Individual Identification of Raccoons (Procyon lotor) Using Track Plate Foot Printing

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Notes and Discussion Piece

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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 from a 225 ha reserve. The probability of identity (PID) for back right feet ranged from 5.72×10^{-9} – 6.71×10^{-12} and from 3.34×10^{-8} – 3.55×10^{-10} for the back left feet, indicating that it was unlikely any two raccoons shared the same papillae pattern. The minimum number of raccoons known to be alive was estimated to be 12–17 individuals depending upon the foot and scale of resolution used, with estimates from program the Capture ranging from 34–38 raccoons. Our results show that track plate footprint can be used to unambiguously identify individual raccoons, may be useful in mark-recapture studies, and is likely to be applicable to other species with large pads.

Introduction

Wildlife biologists use ecological models in conservation planning, management efforts, and to predict future trends; however, acquiring reliable and robust datasets can be difficult (Peterson and Vieglais, 2001; Ciucci *et al.*, 2007). Population studies are often expensive and time consuming. Furthermore, factors such as methodology, population models, home range, sample size, and trap response may also result in a biased estimation of population size (Wegge *et al.*, 2004; Ciucci *et al.*, 2007; Herzog *et al.*, 2007; Foster and Harmsen, 2012; Meek *et al.*, 2014).

Convenience sampling is when samples are obtained from opportunistic locations rather than randomly, and is not representative of populations as these data can only account for abundance near subjective sites (Anderson, 2001). Alternatives to convenience sampling include camera monitoring, which may be able to differentiate individuals in some cases (Silver *et al.*, 2004; Simchareon *et al.*, 2007), but does not work well for species without individually distinguishable characteristics (Herzog *et al.*, 2007). Some of these difficulties can be overcome with individual identification via noninvasive genetic analysis (Taberlet *et al.*, 1999). However, genetic sampling can be difficult, time consuming, and expensive, which limits its practicality (O'Neil and Swanson, 2010).

A noninvasive methodology that is inexpensive and can unambiguously identify individuals is needed to facilitate mesocarnivore research. One such possibility is 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 measuring 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 interpapillae distances for fisher footprints (Herzog *et al.*, 2007). The distribution was used to predict the probability that two prints made by different fishers would match by chance alone (Probability of Identity – PID), as the product of the probability of 10 interpapillae distances (Herzog *et al.*, 2007; O'Neil and Swanson, 2010). The average PID values for fisher, 1.70×10^{-6} showed that it was highly unlikely that any two individuals shared the same footprint pattern (O'Neil and Swanson, 2010).

Accurate population estimates of generalist species, such as the raccoon (*Procyon lotor*) are important for multiple reasons. Raccoons can be highly invasive (Ikeda *et al.*, 2004; García *et al.*, 2012) and detrimental to native species by means of predation and cross species transmission of pathogens (Fernández-Aguilar *et al.*, 2012; Parsons, *et al.,* 2013), such as raccoon roundworm (*Baylisascaris procyonis*)

