Estimating Raccoon (Procyon lotor) Density Using Track plate Foot Printing in a Mark recapture Study

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ABSTRACT

Population studies are widely used in conservation and management efforts, but acquiring necessary data sets can be difficult. Convenience sampling or camera monitoring may result in biased outcomes, while explicit approaches such as genetic analysis may be impractical due to cost and time. Traditional mark recapture methods are frequently intrusive and pose risk to both animals and handlers that could lead to mortality. These factors highlight the need for a simple, inexpensive, and non-invasive approach to assess species density. One possible technique which addresses these issues is track plate footprinting. We collected raccoon (*Procyon lotor*) footprints and examined the ability to distinguish individuals by their metacarpal pads. The minimum number of raccoons known within Pierce Cedar Creek Institute property was estimated to be 15 individuals, with estimates derived from Schnabel and Cormack Jolly-Seber models inter papillae ranging from 13-36. The average probability of identity, based on the distribution of distances was 1.84E-9 for the back right feet, and 9.23E-9 for back the left feet, indicating that is unlikely any two raccoons shared the same papillae pattern. Raccoon density was unevenly distributed and concentrated toward areas of water and human use. This mark recapture study allowed us to showcase the foot printing methodology beyond the one other species in which it has been used.

INTRODUCTION

Wildlife biologists are continuously challenged to attain reliable and robust data sets in order to assess population structure and dynamics, apply these models in conservation and management efforts, and project future trends (Zielinski *et al*., 1995; Solberga *et al*., 2006). Population studies are often expensive, time consuming, and may have reduced reliability due to the biases if convenience sampling is used (Anderson, 2001; Van Der Ree *et al*., 2011). Obtaining biologically and statistically sound data sets at the population level is not a trivial matter and acknowledgement of potential sources of bias should be common practice (Herzog *et al*., 2007).

Alternatives to convenience sampling include camera monitoring, which, while able to differentiate individuals in some cases (Silver *et al*., 2004; Simchareon *et al*., 2007), may be difficult to apply for species without individually distinguishable characteristics (Waldstein, 2010). Factors such as camera placement, home range, habitat, and trap response may also result in bias estimation of population density (Wegge *et al*., 2004; Soisalo, and Cavalcanti, 2006). In one study only 41% of tagged raccoons known to be alive at the time of study were sighted (Raphael *et al*., 1994). Some of these difficulties can be overcome with individual identification, via genetic analysis, in a noninvasive way (Taberlet *et al*., 1999). However, genetic sampling is difficult, time consuming and expensive limiting its practicality (O'Neil and Swanson, 2010). A noninvasive methodology that is inexpensive and can unambiguously identify individuals is needed to facilitate meso carnivore work. One such possibility is the through the use of footprinting. This technique was used successfully to estimate fisher (*Martes pennati*) population sizes by distinguishing papillae patterns of the metacarpal pads collected at baited track plate enclosures (Herzog *et al*., 2007; O'Neil and Swanson, 2010).

Individuality of the prints was established by the distance between papillae. Researchers assumed the spacing between any pair of papillae was independent of the spacing of nearby pairs and generated a frequency distribution of inter papillae distances for fisher footprints (Herzog *et al*., 2007). The distribution was used to predict the odds that two prints made by different fishers would match, by chance alone (Probability of Identity – PID), as the product of the probability of 10 inter papillae distances (Herzog et al., 2007; O'Neil and Swanson, 2010). The average PID values were low enough: 1.84E-9 for the back right feet, and 9.23E-9 for back the left feet, to suggest that it was highly unlikely that any two individuals shared the same footprint pattern (O'Neil and Swanson, 2010).

Accurate population size estimates of generalist species such as the raccoon (*Procyon lotor*) are important for multiple reasons. Raccoons are highly invasive (Ikeda *et al*., 2004; García *et al*., 2012) and detrimental to native species (Wilcove, *et al*., 1998). Raccoons are also synanthropic as they are reservoirs for both human and raccoon pathogens (e.g., rabies, *Physaloptera sp, Strongyloides procyonis*, *Baylisascaris procyonis*) (Gordon *et al*., 2003; Houle *et al*., 2011). Accurate population estimates facilitate management as infection rates are often density dependent (Ordeñana *et al*., 2010). Raccoons carrying diseases to which humans are susceptible are especially concerning as raccoons show a high degree of tolerance for developed areas, with raccoon densities often positively correlated with the degree of urbanization (Prange *et al*., 2003).

