

# Assessing Urban Biodiversity With the eBird Citizen Science Project: A Course-Based Undergraduate Research Experience (CURE) Module

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## Abstract

The eBird citizen science module takes advantage of technology tools and online resources developed by the Cornell Laboratory of Ornithology (<http://ebird.org>) to achieve several learning objectives embedded in a semester-long upper-level biology course. These include defining and articulating correlates of species diversity; applying technology, natural history, and field-based skills to participate in citizen science; and collaborating in the design and implementation of a field study. As a charismatic group that has suffered global decline, birds are excellent model organisms for connecting students to their immediate environment and igniting interest in conservation and citizen science. This module has been field-tested in two lecture courses, including self-assessments by participating students. Here, I provide materials developed for the module such as mini labs to train students in using apps for bird identification, activities for experimental design and data analysis, and formats for final written reports. I also provide an overview of how I implemented the module in the context of two different upper level undergraduate courses: Conservation Biology and Introduction to Research. According to course assessments and student evaluations, this module successfully increased awareness of urban biodiversity and conservation, honed skills in experimental design, and inspired students to participate in citizen science. The eBird Citizen Science module may be adapted for high school groups or serve as a model for similar initiatives based on other citizen science platforms.

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## Learning Goal(s)

From the Ecology Learning Framework:

- What is biodiversity at the genetic, species, and functional (niche) level within an area, a biome, or on the earth?
- How do species interact with their habitat?
- What impacts do humans have on ecosystems?
- What can humans do to mitigate negative impacts they have on ecosystems?

From the Science Process Skills Learning Framework:

- Reading Research Papers
- Formulating Hypotheses
- Designing/Conducting Experiments
- Gathering Data
- Analyzing Data
- Communicating Results

## Learning Objective(s)

Students will be able to:

- Apply technology and field-based skills (such as bird identification and use of binoculars) to contribute to a citizen science database.
- Collaborate as part of a group in the design and implementation of a field study.
- Analyze and interpret original data.
- Communicate their results in the form of a written or oral report.
- Define species diversity and describe correlates of species diversity based on original data and the scientific literature.

## INTRODUCTION

Course-based undergraduate research experiences (CUREs) have been introduced across higher education as a strategy to make research opportunities available to a broader array of students (1,2,3). A large body of evidence indicates independent research experiences can improve student understanding, confidence, and awareness, leading to greater retention in STEM majors and increased interest in graduate studies (4,5,6,7). These benefits have been especially important for students from backgrounds that are historically underrepresented in the sciences (8,9,10). Here, I present materials and protocols developed for a CURE module focused on avian diversity in urban habitats. The module takes advantage of resources provided by the Cornell Lab of Ornithology eBird Project (11). Through the eBird CURE module, students contribute as citizen scientists to the eBird database while participating in an undergraduate research experience. In this way, the module expands upon the traditional focus of the CURE model by encouraging students to view their community as a living laboratory and introducing them to citizen science as a pathway toward scientific engagement (12).

Inspiring with their flight, color, and song, birds provide many ecosystem services and can serve as bioindicators of diversity, stability, and environmental contamination (13,14,15). For persons residing in urban areas, birds represent a positive and engaging component of local wildlife, which in turn can improve overall well-being and mental health (16). Like many organisms, population sizes of many bird species have declined with significant biological effects. North American populations alone have declined 29% since 1970, representing the disappearance of some 3 billion individuals (17). The fact that avian population losses are widespread, extending across multiple landscapes and taxonomic groups, suggests a broad array of interacting threats (17). In this light, every habitat that supports birds is important, and the question of how to improve land management for local avifauna has extended into urban environments (18,19,20,21). The eBird CURE module brings students face-to-face with one of the critical conservation challenges of our time and allows them to consider how habitat management in urban areas influence bird diversity and abundance.

Established in 2010, the eBird Project recruits citizen scientists to collect data on bird species year-round and on a global scale (11,22). As an open-access database, eBird can be used for research, education, and conservation. In general, citizen science projects facilitate collection of data over multiple spatial and time scales, making them a powerful tool for addressing landscape-level and global challenges such as biodiversity conservation and climate change (23). Citizen science data are most likely to contribute to published research if three criteria are met: (a) the data are sampled at large spatial scales and over long time periods, (b) they are publicly available, and (c) volunteers are trained in species identification methods (23). Public participation in citizen science already contributes tens of millions of dollars-worth of in-kind time to data collection activities, and established citizen science databases have facilitated a better understanding of global declines in wildlife populations, resulting in tangible conservation actions (17,22,23).

By contributing to citizen science projects such as eBird, students may collect data for one semester in a single location, but their observations become part of a long-term, large-scale,

publicly available data set. In this way, the CURE model can be envisioned as a mechanism to promote general scientific literacy and inspire all students to become citizen scientists, no matter what their profession of choice. With the number of citizen science opportunities expanding exponentially and the technology for participation becoming ever more accessible (23), opportunities abound for students to make life-long contributions to large-scale scientific projects. The model presented here focuses on avian biodiversity and eBird, but the protocols can be adapted to other citizen science platforms and taxa, such as insects and plants.

