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Brief Report

Predicting *Baylisascaris procyonis* roundworm prevalence, presence and abundance in raccoons (*Procyon lotor*) of southwestern Ohio using landscape features

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ABSTRACT

Raccoon roundworm is a leading cause of a neurological disease known as larva migrans encephalopathy in vertebrates. We determined that roundworm prevalence is significantly lower in Beavercreek Township than other townships surveyed, and that mean patch size and proportion of landscape modified by urbanization or by agriculture are good predictors of roundworm prevalence and abundance in raccoons. The proportion of landscape modified by urbanization was the best predictor of roundworm presence. These data will facilitate predictions regarding roundworm prevalence in areas that have not been previously sampled, and contribute to devising management strategies against the spread of raccoon roundworm.

1. Introduction

The raccoon, *Procyon lotor*, has the ability to adapt to utilizing agriculture (such as corn) and other anthropogenic resources, and is distributed across North and Central America (Parsons et al., 2011). It ranges throughout rural and urban areas of North America (Parsons et al., 2011). Parsons et al. (2011) also noted that raccoons thrive in areas where there are human developments and the absence of large predators. Prange et al. (2003) reported that raccoons in urbanized landscapes had higher survival, reproductive, and recruitment rates than in rural settings. Raccoons have highest breeding success in area with large patches of forest fragmented by urbanization (Soga and Koike, 2013). These landscapes provide reliable food and denning sites. Anthropogenic resources available in urban and agricultural landscapes have allowed raccoon populations to reach higher densities compared with purely rural landscapes (Prange et al., 2003). In urban and suburban landscapes, raccoon densities can be estimated to be as high as 90 raccoons/km^2, whereas densities rarely exceeded 15 raccoons/km^2 in rural settings of North America (Prange et al., 2003). Raccoon home ranges decrease in highly fragmented landscapes, being as small as 25 hectares in some areas, yet exceeding 100 hectares in more rural areas (Beasley et al., 2007). Southwestern Ohio is a region with many areas of human developments, and few large predators. Most of the natural landscape has been converted into cultivated cropland. Within the landscape mosaic, corn is the most common crop, and provides a reliable food source for raccoons in the late summer and autumn months. The native landscape exists as small patches surrounded by agriculture and urbanization. Page et al. (2005) noted that raccoon densities are higher in urban settings, but that fewer of these raccoons are estimated to have the raccoon roundworm, *Baylisascaris procyonis*.

The Raccoon, *P. lotor*, is the definitive host for the raccoon roundworm, *B. procyonis* (see Page et al., 2005). Raccoon roundworms are the leading cause of the dangerous neurological disease known as larva migrans encephalopathy in vertebrates, found in over 90 vertebrate species (Blizzard et al., 2010b). The intermediate hosts (usually small mammals that use the raccoon feces as a source of food) are attracted to raccoon latrines, where raccoons repeatedly defecate and roundworm eggs can concentrate (Page et al., 2001b). As the density of raccoon latrines increases, the possible transmission of *B. procyonis* increases (Roussere et al., 2003). Smyser et al. (2010) noted that rather than the entire latrine,

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individual scats within a latrine should be used to assess exposure risk for intermediate hosts. Landscape fragmentation also affects the prevalence of *B. procyonis* parasites in intermediate hosts that use raccoon feces a source of food, leading to higher prevalence among raccoons preying on these hosts (Page et al., 2005). Comparisons of *B. procyonis* prevalence in raccoons and intermediate hosts tend to group the animals into areas that have drastically different landscapes and degrees of landscape fragmentation (Page et al., 2001a,b). *B. procyonis* prevalence appears to change as a function of landscape (Page, 2013). Page et al. (2001a) reported that *B. procyonis* prevalence was higher in smaller, more isolated fragments in an agricultural landscape. Page et al. (2005) found that *B. procyonis* prevalence was lower in urban portions of Chicago than in rural areas. However, Blizzard et al. (2010a) reported higher *B. procyonis* prevalence among raccoons in an urban landscape than in a rural landscape. As the prevalence of raccoon roundworm increases in raccoons, more intermediate hosts become infected, exposing more raccoons to the parasite.

The purpose of this study was to investigate if landscape features are useful predictors of both presence and abundance of *B. procyonis* among definitive hosts, and to help determine the relationship between increased anthropogenic landscape and *B. procyonis* prevalence. By testing the ability to predict the presence and abundance of parasites in a raccoons from landscape features, we aim to provide valuable information for researchers assessing the potential impact of *B. procyonis* in areas that have not yet been sampled, and for those investigators interested in the potential for zoonoses.

2. Materials and methods

We investigated raccoons from nine townships from Greene and Clark Counties in Southwest Ohio. We chose townships as the sampling scale so as to have areas larger than a typical raccoon home range in a fragmented agricultural landscape, such as that found in southwestern Ohio. The largest mean patch size in a township is less than 20 hectares (1 hectare = 10,000 m^2). With a home range of 92 ± 6 hectares for males and 58 ± 7 for females (Beasley et al., 2007), raccoons are likely to use habitat in multiple patches within a sample area. We collected raccoons from Beavercreek, Xenia, and Miami Townships in Greene County, and from German, Green, Harmony, Mad River, Moorefield, and Springfield Townships in Clark County. Municipalities were included in their respective townships for analyses (Fig. 1).

