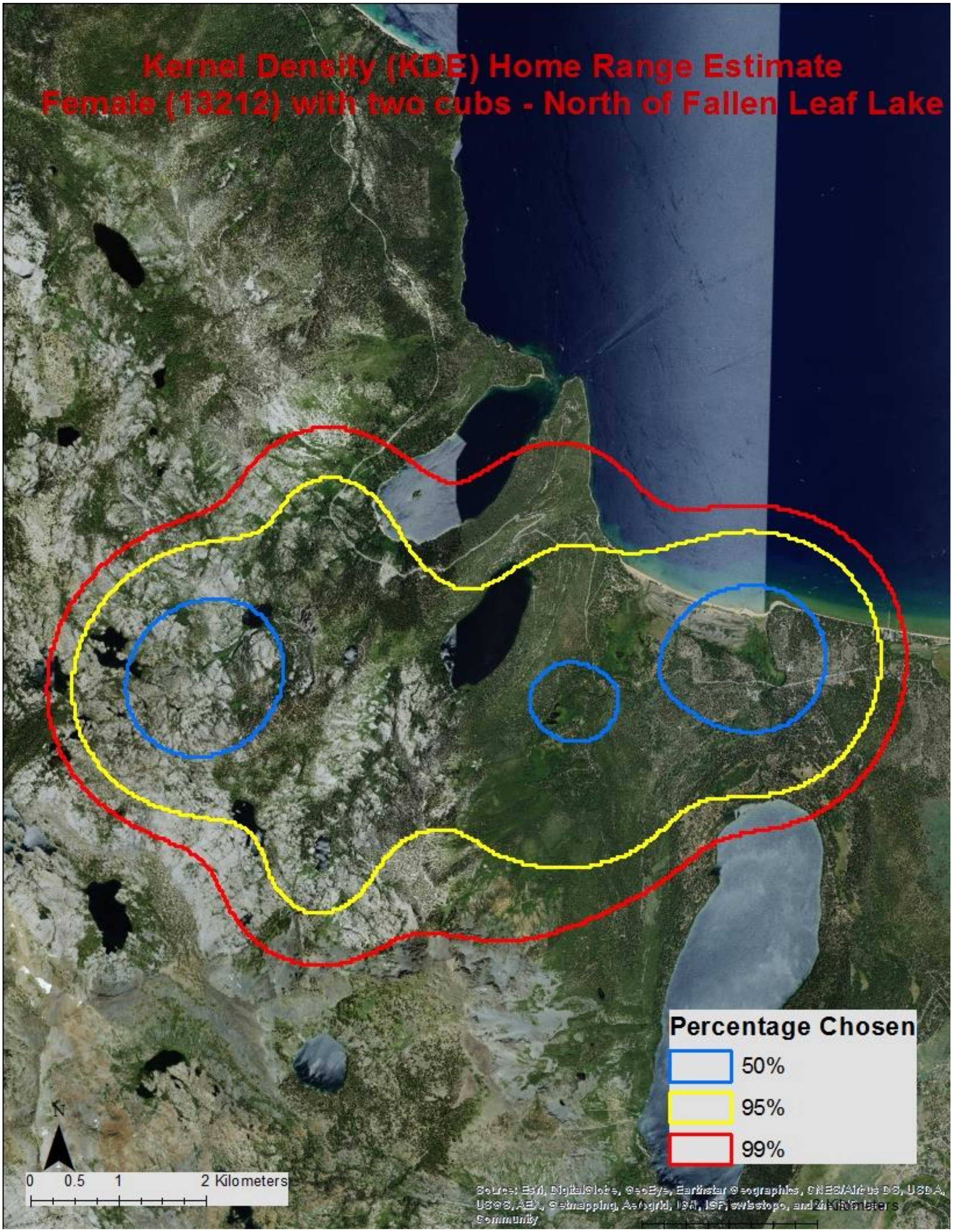
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6F: Individual home range based on KDE method.



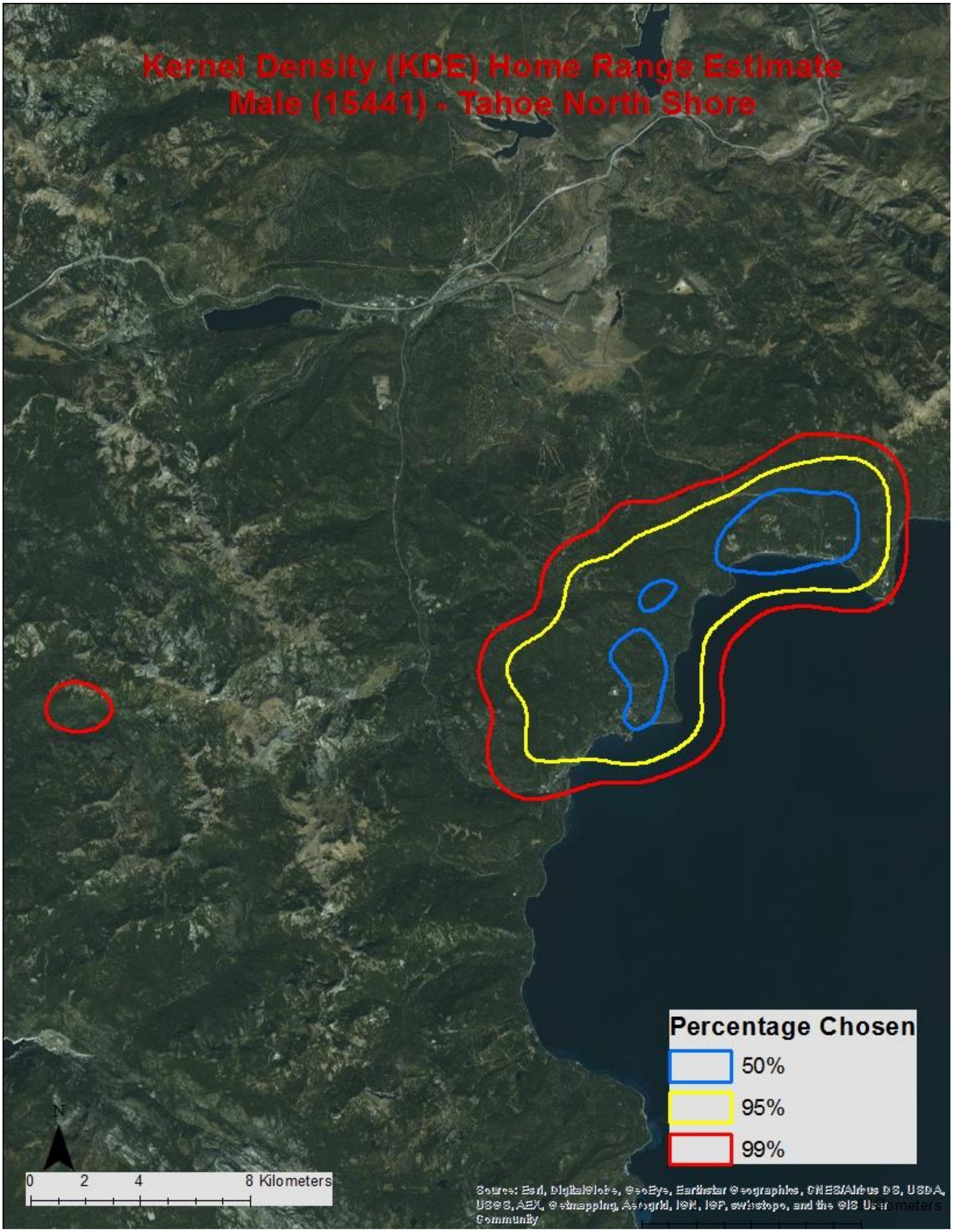
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6G: Individual home range based on KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

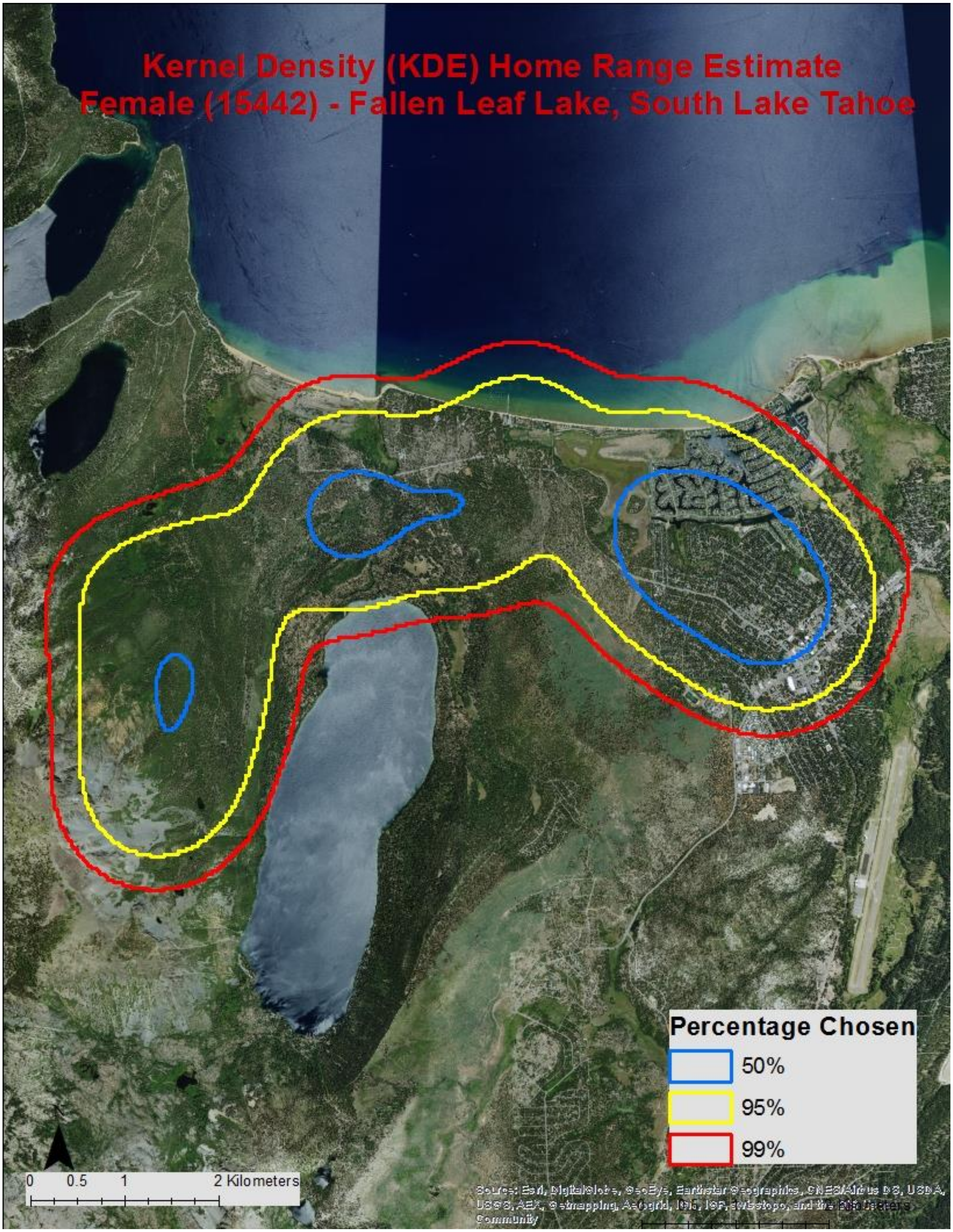
Figure 6H: Individual home range based on KDE method.



Kernel Density (KDE) Home Range Estimate
Male (15441) - Tahoe North Shore

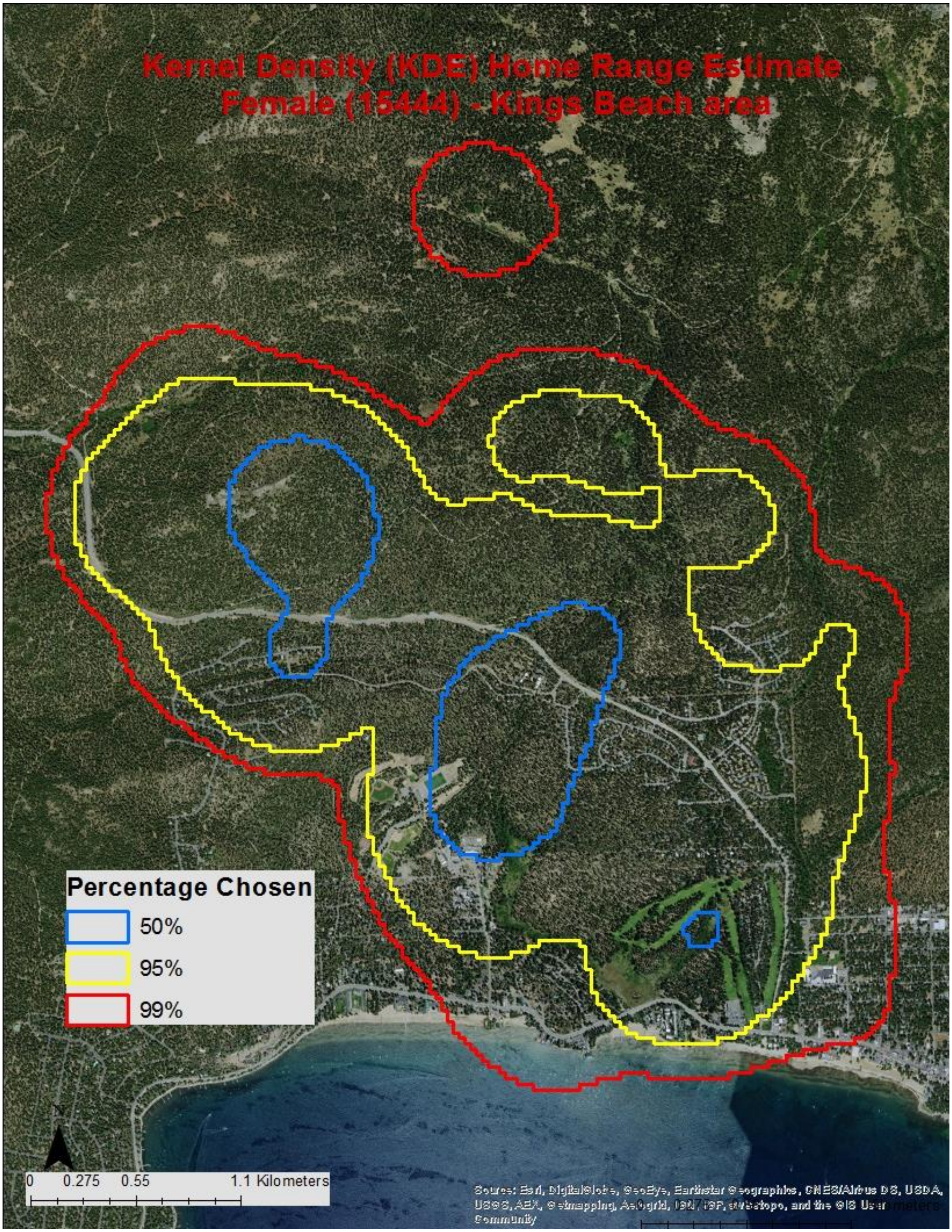
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6I: Individual home range based on KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6J: Individual home range based on KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6K: Individual home range based on KDE method.

