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# Calculating the rate of spread of Phragmites australis in Summit County, OH using GIS

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Honors Research Project

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**Abstract**

*Phragmites australis* subspecies *australis* is a non-native species that forms dense monocultures and negatively affects wetland ecosystems. In this study, Geographic Information System (GIS) was used to analyze and compare intrinsic rates of growth between *Phragmites* populations located along highways and those within parks in Summit County, Ohio. No significant difference in expansion rate was seen between the two population types during a 4-year time period, although the average expansion rate was higher in park populations. Obstruction by roads may have prevented highway populations from expanding radially, while 2/3 of park populations were unobstructed in terms of physical barriers to expansion.

**Introduction**

Invasive species are one of the major threats to biodiversity (Brown and Sax 2004). Competition and predation by invasive species contribute to over 40% of the species listed as threatened or endangered under the Endangered Species Act (Pimentel, Zuniga, and Morrison 2005). With the globalization of human trade and transport, the number of species being introduced to non-native ranges is increasing. Human transportation networks such as roads and railways have allowed invasive species to spread not only along those networks but also into habitats of conservation and restoration interests (Hulme 2009). In the United States, there are approximately 50,000 non-native species (Pimentel, Zuniga, and Morrison 2005). One such species is *Phragmites* australis, the common reed.

The common reed, *Phragmites australis* (hereafter referred to as *Phragmites*), is one of the most widespread plants in the world and is considered the most invasive wetland plant of

eastern North America (Lambert, Dudley, and Saltonstall 2010, Tougas-Tellier, et al. 2015). The non-native subspecies, *Phragmites australis* subspecies *australis*, was introduced to North America at the turn of the nineteenth century. Native to Europe and the Middle East, this subspecies of *Phragmites* arrived in the New World from the ballasts of ships. The non-native subspecies can be differentiated from the native subspecies, *Phragmites australis* subspecies *americanus*, through a variety of morphological, vegetative, and floral characteristics. One of the main ways to differentiate the native and non-native subspecies is by observing stem density. The non-native *Phragmites* typically grows in a dense monoculture while the rarer native *Phragmites* typically grows scattered amongst other plants (Swearingen and Saltonstall 2010). *Phragmites* can be found in a variety of environments including in freshwater and saltwater marshes, along rivers, around lakes, and within ditches (Lambert, Dudley, and Saltonstall 2010). Once *Phragmites* is introduced into an ecosystem, it outcompetes native plants and negatively affects food webs, nutrient cycles, and sedimentation rates (Fussell, Dionne, and Theodose 2015, Price, Fant, and Larkin 2013, Lambert, Dudley, and Saltonstall 2010).

*Phragmites* is successful in invading wetlands for several reasons. First, *Phragmites* reproduces primarily through vegetative growth using its underground rhizomes (Saltonstall 2002). This form of growth as well as the plant's height create dense monocultures that crowd out other plants and prevents light from reaching any plants that try to establish themselves (Rice, Rooth, and Stevenson 2000). Second, *Phragmites* is able to utilize resources and tolerate disturbances better than many wetland plants (Price, Fant, and Larkin 2013). Over the past 150 years, the distribution and abundance of *Phragmites* has rapidly increased, and it is likely that

this is the result of the development of railroads and highways throughout the United States (Saltonstall 2002). Highways have become an avenue for invasion as road construction and maintenance have allowed *Phragmites* to establish and grow in drainage ditches and adjacent marshes (Jodoin, et al. 2008).

The objective of this study of *Phragmites* in northeastern Ohio was to determine whether expansion rates varied between populations located along highways and populations located within recreational parks over the course of four years using GIS software. I hypothesized that expansion rates would be greater along highways because of their potential for favorable habitats (with high rates of disturbance) for establishment and growth (Jodoin, et al. 2008).

## Materials and Methods

### *Study Sites*

Potential *Phragmites* populations within Cuyahoga Valley National Park (CVNP), Summit Metro Parks (SMP), and Bath Nature Preserve (BNP) and along the interstate and state-route highways, I-76, I-77, and SR-08, were identified using Google Earth and verified through field observations. Highway populations were typically bordered by one or two roads while park populations tended to be less constrained by constructed barriers allowing for expansion in virtually every direction. On aerial photographs, patches of *Phragmites* were identified by their light blue-green color and smooth texture (Rice, Rooth, and Stevenson 2000).

