Establishing a Wildlife Monitoring Framework for Schenck Forest: Lessons Learned

A Project Report

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Abstract:

Wildlife monitoring programs are important for monitoring changes in wildlife abundance and diversity and can be used to highlight specific patterns and possible drivers of population change. Data created from long-term monitoring projects can provide information to managers and researchers to guide management decisions and development of research hypotheses. Long-term wildlife monitoring projects can also provide opportunities for undergraduate students to gain important skills in preparation for future employment. I laid the foundation for a long-term wildlife monitoring project at the Carl Alwin Schenck Memorial Forest to both establish baseline data on wildlife populations and offer opportunities for hands-on learning by undergraduate students in the College of Natural Resources at North Carolina State University. I established 31 survey points within the forest where coverboards were placed and bird point counts were conducted. Additional surveys were conducted by students as part of several courses. Wildlife detections in 2021 included 96 bird species, 10 reptile species, 9 amphibian species, and 8 mammal species. Herein, I summarize a possible sampling framework for long-term monitoring, outline potential challenges and limitations of various survey methods, and describe examples of how to engage students in the process.

Introduction:

Long-term wildlife monitoring projects are important for observing changes in species abundance and diversity (Ingersoll et al., 2013; Stokes et al., 2010; Yoccoz et al., 2001). These monitoring programs fill gaps in knowledge and help to establish research questions by highlighting important observations and identifying spatial-temporal patterns in changes in wildlife populations (Burton, 2012; Nichols & Williams, 2006). Monitoring programs help to provide information to managers and researchers on the state of wildlife populations to guide conservation efforts or establish research hypotheses. Monitoring programs also establish whether wildlife populations have a positive or negative response to management activities and create a feedback loop that can be used in adaptive management to improve upon management practices (Stokes et al., 2010). Examples of large-scale monitoring projects include continent-wide efforts like the North American Breeding Bird Survey (USGS, 2021), and local-scale programs like the Hubbard Brook Ecosystem Study (Porzig et al., 2011). The Breeding Bird Survey has provided data to help monitor population changes of over 500 species of birds across North America and has helped to establish conservation strategies for multiple bird species.

Additionally, establishing an ongoing long-term monitoring framework can create learning opportunities for undergraduate students with interest in careers related to natural resources conservation. Experiential learning is impactful to student learning and helps prepare students for future employment (Flaherty et al., 2019; Millenbah and Millspaugh, 2003; Moen et al., 2000), especially in the realms of fieldwork, critical thinking, and the establishment of research questions. Documenting and understanding population status are important skills for students in wildlife management curricula (Sauer and Knutson, 2008). Hence, the Fisheries, Wildlife, and Conservation Biology (FWCB) program at North Carolina State University incorporates experiential learning in its undergraduate curriculum and requires students to reflect on what they learned. Examples of experiential learning in the FWCB program include the 6-week summer camp program, internships with appropriate agencies, and independent research. Each summer, there are 30 spots available for wildlife students to participate in summer camp, but with increased enrollment in the FWCB degree approximately ½ of enrolled students do not participate in the summer camp experience. Hence, it is becoming more difficult for students to participate in a wide diversity of hands-on activities.

Herein, I laid the foundation for a long-term wildlife monitoring project at the Carl Alwin Schenck Memorial Forest to both establish baseline data on wildlife populations and offer opportunities for hands-on learning by undergraduate students in the FWCB program at North Carolina State University.

Objectives:

The primary objective for my project was to develop a structure for long-term monitoring, with emphasis on engaging undergraduate students in the monitoring activities. My project established a monitoring framework on Schenck Forest due to its proximity to campus and the added benefit of university ownership. My primary objectives were to: 1) establish a wildlife monitoring framework along with suggested survey protocols, 2) create a baseline data set, especially through avian point counts, and 3) store and share the framework and preliminary data so it is accessible to students in the FWCB program, the Department of Forestry and Environmental Resources, and the College of Natural Resources. I concentrated primarily on establishing avian monitoring through point counts and assisted with placing coverboards used to survey reptiles and amphibians.

Study Area

I established an ecological monitoring framework within the Carl Alwin Schenck Forest, a 115-hectare research and teaching forest operated by North Carolina State University (https://cnr.ncsu.edu/about/forests-facilities/). Schenck Forest was originally part of the North Carolina Camp Polk Prison Farm and was purchased in 1937 and named Richland Creek Forest. Two decades later, it was re-dedicated as the Carl Alwin Schenck Memorial Forest. The property includes a variety of forest types, including planted pine, natural pine, mixed hardwood, oak-pine woodland restoration, and bottomland hardwood. In addition, Richland Creek flows through the western section of Schenck Forest. North Carolina State University uses the property as an outdoor laboratory and demonstration site for multiple courses. Examples of management activities that occur in the forest include timber harvest, invasive plant control, and controlled burns. Because of these management strategies, there is the potential for a large diversity of wildlife. Monitoring wildlife within Schenck Forest can be used to demonstrate to students the changes in wildlife following specific management activities.