The association between raccoons and urbanization likely results from their ability to exploit human garbage as a food source, given their ability to deftly manipulate objects with their paws (Whipple, 1904; Curtis *et al*., 1995). Part of this ability relates to the papillae on mammals' pads (homologous to the ridges on human fingers) increasing friction which facilitating the animal's

ability to manipulate objects (Loukmas *et al*., 2003). This suggests that raccoon footprints (Fig. 1) may provide detailed enough information to be used as a mark recapture method from which population density estimates can be made.

Our study evaluated the ability to use footprinting to uniquely identify raccoons and estimate their population density based on mark recapture methods. Individual identification from examining metacarpal patterns is not commonly done, so extending the technique to species beyond fishers will provide an inexpensive and reliable method for nonintrusive population estimation method that will facilitate mark recapture studies.

METHODS

Track plate surveys of raccoons were conducted within the rural 225ha of Pierce Cedar Creek Institute in Barry County Michigan, from June 18th through July 14th, 2014. We placed track plate enclosures every 300m using GPS location (Fig. 2). A 20m placement buffer was used when coordinates for an enclosure were located on trails, or overly wet areas such as a cedar swamp or a lake. A Pierce Cedar Creek trail map was used to classify habitat type as prairie, wetland, forest, or field, in order to gain knowledge of raccoon concentration. (Fig. 3).

Enclosures were fabricated from 88cm x 120cm pieces of light, waterproof coroplast plastic sheets (Kittrich Corporation, Vanceburg, KY) bent into a 36 cm high triangle fastened with wire (O'Neil and Swanson, 2010). The roofline was sealed with duct tape to help prevent periods of intense precipitation from impacting footprint quality (O'Neil and Swanson, 2010). The back of each enclosure was closed with a triangular piece of the coroplast and fastened with wire to prevent removal of the bait from the rear. The track plates were constructed from 1mm (0.063 gauge) aluminum flat stock sheeting that measured 75cm x 20cm in dimension. A nontoxic copy toner was placed in a 30cm x 20cm area to be used as the print medium and Con-Tact brand light

tack shelf liner (Con-Tact Brand, Pomona, CA) was used as the print surface, also in a 30cm x 20cm area. Track plates were baited with peanut butter placed on a piece of coroplast at the back of the enclosure. About 64g of Diatomaceous earth was sprinkled within ~10cm outside the enclosures to prevent slugs from entering.

Track plates were checked every other day during the week for imprints and to replace bait, toner, contact paper, and diatomaceous earth; as well as make any repairs as needed. Trapping sessions were not able to be partitioned because the weather did not allow for consecutive trap days. However, we tried to gain the maximum amount of successive periods between stormy conditions. Raccoon prints were photographed with a Canon EOS 70D (Canon USA, Farmington Hills, MI) with a 50mm F/2.5 macro lens. Images were then imported into the software program IMAGEJ (http://rsb.info.nih.gov/ij/) for examination.

Similar to Herzog et al.'s method of fisher footprint identification, three levels of individual track recognition from coarse to fine scale were used in this study (Fig. 1). Initial coarse interpretation of the prints was used to eliminate non target species and determine which foot was represented by the print. At the intermediate level of examination, unique marks such as scars and creases were used for individual identification. The fine level of detail allowed for calculation of the PID, the probability that two individuals could share the same footprint pattern. On each individual print identified we measured the distance between 10 nearest neighbor pairs of papillae from the same location on the footpad. These distances were used to produce a frequency distribution of inter papillae distance classes used to estimate the PID. An individual's PID was calculated as the product of the probability of 10 inter papillae distances (based on the frequency distribution) for each individual calculated from the same location on the foot for each animal.

By examining footprints at an intermediate scale, we were able to determine a minimum number of raccoons known to be alive (MNKA). We also used the Schnabel and Jolly-Seber models to produce population estimates June 18th through July 14th, 2014. The Schnabel model assumes a closed population with random sampling, while the Jolly-Seber model assumes an open population allowing for additions and losses in the population such as births, deaths, immigration, and emigration (Pollock, 1991). Other assumptions of Jolly-Seber include each individual having the same probability of survival and chance of encounter, while both assume footprints are not lost, overlooked, or misidentified (Pollock, 1991). Back left and back right feet were compared and treated independently from each other when producing population estimates for all models. GIS software ArcMap was used to show densities of raccoons based on number of contact paper sheets pulled from each enclosure.