### *Intended Audience*

I designed this module for upper-level undergraduate biology students. To date, I have implemented the module in two different courses: *Conservation Biology* and *Introduction to Research*. Both are discussed here. The subject matter can be adapted for introductory ecology and environmental science courses as well as for high school classrooms (see Teaching Discussion below).

### *Required Learning Time*

The module consists of activities spread across 8-10 weeks, including 3 to 5 weeks of data collection. This time is divided into three parts: Introductory Mini-Labs, Field Research, and Data Analysis and Final Reports.

Three Introductory Mini-Labs familiarize students with birding skills and associated technology skills. Each mini-lab lasts 50 minutes and requires students to complete about 30 minutes of work ahead of class.

The Field Research component includes one experimental design session plus collection of field data. The period of data collection can vary, but I recommend 3-5 weeks with one 30- or 45-minute transect per week. In this module, we defined a transect as a walk through the focal habitat, reporting all birds identified during the timed period. Point observations, where students remain stationary for the observation period and identify birds observed from that point, may also be used.

The Data Analysis lab requires one 50-minute class period. To facilitate efficient use of class time, data must be collated beforehand in preparation for summarizing results and calculating diversity indices. Following the Data Analysis lab, students present their results through written and oral formats.

### *Prerequisite Student Knowledge*

As designed, the module is appropriate for undergraduate students with foundational knowledge equivalent to one semester of introductory biology (ecology/evolution) with laboratory. Working knowledge of essential software such as Excel is also useful, but not required for small data sets. If the data set to be analyzed is large, instructors should consider allowing extra time to complete data analysis to accommodate students unfamiliar with Excel.

### *Prerequisite Teacher Knowledge*

To teach this module, I recommend a background in ecology. The concept of biodiversity, particularly ecological determinants of biodiversity and how we measure diversity at the species level, is a core component.

Prior to implementing the module, I spent several weeks using eBird and Merlin Bird ID. I also familiarized myself with other resources available through the Cornell Lab of Ornithology. It's important to be comfortable with these tools, including how to use binoculars, before introducing them to students. I developed the eBird module as an experienced birder, having engaged in birding in a variety of contexts for a couple decades. For inexperienced birders, keep in mind many communities have active ornithological societies, such as chapters of the Audubon Society, whose members will likely be eager to work with your students. Do not hesitate to reach out for support, especially if you are a first-time birder.

A review of the literature on urban biodiversity prior to the course is not critical, but it is very helpful in facilitating development of a tractable hypothesis. Also, know your local landscape and scout out habitats near campus that students could use for sampling. Be ready to guide students toward a proper contextualization of their hypotheses and predictions by suggesting appropriate sites for their sampling protocol. In Kansas City, Missouri, we had a variety of options available close to campus. These included multi-use parks and nature preserves, as well as residential areas and the campus itself. Our campus is small, but a large university could provide a variety of on-campus habitats. Students may also want to consider similar habitats (e.g., multi-use parks) in different areas relative to the urban core (e.g., close to the urban center versus on the outskirts of the city). The urban ecology literature and in particular a growing body of work on avian diversity in urban areas can provide instructors and students with ideas for framing hypotheses (17,18,19,20,21).

## SCIENTIFIC TEACHING THEMES

### Active Learning

Students actively engage in learning concepts by collecting data on avian species diversity in their home community. After completing field activities during introductory labs, they collaborate in the design of a field project. They then implement their study, working in partners or small groups to collect and analyze their own data. Students interpret and communicate their results in the form of oral and written reports.

### Assessment

Because this was a semester-long module, I applied different assessment tools throughout implementation. In this section, I provide examples of these assessments, some of which are incorporated into the handouts provided in the supporting materials.

*Applied technology and field-based skills (such as bird identification and use of binoculars) to contribute to a citizen science database.* I assessed student skills in using binoculars, Merlin BirdID, and eBird in the Introductory Mini-Labs and quizzes. For example, as part of the first mini-lab, students completed a quiz over basic techniques of bird identification and external anatomy. As an assessment of their ability with Merlin BirdID, students used the app to identify model birds in the lab and on campus. Student contribution to the citizen science database was measured by the sum-total of birds reported as part of the class project. In the first semester I implemented this module, *Conservation Biology* students reported 368 individuals representing 33 species during five

weeks of data collection in eight urban habitats. In the second semester, *Introduction to Research* students reported 134 individuals representing 29 species during three weeks of data collection in three urban habitats.