Methods

Sampling Grid

I created a grid to frame a standardized sampling area. I established a grid of points spaced 200m apart within the Schenck Forest boundary using the ESRI ArcGIS suite and Schenck boundary and stand type shapefiles provided through the University. I generated a 100-m buffer around each grid point. I removed any points where any portion of the buffer did not fall within the Schenck Forest boundary. This resulted in 38 points with associated buffer areas. Out of the 38 points, 31 points were used in the final framework to reduce the number of points occurring in pine stands, and to reduce the sampling time (Figure 1). Points were ground-truthed with a Garmin eTrex 20x GPS unit and marked with yellow or pink flagging for ease of location at later dates. All shapefiles were saved within a Geodatabase feature class and shared within the established Google drive (Appendix: Data 1).

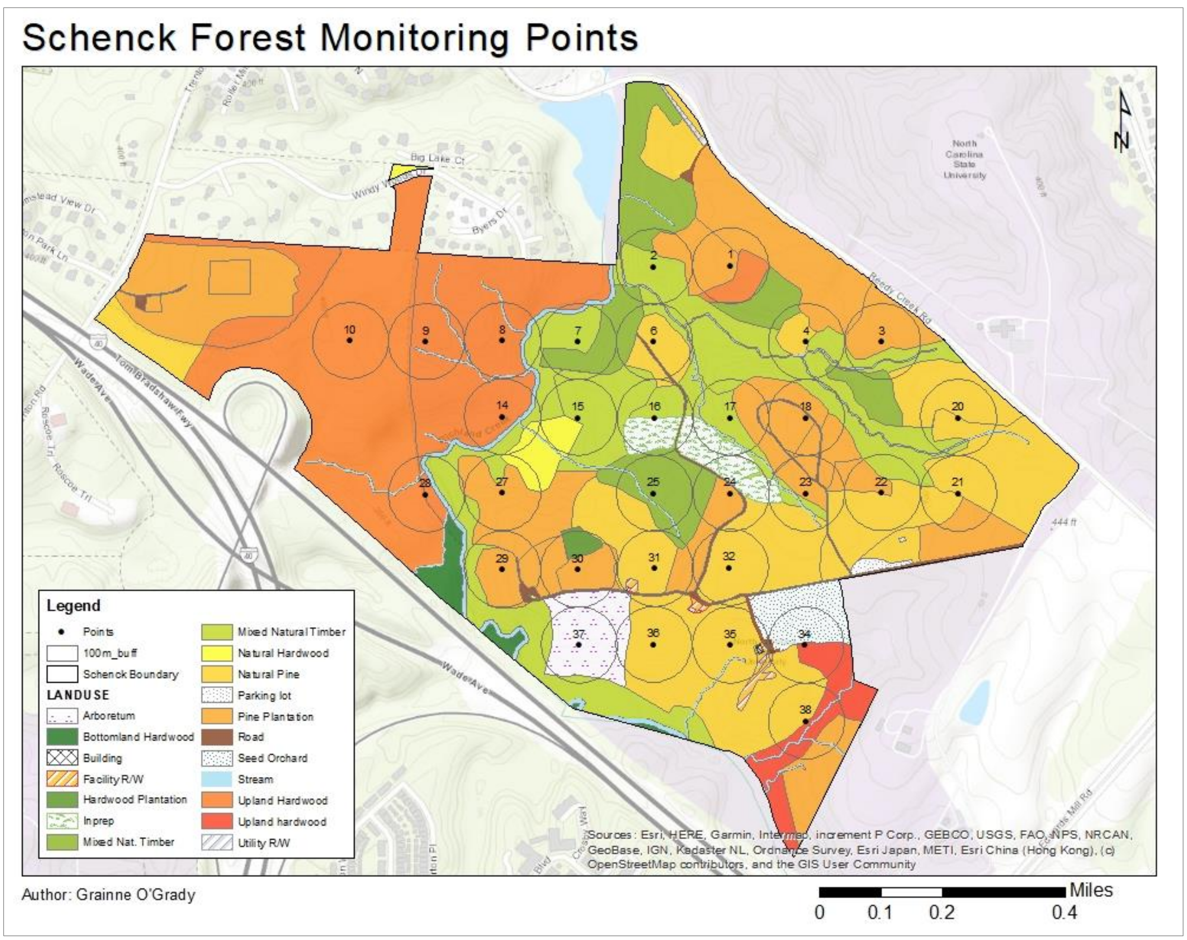

Figure 1: A map of Carl Alwin Schenck Memorial Forest. Colors depict forest cover types and points show locations of the 31 study points with the 100-m buffer.

Avian Point Counts

I conducted avian point counts at each grid point to serve as a baseline for comparison to future data gathered during monitoring activities. I conducted fixed-radius point count surveys at each of the 31 points from February - August 2021. I visited each point on 10 separate occasions between these dates. I conducted counts between sunrise and 3 hours after sunrise. I recorded all birds seen and heard for 5 minutes within a 100-m radius of each point. I recorded the species using a four-letter alpha code, the time of detection by minute, and the distance from the center point. For ease of recording, symbols were used to record the time of detection per minute on a target sheet (Appendix: Resources 1). In addition, I recorded temperature, cloud cover, and wind speed using protocols from the Breeding Bird Survey (USGS, 2021) as well as any additional pertinent notes (Appendix: Data 2). Point counts were not conducted during rain or constant wind speeds of greater than 8mph.