RESULTS

We collected 159 sheets containing raccoon prints from 729 trap days. Heavy rain rendered 15% of the sheets unusable while wet feet caused an additional 13% of the total prints to be unusable. We initially had severe problems with slugs entering the enclosures and ruining the print quality. In the first 5 days slugs destroyed 45% of the prints we collected. However, placing diatomaceous earth in front of the enclosures significantly reduced the percentage of unusable prints caused by slugs to 16% (χ^2= 3.66; P = 0.036) for the remained of the study. In addition, various other factors such as debris and overlapping prints caused 9% of the sheets to be unusable.

We collected a total of 35 usable back left prints, 32 back right, 50 front left and 51 front right prints from 74 different sheets. Though, the prints from the front feet did not prove useful

as they lacked the distinguishing marks at the intermediate level (scars and creases), and the papillae pattern was too fine to resolve individual differences at the fine scale.

The minimum number known to be alive (MNKA) derived from our intermediate scale interpretation of back left feet was 15 raccoons; while back right feet produced 12 distinct individuals. The Schnabel model, based on the back left feet, estimated 30 raccoons (95% CI = 17-108) whereas back right feet resulted in 13 individuals (95% CI=10-13). Jolly-Seber based estimates from the back left feet was 36 raccoons (CI=4-1989) and 23 individuals from the back right feet (CI=5-731). The probability of identity for back right feet ranged from 6.71E-12 – 5.72E-09 and the PID from back left feet ranged from 3.55E-10 – 3.34E-08.

The majority of raccoons were only caught once for both back left and back right feet (Fig. 5). Raccoon density was not evenly distributed based on the quantity of print sheets collected from each enclosure. The majority of print sheets were collected in clusters around forested areas and those of human use, followed by field locations. The least amount of print sheets were collected in the prairie and wetland areas (Fig. 6).

DISCUSSION

Using the intermediate level of resolution, we were able to identify a minimum of 15 individuals at our study site and were able to identify recaptures of several individuals. Our population estimates for the 225ha of PCCI were between 6.5 –18 raccoons/ha depending upon the foot and method used. This number is in general agreement with other studies suggesting 4.7 – 19.1 raccoons / ha in rural areas (Pery *et al*., 1989; Graser *et al*., 2012). Our results suggest that track plate footprinting of raccoons is a viable method for individually identifying raccoons and performing mark recapture population estimates.

The MKNA, Schnabel, and Jolly-Seber models each produced quantitatively similar results, supporting the accuracy of our population estimate and the consistency of the footprinting methodology especially given the similarity in densities we estimated compared to other studies (Pery *et al*., 1989; Graser *et al*., 2012). The inter papillae distance frequency and PID suggest a low probability of individuals sharing the same footprint pattern, supporting the reliability of distinguishing individuals by footprint evaluation. The low number of recaptures increased the size of the confidence interval associated with our population estimates. We feel with more confirmed recaptures, both models will produce a more realistic confidence of raccoon densities.

The most direct way to increase recaptures is to leave the enclosures out for longer periods of time, although this will increase the likelihood of violating the assumptions of a closed population. We also found that spreading diatomaceous earth in front of the enclosures significantly improved the number of usable prints by reducing slug activity. Additionally, we lost a high percentage of prints due to rainfall, either directly through the water dripping on to the contact paper or indirectly through wet paws causing clumping of the toner and poor print resolution on the contact paper. Although we duct taped the seams as suggested by O'Neil and Swanson (O'Neil and Swanson, 2010) we still lost a high percentage of prints. Extending the roofline and epoxying the seams may reduce the rate of loss (O'Neil and Swanson, 2010), as well as sealing the back of the enclosure more tightly than is possible with just wire ties.

Track plate foot printing has shown to be successful in estimating raccoon densities by identifying individuals from footprints left in track plate enclosures. Our results indicate this method may be feasible for population density estimates and habitat preference of other meso carnivores as well. It is possible for track plate foot printing to allow researchers to produce

biologically sound estimations of population and other ecological factors that can be achieved at a low cost and fast rate.