*Collaborated as part of a group in the design and implementation of a field study.* I assessed this objective based on the overall success of the group project with respect to two criteria: whether the class identified and tested a clear hypothesis, and efficacy of group collaboration during data collection. With respect to the first measure, *Introduction to Research* students were more successful at identifying a clear hypothesis that they tested by gathering data from a small number of study sites. This also facilitated a better organization of group work in the field and more meaningful analysis and interpretation of the final data set. *Conservation Biology* students were enthusiastic about sampling a wide range of habitats across the city (and very successful in doing so), but had a harder time consolidating their efforts into a focused class question and hypothesis.

*Analyzed and interpreted original data.* I assessed this objective based on questions answered in the Data Analysis Lab completed by the students. The lab report included qualitative and quantitative analyses as well as questions regarding interpretation of the data. Qualitative analyses included detailed descriptions of habitats studied as well as natural history summaries of designated 'species of interest.' Quantitative analysis included calculation of the Simpson's Index and comparison of indices across habitats studied. At the end of the lab report, students wrote a brief summary of their results and provided a statement as to whether the results supported the class hypothesis. During the data analysis lab, students worked in small groups to complete the lab, but they submitted individual reports.

*Communicated their results in the form of a written report.* I assessed this objective based on individual written reports submitted by students at the end of the semester. The second semester I ran the module, I used a 'short form,' while in the first semester, I used a 'long form.' The short form is essentially a partial scientific paper that includes a statement of hypothesis and predictions as well as 'Results' and 'Discussion' sections. For the long form, students completed a habitat assessment based on the class data. The short form appeared more effective in terms of meeting the objectives of the module. By narrowing the focus of the written report, students could concentrate on the meaning of the data and better contextualize their study within a larger body of literature.

*Defined species diversity and articulated correlates of species diversity based on original data and the scientific literature.* Students addressed this objective by completing a report for the Data Analysis Lab. They also participated in class discussions and submitted final written reports. On the final exam for both courses, I included an essay question that asked students to apply what they learned from the CURE project to a habitat management scenario on the university campus. Finally, at the end of the semester, students completed a written self-assessment of what they learned about biodiversity from completing the research experience.



### *Inclusive Teaching*

A large body of evidence indicates undergraduate research experiences increase inclusivity in science education (1,2,3,8,9,10). To enhance the impact of the CURE model, I integrated group work throughout the module, encouraging students to divide tasks in ways that took advantage of diverse skill sets. For example, in the field students worked in pairs or small groups to collect data. Individuals more comfortable managing binoculars would spot birds while record keepers consulted Merlin Bird ID and kept notes.

When setting up experimental design and working groups, instructors must keep in mind time constraints, transportation needs, and mobility limitations that might affect students. For group projects, an important challenge is scheduling time outside of class when all members of the group are available. Field work, which must be amenable to a variety of factors including weather conditions, further complicates this effort. For this reason, I set aside dedicated class time for field data collection. When groups collected data at off-campus sites, we organized carpools to ensure everyone had a ride. For most of my students, mobility was not a limitation for walking transects. Also, some of our sites were wheel-chair accessible. However, as mentioned earlier walking transects is only one method of sampling. Spot-sampling, where the group remains in one place and records birds over a set period, is another option.

In situations where students cannot participate in group fieldwork, alternative plans should be developed. For example, one of my students was on maternity leave during the field work portion of the CURE project. Instead of joining an assigned group, she collected her own data on residential birds in her neighborhood. She then rejoined the class for data analysis, group discussion, and the final reports at the end of the semester. Many approaches can be taken to implementing this module. In the interests of inclusion, it is important to remain flexible and avoid a one-size-fits-all mindset.

As a citizen science platform with global reach, eBird appealed to all my students, who represented diverse racial, ethnic, economic, and international backgrounds. At the start of this project, none of my students had worked with birds, and some were skeptical of the project objectives. By the end of the semester, all had gained from and enjoyed the experience, as evidenced by assessment results as well as informal and formal feedback (see Teaching Discussion, below).

## **LESSON PLAN**

Prior to the first introductory mini-lab, I took 15-20 minutes of class time to give an overview of Cornell Lab of Ornithology's eBird Project and the eBird citizen science module (11). This included viewing a brief video about eBird (<http://ebird.org/home>). I also posted all module activities, links, associated assignments, handouts, and assigned readings online as part of our course Canvas section so students could access and review these at their convenience.

As described earlier, the CURE module is divided into three parts: Introductory Mini-Labs, Field Research, and Data Analysis and Final Report. Because I intended this module for lecture courses that do not have an external lab, all "mini-

labs" were designed to last one class period (50 minutes). Corresponding student handouts, including rubrics as appropriate, are provided in the supporting files.

### *Part I: Introductory Mini-Labs to Learn Field-Based Skills*

The Cornell Lab of Ornithology eBird website provides videos on birding that are short, engaging, and break down bird identification into simple steps that integrate well with Merlin Bird ID (11). My introductory mini-labs build on these videos to help students practice basic skills necessary to complete the field work for this module.