Coverboards, PVC frog tubes, and vegetation sampling

In the spring semester of 2021, I placed 4' x 4' wooden coverboards (Image 1A) at 26 of the points east of Richland Creek. Initial checks of the coverboards were performed by students in the 2021 FWCB summer camp, but detections were sparse because the boards had limited time to season (i.e., develop the appropriate micro-climate favorable to many species). Polyvinyl chloride (PVC) frog tubes (Image 1B) also were placed along Richland Creek (Appendix: Data 3), although not at grid points, to create refugia for frogs (e.g., green treefrog, gray treefrog). These tubes collect small amounts of water that increase the humidity within the tubes. The coverboards and tubes can be checked every week or 2 for presence or absence of wildlife use. Lastly, I helped direct undergraduate students to measure vegetation structure and composition at a sub-sample of grid points. The vegetation sampling was organized as part of the spring 2020 Wildlife Techniques (FW 495) course. The students collected data at points 20-25, 31, 32, 35 and 38. A survey was conducted at each point and at a randomly selected point within the 100-m buffer. The vegetation surveys estimated basal area, understory cover, ground cover, canopy cover, tree diameter at breast height (dbh), and tree height. Basal area of pine and hardwood was measured with a 10-factor prism (Appendix: Data 4).

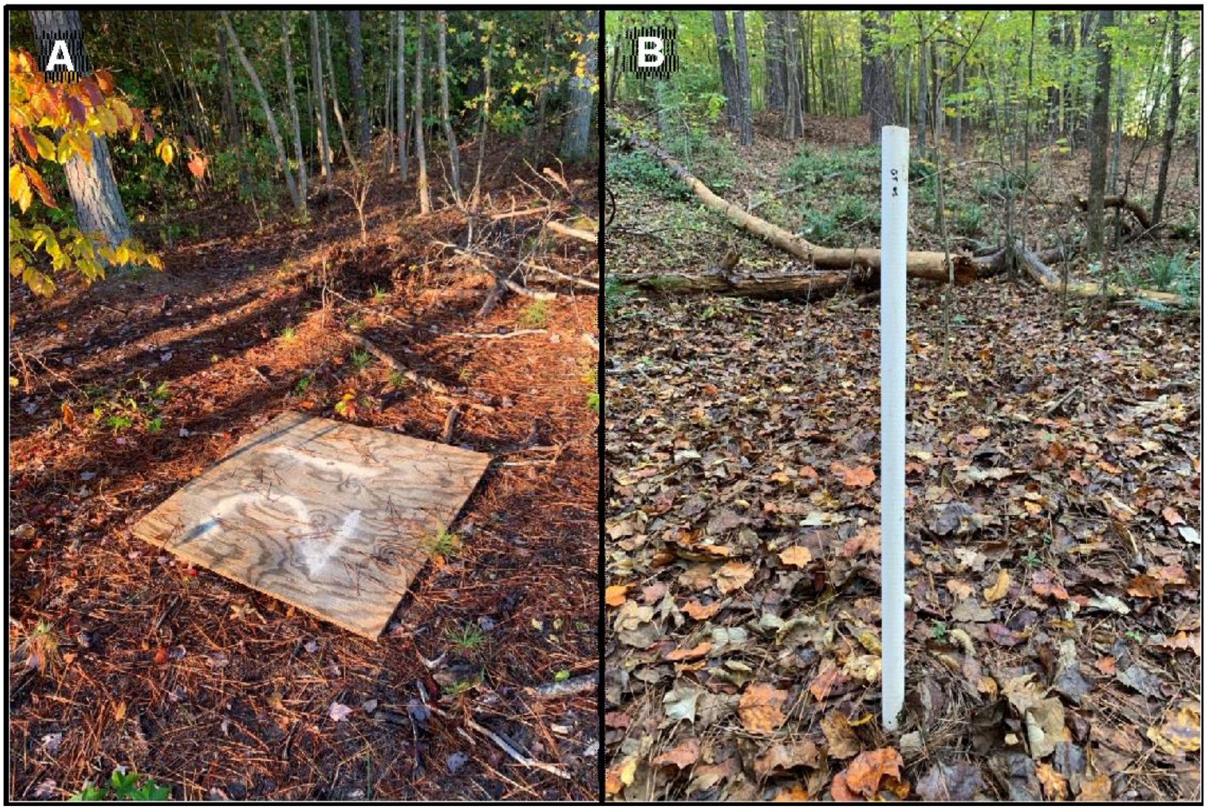

Image 1: A) An example of a coverboard placed at one of the survey points withing Schenck Forest. The number represents the point number. B) An example of a PVC frog tube placed along Richland's Creek in Schenck Forest.

Data Analysis

Although extensive data analysis was not part of this project, collected data could be analyzed in a variety of ways. For example, occupancy analysis for individual species or communities can be performed using data from bird point counts, frog tubes, wildlife camera traps, and coverboards. Additionally, bird point count data could be used to analyze differences in relative abundance among forest types, stand ages, and forest management practices, and over time and among seasons.

Initial Observations from Monitoring

During avian point counts, I detected 76 species, not including flyovers (Table 1 and Appendix: Data 5). The most frequent detections were Carolina chickadee (*Poecile carolinensis*), northern cardinal (*Cardinalis cardinalis*), and tufted titmouse (*Baeolophus bicolor*).