*Image Preparation*

Aerial photographs of Summit County, Ohio were obtained from the USGS EarthExplorer database. Four-band images (containing red, green, blue, and near-infrared bands) for 2009, 2011, and 2013 were taken by the National Agriculture Imagery Program (NAIP) during the summer months of July and August for precise comparison. These years were chosen since data from NAIP is limited. NAIP has a 1-meter ground sample distance and is 95% confident that any point falls within 6 meters of true ground (USDA 2013). The Spatial Reference System (SRS) for NAIP's 2009 and 2011 imagery was North American Datum 1983 (NAD83) Universal Transverse Mercator (UTM) Zone 17N while the SRS for NAIP's 2013 imagery was World Geodetic Sphere 1984 (WGS84) Web Mercator (Auxiliary Sphere). The 2013 imagery was projected from WGS84 Web Mercator (Auxiliary Sphere) to NAD83 UTM Zone 17N to match the images from 2009 and 2011.

*GIS Analysis*

For the purposes of this study, ArcGIS 10.3.1 software (ESRI 2015) was used for analysis and visualization of *Phragmites* populations. For each year, the NAIP images were added as base layer for the map. Using the editor tool, each *Phragmites* population was traced into a polygon feature. By opening the attribute table of the created feature class, areas for each *Phragmites* population could be viewed.

Analyzed *Phragmites* populations were narrowed down from those originally identified based on whether a population was recognizable in the NAIP image. Distinct boundaries could

be seen as a result of *Phragmites* vegetative growth strategy. Populations were considered the same population if between 2009 and 2013 they converged with each other (*Figure 1*).


*Figure 1. Shows an example of traced populations in CVNP between 2009 (on left) and 2011 (on right). Population Z was two populations before they converged into each other. For area analysis in 2009, the two Z populations would be added together to find the total area for population Z.*

*Calculations of Intrinsic Growth*

Spatial coverage was compared between 2009 and 2011, 2011 and 2013, and 2009 and 2013. If a population was absent in 2009 but had measurable areas in 2011 and 2013, the area recorded for 2009 was 1 $m^2$ for statistical analysis.

Changes in patch sizes were calculated using a logarithmic growth equation. This normalizes the area change between large and small *Phragmites* populations (Rice, Rooth, and Stevenson 2000). The following equation was used (Wilson and Bossert 1971):

$$N = N_0 e^{rt}$$

Where *N* is the total area at time 1, $N_0$ is the total area at time 0, *e* is 2.71828 (the base of the natural logarithm), *r* is the intrinsic rate of increase per year, and *t* is the difference in years between *N* and $N_0$. The equation was solved for *r*: $r = (1/t) * \ln (N/N_0)$.

## Results

*Analyzed Study Sites*

Of the 86 originally identified, a total of 64 *Phragmites* populations were analyzed in this study. Of those populations, 33 occurred along highways (7 on I-76, 20 on I-77, and SR-08), and 31 occurred within recreational parks (10 in Summit Metro Parks, 19 in Cuyahoga Valley National Park, and 2 in Bath Nature Preserve). The two populations in Bath Nature Preserve did not have measurable areas until 2011. A spatial representation of where these populations were located within Summit County, Ohio can be found in *Figure 2.*

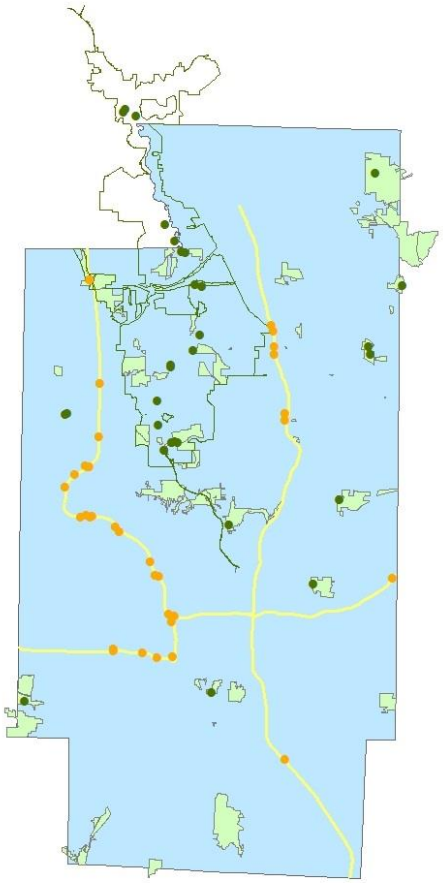

*Figure 2. Locations of analyzed park Phragmites populations in Summit Co., OH represented by green circles. Highway populations represented by orange circles. Yellow lines represent I-76, I-77, and SR-08, light green shapes represents units of SMP, and the dark green outline represents the boundary of CVNP.*