#### Mini-Lab 1: Size, Shape, and Color Pattern in Birds

##### *Pre-Lab Assignment*

Before class, students explored the eBird website on their own (Supporting File S1. Urban Biodiversity and eBird – Mini Lab on Size, Shape, and Color Pattern). They also downloaded Merlin Bird ID to their iOS or Android devices. Most importantly, they watched two ten-minute videos about birding on the Cornell Lab of Ornithology web site: Inside Birding, Size and Shape (<https://www.allaboutbirds.org/inside-birding/>) and Inside Birding, Color Pattern (<https://academy.allaboutbirds.org/inside-birding-color-pattern/>). Students completed a short quiz over both these videos.

##### *Merlin Bird ID*

At the beginning of the lab, we discussed important concepts from the videos; in particular, how size, shape, and color pattern are used to identify birds. We reviewed basic body parts of a bird, focusing on key external features. I issued binoculars to the students (10x36mm), introduced them to the parts of binoculars, and walked them through how to prepare binoculars for personal use. Basic binoculars were provided by the university's laboratory budget, with one set of binoculars shared between 2-3 students. The Cornell Lab of Ornithology also provides a short video on adjusting binoculars and using them to spot birds that served as a useful supplement for this lab.

Working first with bird models in the classroom, I walked students through the steps used for identification with Merlin BirdID. Students then collaborated in pairs to identify model birds placed in different habitat contexts on campus (Supporting File S1. Urban Biodiversity and eBird – Mini Lab on Size, Shape, and Color Pattern). I have holiday ornaments I used for the lab, but cardboard cutout models could be made, for example, by using photos obtained online. For this activity, one student used binoculars, while a second entered information into Merlin BirdID. Students switched tasks during the activity, so everyone had a chance to practice with both binoculars and the app. Because we were working with models, I instructed students not to press the "This is my bird!" button on Merlin BirdID, as the app uses this feedback to update its algorithms.

#### Mini-Lab 2: Using Merlin BirdID

##### *Pre-Lab Assignment*

Before coming to class, students watched two more 10-minute videos about birding: Inside Birding: Behavior (<https://academy.allaboutbirds.org/inside-birding-behavior/>) and Inside Birding: Habitat (<https://academy.allaboutbirds.org/inside-birding-habitat/>). Again, students completed a short quiz over these videos.

### *Field Activity*

For this lab, we met at a park near campus. Students worked with partners to identify 5 birds using Merlin Bird ID (Supporting File S2. Urban Biodiversity and eBird – Mini Lab for Using Merlin Bird ID). They also used the app to access natural history information about the birds they identified. Because my classes were small (14-16 students), I could give students individualized attention to confirm identifications and answer questions in the field. As part of the exercise, students also self-assessed the degree of certainty they felt for each identification. They considered implications of false identifications when contributing to a citizen science database. Students then engaged in a group discussion about the ethics of data collection and the importance of not reporting a species unless certain about the identification.

### Mini-Lab 3: eBird Field Protocol

#### *Pre-Lab Assignment*

Before lab, students signed up for an eBird account at <https://ebird.org> and downloaded the eBird app to their iOS or Android device. They also designated a notebook to use as their field notebook.

#### *Field Activity*

We met at a park near campus. I introduced students to the eBird app and walked them through the steps of starting their transect, reporting birds, and submitting their lists to eBird. Students then worked in partners to practice a standard field protocol for collecting data (Supporting File S3. Urban Biodiversity and eBird – Mini Lab for Using eBird). They walked a transect, defined as 30-minutes along a trail in the habitat. They recorded birds they sighted and positively identified during this time. I emphasized that while in the previous field exercise, students had to find a certain number of birds (five), here the sampling protocol would likely result in different numbers of individuals and species reported by each group. In addition to reporting species and number of individuals with the eBird app, students used a small field notebook to keep a paper record of their bird list, as well as date, time, location, and weather information.

### *Part II: Experimental Design and Field Investigation*

#### Pre-Lab Preparation

By the time we began experimental design, students had read and taken notes on at least one representative primary literature article on urban ecology and/or bird diversity (e.g., 17, 18, 19, 20 or 21). Reading primary literature was an important precursor to experimental design as it gave students a framework for considering different hypotheses regarding correlates of avian diversity.

#### Mini-Lab on Experimental Design

We began the mini-lab with a discussion of the reading assignment. Based on this discussion, students identified factors that might influence urban avian diversity. These factors included amount of tree cover, understory vegetation, density of construction or parking lots, and socioeconomic status of the neighborhood (18,19,20,21). They used this list as a point of departure to brainstorm potential patterns of bird diversity in Kansas City, Missouri. As part of this discussion, students identified habitats to include in their study. For example, one of my classes asked whether different categories of parks supported distinct avifauna relative to residential areas. For

this study, they compared three sites: a multi-use park, an urban nature reserve, and a residential area. They developed a null hypothesis of no difference between these areas, with an alternate hypothesis that the nature reserve would house the greatest abundance and diversity of birds, with multi-use parks second and residential areas lowest in terms of diversity and abundance. Once the question and hypothesis were identified, protocols for data collection were defined and agreed upon. I used these protocols to develop a detailed handout with instructions for class data collection (Supporting File S4. Urban Biodiversity and eBird – Sample Field Protocol).