Student Involvement

In the spring and summer of 2021, undergraduates conducted wildlife, insect, and vegetation surveys as part of 3 courses. In the spring, as part of FW 495 Wildlife Techniques, and in the summer during the FW 311 and FOR 264 summer camp courses, students detected 96 bird species, 10 reptile species, 9 amphibian species, 8 mammal species, 23 invertebrates from 10 orders, and 126 plant species. (Appendix: Data 6). Data was collected by students using Sherman traps, camera traps, and mist nets during bird banding, and during bird walks and stream surveys. Notable observations included an active great horned owl (*Bubo virginianus*) nest, a larval red salamander (*Pseudotriton ruber*), and a prothonotary warbler (*Protonotaria citrea*) captured while bird banding.

Moving Forward

<u>Avian Point Counts</u>

For long-term monitoring, avian point counts should be conducted throughout the year with more frequent visits during migration events. Point count visits should occur minimally once a month at each point for there to be a running baseline of data to show species richness including species with low detection probabilities (Sliwinski et al., 2016). This data would be detailed enough to show population and community changes among seasons, and across different forest types and management scenarios. Visits could be adjusted to accommodate specific research questions and associated experimental designs. Potential challenges with this survey method are observer inexperience with avian detection by sound, and the difficulty of estimating distance. To improve the quality of data collected, students should become familiar with bird songs or calls before conducting point counts. Fortunately, there are references to aid in learning how to identify birds by sight and sound. Multiple guides, websites, and apps are available, including Merlin Bird ID, Dendroica, and the Patuxent Bird Quiz (Appendix: Resources 2).

<u>Coverboards</u>

Coverboards are used to check for the presence of reptile and amphibian species known to seek surface cover (e.g., downed logs). Sampling should be timed based on the activity levels of focal taxa. For example, reptile activity will be greatest during warmer months between May and November and salamander activity will be greatest during cooler months between September and

March. Ideally, if possible, coverboards should be checked weekly or at least every 2 weeks if weekly visits are not possible (Retamal Diaz and Blouin-Demers, 2018). The addition of tin coverboards paired with the wooden coverboards may increase the detection of reptiles (Hampton, 2007).

<u>Other Possible Sampling Methods</u>

Leaf litter traps may be used to sample aquatic salamanders or larval stages of semi-aquatic species (Waldron et al., 2003). Leaf litter bags are made of plastic netting with openings between ¼"- ¾" inch. These bags are filled with leaf litter and placed in a stream and anchored to the bank, so they do not float away. The traps would be placed and left for 3 to 4 days and then checked. Leaf litter trapping could be conducted every few months.

Pitfall traps - Drift fences with pitfall traps can be used for both reptile and amphibian capture and may also capture small mammals such as shrews (Umetsu et al., 2006). Pitfall traps could be placed within the 100-m buffers of each grid point. A standard drift fence and pitfall trap design consists of a Y-shaped array with 3 arms extending from a central point and 5-gallon buckets buried flush with the ground at the center and at the end of each arm. Surveys could be done once a month and increased during active breeding months. Traps should be opened the night before and checked the following morning to decrease wildlife fatalities.

Frog Tubes - Frog tubes already are present along the Richlands Creek but additional tubes could be placed at a subset of grid points, which would increase the probability of detecting some species. The tubes can be checked every week or 2 from mid-summer to early fall for presence of treefrogs (Boughton et al., 2000)

Camera Traps - Camera traps are an increasing popular non-invasive method to monitor wildlife species occurrence and relative abundance, especially for medium-sized to large mammals (Ahumada et al., 2020; Kays et al., 2020). Previously, camera traps were deployed in Schenck Forest by undergraduates in the spring of 2021, and white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), gray squirrel (*Sciurus carolinensis*), Virginia opossum (*Didelphis virginiana*), and even barred owls (*Strix varia*) have been detected (image 2). It is most optimal to standardize camera type and model, position of the camera, and camera settings (Kays et al., 2020; Meek et al., 2014). I recommend that at least 1 camera trap be placed at each grid point during a portion of the year. Cameras should be checked once monthly to download images, reset the cameras, replace batteries, and test the cameras to make sure they are continuing to collect data. Data collection should follow the Camera Trap Metadata Standard (CTMS), which is described excellently in Forrester et al. (2016). A historic record of camera trap data for Schenck Forest is available via R. Kays (Appendix: Data 7).

Image 2: Camera trap photos captured during the spring FW 495 Wildlife Techniques course. top left) coyote (*Canis latrans*) detected at point 21; top right) raccoon (*Procyon lotor*) detected at point 22; bottom left) gray squirrel (*Sciurus carolinensis*) detected at point 23; bottom right) barred owl (*Strix varia*) detected at point 23.

Sherman Traps could be used to inventory small mammals, especially those too small to be effectively monitored with camera traps (Hayes et al., 1996). A Sherman trap, or multiple traps, can be placed at each grid point to capture presence or absence of species or gather a rough estimate of species richness. Conversely, traps could be placed out in a grid over a formal sampling period to estimate species-specific occupancy or density in association with grid characteristics (e.g., forest type, management history). Sampling could occur on 3-5 consecutive nights during appropriate weather conditions and ideally around the new moon (Prugh and Brashares, 2010). The traps should be placed or opened the afternoon before and baited then checked the following morning to reduce mortality.