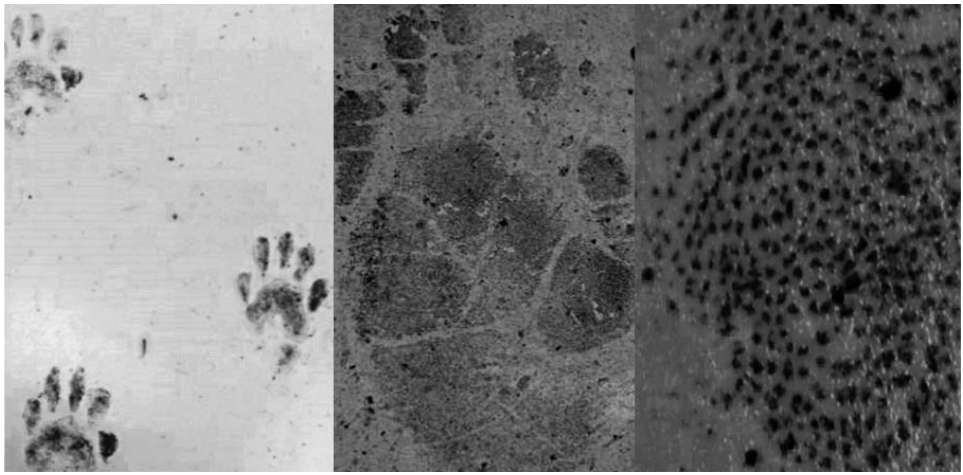

FIG. 1.—Course scale (left), Intermediate scale (middle), and fine scale (right) of raccoon (*Procyon lotor*) prints taken from track plate enclosures in Hastings, Michigan

and rabies (Houle *et al.*, 2011; Smyser *et al.*, 2013). Accurate population estimates facilitate management because infection rates are often density dependent (Houle *et al.*, 2011) and raccoon densities are often positively correlated with the degree of urbanization (Prange *et al.*, 2003; Waldstein, 2010).

The association between raccoons and urbanization likely results from their ability to exploit human garbage as a food source given their ability to manipulate objects with their paws deftly (Whipple, 1904) and the catholic diet of the raccoon (Gehring and Swihart, 2003). At least two factors relate to the dexterity of the raccoon, the morphology of the pes and manus (Sustaita *et al.*, 2013), and the papillae on mammal's pads (homologous to the ridges on human fingers), which facilitates the animal's ability to manipulate objects (Yasui *et al.*, 2008). The importance of the papillae suggests that raccoon footprints (Fig. 1) may provide enough detailed information to identify individuals uniquely and be used as a mark-recapture method to estimate population size.

Our study extends the use of examining metacarpal pad patterns beyond fishers to raccoons. Specifically, we evaluated footprinting as a method to uniquely identify raccoons and estimate their population density based on mark-recapture methods.

METHODS

We set out 27 raccoon track plate survey stations within a rural 225-ha reserve in Barry County Michigan (42°32′6.3234″N, –85°18′5.7852″W), from June 18th through July 17th, 2014. We placed track plate enclosures every 300 m based on a GPS location. A 20-m placement buffer was used when coordinates for an enclosure were located on trails or overly wet areas, such as a cedar swamp or lake.

Enclosures were fabricated from 88 cm × 120 cm 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 1 mm (0.063 gauge) aluminum flat stock sheeting that measured 75 cm × 20 cm in dimension. A nontoxic copy toner was placed in a 30 cm × 20 cm 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 30 cm × 20 cm area. Track plates were baited with peanut butter

placed on a piece of coroplast at the back of the enclosure. Approximately 64 g of diatomaceous earth was sprinkled within ~10 cm 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 needed repairs. On three occasions weather prevented us from checking every other day as it was not feasible to remove the contact paper in strong rain without ruining the prints. Raccoon prints were photographed with a Canon EOS 70D (Canon USA, Farmington Hills, MI) with a 50 mm F/2.5 macro lens. Images were then imported into the software program IMAGEJ (http://rsb.info.nih.gov/ij/) for examination.

Following Herzog et al. (2007), 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 (size and shape) and determine which foot was represented by the print (dimensions of the print and placement of the pollex and hallux). At the intermediate level, unique marks such as scars and creases were used for individual identification. Fine scale analysis consisted of examining the papillae patterns and calculating the interpapillae distances in the program IMAGEJ. Prints which matched at the intermediate level were opened in separate windows of IMAGEJ with roughly 5° of misalignment. The windows were superimposed and flipped between rapidly; matching prints produce a sensation of the print turning slightly, while non-matching prints appear to be jarringly different images (Herzog *et al.*, 2007). All prints were individually compared by two evaluators in a blind fashion.

The distance between pairs of papillae were used to calculate (PID), the probability that two individuals share the same footprint pattern. We measured the distance between 10 nearest neighbor pairs of papillae from the same location on the footpad of each individual print. These distances between these pairs was then calculated to produce a frequency distribution of interpapillae distance classes. An individual's PID was calculated by measuring the distance between ten pairs of nearest neighbor papillae, from an adjacent region on the pad, and determining the probability of that distance occurring based on the frequency distribution described above. The total PID for an individual was the product of the probability of the 10 interpapillae distances.