#### Data Collection

For data collection, I organized students into teams of 4-5 based on complementary field skills as assessed during the mini-labs, as well as site preferences, transportation needs, and other information provided by students in a confidential questionnaire. Each team collected data once a week in habitats designated by the class experimental design (Supporting File S4. Urban Biodiversity and eBird – Sample Field Protocol). Data collection was conducted during regular class time. Teams submitted the following every week: a copy of their eBird lists, a screen shot of the transects they walked (mapped by eBird), and a selfie of the group in the habitat. Weekly submission of transect data constituted a critical portion of the module grade. Late transects or duplicate transects done during the same week did not count toward course credit. During the data collection period, I accompanied each team at least once in the field to support and supervise their work.

### *Part III: Data Analysis and Final Report*

#### Pre-Lab Assignment

Prior to the mini-lab on data analysis, student data was summarized on an Excel template (Supporting File S5. Urban Biodiversity and eBird – Sample Data Template for Data Analysis Lab). In addition, students read and took notes on at least 3 primary literature articles relevant to the study. Review of the literature provided students with background information to assist in interpreting their results and prepared them for writing their final report.

#### Mini-Lab: Assessing Bird Diversity at an Urban Field Site

Students worked in groups to complete qualitative and quantitative analyses of the class data (Supporting File S6. Urban Biodiversity and eBird – Mini Lab for Data Analysis). Qualitative analysis included habitat descriptions as well as a discussion of the natural history of species of interest. Quantitative analysis included calculation of the Simpson Diversity Index. In the interest of time management, each team did an in-depth analysis of only one habitat sampled during the study. Results for all habitats were then shared with the entire class in brief oral presentations from each group. I led the class in a discussion focused on comparing the results with their initial hypothesis. Students submitted their preliminary analysis and conclusions as a group lab report.

#### Final Written Report

As a final comprehensive assessment, students submitted a final written report. The structure of the written report differed between semesters. Introduction to Research students assessed whether the data supported the class hypothesis that focused on, comparing bird diversity between different urban habitats

(Supporting File S7. Urban Biodiversity and eBird – Instructions and Rubric for Final Written Report, Short Form). Conservation Biology students completed a habitat assessment (S8. Urban Biodiversity and eBird – Instructions for Final Written Report, Long Form). In both cases, students were expected to situate their results in the context of other studies of urban bird diversity and make recommendations for future research.

## TEACHING DISCUSSION

In this section, I discuss three dimensions of implementing the eBird CURE module: introducing students to necessary field and analytical skills; student response to the module; and alternative formats for undergraduate and high school classrooms.

### *Field and Analytical Skills*

Merlin Bird ID together with associated media developed by the Cornell Lab of Ornithology provided the key to making this aspect of the module work. Brief and engaging videos broke down bird identification into a handful of simple concepts, namely size, shape, color pattern, behavior, and habitat. Merlin Bird ID applies these same concepts, along with location and time of year, to narrow options down to a handful of species that can be matched to birds commonly seen in urban areas like Kansas City, Missouri. The app also provides several photos of each species – males, females, and juveniles at different times of year – along with natural history information and recordings of songs and calls. Using Merlin Bird ID, students correctly identified birds in the field on the first or second attempt during introductory field exercises. On the evaluation at the end of the semester, 100% of the students agreed the module was effective in teaching them how to bird, and that Merlin Bird ID was an effective tool for learning bird identification.

As a safeguard against false IDs, the eBird app red flags any species identification that appears out of place in real time. For example, if a user reports a species that should not be in Kansas City in November, eBird demands verification before accepting the data. Throughout the project, I made it clear to my students that any bird they could not positively identify should not be included in their data. Students understood the accuracy of their checklist was much more important than the number of species reported. Awareness of the global nature of eBird instilled a great sense of personal responsibility, making the eBird module an effective vehicle for emphasizing integrity in data collection. For instructors uncomfortable with students uploading data to eBird, this module could be conducted using Merlin Bird ID for identification and keeping data in a field notebook, though this would eliminate the citizen science aspect of the module.