Acoustic monitoring can be used to detect any vocalizing wildlife, including birds, bats, and frogs and toads (Larsen et al., 2021; Wimmer et al., 2013). Acoustic recorders should be placed near bodies of water to best detect bats (Rodhouse et al., 2011), possibly along Richlands Creek near canopy openings.

Bird banding could be employed to gather population data on birds and create an excellent hands-on opportunity for students. Multiple 12-m nets would be arranged with a net density of 1.5 nets per hectare (DeSante et al., 2021). Nets should be placed in areas where birds are most likely to be captured, including in young forest, dense understory, or along forest edges. Bird banding sessions could be performed at least once a month to monitor seasonal changes in bird communities. Banding effort could be increased during spring and fall migrations when community change is more rapid. Nets should be opened no earlier than 30 minutes before sunrise and closed once activity diminishes or when temperatures become too warm. Captured individuals would be banded and data would be recorded on the species, age, sex, and body condition (e.g., fat, molt, weight, wing chord). Mark-recapture analysis could be performed to estimate species-specific density or survival. Bird banding requires oversight by an individual with a Master banding permit issued by the USGS Bird Banding Lab.

<u>Student Involvement</u>

Undergraduates should be a driving force in the monitoring efforts. Undergraduate involvement in wildlife monitoring can be incorporated into existing FWCB courses, including FW 311 Summer Camp, FW 373 Vertebrate Natural History, FW 404 Wildlife Habitat Management, FW 453 Principles of Wildlife Science, and FW 495 Special Topics in Fisheries and Wildlife Science. The Leopold Wildlife Club, the NC State Student Chapter of The Wildlife Society, could also assist with continued monitoring. The club provides opportunities for professional development, networking, and extracurricular training for students interested in careers in fisheries and wildlife conservation. This monitoring project creates an additional resource for students to participate in collecting data and learn wildlife monitoring techniques. Additionally, multiple courses are offered for undergraduate students to gain formal research experience, including FW 293/294 Independent Study in Fisheries, Wildlife and Conservation Biology and FW 493/494 Independent Study in Fisheries, Wildlife and Conservation Biology. Projects and research questions can be developed for undergraduate research and independent studies using the existing monitoring data. There is a myriad of topics that could be researched, including: 1) distribution of specific species among vegetation types; 2) seasonal changes in detection rates of specific species; and 3) changes in wildlife diversity associated with forest management practices or among different seral stages in Schenck Forest.

Limitations of Survey Methods

There is a risk with long-term monitoring because, although the intentions are good, sometimes it only creates an illusion that something useful was done. Numerous authors have warned about why monitoring programs often fail due to poor survey design, poor data quality, lack of detail-oriented goals, and poor hypothesis formation (Legg and Nagy, 2006). Conversely, others have described how monitoring can be done effectively when it is adaptive (Haughland et al., 2010; Lindenmayer & Likens, 2009; Nichols & Williams, 2006). Adaptive monitoring is essential for long-term monitoring programs because no matter how much planning goes into developing protocols, changes and improvements will need to be made for field methodology, data collection, and data analysis. Multiple limitations should be considered for monitoring at Schenck Forest.

1) Time is one of the greatest limitations. It takes a substantial amount of time to collect and process data. For example, on average it took me 8 hours (spread over 3 days) to complete 1 visit to each of the 31 points in Schenck Forest. Student availability also changes based on the semester with breaks between semesters and holidays. Limited time could limit the amount of wildlife monitoring that can be accomplished, especially in the summer and winter holidays when students are no longer on campus.

2) Safety is always a limitation for wildlife monitoring. Students should be trained by an experienced individual before handling equipment or wildlife to limit injuries to the student and decrease wildlife injury or fatalities.
3) Road noise was a constant presence at all survey points, due to the close proximity to Wade Avenue and Edwards Mill Road. Hence, I recommended to not conduct aural surveys at points closest to Wade Avenue or to adjust data analysis to account for the decreased rate of detection due to ambient noise. The 3 points that I suggest being removed or adjusted are points 28, 29, and 37 (Figure 1).
4) High human activity could be a challenge because Schenck Forest is also a popular location for the public to visit. Human presence can be an issue when conducting some types of wildlife monitoring. For example, multiple times coverboards closest to trails were moved from their original location or lifted and not returned. Hence, I recommend all monitoring equipment by marked clearly with "Do not disturb" or "research in progress" or additional signage about ongoing monitoring be erected in areas of greater foot traffic. Challenges with visitor interactions are likely to increase with the establishment of the new Bandwidth headquarters across from the forest entrance. It's also possible that a larger presence of the public could mean that some monitoring practices, including bird banding or the use of live traps, could be viewed negatively.

Conclusion

The establishment of a long-term wildlife monitoring protocol at Schenck Memorial Forest will be beneficial to students, instructors, and managers by providing hands on learning opportunities and accessible baseline data. As the area in and around the forest changes from increased urbanization, the collected data can help determine changes in wildlife diversity and guide adaptive management plans.