By examining footprints at an intermediate and fine scale, we were able to determine a minimum number of raccoons known to be alive (MNKA). Capture records, based on identified prints, were analyzed in the program Capture (White and Burnham 1999) as a mark recapture survey. We evaluated the fine scale data with the $M_{(o)}$ and $M_{(t)}$ models, which assume a constant capture probability over time and a changing capture probability over time, respectively. Back left and back right feet were compared and treated as independent of each other when producing population estimates.

RESULTS

We collected 159 sheets containing raccoon prints during 810 trap days over the 30-d study. Heavy rain rendered 15% of the sheets unusable. Similarly, wet feet caused 13% of the total prints to be unusable. We initially had severe problems with slugs entering the enclosures and ruining the print quality. Over the first 5 d slugs destroyed 45% of the prints we collected. However, placing diatomaceous earth in front of the enclosures significantly reduced ($\chi^2 = 3.66$; $P = 0.036$) the percentage of unusable prints caused by slugs to 16% for the remainder of the study. In addition, other factors, such as debris and overlapping prints caused 9% of the prints to be unusable. Overall, a total of 74 sheets were deemed usable in our analysis, 35 usable back left prints, 32 back right, 50 front left and 51 front right prints. However, 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 often too fine to resolve individual differences.

The majority of raccoons were only caught once for both back left and back right feet. Raccoon activity was not evenly distributed across the study site 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 (average of 5.5 sheets per enclosure), followed by field locations (average of 3.5 sheets per enclosure). The lowest number of prints were collected in the prairie and wetland areas (average of 1 sheet per enclosure).

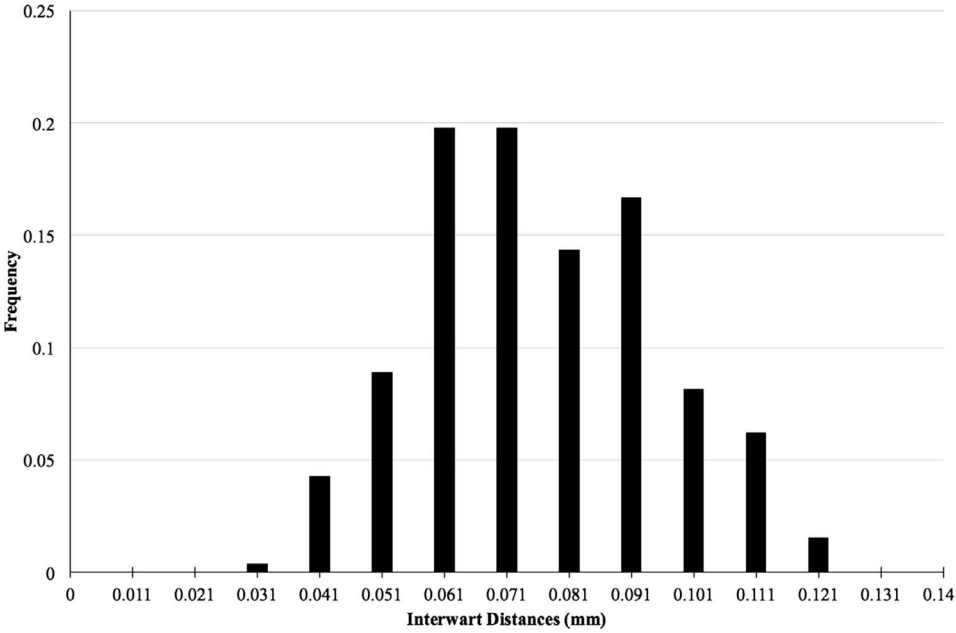

FIG. 2.—Frequency of inter-wart distances (mm) for 10 nearest neighbor papillae from 15 different raccoon (*Procyon lotor*) prints collected from track plate enclosures in Hastings, Michigan