*Expansion Rates: Comparison between Highways and Parks*

Statistical analysis for this study was done in JMP Pro 10.0.1. An independent-samples t-test was conducted to compare the intrinsic expansion rate from 2009 to 2011 of *Phragmites* populations along highways and in recreational parks. There was not a significant difference in expansion rates for highways (Mean = 0.087, SD = 0.255) and recreational parks (Mean = 0.113, SD = 0.749); t = 0.858, DF = 36, p = 0.571. A visual representation of the relationship can be found in *Figure 3.* A positive mean value for intrinsic rate indicates an increase in population size from the previous year while a negative value indicates a decrease in population size from the previous year. Between 2009 and 2011, there was an 8.7% increase in patch size for *Phragmites* populations along highways, and there was an 11.3% increase in patch size for *Phragmites* populations within parks.

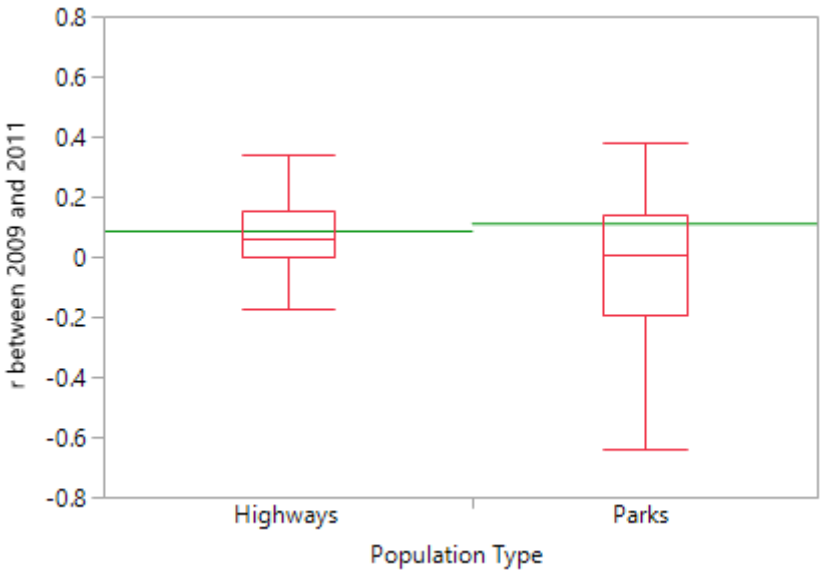


*Figure 3. Compares the quantiles between highway and park populations for 2009 to 2011. The green line represents the mean intrinsic rate of increase.*

An independent-samples t-test was also conducted to compare the intrinsic expansion rate from 2011 to 2013 of *Phragmites* populations along highways and in recreational parks. There was not a significant difference in expansion rates for highways (Mean = 0.078, SD = 0.147) and recreational parks (Mean = 0.138, SD = 0.288); t = 0.309, DF = 44, p = 0.845. A visual representation of the relationship can be found in *Figure 4.* Between 2011 and 2013, there was a 7.8% increase in patch size for *Phragmites* populations along highways, and there was a 14.7% increase in patch size for *Phragmites* populations within parks.

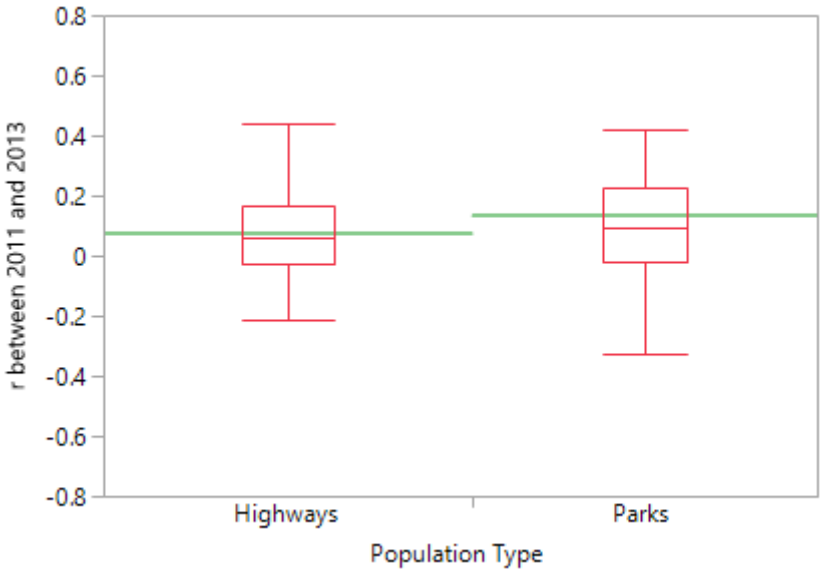


*Figure 3. Compares the quantiles between highway and park populations for 2011 to 2013. The green line represents the mean intrinsic rate of increase.*