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Literature Cited

Ahumada, J. A., Fegraus, E., Birch, T., Flores, N., Kays, R., O'Brien, T. G., Palmer, J., Schuttler, S., Zhao, J. Y., Jetz, W., Kinnaird, M., Kulkarni, S., Lyet, A., Thau, D., Duong, M., Oliver, R., & Dancer, A. (2020). Wildlife Insights: A Platform to Maximize the Potential of Camera Trap and Other Passive Sensor Wildlife Data for the Planet. *Environmental Conservation*, *47*(1), 1–6. https://doi.org/10.1017/S0376892919000298

Boughton, R. G., Staiger, J., & Franz, R. (2000). Use of PVC Pipe Refugia as a Sampling Technique for Hylid Treefrogs. *The American Midland Naturalist*, *144*(1), 168–177. https://doi.org/10.1674/0003-0031(2000)144[0168:UOPPRA]2.0.CO;2

Burton, A. C. (2012). Critical evaluation of a long-term, locally-based wildlife monitoring program in West Africa. *Biodiversity and Conservation*, *21*(12), 3079–3094. https://doi.org/10.1007/s10531-012-0355-6

DeSante, D. F., Burton, K. M., Kaschube, D., Velez, P., Froehlich, D., & Albert, S. (2021). *MAPS Manual*. 92.

Flaherty, E. A., Day, C. C., Urbanek, R. E., Wood, D. M., D'Acunto, L. E., Quinn, V. S., & Zollner, P. A. (2019). Mentored conference experiences support students' career exploration and professional development. *Wildlife Society Bulletin*, *43*(4), 565–575. https://doi.org/10.1002/wsb.1013

Forrester, T., O'Brien, T., Fegraus, E., Jansen, P. A., Palmer, J., Kays, R., Ahumada, J., Stern, B., & McShea, W. (2016). An Open Standard for Camera Trap Data. *Biodiversity Data Journal*, *4*. https://doi.org/10.3897/BDJ.4.e10197

Hampton, P. (2007). A comparison of the success of artificial cover types for capturing amphibians and reptiles. *Amphibia-Reptilia*, *28*(3), 433–437. https://doi.org/10.1163/156853807781374809

Haughland, D. L., Hero, J.-M., Schieck, J., Castley, J. G., Boutin, S., Sólymos, P., Lawson, B. E., Holloway, G., & Magnusson, W. E. (2010, April 1). *Planning forwards: Biodiversity research and monitoring systems for better management*. https://www.sciencedirect.com/science/article/pii/S0169534709003474

Hayes, J. P., Adam, M. D., Anthony, R. G., & Witt, J. W. (1996). Comparison of the Effectiveness of Sherman and Modified Fitch Live-Traps for Capture of Small Mammals. *Northwestern Naturalist*, *77*(2), 40. https://doi.org/10.2307/3536617

Ingersoll, T. E., Sewall, B. J., & Amelon, S. K. (2013). Improved Analysis of Long-Term Monitoring Data Demonstrates Marked Regional Declines of Bat Populations in the Eastern United States. *PLoS ONE*, *8*(6), e65907. https://doi.org/10.1371/journal.pone.0065907

Kays, R., Arbogast, B. S., Baker-Whatton, M., Beirne, C., Boone, H. M., Bowler, M., Burneo, S. F., Cove, M., V., Ding, P., Espinosa, S., Sousa Goncalves, A. L., Hansen, C. P., Jansen, P. A., Kolowski, J. M., Knowles, T. W., Moreira Lima, M. G., Millspaugh, J., McShea, W., Pacifici, K., … Spironello, W. R. (2020). An empirical evaluation of camera trap study design: How many, how long and when? *Methods in Ecology and Evolution*, *11*(6), 700–713. https://doi.org/10.1111/2041-210X.13370

Larsen, A. S., Schmidt, J. H., Stapleton, H., Kristenson, H., Betchkal, D., & McKenna, M. F. (2021). Monitoring the phenology of the wood frog breeding season using bioacoustic methods. *Ecological Indicators*, *131*, 108142. https://doi.org/10.1016/j.ecolind.2021.108142

Legg, C. J., & Nagy, L. (2006). Why most conservation monitoring is, but need not be, a waste of time. *Journal of Environmental Management*, *78*(2), 194–199. https://doi.org/10.1016/j.jenvman.2005.04.016

Lindenmayer, D. B., & Likens, G. E. (2009). Adaptive monitoring: A new paradigm for long-term research and monitoring. *Trends in Ecology & Evolution*, *24*(9), 482–486. https://doi.org/10.1016/j.tree.2009.03.005

Millenbah, K. F., & Millspaugh, J. J. (2003). Using Experiential Learning in Wildlife Courses to Improve Retention, Problem Solving, and Decision-Making. *Wildlife Society Bulletin*, *31*(1), 127–137.

Moen, A., Boomer, S., & Runge, M. (2000). Professional Development of Undergraduates in Wildlife Ecology and Management. *Wildlife Society Bulletin*, *28*(1), 180–190.