In my courses, the data analysis lab coincides with coverage of diversity indices in lecture and textbook readings (24). An introduction to the concept of diversity and how diversity indices capture and communicate this concept is fundamental for facilitating student understanding and interpretation of the data. As advanced biology students, my students also had working knowledge of Excel, although most calculations could be done with a hand calculator. Having students calculate diversity indices based on their own observations made concepts of richness and evenness more tangible. On an

end-of-semester student evaluation, most students agreed or strongly agreed with the statement, “I learned how biological diversity is quantified (measured and analyzed) as a result of this project.” Students also performed well on the lab reports, group presentations, and diversity-related questions on the final exam. Overall, the degree to which students demonstrated proficiency in knowledge and skills related to biodiversity as a result of this module exceeded my expectations.

### *Student Response to the Module*

At the end of both courses in which this module was implemented, students completed a written self-assessment (Supporting File S9. Urban Biodiversity and eBird – Sample Student Self-Assessment). Across both courses, most respondents agreed or strongly agreed with the statement, “I have a better understanding of the importance of urban habitats for conservation as a result of this project.” In response to this question, “What were three important things you learned as a result of the eBird module?” students in *Conservation Biology* most often mentioned how to identify birds and the importance of bird diversity and conservation. When asked this same question, *Introduction to Research* students were more likely to focus on experimental design and the process of science.

The eBird module did not, in all cases, motivate students toward continued birding, but it did ignite a strong interest in citizen science. Across both courses, most students expressed appreciation of the opportunity to learn about the Cornell Lab of Ornithology. Similarly, most agreed or strongly agreed with the statement, “I would like to learn about other citizen science projects.” Finally, the majority of students agreed or strongly agreed with the statement, “I can imagine myself participating in citizen science projects in the future.”

Students provided insightful suggestions for improvement, which varied between semesters. Examples of student suggestions included longer or more weekly transects, additional time to collate and interpret the data, and greater contextualization in terms of regional and historic patterns of avian diversity. Several suggestions from the first semester (*Conservation Biology*) were incorporated in the second semester (*Introduction to Research*).

### *Alternative Formats*

This module was designed to test hypotheses about correlates of urban biodiversity particularly as relates to bird communities. *Introduction to Research* students chose to do a habitat comparison, assessing diversity in different types of parks (multi-use and natural reserve) and comparing these to a residential area. Other correlates of urban avian diversity that have been identified in the literature could be tested with similar protocols (16,18,19,20,21). For example, students could look at parks of different sizes or compare residential areas at different distances from the urban core. They could also consider avian diversity in neighborhoods of different socio-economic status.

College-level courses must be completed inside of one semester. For this reason, adaptation of the module to the high school level could allow a relaxation of the time frame. Instructors could focus fall semester on developing field skills and getting to know the local bird community. The formal



class project could then be implemented in the spring. High school instructors should consider using only Merlin BirdID and having students keep bird lists in field notebooks. This eliminates the citizen science aspect of the module, but it simplifies many tasks for the students, in particular those involved in accessing and communicating their online data. Data analysis could also be simplified by focusing on species richness (number of species) and overall abundance (numbers of individuals) rather than calculating diversity indices. Group oral reports or poster presentations could replace formal written reports. As a closing activity, the eBird Project and app could be introduced to the class to inspire them to continue birding. Depending on timing of semester activities, the class could also participate in eBird's annual Global Big Day, as a way to celebrate the completion of their class project (<https://ebird.org/globalbigday>).

Where considerations of time, transportation, or other logistical constraints limit options for a hypothesis-testing approach, instructors could consider a habitat assessment, as was done in my *Conservation Biology* class. Rather than testing a priori hypothesis, the class - or working groups within the class - focus on a single site of interest. Students gather data on bird abundance and diversity. Then based on this data and habitat characteristics, students make inferences about the importance of that site for bird conservation. Such an approach can be used to generate hypotheses based on the students' own observations. It can also be used to build long-term class data sets for campus avifauna or other sites of special interest. A sample format for the habitat assessment approach is provided in S8. Urban Biodiversity and eBird – Instructions for Final Written Report, Long Form.

Finally, I crafted this module around the eBird citizen science platform. However, multiple citizen science platforms are available that can be used to set up similar projects with other taxa. One example is iNaturalist (<http://iNaturalist.org>). Instructors who would like to develop diversity modules based on insects, plants, or other organisms accessible in their students' home environment are encouraged to explore these options for identification and data collection.

### Summary and Conclusion

Using technologies such as eBird and Merlin Bird ID, participating students collected, analyzed and interpreted data on avian biodiversity in different urban environments. While completing their group project, students also contributed to a real-world, global citizen science database. The eBird connection proved an important motivational factor. As evidenced by student feedback, eBird inspired many students to continue birding and all students to consider other citizen science initiatives. This module can be used to achieve ecology learning goals related to biodiversity and human impacts on biodiversity, as well as scientific process goals related to designing and conducting experiments, gathering and analyzing data, and communicating results. The module was field-tested in two upper level biology courses, *Conservation Biology* and *Introduction to Research*, but it can be adapted for introductory ecology/environmental science courses as well as for high school students.