Finally, an independent-samples t-test was conducted to compare the intrinsic expansion rate from 2009 to 2013 of *Phragmites* populations along highways and in recreational parks. There was not a significant difference in expansion rates for highways (Mean = 0.083, SD = 0.149) and recreational parks (Mean = 0.125, SD = 0.357); t = 0.542, DF = 39, p = 0.729. A visual representation of the relationship can be found in *Figure 5.* Between 2009 and

2013, there was an 8.3% increase in patch size for *Phragmites* populations along highways, and there was a 12.5% increase in patch size for *Phragmites* populations within parks.

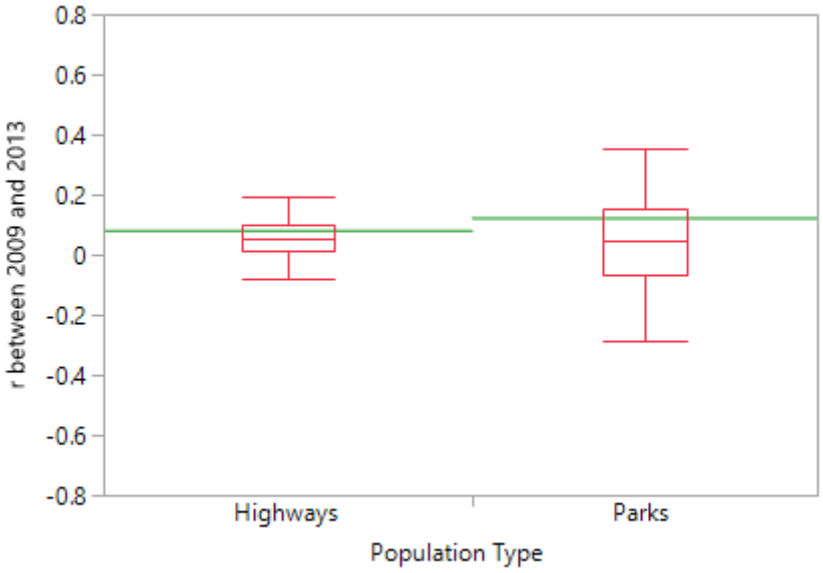


*Figure 3. Compares the quantiles between highway and park populations for 2009 to 2013. The green line represents the mean intrinsic rate of increase.*

**Discussion**

The objective of this study of *Phragmites* was to determine whether growth rates varied between populations located along highways and populations located within recreational parks using GIS software. I originally hypothesized that expansion rates would be greater along highways. After this analysis, it is not possible to conclude that growth rates were faster along highways compared to those within parks.

Although statistical analysis in this study does not show a significant difference between the two types of populations, it is important to note that for each time period calculated, a greater increase in population size occurred in park populations. This is in direct opposition to the trend that the original hypothesis of this study suggests. This trend may be attributed to the

fact that only 1/3 of the analyzed park populations had an obstruction to radial growth from roads, trails, or railways. Almost every analyzed highway population was limited to radial growth from one or more roads. These obstructions may have limited optimal vegetative growth and result in a misrepresentation of expansion rates between the two population types.

I contacted each organization responsible for controlling invasive species in its respective property and asked how each organization controls for *Phragmites.* The Ohio Department of Transportation, as well as the municipalities of Hudson and Stow, responded that no particular control efforts were devoted to *Phragmites*. None had permits to apply herbicides in wetland habitats, and the only methods that could be linked with *Phragmites* control are the occasional mowing along highway edges and dredging of drainage ditches. Many of the analyzed highway populations are outside the reach of both these methods. Both Cuyahoga Valley National Park and Summit Metro Parks apply glyphosate-based herbicides during the early fall to control *Phragmites*. Not every population within the parks is targeted for control, and it may be that the populations in this study are not a priority in invasive species management. A future study could compare populations within parks that are known to be targeted for control to those that are not actively managed.