Nichols, J. D., & Williams, B. K. (2006). Monitoring for conservation. *Trends in Ecology & Evolution*, *21*(12), 668–673. https://doi.org/10.1016/j.tree.2006.08.007

Porzig, E. L., Dybala, K. E., Gardali, T., Ballard, G., Geupel, G. R., & Wiens, J. A. (2011). Forty-five Years and Counting: Reflections from the Palomarin Field Station on the Contribution of Long-Term Monitoring and Recommendations for the Future. *The Condor*, *113*(4), 713–723. https://doi.org/10.1525/cond.2011.100214

Prugh, L., & Brashares, J. (2010). Basking in the moonlight? Effect of illumination on capture success of the endangered giant kangaroo rat. *Journal of Mammalogy*, *91*(5), 1205–1212. https://doi.org/10.1644/10-MAMM-A-011.1

Retamal Diaz, F., & Blouin-Demers, G. (2018). Northern Snakes Appear Much More Abundant in Old Fields than in Forests. *The Canadian Field-Naturalist*, *131*(3), 228–234. https://doi.org/10.22621/cfn.v131i3.1823

Rodhouse, T. J., Vierling, K. T., & Irvine, K. M. (2011). A practical sampling design for acoustic surveys of bats: Design of Acoustic Surveys of Bats. *The Journal of Wildlife Management*, *75*(5), 1094–1102. https://doi.org/10.1002/jwmg.151

Sauer, J. R., & Knutson, M. G. (2008). Objectives and Metrics for Wildlife Monitoring. *Journal of Wildlife Management*, *72*(8), 1663–1664. https://doi.org/10.2193/2008-278

Sliwinski, M., Powell, L., Koper, N., Giovanni, M., & Schacht, W. (2016). Research design considerations to ensure detection of all species in an avian community. *Methods in Ecology and Evolution*, *7*(4), 456–462. https://doi.org/10.1111/2041-210X.12506

Stokes, E. J., Johnson, A., & Rao, M. (2010). *Monitoring wildlife populations for management*. 109.

Strain, G. F., Raesly, R. L., & Hilderbrand, R. H. (2009). A comparison of techniques to sample salamander assemblages along highland streams of Maryland. *Environmental Monitoring and Assessment*, *156*(1–4), 1–16. https://doi.org/10.1007/s10661-008-0459-3
USGS, P. W. R. C. (2021). *North American Breeding Bird Survey*. https://www.pwrc.usgs.gov/bbs/

Umetsu, F., Naxara, L., & Pardini, R. (2006). Evaluating the efficiency of pitfall traps for small mammals in the Neotropics. *Journal of Mammalogy*, *87*(4), 757–765. https://doi.org/10.1644/05-MAMM-A-285R2.1

Waldron, J., Dodd, C. K., & Corser, J. (2003). Leaf litterbags: Factors affecting capture of stream-dwelling salamanders. *Applied Herpetology*, *1*(1–2), 23–36. https://doi.org/10.1163/157075403766451207

Wimmer, J., Towsey, M., Roe, P., & Williamson, I. (2013). Sampling environmental acoustic recordings to determine bird species richness. *Ecological Applications*, *23*(6), 1419–1428. https://doi.org/10.1890/12-2088.1

Yoccoz, N. G., Nichols, J. D., & Boulinier, T. (2001). Monitoring of biological diversity in space and time. Trends in Ecology & Evolution, 16(8), 446–453. https://doi.org/10.1016/S0169-5347(01)02205-4

Appendix

Data – Please copy and paste link into the web browser to access the file.

1. GIS Data: *Shapefiles and Geodatabase files of Schenck Forest. Excel files of Schenck forest vegetation cover type.* https://drive.google.com/drive/folders/1u79JLAMWLi70VOgApXecN5-VHCbM68AA?usp=sharing

2. Temperature, Wind, and Cloud Cover Data: *Environmental data collected during point counts between Feb – Aug 2021.* https://docs.google.com/spreadsheets/d/1ZjhrBCq1ebRPCdNkF0PBNB1OsinAEf3trc74fg0at3k/edit?usp=sharing

3. Frog Tubes: *Locations of each frog tube along Richlands Creek.* https://docs.google.com/spreadsheets/d/10NlWo_O8ILIIASxrd9yd9X3-5xZp2o0FhpEEBrreyrA/edit?usp=sharing

4. Vegetation Data: *Vegetation surveys performed on April 2021. Includes basal area, understory cover, ground cover, canopy cover, DBH, tree height. (Points sampled 17, 20-25, 31, 32, 35, 38)* https://docs.google.com/spreadsheets/d/1WrgEhsKWeJ_uv0K36esaomH9CjTTAbaRmuER1HkRbxI/edit?usp=sharing

5. Point Count Data – *all detections recorded during avian point counts between Feb – Aug 2021.* https://docs.google.com/spreadsheets/d/1F-dP5FPsFsIRJdxmIpp18nj2FTN3pjtvEfi20Mvi480/edit?usp=sharing

6. Species Detected – *An ongoing list of all species detected within Schenck Forest.* https://docs.google.com/spreadsheets/d/1_OvfyHvQRix7Ktt94EzYxX6yAxN0lY1FlrohD9kDlRM/edit?usp=sharing

7. Camera Trap Data – *Data provided by Dr. Roland Kays of historic camera trap detections in Schenck Forest. Includes years 2013, 2016-2020. (Includes data from Umstead Forest as well)* https://docs.google.com/spreadsheets/d/1D0qFw_fqy_GORLkRBXpfVSiCYKwJgEQs/edit?usp=sharing&ouid=112300538338717126981&rtpof=true&sd=true

8. Master Google Docs Shared Folder – *All data available for Schenck Forest wildlife monitoring project.*

https://drive.google.com/drive/folders/0AKWEtpBugRVQUk9PVA

Resources

1. Point Count Data Sheet
   https://docs.google.com/document/d/1xMaVT1TEU6CJ-WdMuJhZcAmQYN5Y3rBS/edit?usp=sharing&ouid=112300538338717126981&rtpof=true&sd=true

2. Bird Song Resources
   https://docs.google.com/spreadsheets/d/19nYl8EB7Wa6bC3cMXJ9m5Jgk7WiSwwTGAiuNTKqHYZI/edit?usp=sharing

Table 1. Birds detected during 5-minute point counts between February and August 2021.