### SUPPORTING MATERIALS

- **S1. Urban Biodiversity and eBird – Mini Lab on Size, Shape and Color Pattern.** Contains instructions for activities designed to introduce students to basic bird anatomy, binoculars, and Merlin BirdID. Handout contains a pre-class assignment and instructions for in-class and field activities.
- **S2. Urban Biodiversity and eBird – Mini Lab for Using Merlin BirdID.** As a follow-up to “Size, Shape and Color Pattern,” this handout contains a pre-class assignment and field activities designed to give students the opportunity to use Merlin BirdID to identify birds in the field.
- **S3. Urban Biodiversity and eBird – Mini Lab for Using eBird in the Field.** This lab introduces students to the eBird app. The handout includes a pre-class assignment and field activities. Students collaborate in pairs or small groups to spot birds in the field, use Merlin BirdID to identify birds, and enter their results using the eBird app.
- **S4. Urban Biodiversity and eBird – Sample Field Protocol.** This handout describes the methods established for one class project based on this module.
- **S5. Urban Biodiversity and eBird – Sample Data Template for the Data Analysis Lab.** Prior to the data analysis lab, class data must be collated to facilitate efficient use of class time. This is a sample template that was used to collate data for one class project. This data template corresponds to the project described in the Sample Field Protocol described in Supporting File S4. Urban Biodiversity and eBird – Sample Field Protocol.
- **S6. Urban Biodiversity and eBird – Mini Lab for Data Analysis.** Instructions for the in-class lab where students summarized and analyzed data from their checklists. Students worked in groups to complete qualitative and quantitative analyses, including a calculation of Simpson diversity indices. Results were then shared between groups.
- **S7. Urban Biodiversity and eBird – Instructions and Rubric for Final Written Report, Short Form.** Instructions for how to write the final written report in an abbreviated scientific format. This handout applies to class projects that test a hypothesis. Includes a grading rubric.
- **S8. Urban Biodiversity and eBird – Instructions for Final Written Report, Long Form.** Constraints such as student interests, time, weather, transportation, etc., may impact the ability to implement a class project that tests a clear hypothesis. This handout provides an alternative approach for writing the final written report as a habitat assessment. Includes a grading rubric.
- **S9. Urban Biodiversity and eBird – Sample Student Self-Assessment.** Copy of the questionnaire I provided to students for their end-of-semester evaluation of the module.

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**Table 1. Assessing Urban Biodiversity Teaching Timeline**

Activity	Description	Estimated Time	Notes
<b>Part I: Introductory Mini-Labs to Learn Field-Based Skills. Lab handouts and instructions are in Supporting Files S1, S2, and S3.</b>			
Introduction to eBird	An overview of the eBird Project at the Cornell Lab of Ornithology, including an introduction to citizen science and the objectives of the CURE Module.	About 20 minutes in class.	<ul style="list-style-type: none"> <li>I include the brief video About eBird (<a href="http://ebird.org">http://ebird.org</a>) as part of this overview.</li> <li>Students should read and take notes on (17), (18) or (21) before class.</li> </ul>
Mini-Lab 1, Pre-Lab Assignment	Students install Merlin Bird ID on their iOS or Android Device and watch 2 brief on-line videos about birding.	5-minutes in class to prep students for the assignment; 30 minutes for students to complete assignment outside of class.	<ul style="list-style-type: none"> <li>Students may be more motivated to watch videos if there's a quiz.</li> </ul>
Mini-Lab 1: Getting to Know Merlin BirdID	Introduce students to bird identification, external anatomy and how to use binoculars. Students practice in pairs with Merlin BirdID to identify field models. One student works with binoculars while the other manages the app. Students should switch tasks during the activity.	50 or 75 minutes in class; plus 15-20 minutes grading time per student for quiz and lab report.	<ul style="list-style-type: none"> <li>It's useful to provide handouts that illustrate bird anatomy. I obtained illustrations online.</li> <li>This lab requires one-on-one time to show students how to use binoculars and Merlin BirdID.</li> <li>Students shared binoculars supplied by the lab fee budget.</li> </ul>
Mini-Lab 2: Pre-Lab Assignment	Students watch 2 more brief on-line videos about birding.	5-minutes in class to prep students for the assignment; 30 minutes for students to complete assignment outside of class.	<ul style="list-style-type: none"> <li>Students may be more motivated to watch videos if quizzed.</li> </ul>
Mini-Lab 2: Field Identification of Birds	Meet with students at a field site close to campus. Students work in small groups to use binoculars and Merlin Bird ID to identify birds in the field. Students should switch tasks (binoculars, app, taking notes) during the activity.	50 or 75 minutes, plus grading time for quiz and lab report.	<ul style="list-style-type: none"> <li>This exercise can be completed on campus or at a nearby park or recreational area.</li> <li>Have the students work in small groups so they can confirm each other's ID's, and so you can reconfirm theirs.</li> <li>I recommend a follow-up assignment where students continue to work with Merlin Bird ID on their own.</li> </ul>
Mini-Lab 3: Pre-Lab Assignment	Students sign up for an eBird account and install the eBird App on their iOS or Android device. They also prepare a small field notebook.	20 minutes for students to complete the assignment outside of class.	
Mini-Lab 3: Recording Data with eBird	Meet with students at a field site close to campus. Walk students through the eBird app and assist them in starting their first eBird list. Students work in small groups, dividing tasks between managing binoculars, the apps, and notetaking. Students will have questions as they identify real birds in the field. They must be certain about their identifications before uploading lists to eBird.	50 or 75 minutes, plus grading time for lab report.	<ul style="list-style-type: none"> <li>This exercise can be completed on campus or at a nearby park or recreational area.</li> <li>Have the students work in small groups so they can confirm each other's ID's, and so you can reconfirm theirs.</li> <li>Students send their eBird checklists to the instructor at the end of the activity.</li> </ul>