**Acknowledgments**

I would like to thank Dr. Randall Mitchell for his mentorship on this project. I would like to express my gratitude to Dr. Anne Wiley and Dr. Sara Carlson for their comments on how I could improve my research paper. I greatly appreciate the help of Bonnie Baumgardner and Megan Bodenschatz for their assistance in driving me along the highways as I noted where *Phragmites* populations were. I also would like to thank Ryan Trimbath for providing me with the shapefiles for SMP and CVNP that saved me countless hours of doing my own polygon tracing. Finally, I would like to thank Dr. Shanon Donnelly for answering all my GIS-related questions.

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## Supporting Information

| Latitude | Longitude | Location | '09 area ($m^2$) | '11 area ($m^2$) | '13 area ($m^2$) | *r* '09-'11 | *r* '11-'13 | *r* '09-'13 |
|---|---|---|---|---|---|---|---|---|
| 41.2587 | -81.6340 | I-77 | 1757.116 | 1909.341 | 1555.921 | 0.0415 | -0.1023 | -0.0304 |
| 41.1977 | -81.6250 | I-77 | 1604.927 | 1549.345 | 1400.825 | -0.0176 | -0.0504 | -0.0340 |
| 41.1667 | -81.6255 | I-77 | 997.670 | 514.253 | 1284.133 | -0.3314 | 0.4576 | 0.0631 |
| 41.1494 | -81.6361 | I-77 | 2445.295 | 2772.025 | 3268.548 | 0.0627 | 0.0824 | 0.0725 |
| 41.1487 | -81.6343 | I-77 | 2533.511 | 2820.696 | 2899.583 | 0.0537 | 0.0138 | 0.0337 |
| 41.1485 | -81.6330 | I-77 | 1619.896 | 1862.009 | 1858.099 | 0.0696 | -0.0011 | 0.0343 |
| 41.1438 | -81.6440 | I-77 | 373.650 | 423.501 | 429.047 | 0.0626 | 0.0065 | 0.0346 |
| 41.1365 | -81.6516 | I-77 | 8277.350 | 9532.993 | 10986.340 | 0.0706 | 0.0709 | 0.0708 |
| 41.1190 | -81.6397 | I-77 | 478.602 | 647.604 | 577.751 | 0.1512 | -0.0571 | 0.0471 |
| 41.1198 | -81.6352 | I-77 | 1364.380 | 1353.882 | 1547.269 | -0.0039 | 0.0668 | 0.0314 |
| 41.1188 | -81.6322 | I-77 | 1513.630 | 1709.301 | 1885.032 | 0.0608 | 0.0489 | 0.0549 |
| 41.1197 | -81.6302 | I-77 | 6848.366 | 7489.308 | 9171.415 | 0.0447 | 0.1013 | 0.0730 |
| 41.1132 | -81.6118 | I-77 | 6430.062 | 8502.731 | 10415.137 | 0.1397 | 0.1014 | 0.1206 |
| 41.1106 | -81.6088 | I-77 | 11582.123 | 12905.141 | 12299.613 | 0.0541 | -0.0240 | 0.0150 |
| 41.0930 | -81.5846 | I-77 | 1516.363 | 661.388 | 1601.194 | -0.4149 | 0.4421 | 0.0136 |
| 41.0847 | -81.5807 | I-77 | 2433.034 | 1726.816 | 1134.802 | -0.1714 | -0.2099 | -0.1907 |
| 41.0841 | -81.5780 | I-77 | 22.297 | 186.257 | 304.090 | 1.0613 | 0.2451 | 0.6532 |
| 41.0619 | -81.5701 | I-77 | 216.069 | 425.988 | 609.373 | 0.3394 | 0.1790 | 0.2592 |
| 41.0612 | -81.5656 | I-77 | 149.670 | 494.353 | 819.693 | 0.5974 | 0.2528 | 0.4251 |
| 40.9765 | -81.4791 | I-77 | 3821.553 | 4667.207 | 4337.788 | 0.1000 | -0.0366 | 0.0317 |
| 41.0402 | -81.6127 | I-76 | 15098.629 | 14965.672 | 20207.849 | -0.0044 | 0.1502 | 0.0729 |
| 41.0413 | -81.6131 | I-76 | 17393.238 | 19552.732 | 17208.103 | 0.0585 | -0.0639 | -0.0027 |
| 41.0392 | -81.5905 | I-76 | 1181.055 | 971.151 | 971.341 | -0.0978 | 0.0001 | -0.0489 |
| 41.0363 | -81.5788 | I-76 | 2788.195 | 3188.930 | 3443.253 | 0.0671 | 0.0384 | 0.0528 |
| 41.0366 | -81.5668 | I-76 | 3206.593 | 4492.269 | 4233.447 | 0.1686 | -0.0297 | 0.0695 |
| 41.0573 | -81.5677 | I-76 | 650.589 | 878.041 | 689.051 | 0.1499 | -0.1212 | 0.0144 |
| 41.0838 | -81.3959 | I-76 | 846.934 | 1204.640 | 1865.130 | 0.1762 | 0.2186 | 0.1974 |
| 41.2328 | -81.4911 | SR-08 | 139.869 | 241.228 | 379.575 | 0.2725 | 0.2267 | 0.2496 |
| 41.2295 | -81.4899 | SR-08 | 807.573 | 823.070 | 1101.658 | 0.0095 | 0.1458 | 0.0776 |
| 41.2204 | -81.4888 | SR-08 | 260.557 | 429.846 | 485.124 | 0.2503 | 0.0605 | 0.1554 |
| 41.2154 | -81.4891 | SR-08 | 2298.786 | 1260.082 | 1669.149 | -0.3006 | 0.1406 | -0.0800 |
| 41.1808 | -81.4805 | SR-08 | 6221.310 | 6797.886 | 10176.034 | 0.0443 | 0.2017 | 0.1230 |
| 41.1768 | -81.4804 | SR-08 | 7322.343 | 9222.551 | 9776.281 | 0.1154 | 0.0292 | 0.0723 |