Bird Species Detected	Feb	Mar	Apr	May	Jun	Jul	Aug
Acadian flycatcher				X		X	X
American crow	X	X	X	X	X	X	X
American goldfinch					X	X	X
American redstart				X		X	
American robin	X	X	X			X	X
barn swallow							X
black-and-white warbler			X	X			
black-throated blue warbler			X	X			
blue grosbeak			X	X	X	X	X
blue jay	X	X	X	X	X	X	X
blue-gray gnatcatcher		X	X	X	X	X	X
blue-headed vireo			X				
brown creeper	X	X	X				
brown-headed cowbird		X	X	X	X	X	
brown-headed nuthatch	X	X	X	X	X	X	X
Canada goose	X		X			X	
Carolina chickadee	X	X	X	X	X	X	X
Carolina wren	X	X	X	X	X	X	X
chipping sparrow	X	X	X	X	X	X	
common grackle				X			
common yellowthroat		X	X	X	X		
Cooper's hawk		X					
dark-eyed junco	X	X	X				
downy woodpecker	X	X	X	X	X	X	X
eastern bluebird	X	X	X	X		X	X
eastern phoebe		X	X	X			
eastern towhee	X	X	X	X		X	
eastern wood-pewee				X	X	X	X
fish crow		X		X			

golden-crowned kinglet	X		X	X			
great crested flycatcher				X	X	X	X
great horned owl		X	X				
hairy woodpecker			X	X			X
hermit thrush			X	X			
hooded warbler				X			
house finch	X		X		X	X	
house sparrow	X		X				
house wren			X				
Indigo bunting				X	X	X	X
killdeer					X		
Louisiana waterthrush			X	X			
mallard	X						
mourning dove	X	X	X	X	X	X	X
northern cardinal	X	X	X	X	X	X	X
northern flicker	X	X	X	X	X		X
northern parula		X	X	X	X	X	
ovenbird			X	X		X	
palm warbler			X	X			
pileated woodpecker	X	X					
pine warbler	X	X	X	X	X	X	X
purple finch		X					
purple martin				X		X	
red-bellied woodpecker	X	X	X	X	X	X	X
red-eyed vireo			X	X	X	X	X
red-headed woodpecker						X	
red-shouldered hawk	X	X	X	X			X
rough-winged swallow						X	
ruby-crowned kinglet	X	X	X				
ruby-throated hummingbird				X		X	
scarlet tanager				X			

song sparrow	X	X	X	X	X	X	
summer tanager			X	X	X	X	X
Swainson’s thrush				X			
swamp sparrow		X	X				
tufted titmouse	X	X	X	X	X	X	X
turkey vulture			X				
white-breasted nuthatch	X	X	X	X	X	X	X
white-eyed vireo			X				
white-throated sparrow	X	X	X				
winter wren	X	X					
wood thrush			X	X			X
yellow-bellied sapsucker	X		X				
yellow warbler		X					
yellow-breasted chat				X	X	X	
yellow-rumped warbler		X					
yellow-billed cuckoo					X		X

Table 2. Location, forest type and number of bird species detected at each point.

Point #	Latitude	Longitude	Forest Type	# Species
1	35.82158	-78.72746	Loblolly seed tree	30
2	35.82157	-78.72925	Mixed natural timber	32
3	35.82012	-78.72386	Shortleaf plantation	25
4	35.82013	-78.72566	Natural pine	32
6	35.82013	-78.72925	Natural pine	26
7	35.82013	-78.73105	Bottomland hardwood	30
8	35.82014	-78.73284	Upland hardwood	29
9	35.82013	-78.73464	Upland hardwood	24
10	35.82014	-78.73644	Hardwood	22
14	35.81869	-78.73284	Upland hardwood	23

15	35.81867	-78.73105	Mixed natural timber	24
16	35.81867	-78.72923	Upland hardwood	24
17	35.81867	-78.72746	Upland hardwood	25
18	35.81867	-78.72566	Genetics demo	25
20	35.81867	-78.72207	Natural pine	34
21	35.81722	-78.72207	Natural Longleaf Pine	34
22	35.81723	-78.72387	2004 Pine Plantation	32
23	35.81721	-78.72566	Silvicultural demo	24
24	35.81722	-78.72744	1981 Pine Plantation	28
25	35.81721	-78.72925	Mixed natural timber	21
27	35.81723	-78.73285	1983 Pine Plantation	23
28	35.81719	-78.73464	Upland hardwood	19
29	35.81576	-78.73285	1962 Pine Plantation	21
30	35.81576	-78.73105	1975 Pine Plantation	19
31	35.81577	-78.72924	Natural pine	20
32	35.81576	-78.72746	Natural pine	33
34	35.8143	-78.72568	Hardwood	27
35	35.8143	-78.72746	Natural pine	29
36	35.81432	-78.72927	Natural pine	19
37	35.8143	-78.73103	Mixed natural timber	23
38	35.81285	-78.725665	Hardwood	18