We accessed and downloaded the 2006 National Land Cover Dataset (NLCD) from mrlc.gov website. The dataset classifies land cover of each 30 × 30 m grid cell as belonging to one of 16 classes in eight categories: water, developed, barren, forest, shrubland, herbaceous, planted/cultivated and wetlands. Using ESRI ArcGIS software, we imported shapefile layers of Greene and Clark County townships in order to clip the NLCD. This resulted in individual land cover maps for each township. We then used Patch Analyst (http://www.cnfer.on.ca/SEP/patchanalyst/) to evaluate various landscape, class, and patch metrics.

We calculated the proportion of landscape modified by urbanization (*Turb*) and the proportion of landscape modified by agriculture (*Tag*) according to the formulas: $Turb = (Do + Dl + Dm + Dh)/TA$, and $Tag = (P + C)/TA$, where land areas are defined as: developed-open (*Do*), developed-low (*Dl*), developed-medium (*Dm*), developed-high (*Dh*), pasture/hay (*P*) and cultivated crops (*C*) for a township, and where *TA* is the total land area in the township (Table 1).

We worked with six fur trappers to gather raccoons for the study. The trappers recorded only the township, where the raccoon was trapped. We collected the viscera from trapped raccoons at two different work sites: one located in Xenia Township and one located in Harmony Township, OH (Fig. 1). We dissected out the viscera, and placed them into two freezer bags marked with the date of collection, the trapper responsible for the raccoon, the township or city where the raccoon was trapped, and the county that the township or city resides in. All samples were stored at −20 °C until they were necropsied. Collections were made from November 10 through December 9, 2012. The skinned carcasses were necropsied, and we examined sections of the gut for *B. procyonis*. We used the term abundance to refer to the number of *B. procyonis* worms present in a single raccoon whether or not it is infected (Margolis et al., 1982; Rozsa et al., 2000). We noticed that many of the necropsied raccoons also contained cestodes, so we also collected and recorded any cestodes found in the intestinal tract, but were unable to identify them to species or determine the number present in the intestines of any of the raccoons sampled. We ran a Chi-Squared equality of distributions test on the *B. procyonis* prevalence data, by combining Springfield Township with the adjacent Mad River Township (Fig 1).

We developed three models to test the correlation of *B. procyonis* features with three landscape features (*Turb*, *Tag* and mean patch size (*M*)), and the predictive capabilities of these landscape features. The first model we developed was the following linear regression: $\text{parasite prevalence} = \beta_0 + \beta_1(Turb) + \beta_2(Tag) + \beta_3(M)$, where β_0 is the intercept, and β_1, β_2 and β_3 are coefficients for the explanatory variables. We used the data from the nine townships surveyed (Table 2) for the first model. The next model tested the relationship between the three landscape features and presence of *B. procyonis*: $\text{presence} = \beta_0 + \beta_1(Turb) + \beta_2(Tag) + \beta_3(M)$, where β_0 is the intercept, and β_1, β_2 and β_3 are coefficients for the explanatory variables. This logistic regression had a binary dependent variable (either the roundworm was present or not). We ran this model on each of the 226 raccoons necropsied. The final model tested the ability of the three landscape features to predict *B. procyonis* abundance: $\text{parasite abundance} = \beta_0 + \beta_1(Turb) + \beta_2(Tag) + \beta_3(M)$. We also ran this model on each of the 226 raccoons necropsied.

After noting that many raccoons infected with *B. procyonis* were also infected with at least one cestode, we tested the ability of these landscape features to predict the cestode features: cestode prevalence in the nine townships and cestode presence in each raccoon. We used the same models as above with the cestode feature as the dependent variable. We also constructed a model to test the correlation between *B. procyonis* presence and cestode presence: $\text{roundworm presence} = \beta_0 + \beta_1(\text{cestode})$, with *B. procyonis* presence as the dependent variable and cestode representing the presence of at least one cestode at necropsy.

After preliminary analyses, we decided to drop the intercept from all of the models as the dependent variables should all be zero when all of the independent variables are zero. We added the independent variables stepwise in the linear regressions, and added the variables conditionally in the binary logistic regressions to generate the best models without introducing unnecessary variation with additional independent variables.

3. Results and discussion

We calculated the proportion of landscape modified by agriculture, and the proportion of landscape modified by urbanization for each of the nine townships (Table 1). The values for *Tag* ranged from 0.5144 in Beavercreek Township to 0.8603 in Harmony Township (Mean ± Standard Error, 0.6799 ± 0.1167). The proportion of landscape modified by agriculture exceeds 0.8 (or 80%) in two of the nine townships: Harmony and Green. We also calculated the proportion of landscape modified by urbanization