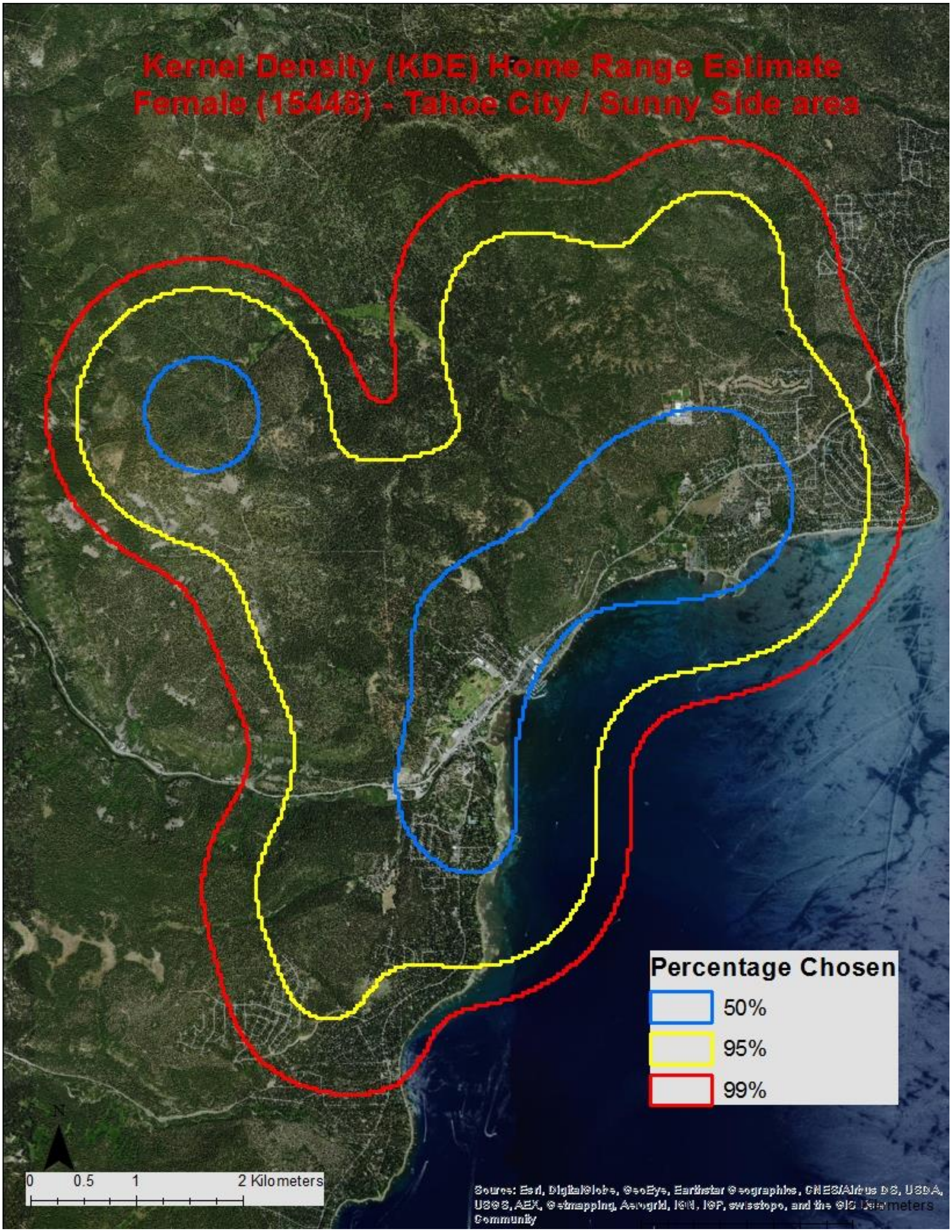
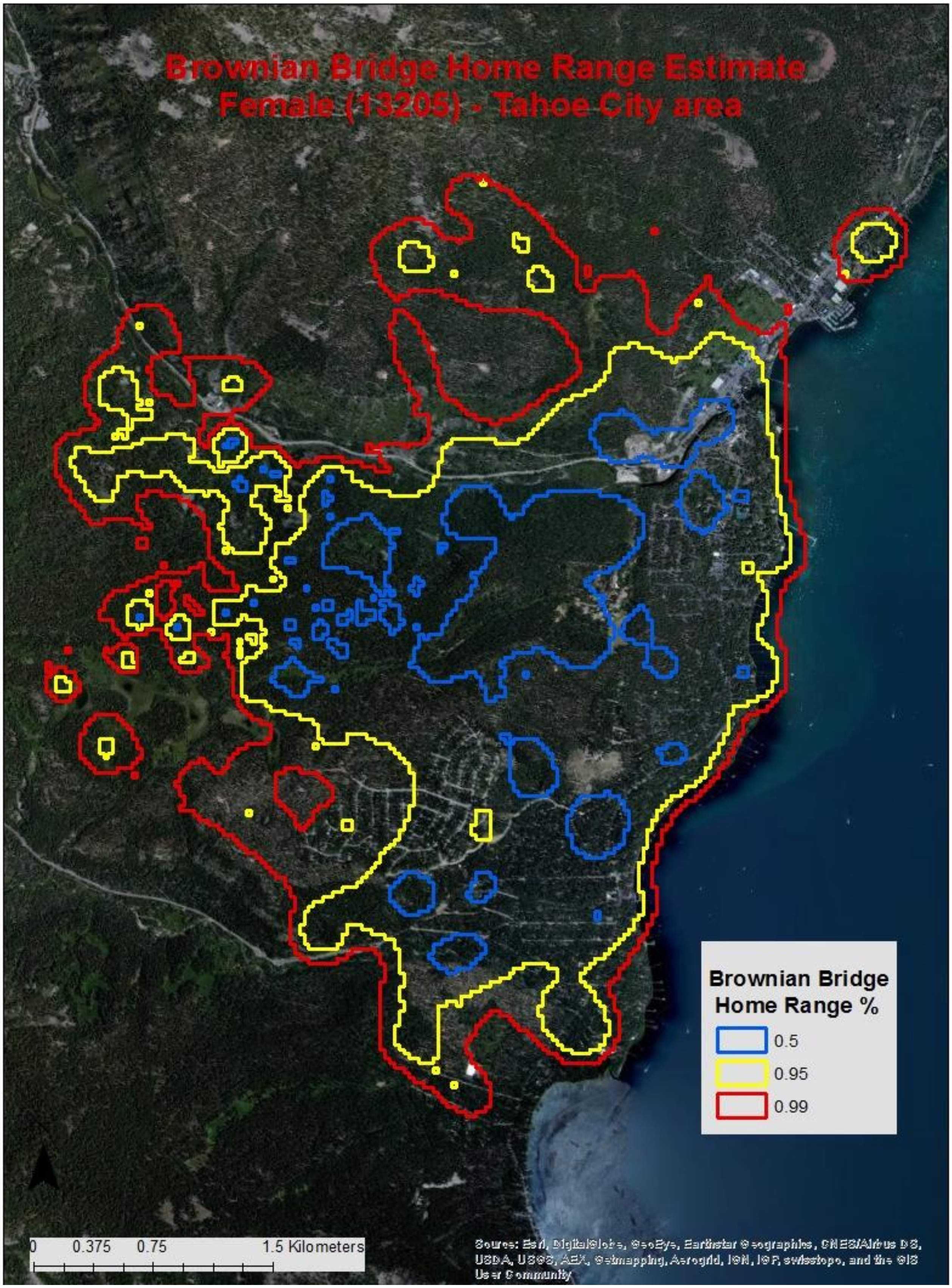


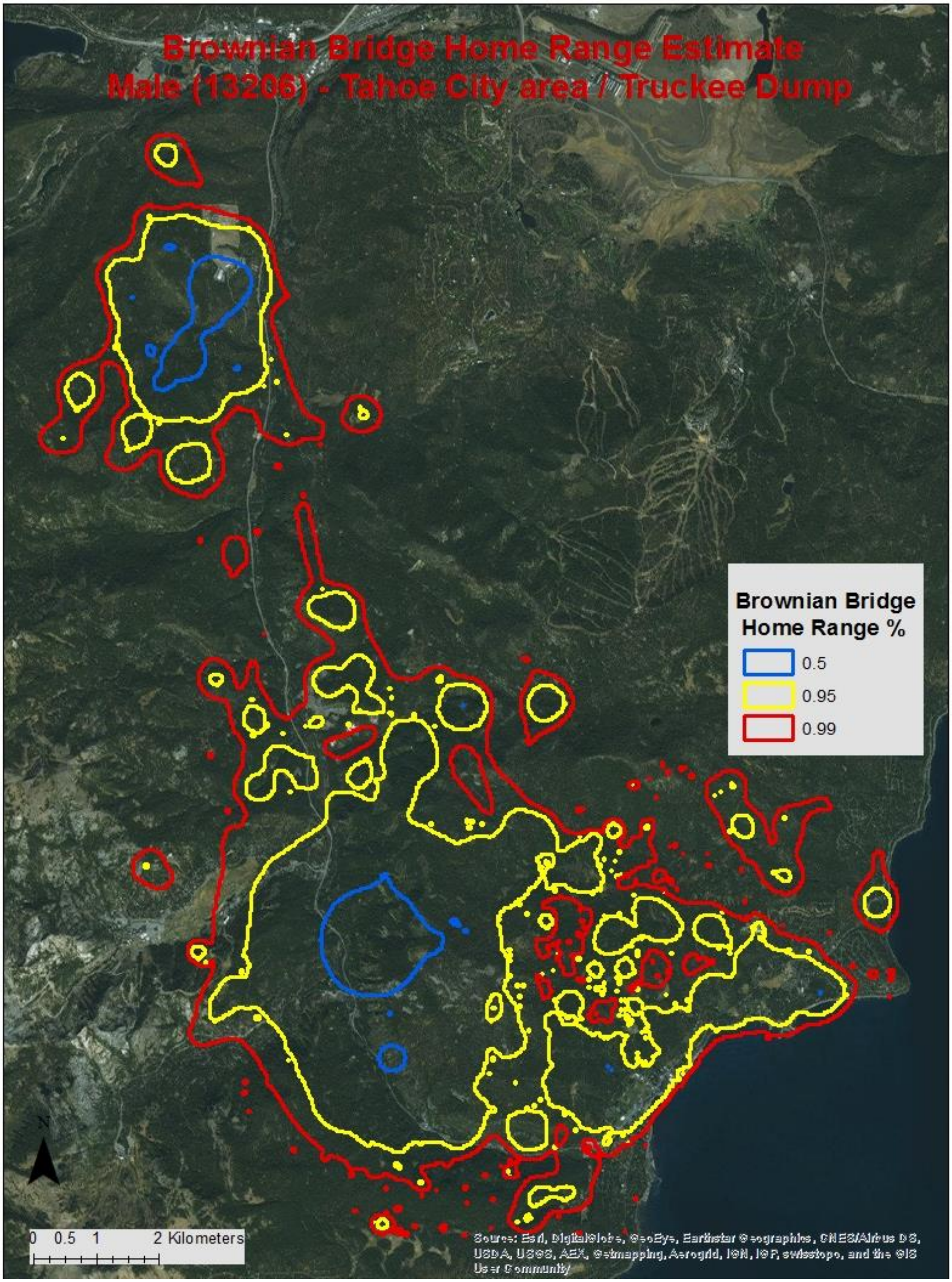
Figure 6L: Individual home range based on KDE method.

Figures 7 A thru L - Individual Home Ranges based on BBMM



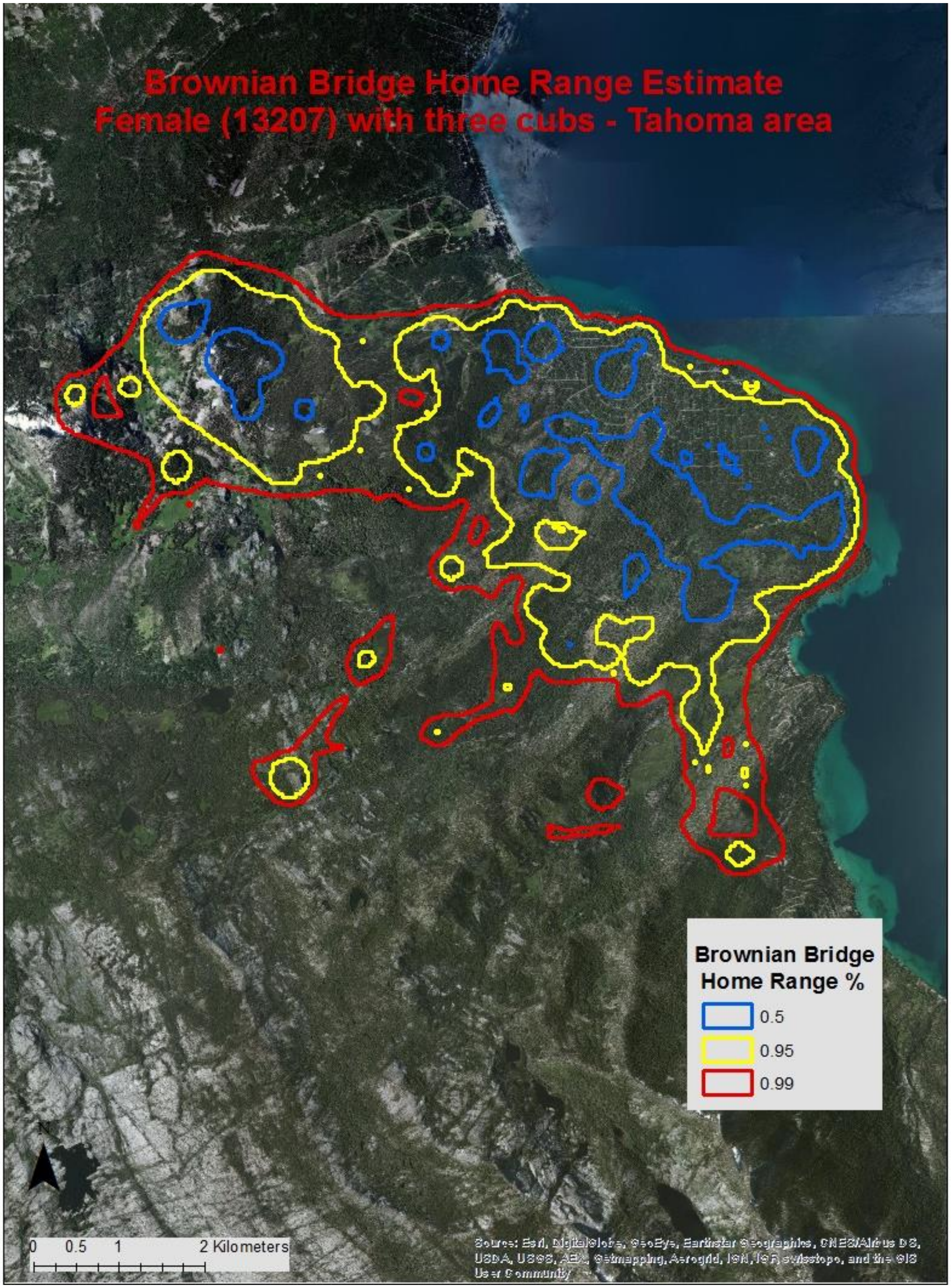
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7A: Individual home range based on BBMM method.