*Table S1. Location, area, and intrinsic expansion rates of analyzed highway populations.*

| Latitude | Longitude | Pop. Type | '09 area ($m^2$) | '11 area ($m^2$) | '13 area ($m^2$) | *r* '09-'11 | *r* '11-'13 | *r* '09-'13 |
|---|---|---|---|---|---|---|---|---|
| 41.0102 | 81.6823 | SMP | 277.338 | 279.417 | 146.445 | 0.0037 | -0.3230 | -0.1596 |
| 41.0161 | 81.5365 | SMP | 37662.616 | 32363.037 | 28440.474 | -0.0758 | -0.0646 | -0.0702 |
| 41.0802 | -81.4579 | SMP | 413.307 | 591.320 | 570.456 | 0.1791 | -0.0180 | 0.0806 |
| 41.1151 | -81.5236 | SMP | 733.998 | 434.869 | 356.892 | -0.2617 | -0.0988 | -0.1803 |
| 41.1631 | -81.5639 | SMP | 8061.580 | 8367.904 | 8243.939 | 0.0186 | -0.0075 | 0.0056 |
| 41.1299 | -81.4372 | SMP | 131.588 | 223.796 | 256.374 | 0.2655 | 0.0680 | 0.1667 |
| 41.2158 | -81.4141 | SMP | 527.387 | 170.788 | 332.427 | -0.5638 | 0.3330 | -0.1154 |
| 41.2206 | -81.4157 | SMP | 2351.935 | 2417.346 | 1809.411 | 0.0137 | -0.1448 | -0.0656 |
| 41.3231 | -81.4111 | SMP | 433.678 | 446.349 | 713.584 | 0.0144 | 0.2346 | 0.1245 |
| 41.2567 | -81.3894 | SMP | 826.711 | 6970.216 | 8618.532 | 1.0660 | 0.1061 | 0.5861 |
| 41.1589 | -81.5746 | CVNP | 382.260 | 152.128 | 318.432 | -0.4607 | 0.3693 | -0.0457 |
| 41.1631 | -81.5686 | CVNP | 2472.747 | 2383.238 | 2287.445 | -0.0184 | -0.0205 | -0.0195 |
| 41.1634 | -81.5686 | CVNP | 298.285 | 83.098 | 1216.268 | -0.6390 | 1.3418 | 0.3514 |
| 41.1636 | -81.5665 | CVNP | 1082.610 | 1014.507 | 896.146 | -0.0325 | -0.0620 | -0.0473 |
| 41.1734 | -81.5796 | CVNP | 656.083 | 1400.425 | 2302.273 | 0.3791 | 0.2486 | 0.3138 |
| 41.1877 | -81.5803 | CVNP | 532.665 | 775.652 | 1080.820 | 0.1879 | 0.1659 | 0.1769 |
| 41.2077 | -81.5695 | CVNP | 1203.099 | 1495.157 | 1601.005 | 0.1087 | 0.0342 | 0.0714 |
| 41.2087 | -81.5699 | CVNP | 514.952 | 566.616 | 684.066 | 0.0478 | 0.0942 | 0.0710 |
| 41.2178 | -81.5522 | CVNP | 712.157 | 280.299 | 650.518 | -0.4662 | 0.4210 | -0.0226 |
| 41.2265 | -81.5471 | CVNP | 334.412 | 333.015 | 406.465 | -0.0021 | 0.0997 | 0.0488 |
| 41.2556 | -81.5457 | CVNP | 558.068 | 697.063 | 1039.472 | 0.1112 | 0.1998 | 0.1555 |
| 41.2567 | -81.5515 | CVNP | 2132.791 | 1446.182 | 1321.513 | -0.1943 | -0.0451 | -0.1197 |
| 41.2754 | -81.5591 | CVNP | 13817.819 | 18221.765 | 22156.093 | 0.1383 | 0.0977 | 0.1180 |
| 41.2761 | -81.5623 | CVNP | 2636.768 | 2602.859 | 3228.448 | -0.0065 | 0.1077 | 0.0506 |
| 41.2821 | -81.5674 | CVNP | 9760.180 | 2043.042 | 7167.369 | -0.7819 | 0.6275 | -0.0772 |
| 41.2917 | -81.5749 | CVNP | 11735.839 | 3383.411 | 3737.922 | -0.6219 | 0.0498 | -0.2860 |
| 41.3556 | -81.5987 | CVNP | 469.250 | 472.531 | 595.427 | 0.0035 | 0.1156 | 0.0595 |
| 41.3583 | -81.6081 | CVNP | 2949.299 | 2734.117 | 4312.299 | -0.0379 | 0.2278 | 0.0950 |
| 41.3600 | -81.6071 | CVNP | 3523.588 | 3045.857 | 3656.592 | -0.0728 | 0.0914 | 0.0093 |
| 41.1791 | -81.6518 | BNP | 1.000 | 217.364 | 220.746 | 2.6908 | 0.0077 | 1.3493 |
| 41.1798 | -81.6506 | BNP | 1.000 | 149.005 | 152.863 | 2.5020 | 0.0128 | 1.2574 |