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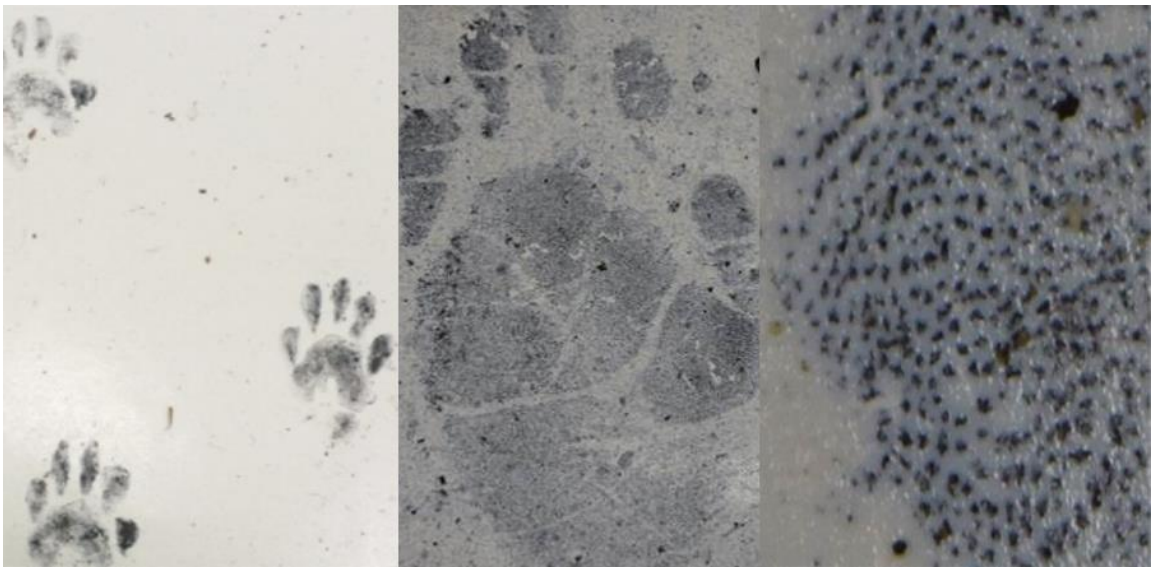

Fig 1: Course scale (left), Intermediate scale (middle) and fine scale (right) of raccoon (*Procyon lotor*) prints taken from track plate enclosures at the Pierce Cedar Creek in Hastings, Michigan from June-July, 2014.