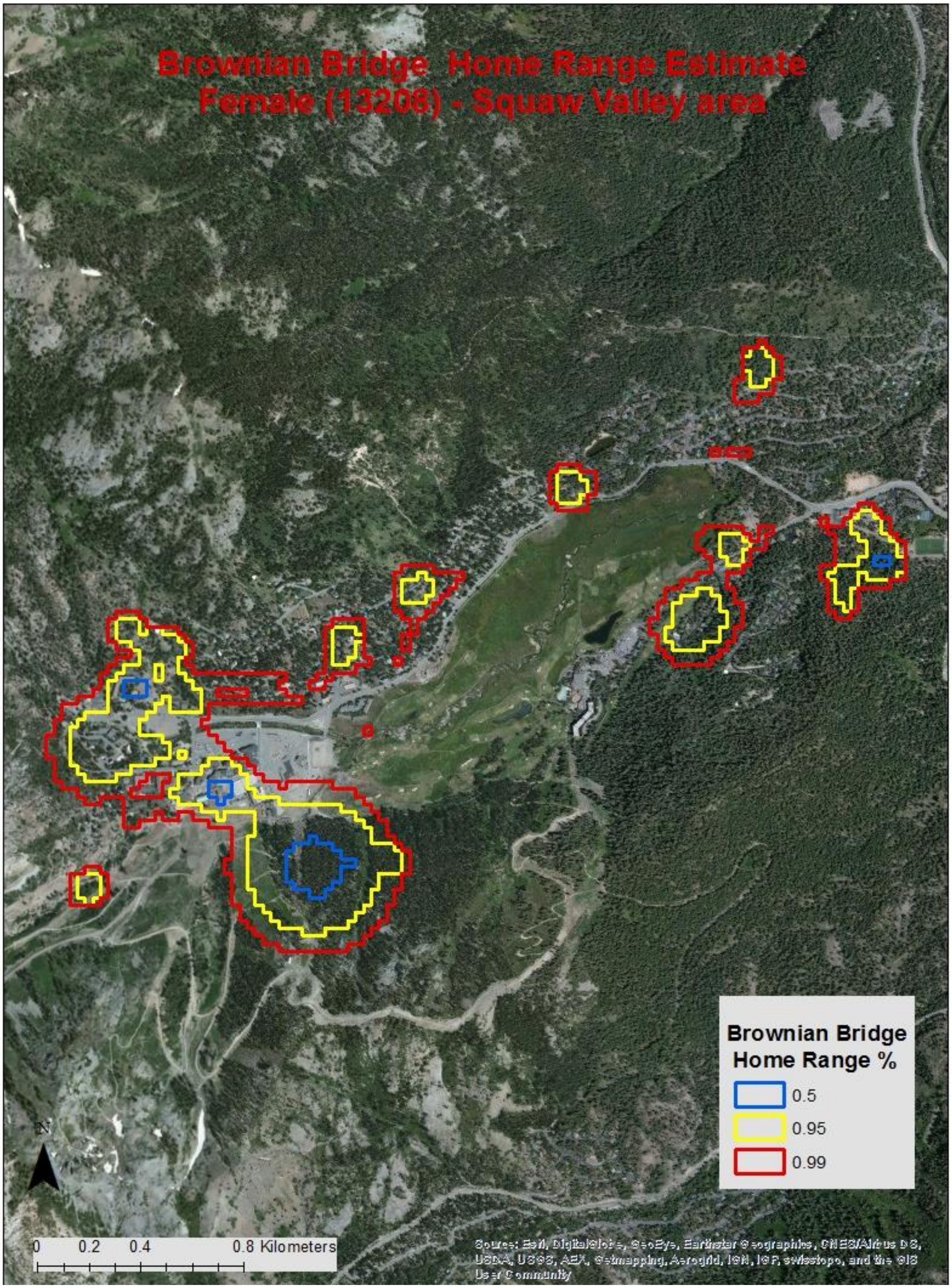
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7B: Individual home range based on BBMM method.



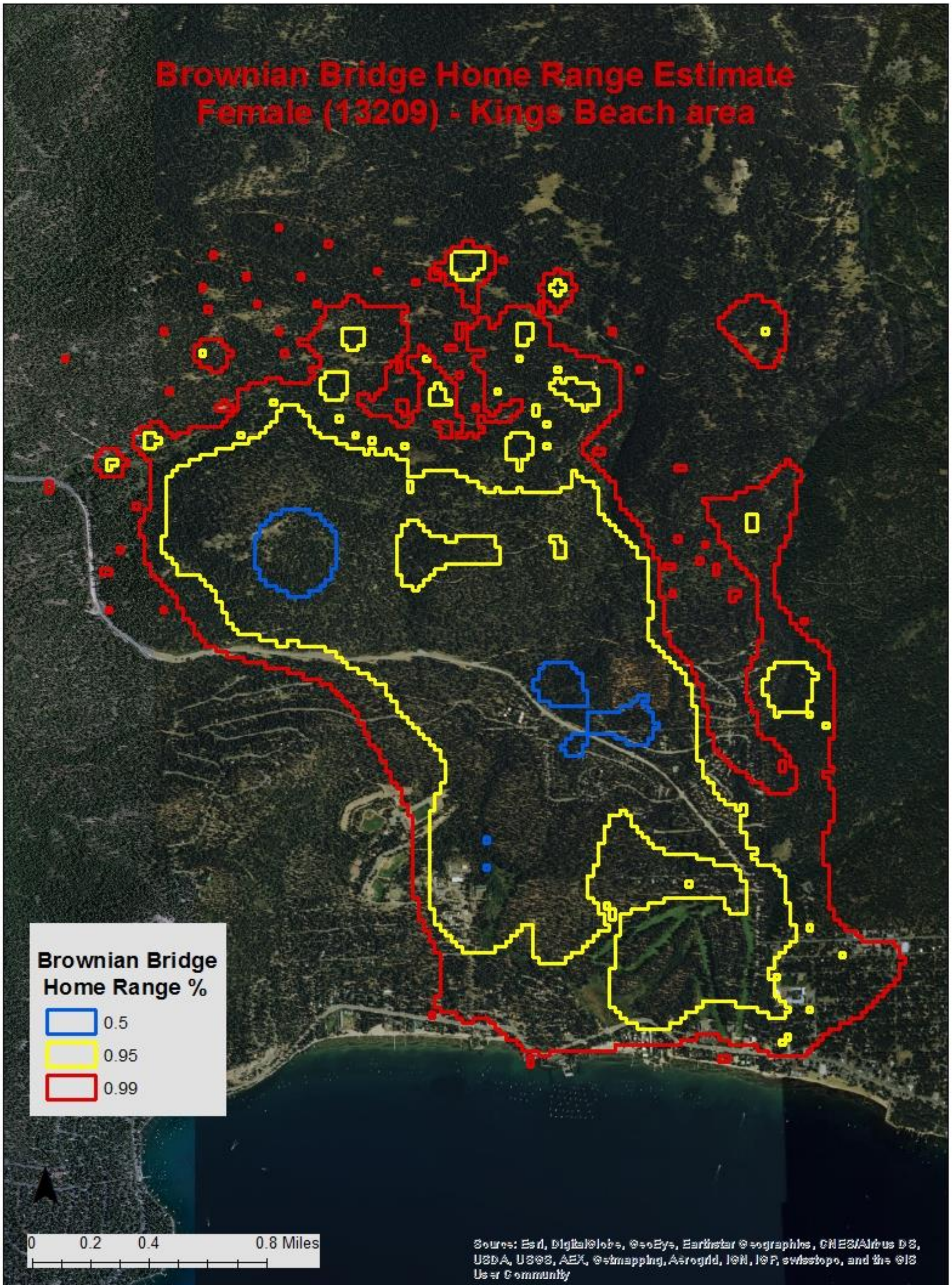
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7C: Individual home range based on BBMM method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7D: Individual home range based on BBMM method.



Brownian Bridge Home Range Estimate
Female (13209) - Kings Beach area

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7E: Individual home range based on BBMM method.