*Table S2. Location, area, and intrinsic expansion rates of analyzed park populations.*

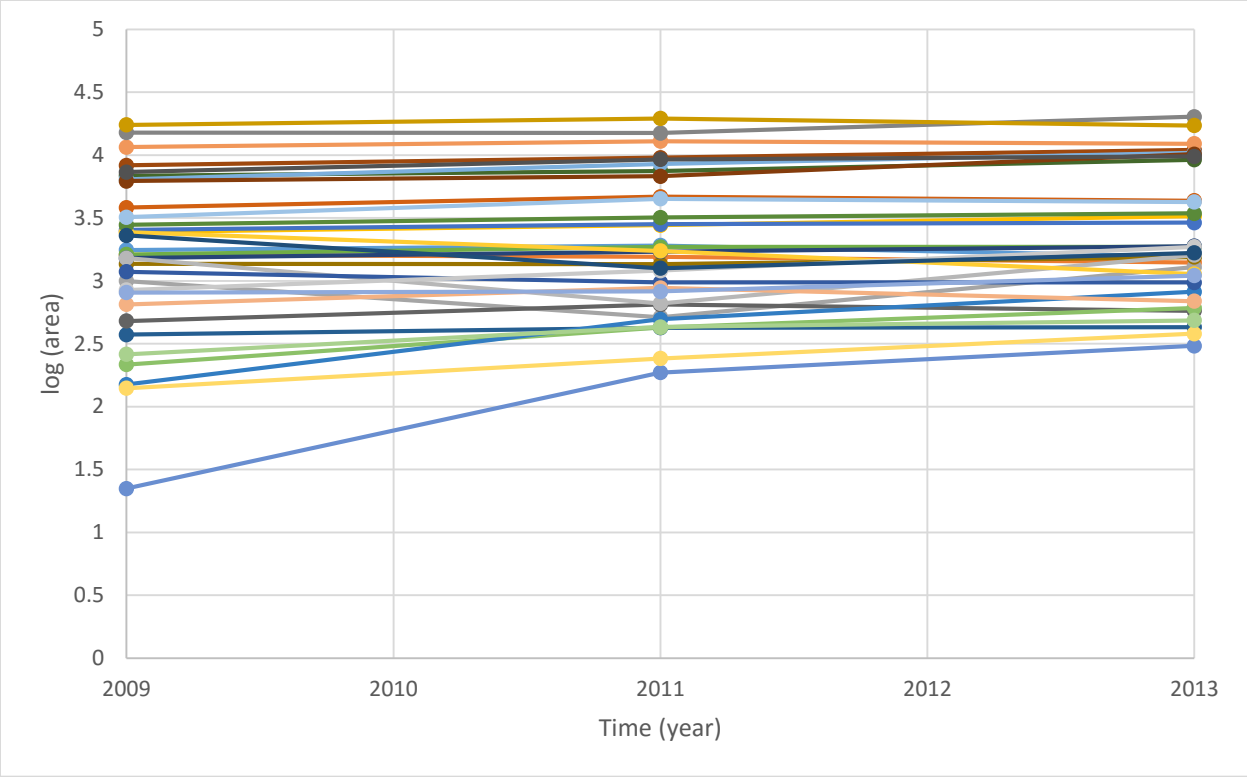


*Figure S1. The log of the area for analyzed highway populations between 