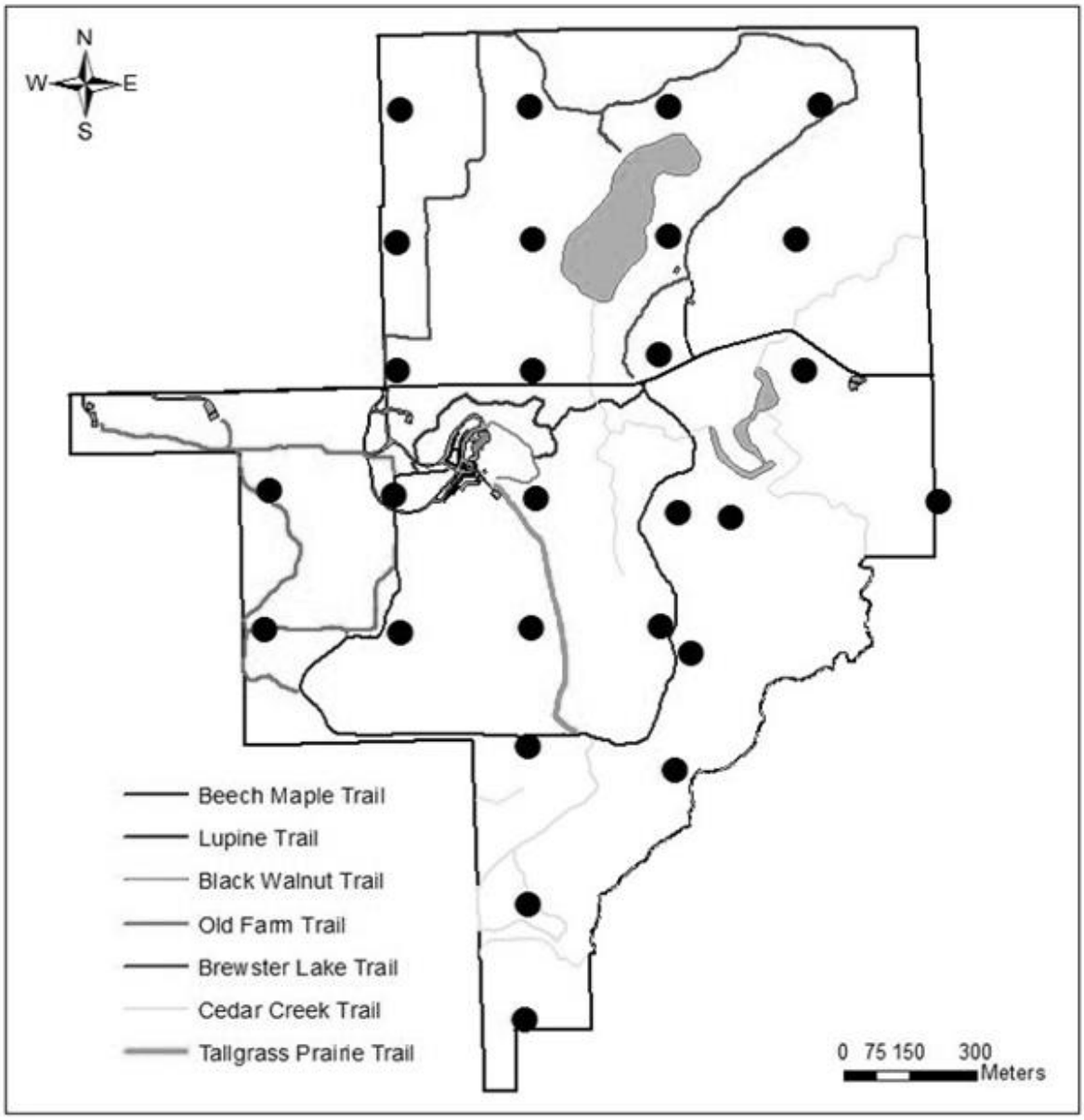

Fig 2: Track plate enclosure locations where raccoon (*Procyon lotor*) prints were collected during a mark recapture study (June-July, 2014) at the Pierce Cedar Creek Institute Pierce Cedar Creek in Hastings, Michigan.