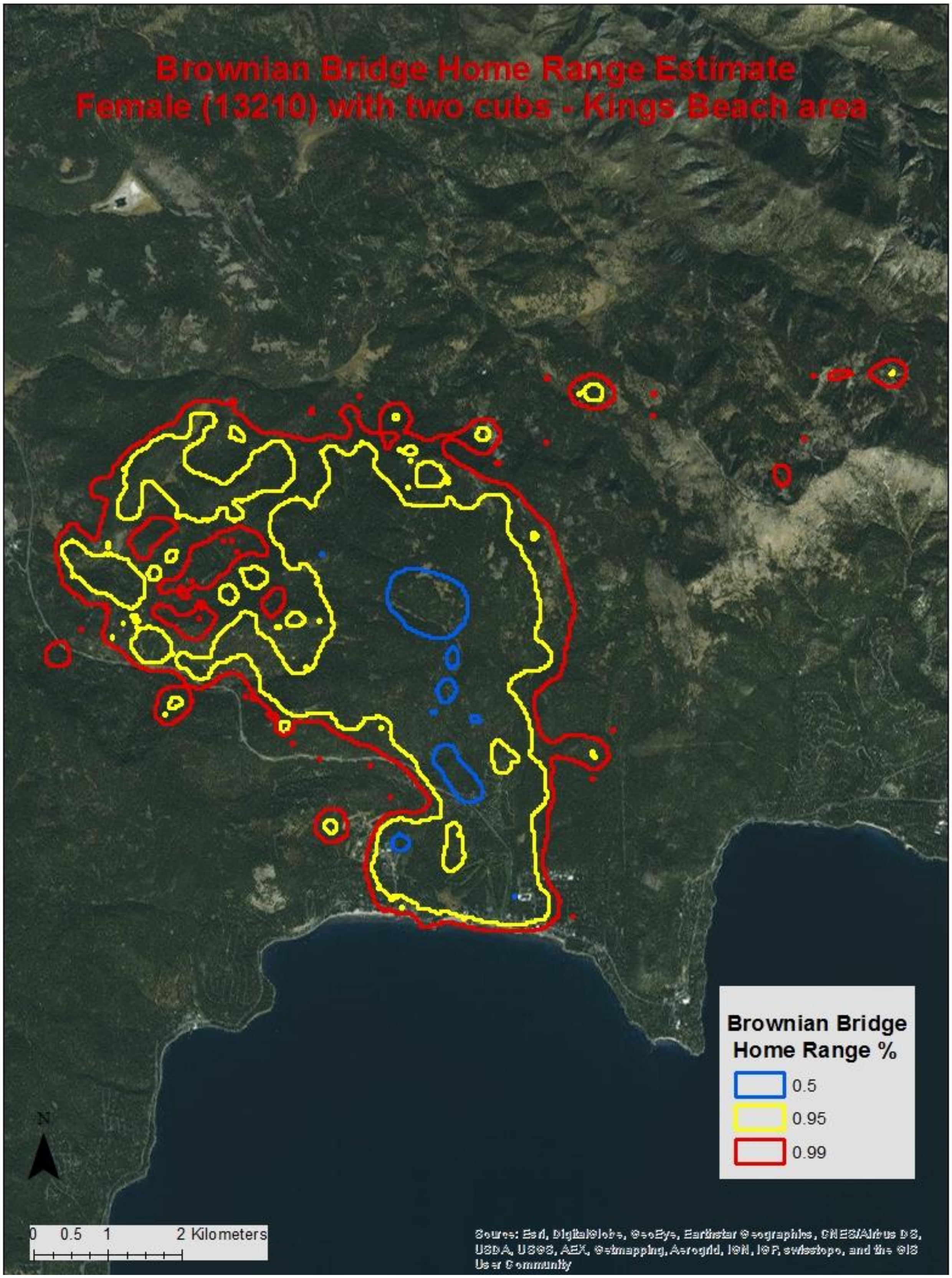
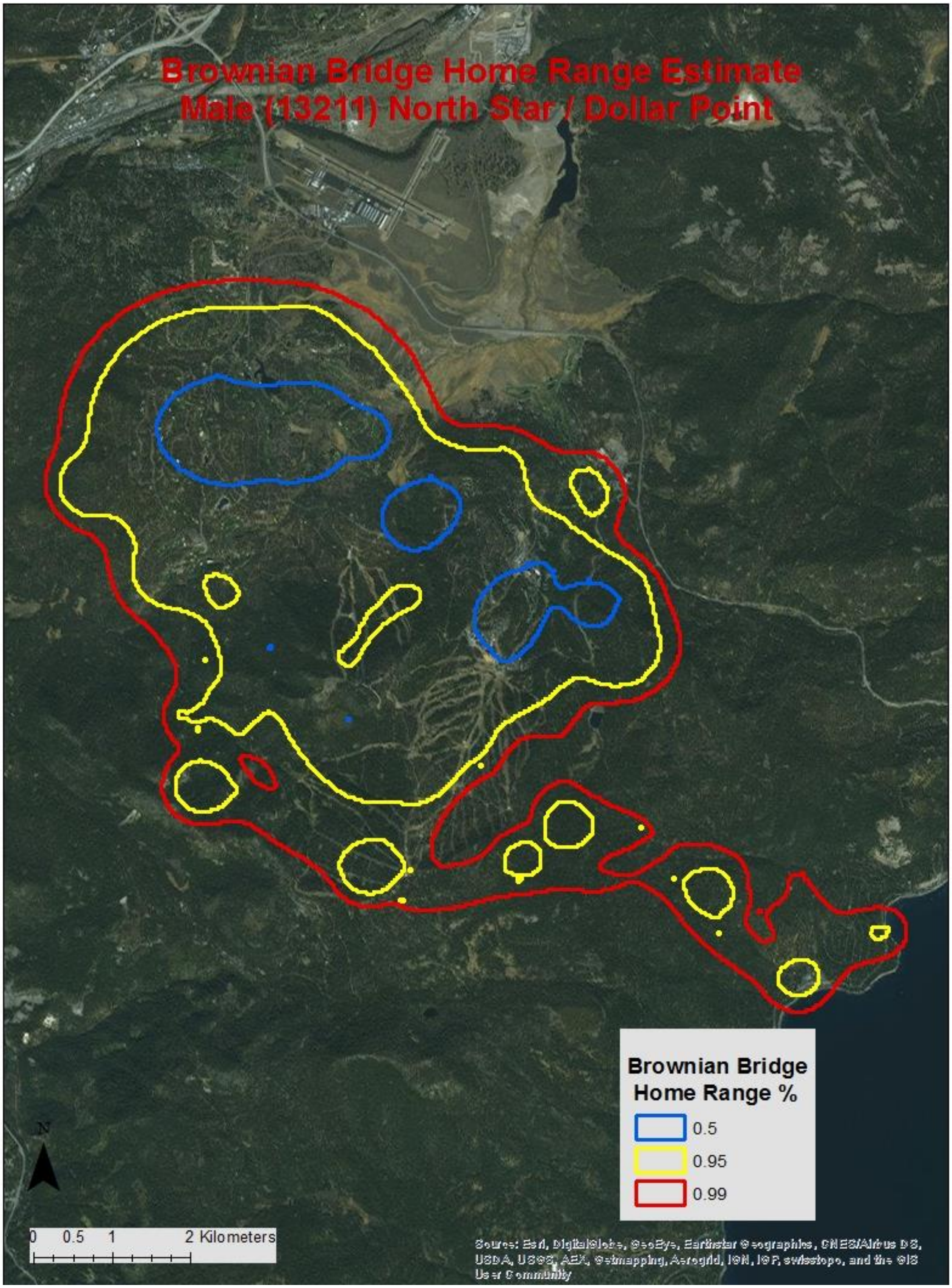
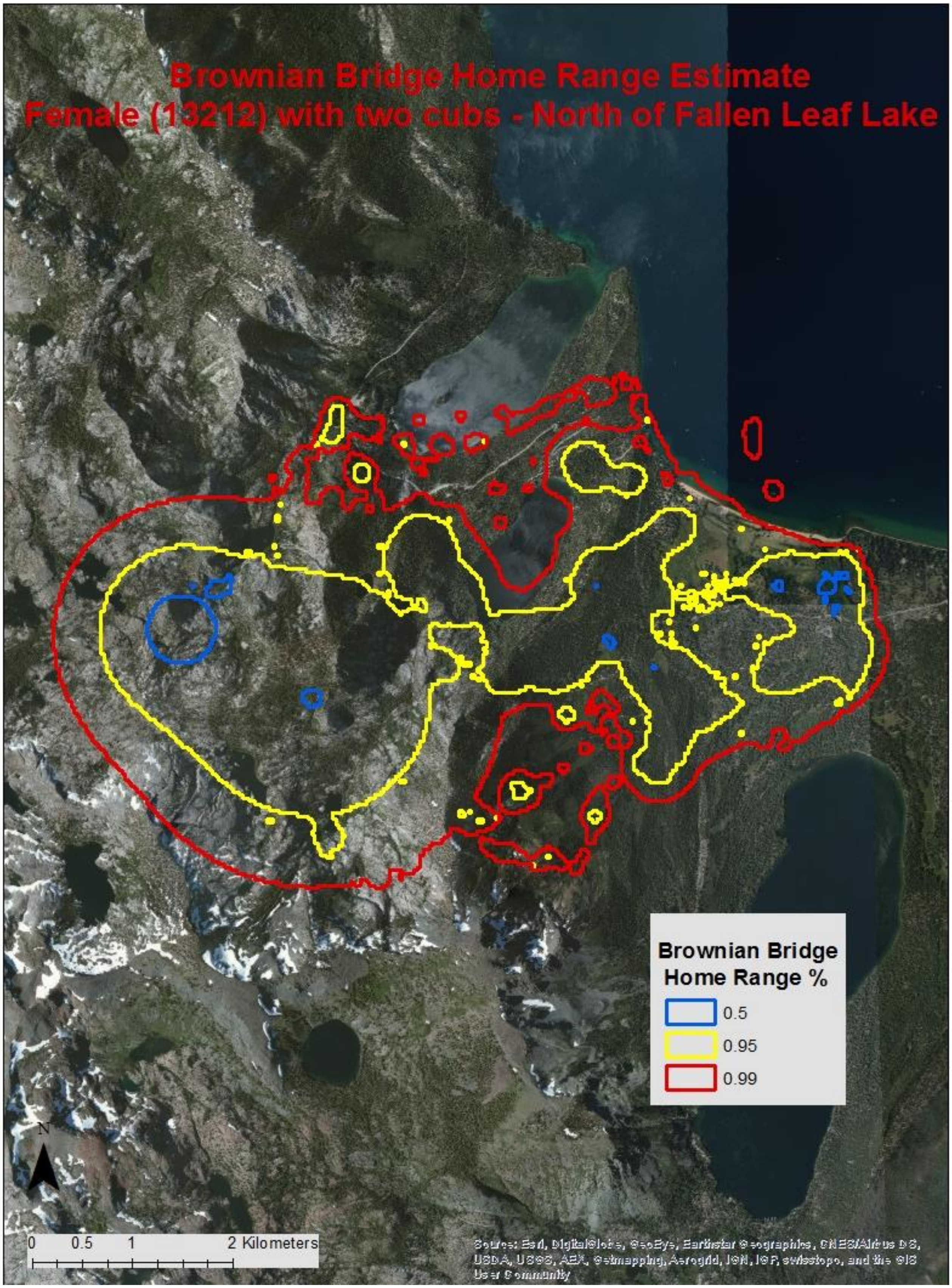


Figure 7F: Individual home range based on BBMM method.



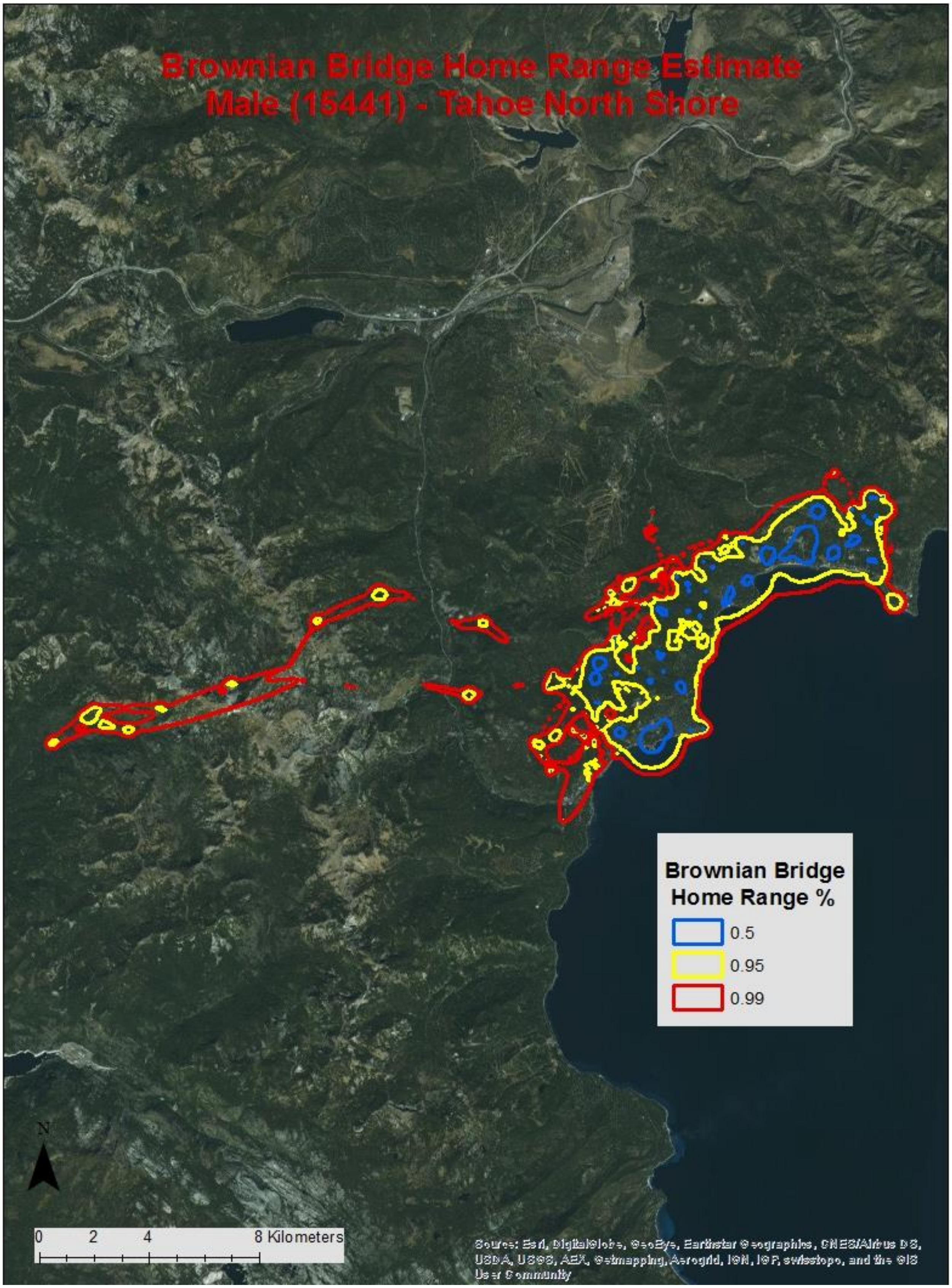
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7G: Individual home range based on BBMM method.



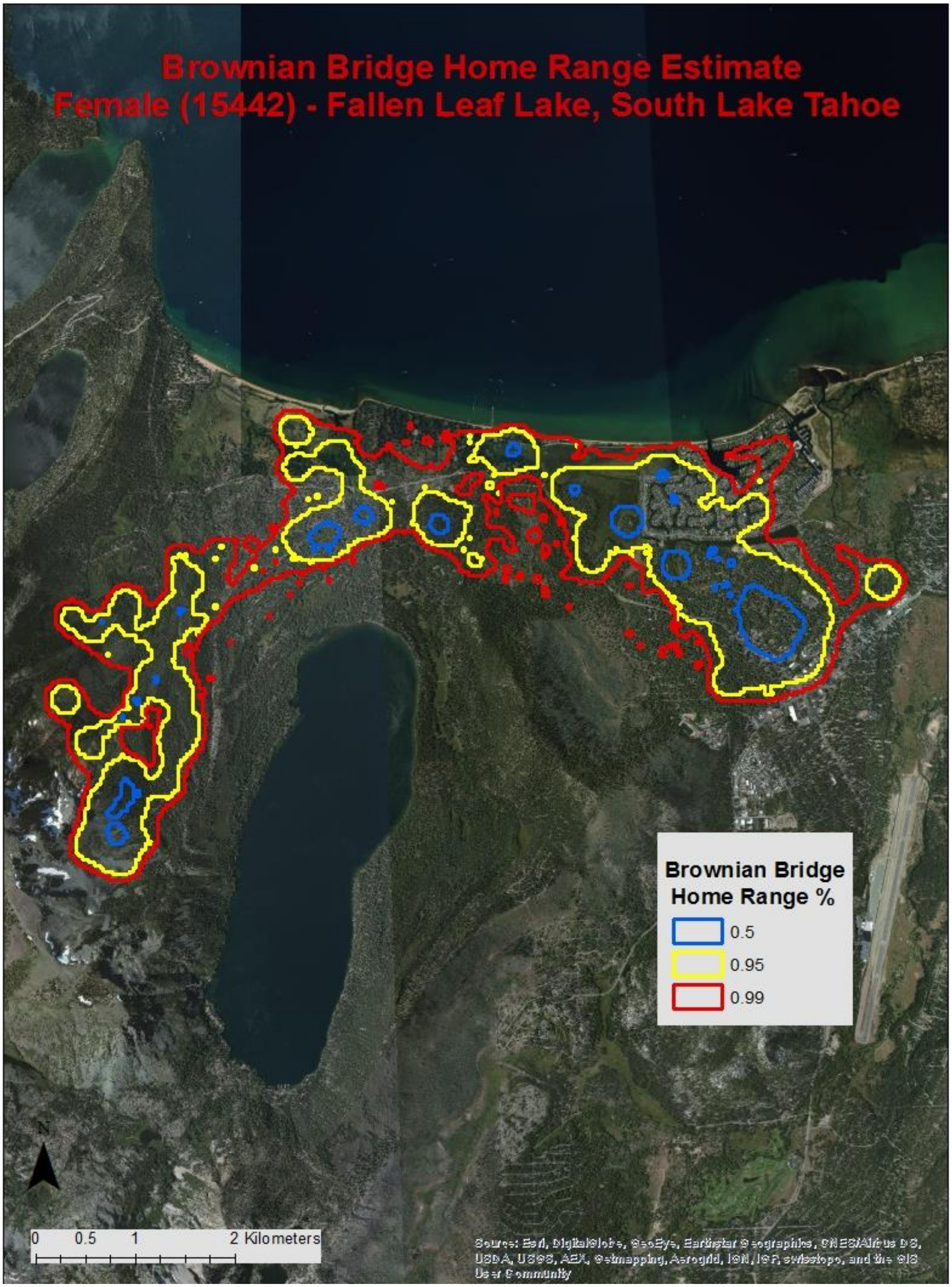
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7H: Individual home range based on BBMM method.