2009 and 2013. Area was measured in m².*

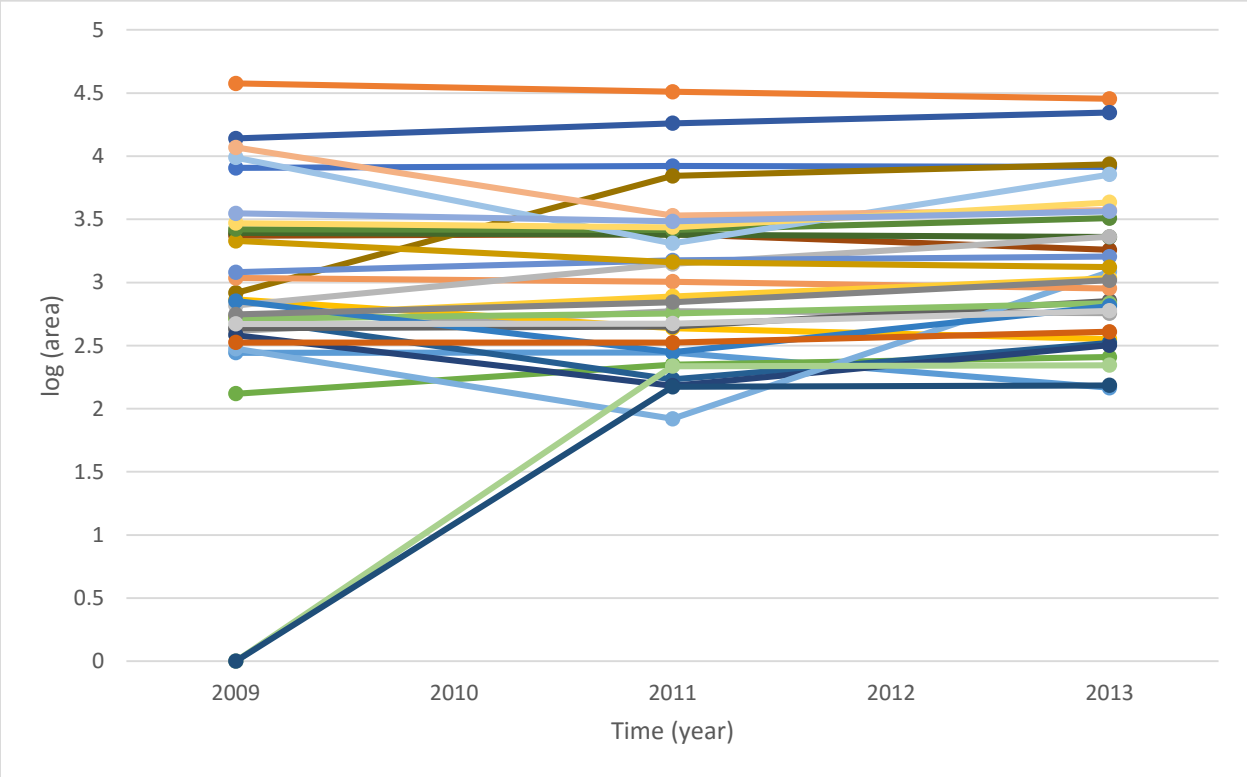


*Figure S1. The log of the area for analyzed highway populations between 2009 and 2013. Area was measured in m².*