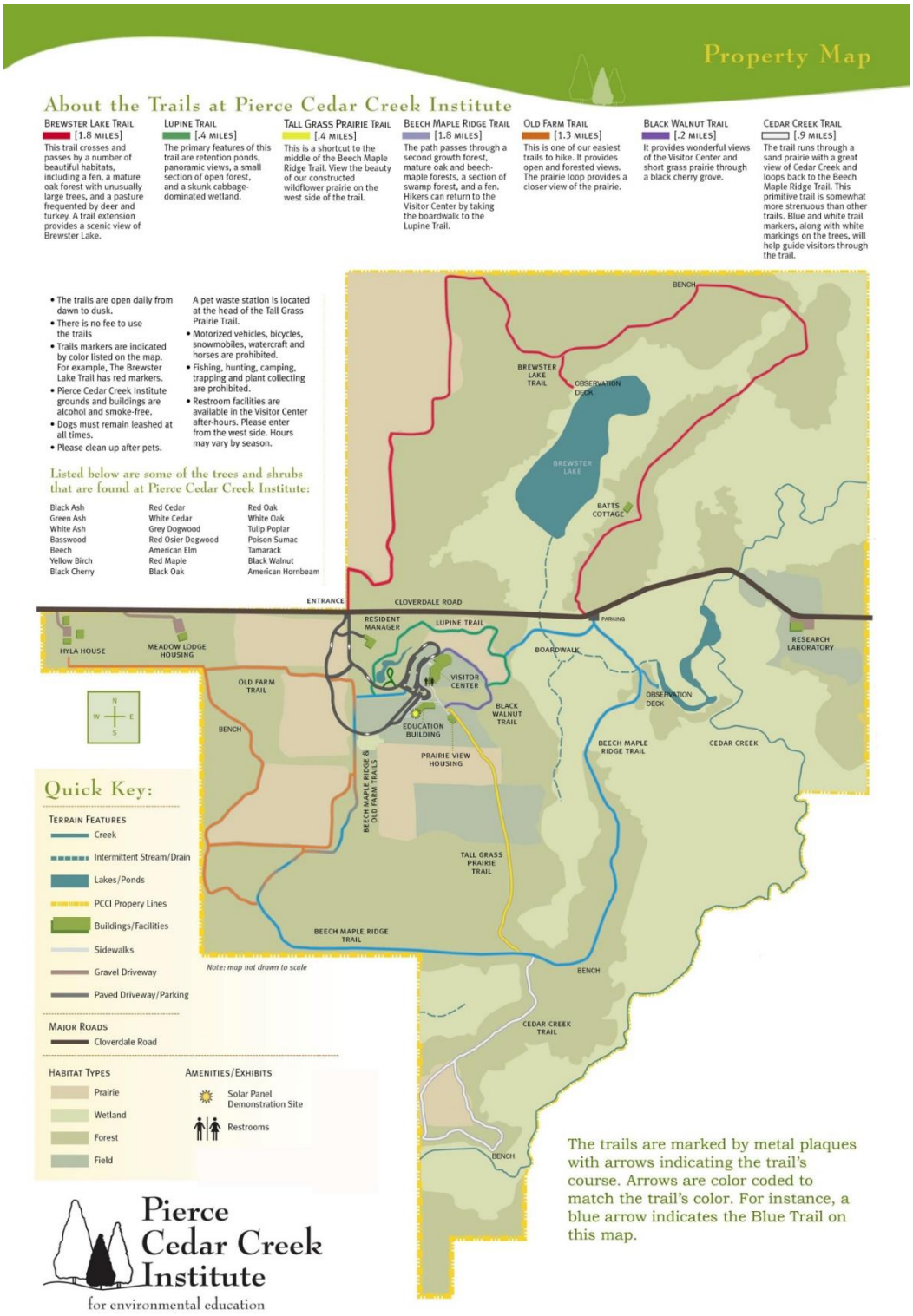

Fig 3: Property map of Pierce Cedar Creek Institute in Hastings, Michigan showing classification of habitat type (prairie, woodland, forest, field).

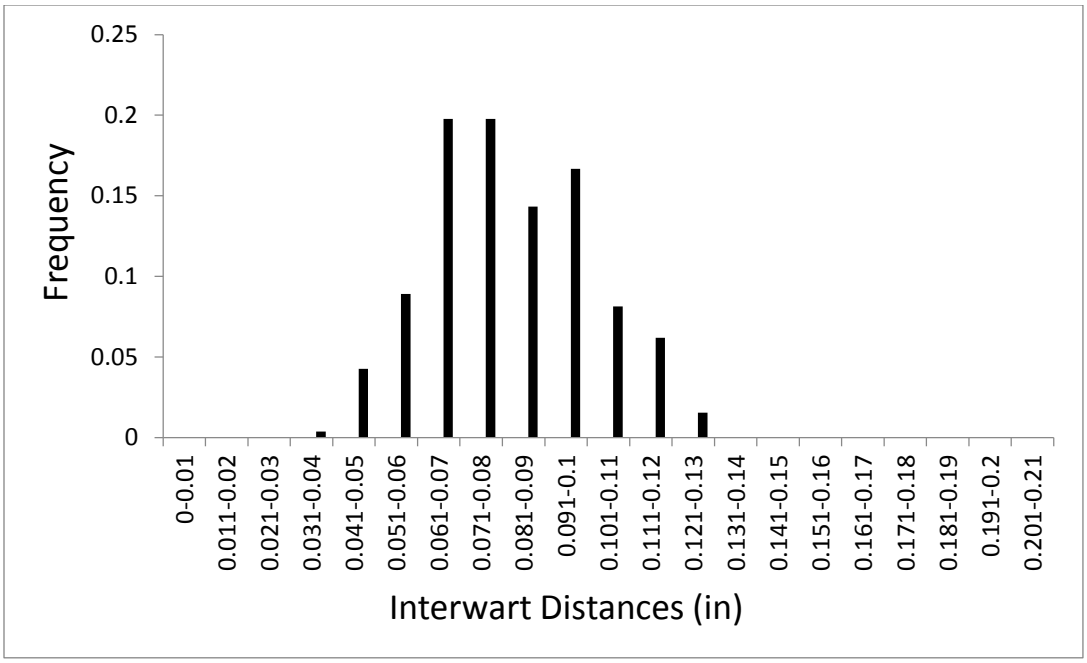

Fig. 4: Frequency of inter-wart distances measured in inches from raccoon (*Procyon lotor*) prints collected from track plate enclosures at the Pierce Cedar Creek Institute Pierce Cedar Creek from June-July, 2014, in Hastings, Michigan.