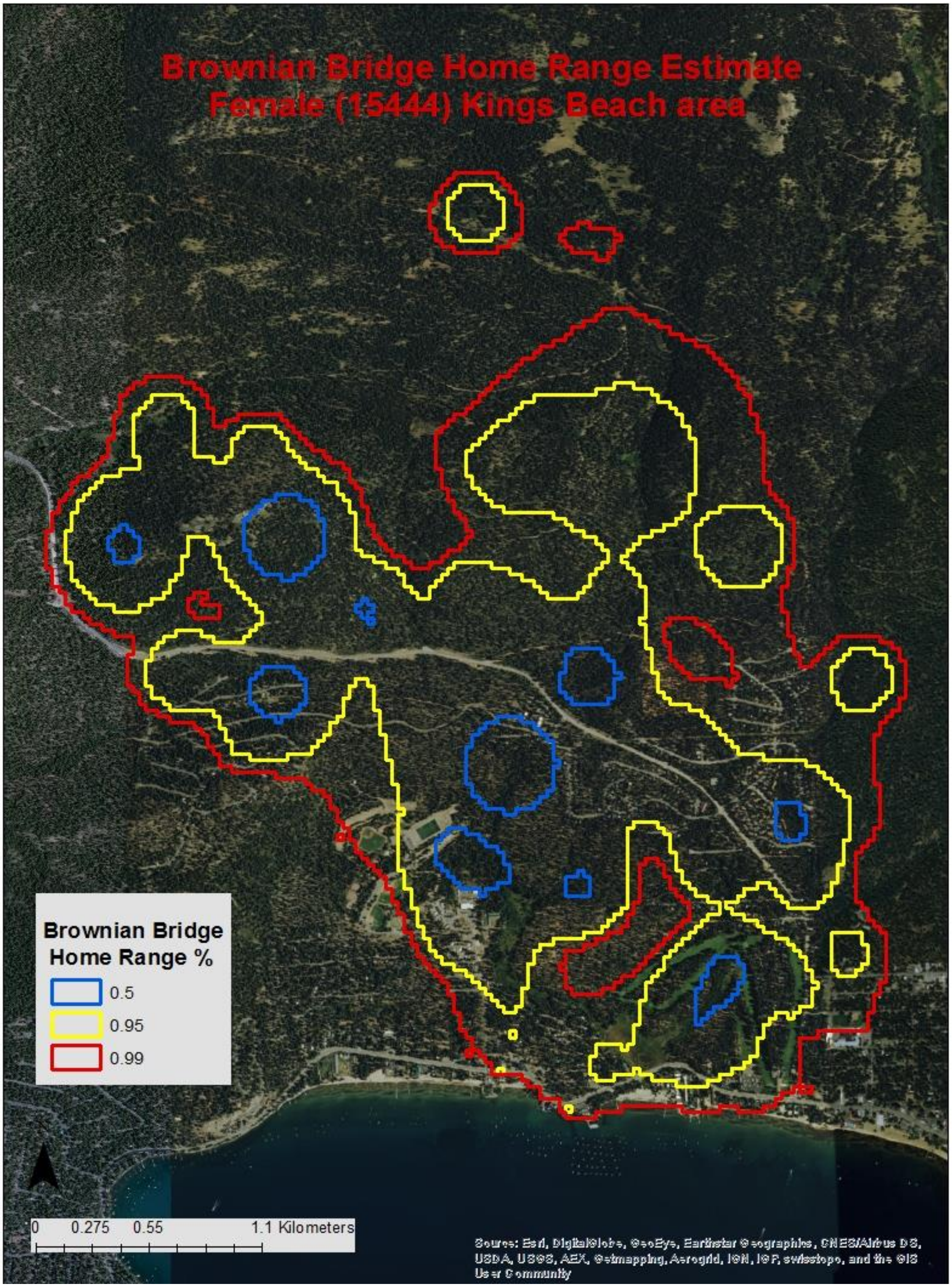
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7I: Individual home range based on BBMM method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7J: Individual home range based on BBMM method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7K: Individual home range based on BBMM method.

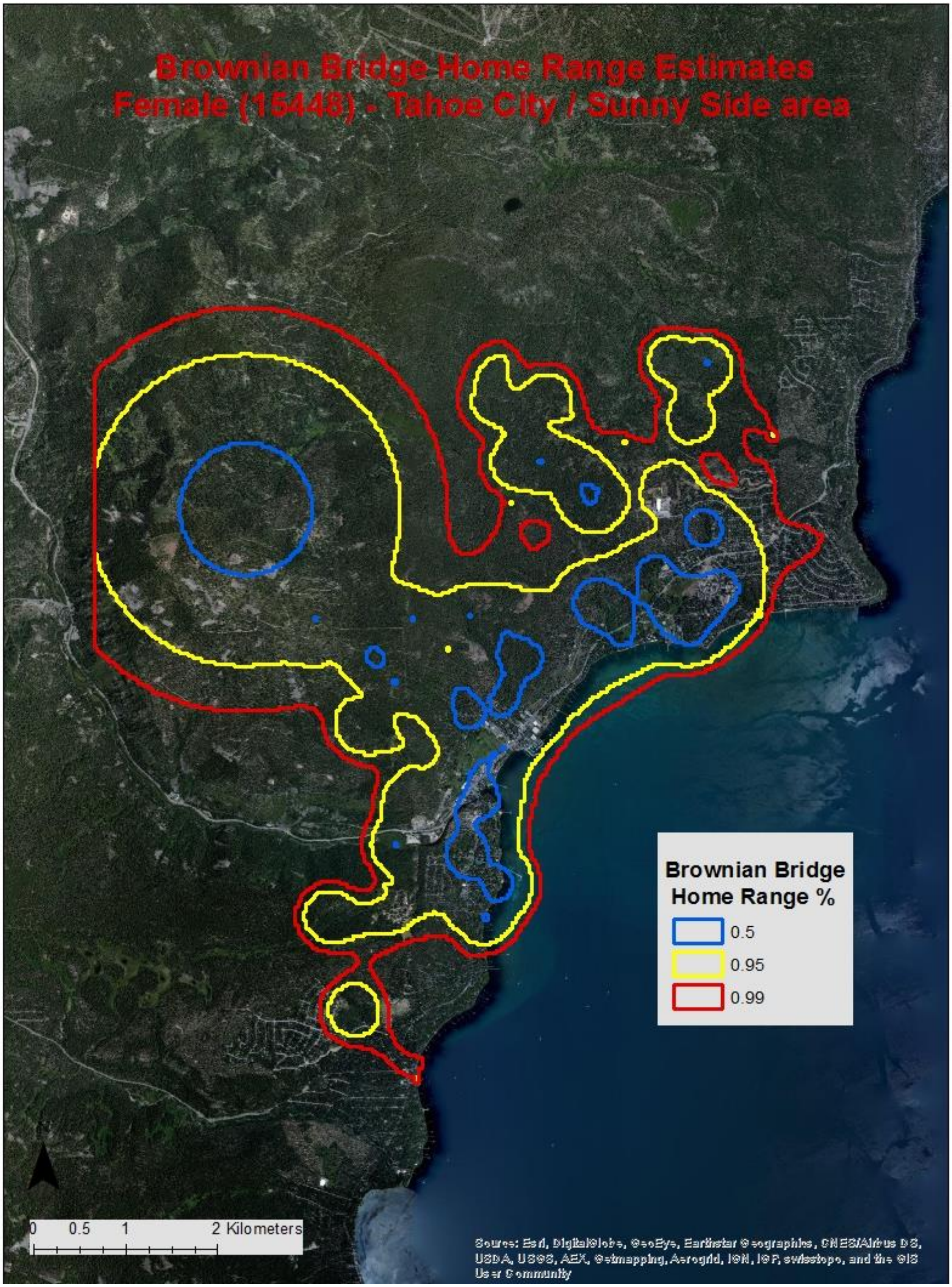


Figure 7L: Individual home range based on BBMM method.

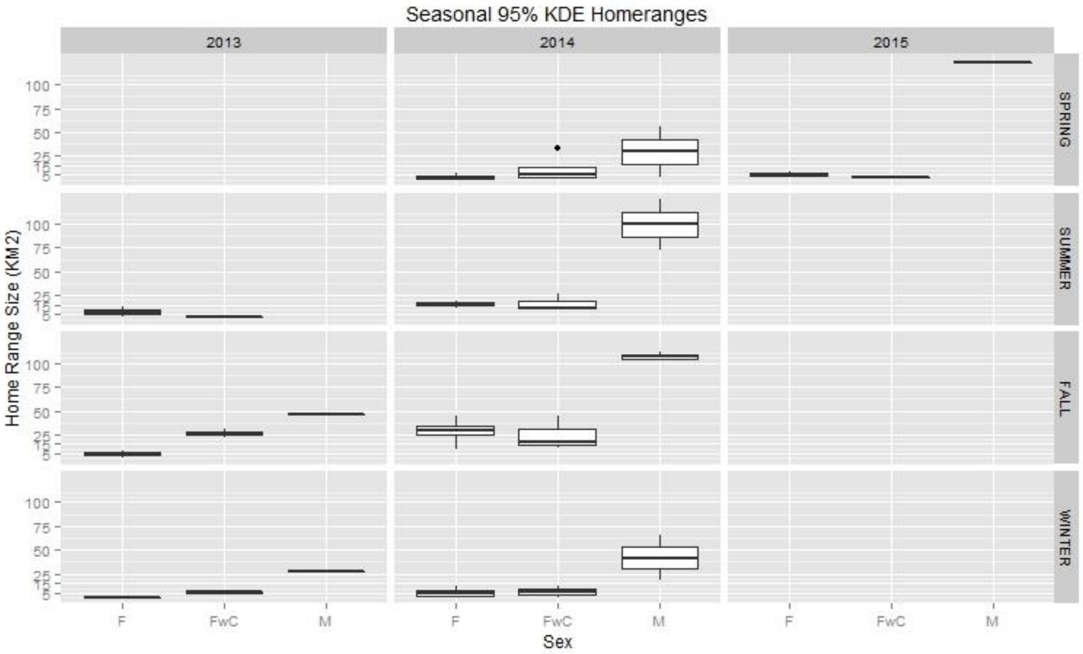
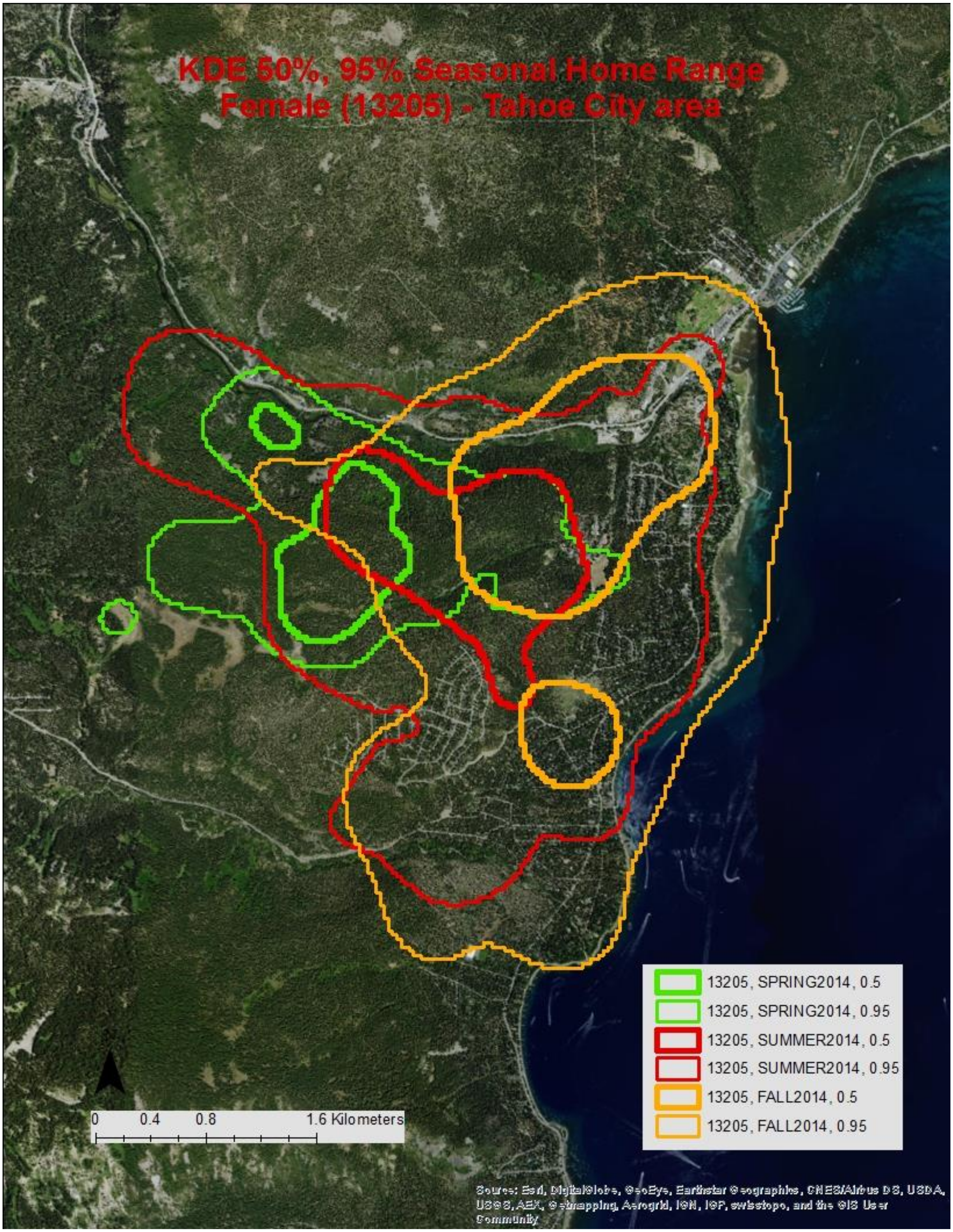