MNKA derived from our intermediate scale interpretation of back left feet was 15 raccoons; while back right feet produced 12 distinct individuals. Using the fine scale analysis of the back left feet we found MNKA = 17 while MNKA = 16 based on the back right foot. Using the intermediate scale of analysis, the program Capture returned a population estimate of 38 raccoons (95% CI = 17–108) based on the back left foot and 34 individuals (95% CI = 21–93) for the back right foot for both the $M_{(0)}$ and $M_{(t)}$ estimators. Using the fine scale analysis, Capture estimated a population size of 36 raccoons (CI = 18–122) based on the back left foot and 30 individuals from the back right foot (CI = 15–103). The probability of identity for back right feet ranged from 5.72×10^{-9} – 6.71×10^{-12} and the PID from back left feet ranged from 3.34×10^{-8} – 3.55×10^{-10} (Fig. 2).

DISCUSSION

Track plate footprinting is a viable method to uniquely identify individual raccoons in a non-invasive manner. Using the fine scale resolution resulted in a higher MNKA than the intermediate scale of resolution as not all animals had unique scaring on their pads. The PID from the fine scale analysis indicated a low probability of any two raccoons sharing the same footprint pattern, supporting the reliability of distinguishing individuals by footprint evaluation via this method. Even assuming that the PID is the highest estimated value (5.72×10^{-8}), only one in about 17 million raccoons should share a papillae pattern. In cases where a PID estimate may not be considered to be sufficient, one can simple incorporate a larger number of interpapillae distances to decrease the PID (Osterburg et al., 1977).

Our population estimates for the 2.25 km^2 of PCCI were between 6.1–16.9 raccoons/km^2 depending upon the foot and method used. The similarity of the MNKA and the program Capture estimate is in general agreement with other studies suggesting 4.7–19.1 raccoons/km^2 in rural areas (Perry *et al.*, 1989; Smith *et al.*, 1994; Blackwell *et al.*, 2004; Totton *et al.*, 2004; Roy Nielsen and Nielsen, 2007; Rosatte *et al.*, 2010; Beasley *et al.*, 2012; Graser *et al.*, 2012; Sollmann *et al.*, 2013; Waldstein Parsons *et al.*, 2013). Our

confidence intervals were too large to produce biologically useful population estimates, likely a result of the low number of recaptures we had over our short trapping season. A longer trapping season would generate more recaptures relative to new captures and would have produced narrower confidence intervals for raccoon densities.

One area where this technique is likely to be especially valuable is in gaining a better understanding of which animals are taking up oral vaccines such as the rabies vaccine. The control of rabies in the wild has shifted from removing infected animals to administering oral vaccines in the wild (Rosatte, 2013) with suggestions that at least a 60% vaccination rate is required to be effective (Eisinger and Thulke, 2008). The distribution of rabies vaccines in areas with low human densities is often done in a broadcast method from aircraft (Slate *et al.*, 2008), but this method is not feasible for suburban areas (Boulanger *et al.*, 2008). The use of track plates in conjunction with bait stations (Boulanger *et al.,* 2006) will facilitate knowing when the 60% threshold of vaccination is crossed, freeing up effort for vaccination programs in other areas. As raccoons continue to expand their range in an invasive fashion (Ikeda *et al.*, 2004), track plate footprinting will aid in producing accurate estimates of the number of individuals in an area allowing improved management (Beltrán-Beck *et al.*, 2012).

Our results indicate that track plate footprinting is a feasible methodology for identifying individual raccoons and is likely to be useful in mark-recapture studies when the sets are left out over a longer study period. Our suggestions for improving the methodology are to (1) spread diatomaceous earth in front of the enclosures to reduce the prints ruined by slug activity, (2) extend the roofline of the set beyond the entrance, and (3) fully seal all of the seams and back.

The expansion of this method to another species, in addition to the fisher, suggests that it is likely to work with other mesocarnivores as well. However, as shown by our inability to obtain identifiable papillae patterns from the smaller front feet of the raccoons, print size will limit the applicability of this method to animals with larger pads.

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