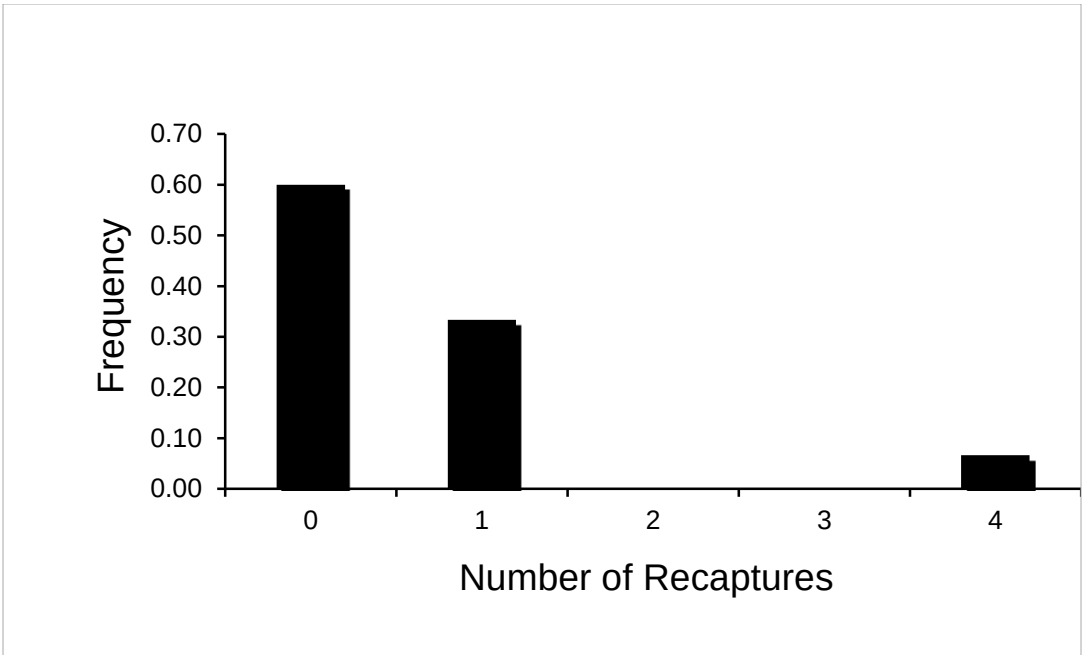

Fig. 5a

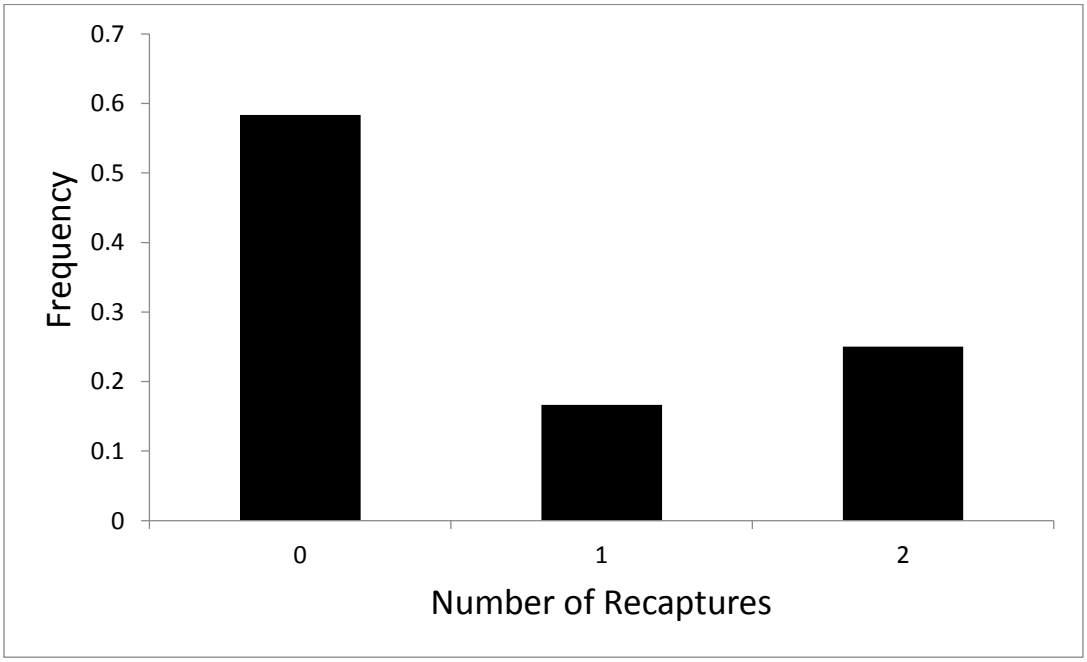

Fig. 5b

Fig 5: Frequency of raccoon (*Procyon lotor*) recaptures from a mark recapture study (June-July 2014) at the Pierce Cedar Creek Institute in Hastings, Michigan for the back left foot (5a) and back right foot (5b).