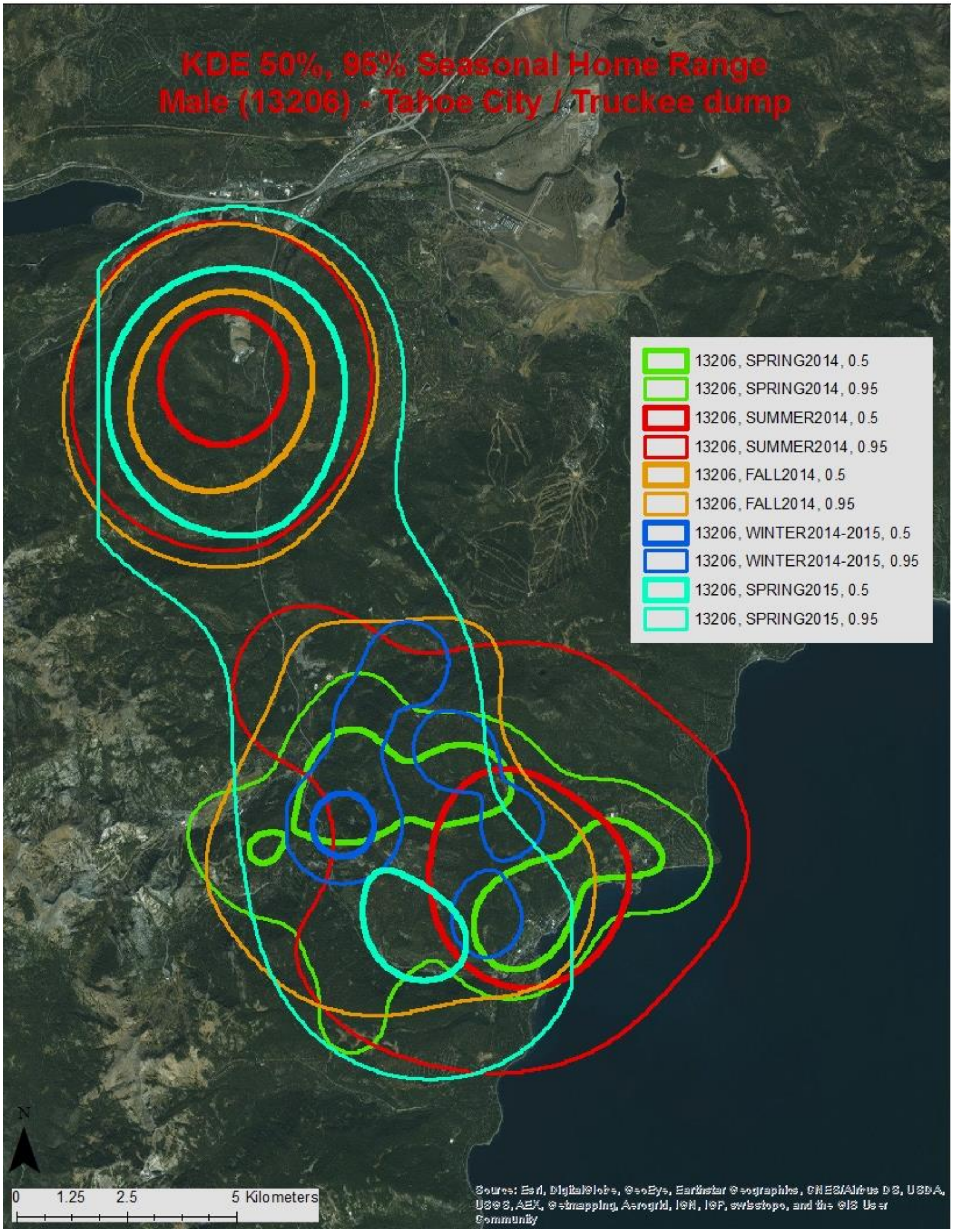
Figure 8: Seasonal home ranges by sex, year and season based on 95% KDE. Boxplots indicate the mean and the 25th percentile and 75th percentile, Seasons without data did not have any collars deployed.

Figures 9 A thru L – Seasonal Individual Home Ranges based on 50 and 95% KDE



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9A: Seasonal individual home range based on 95% KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9B: Seasonal individual home range based on 95% KDE method.

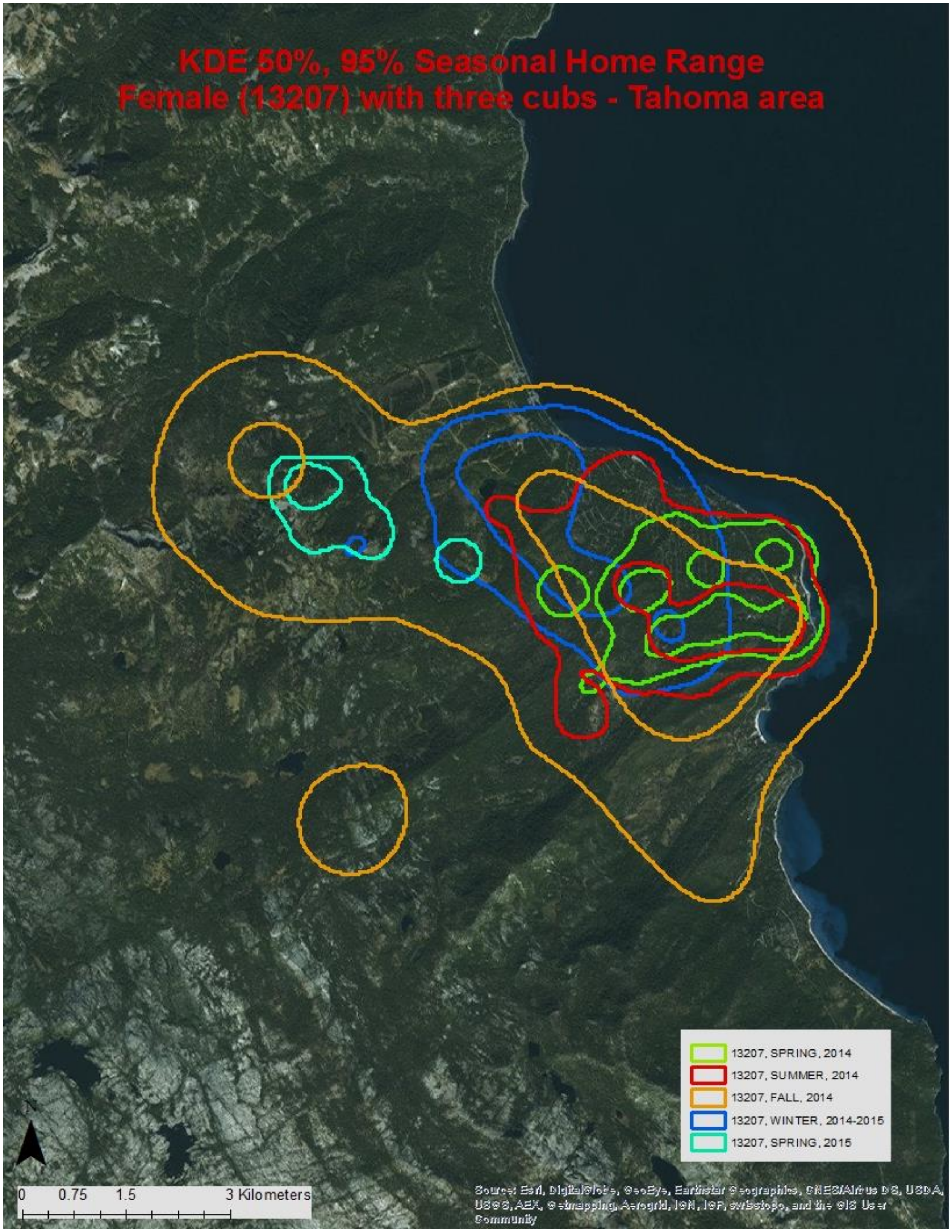


Figure 9C: Seasonal individual home range based on 95% KDE method.

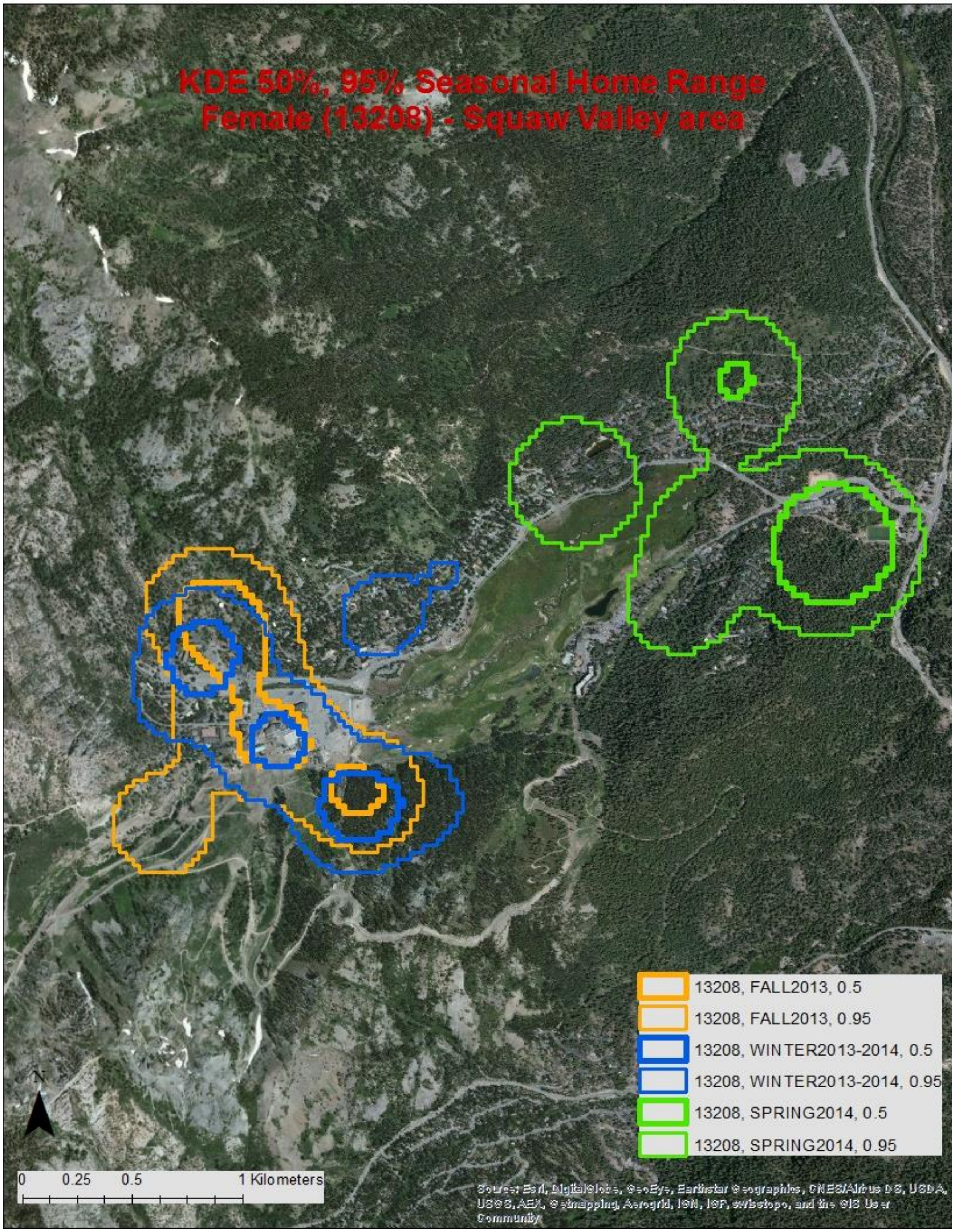
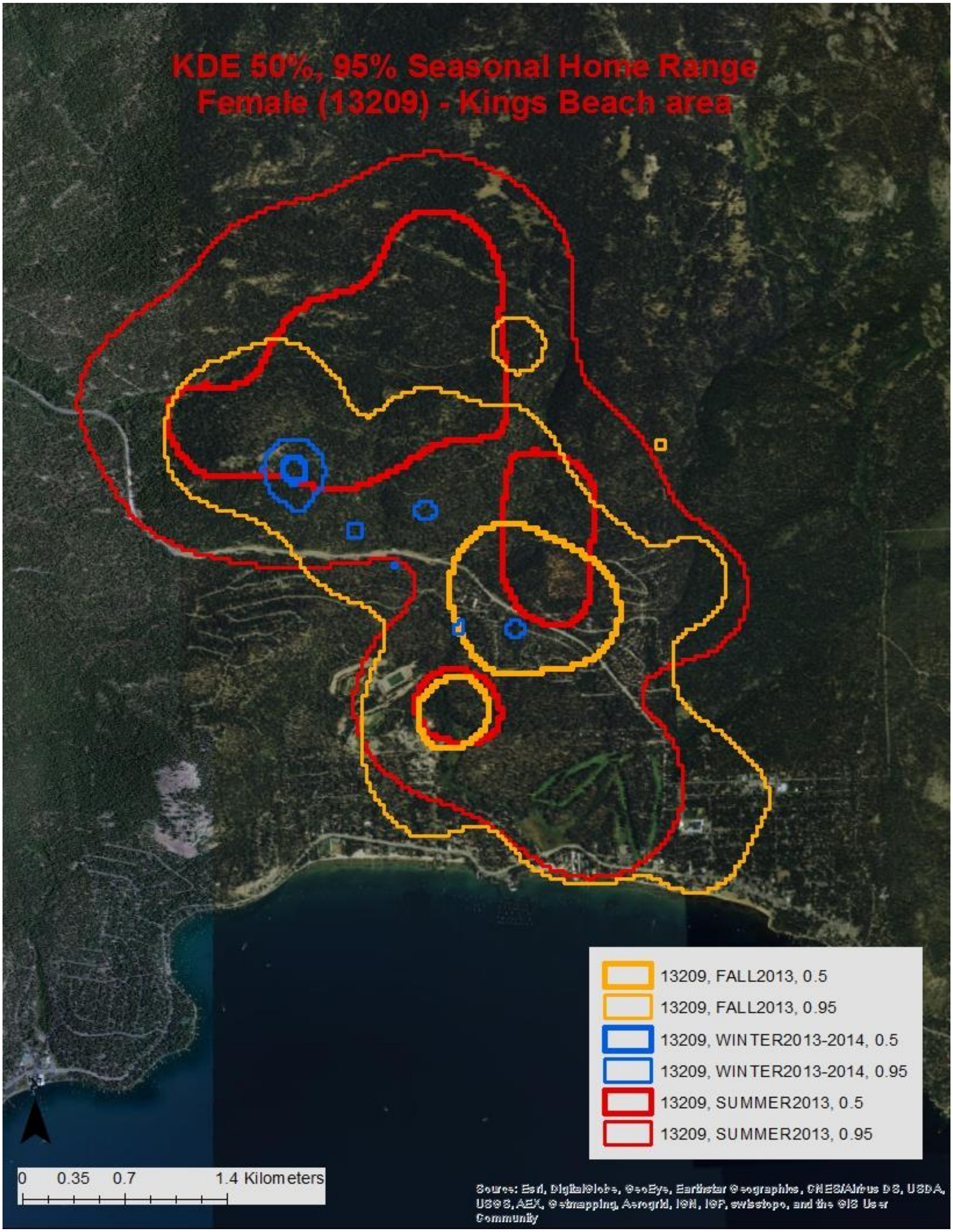
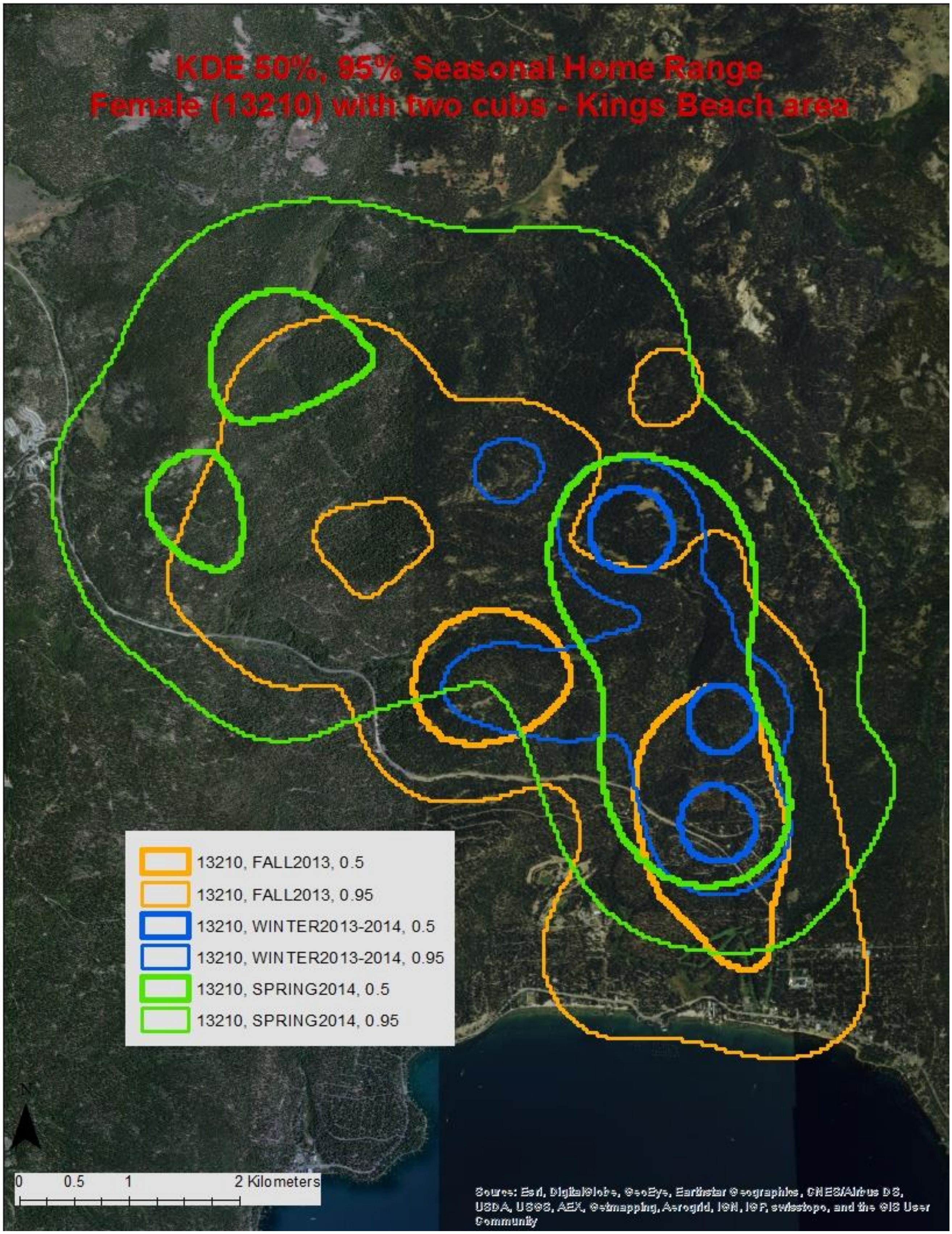