Activity	Description	Estimated Time	Notes
<b>Part II: Experimental Design and Field Investigation. Sample field protocol for class project is provided in Supporting File S4.</b>			
Pre-Lab Assignment	Students read primary literature on urban bird diversity.	Reading time will vary for students.	<ul style="list-style-type: none"> <li>I recommend having students submit notes on assigned primary literature.</li> <li>Instructors may also want to include a quiz pertaining to the assigned reading.</li> </ul>
Mini Lab on Experimental Design	Students brainstorm questions generated by the reading and their field experience to identify testable hypotheses about urban bird diversity. Under the instructor's guidance, the class agrees on a survey protocol for the project.	50-75 minutes in class. 30-60 minutes after class to formalize the protocol handout.	<ul style="list-style-type: none"> <li>Additional class time may be necessary for this stage depending on students' familiarity with the scientific method and the degree of autonomy granted by the instructor in the design process.</li> <li>Once the class agrees on a protocol, the instructor should formalize this protocol in a handout that will guide students during data collection.</li> </ul>
Data Collection	Students collect data in the form of eBird checklists. I recommend students work in small groups for collecting field data, dividing tasks between 'bird spotters' and 'notetakers.' Ideally, the instructor should accompany each group at least once in the field during this period.	Students need 30-60 minutes per week to complete checklists.  Length of data collection can vary, from 3 to 5 weeks.  Grading is minimal, but students should be supervised in the field if possible (see notes).	<ul style="list-style-type: none"> <li>My classes ran their project for 3-5 weeks, but the survey time could be shorter or longer.</li> <li>I did not grade checklists but rather awarded points for submission, making sure the time stamp corresponded to the appropriate due date and that birds reported made sense given the area surveyed. (eBird does automatic policing, red flagging in real time any species reported where it doesn't belong).</li> </ul>
<b>Part III: Data Analysis and Final Report. Lab handout and instructions for final reports are provided in Supporting Files S6, S7, and S8.</b>			
Pre-Lab Assignment	Students collate their data in a single excel spreadsheet.	Students need 30-45 minutes to collate their data, depending on how adept they are with excel. 15-20 minutes grading time per group submission.	<ul style="list-style-type: none"> <li>Depending on the nature of the data and project, the instructor may need to spend additional time collating before the beginning of lab.</li> <li>An example of data prepared for analysis as part of a class project is provided in Supporting File S5.</li> <li>Review all data well before class so that if students mis-entered or misunderstood the assignment, they can make corrections.</li> </ul>
Mini-Lab: Assessing Bird Diversity at an Urban Field Site	Students analyze data from a qualitative and quantitative perspective. They calculate Simpson diversity indices, comparing different urban habitats.  Calculations can be done with a calculator or with Excel.	50-75 minutes in-class time. 15-20 minutes grading time per submission.	<ul style="list-style-type: none"> <li>Students may complete the data analysis in groups.</li> <li>If using Excel, it may be useful to pre-load some of the formulas in the template. See supporting File S5 for an example.</li> </ul>

Activity	Description	Estimated Time	Notes
Final Written Report	Students summarize their findings in a final written report.	10-15 minutes in-class time to explain objectives of written report. Student time investment will vary. Grading time per report varies depending on length and quality.	<ul style="list-style-type: none"> <li>Alternative formats for the final written report may be used. For examples, see Supporting Files S7 and S8.</li> <li>If time allows, I recommend students submit drafts to provide opportunity for feedback and improvement.</li> <li>Oral reports can also enhance sharing of the class experience.</li> </ul>
Final Exam	Students complete an essay question that applies knowledge gained during the eBird module.	Student time investment will vary. Grading time per essay will vary depending on length and quality of the essays.	<ul style="list-style-type: none"> <li>For one class (Conservation Biology), the essay question asked students to make specific recommendations about habitat management on campus; in another class (Introduction to Research), students were asked to design a follow-up study to the class project.</li> </ul>