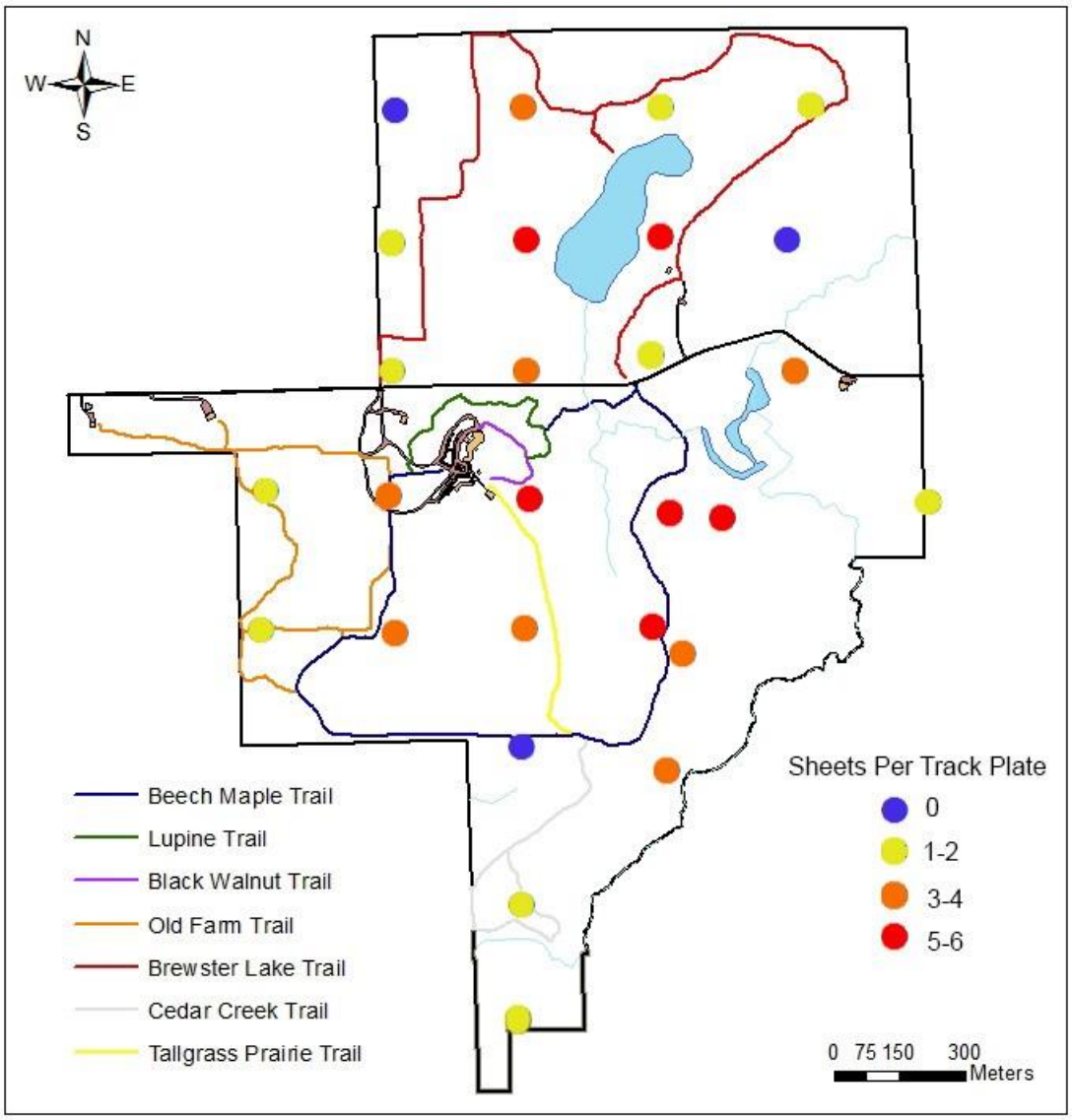

Fig 6. Raccoon (*Procyon lotor*) density distribution at Pierce Cedar Creek in Hastings, Michigan derived from total number of print sheets taken from track plate enclosures (shown by colored circles) between June-July 2014.