Figure 9D: Seasonal individual home range based on 95% KDE method.



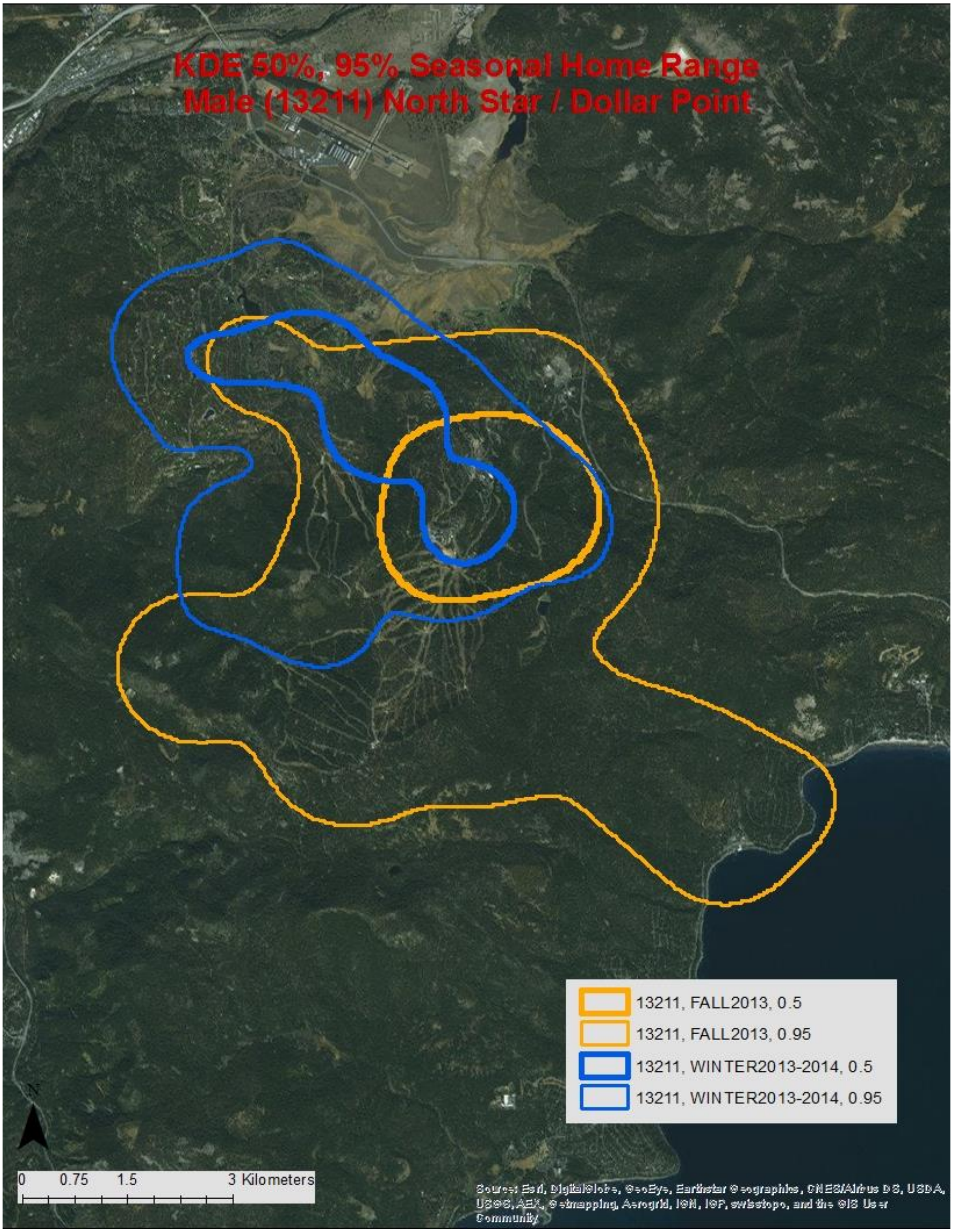
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9E: Seasonal individual home range based on 95% KDE method.



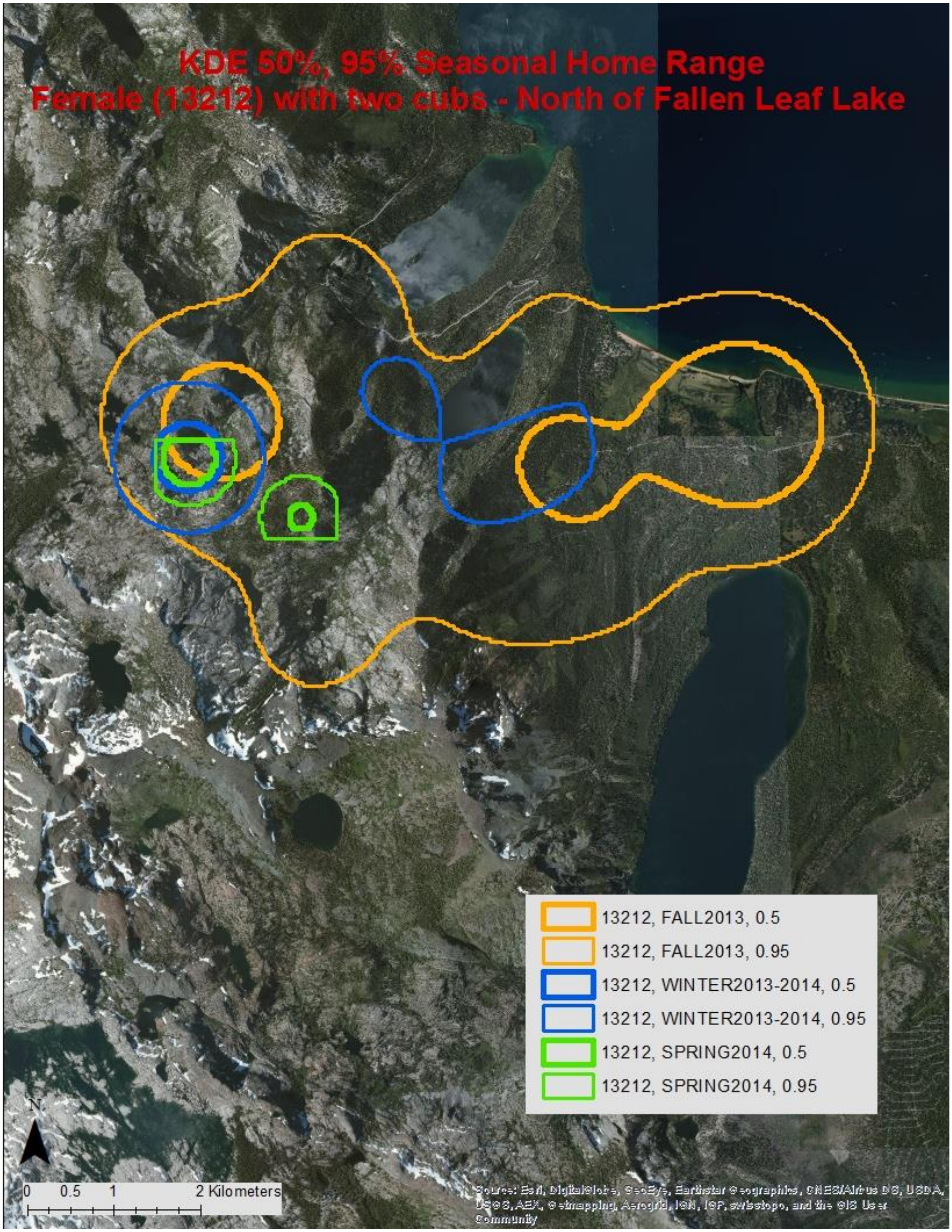
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9F: Seasonal individual home range based on 95% KDE method.



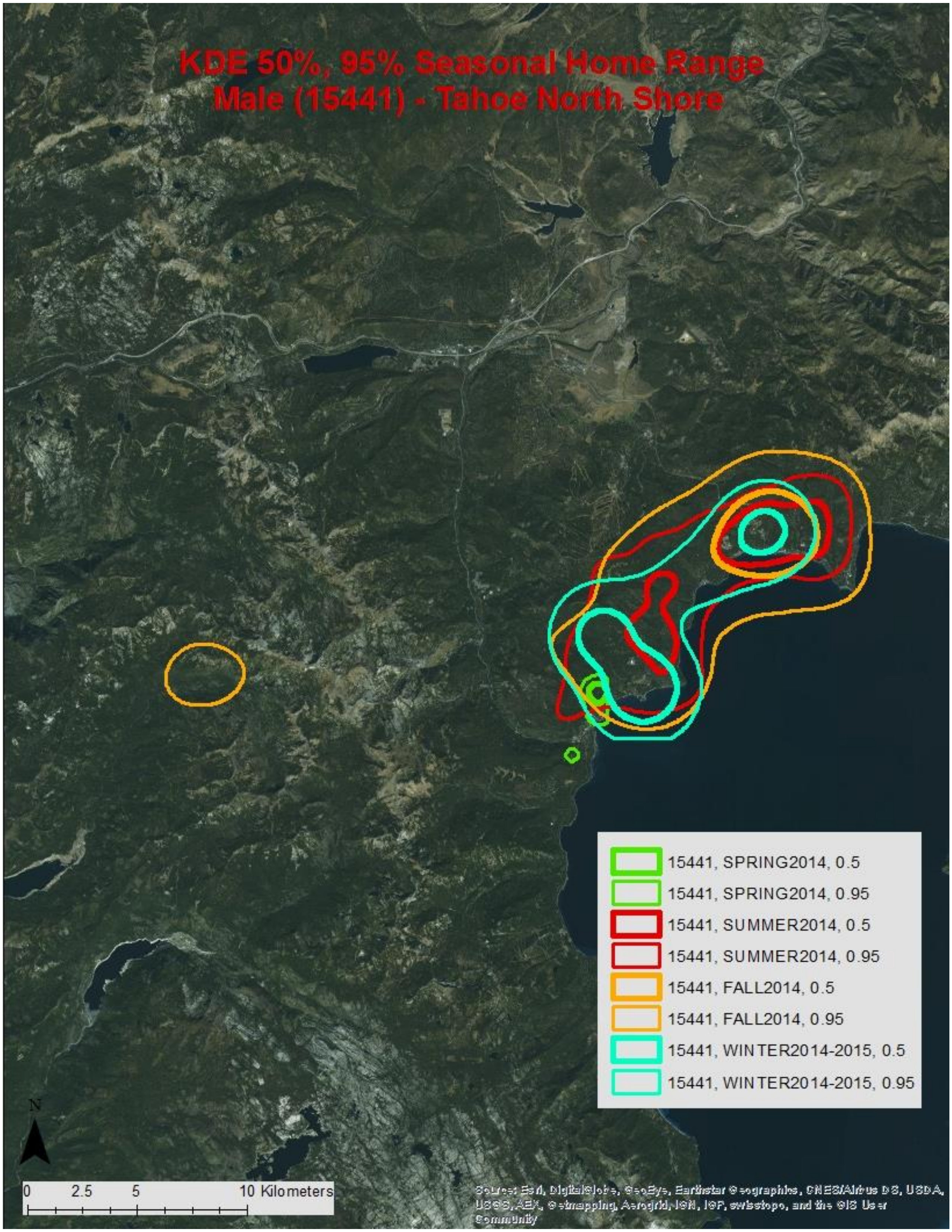
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9G: Seasonal individual home range based on 95% KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9H: Seasonal individual home range based on 95% KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9I: Seasonal individual home range based on 95% KDE method.

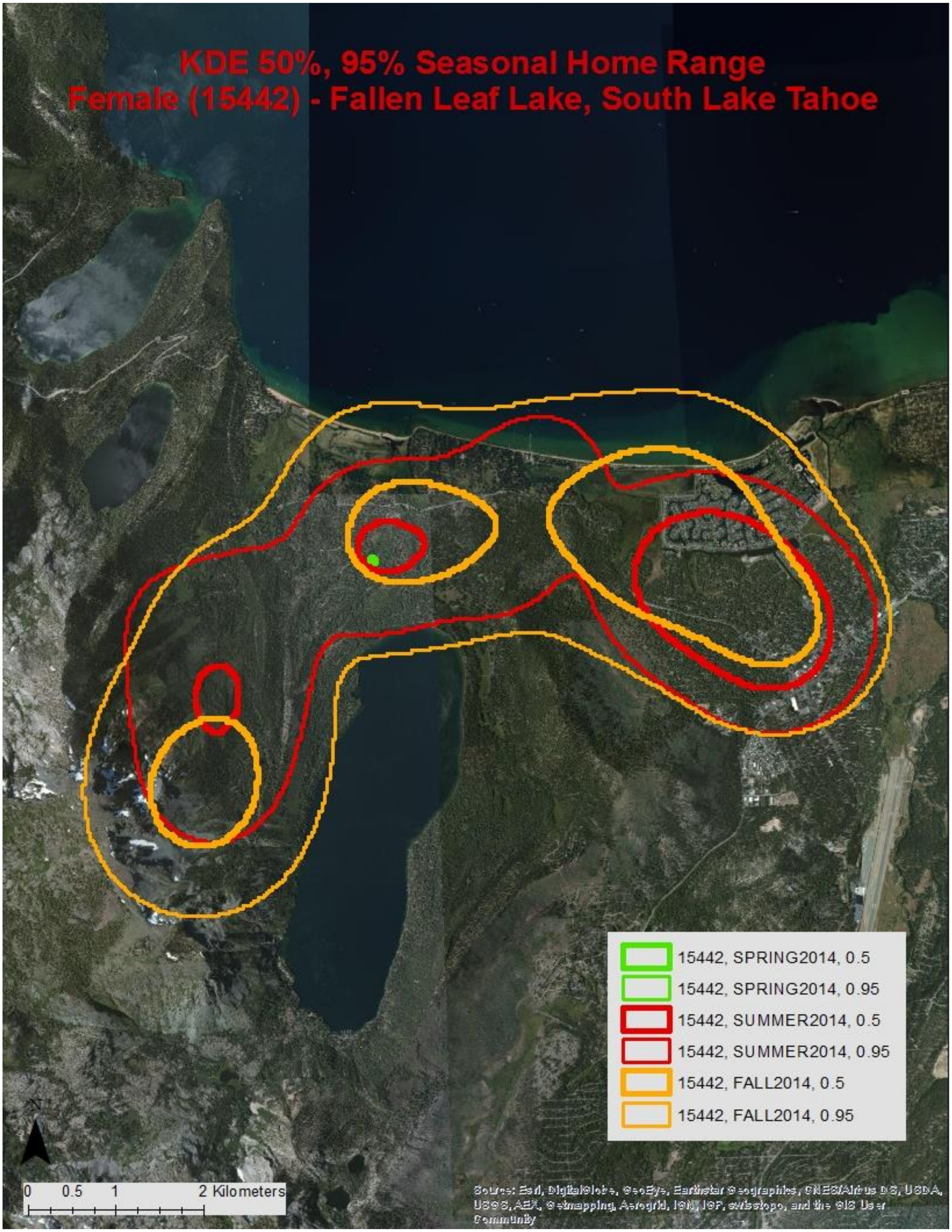
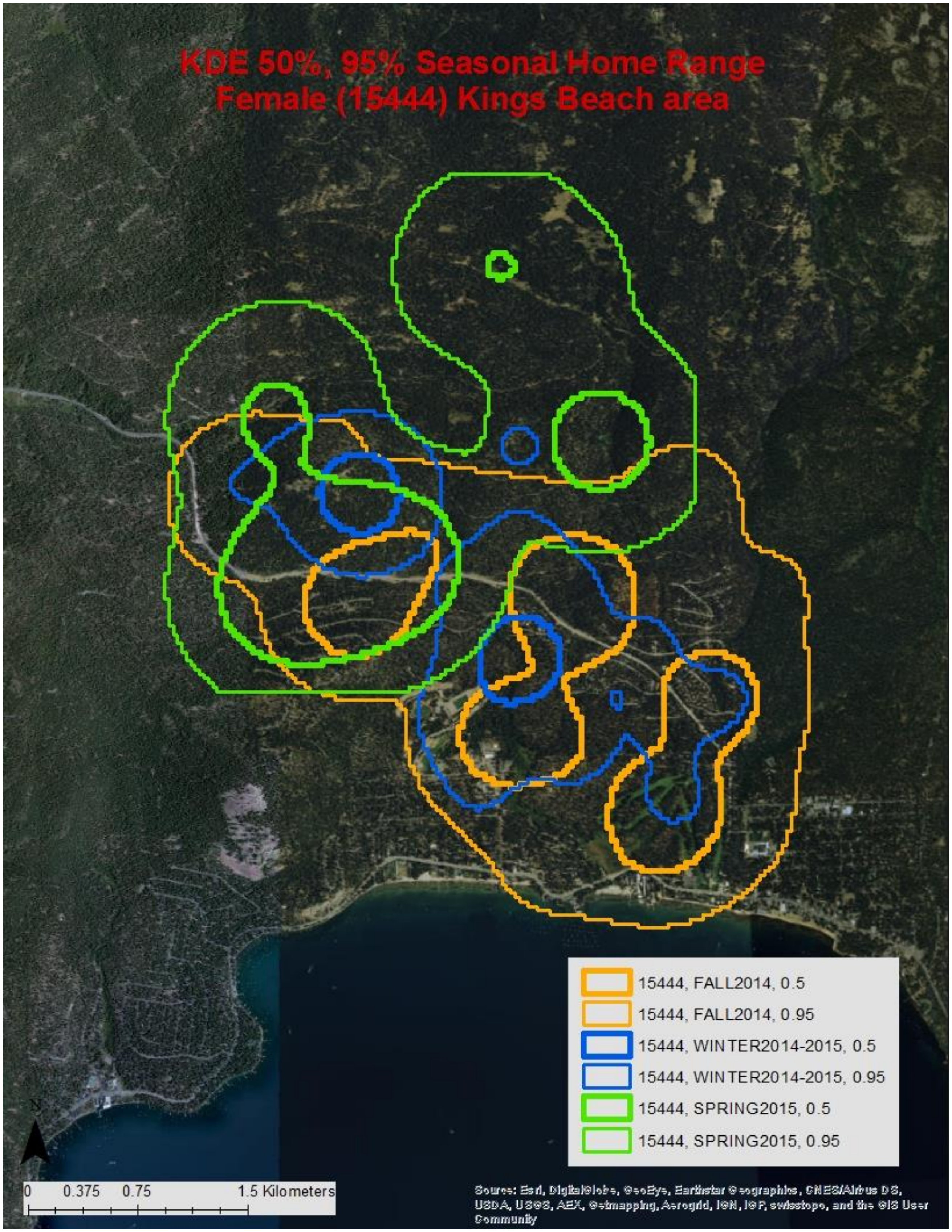
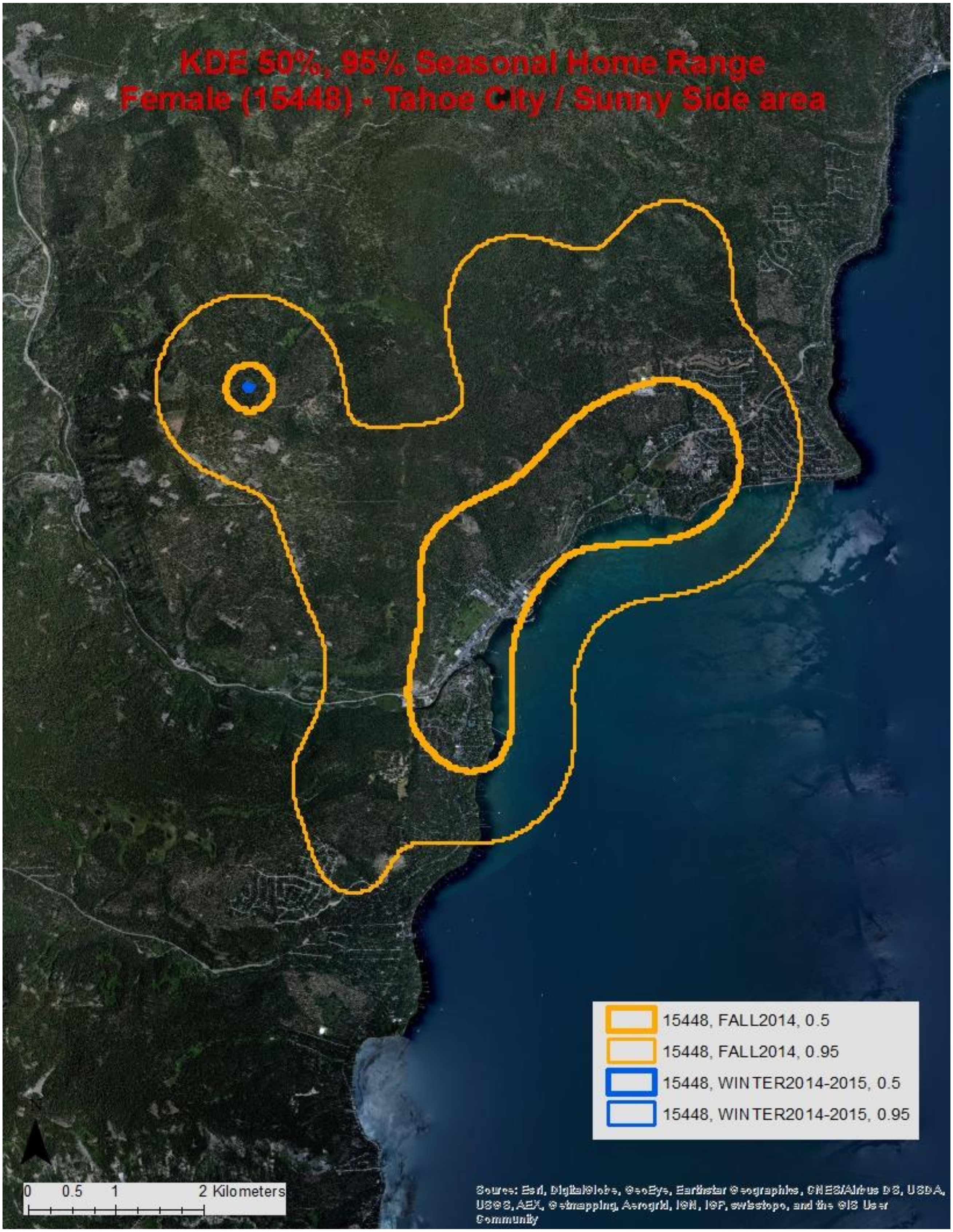


Figure 9J: Seasonal individual home range based on 95% KDE method.


KDE 50%, 95% Seasonal Home Range
Female (15444) Kings Beach area

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9K: Seasonal individual home range based on 95% KDE method.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9L: Seasonal individual home range based on 95% KDE method.

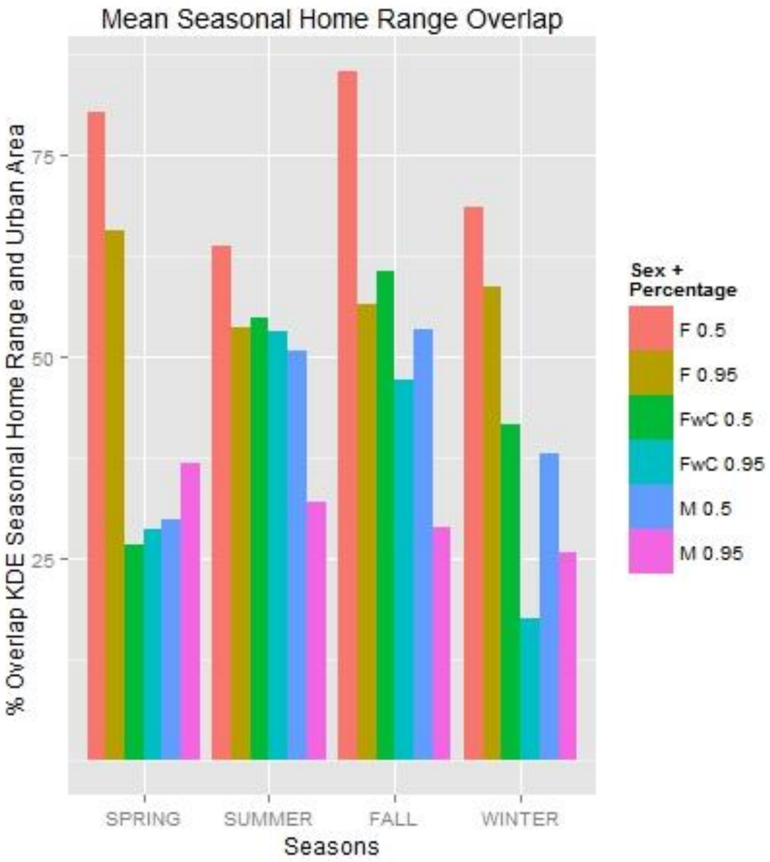


Figure 10: Mean urban home range overlap by season. Females (F), Females with Cubs (FwC) and Males (M).