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Lesson

# Developing Data Literacy Skills and Connecting the Student Experience in the Classroom to the Community Through Biodiversity Projects

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## Abstract

Undergraduate education and long-term science literacy are enhanced by integrating data projects with public datasets and creating analysis summaries. Underutilized public datasets are often generated by community-based or citizen science projects to address conservation issues supported by local residents. The objectives of this course activity are for students to contribute to a community science project, observe local species diversity, develop biodiversity questions, and apply data science techniques. Engaging students in these local projects enhances their understanding of the scientific process and its broader impacts on their community. The City Nature Challenge (CNC) is an annual global community science event where students participate by documenting species observations with the iNaturalist application, similar to localized BioBlitz events. Students are guided through using the iNaturalist database to practice biodiversity calculations then data is collected through participation in CNC (or a BioBlitz event an instructor arranges for their class). Spreadsheet software is used by students to organize, analyze, and summarize their relevant data to their peers. Students join the iNaturalist community of observers, which includes professional and non-professional naturalists. Therefore, students can see the themselves as scientists by contributing locally relevant data to a global and digital community of scientists. Experience working with large datasets such as the CNC iNaturalist dataset is essential for STEM careers and building data literacy. Implementing these experiences in classrooms will provide students unique opportunities to learn more about local biodiversity, develop interdisciplinary skills and positively influence a global network of scientists.

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## Learning Goals

Students will:

- gain a broader understanding of biodiversity, especially in developing urban ecosystems.
- strengthen their data literacy as they collect, share, and analyze biodiversity assessment data.
- engage with a broad network of community scientists via iNaturalist and experience the applications of ecological concepts in their daily environment.

## Learning Objectives

Students will be able to:

- plan and conduct a biological inventory of a specific habitat.
- contribute to a community/citizen science research project.
- explain how the interactions among the biotic and abiotic factors of a system can vary (direction, magnitude, frequency) in space and time.
- compare biodiversity among microhabitats (e.g., parks and coastline, streets and subways)
- explain a specific species habitat and estimate species distributions.
- hypothesize how populations adapt to their environment.

## INTRODUCTION

*Urban Ecosystem*

The urban environment is often portrayed as a concrete jungle with humans, rats, and roaches as the most common living organisms. However, there is more biodiversity than the buildings and streets suggest, and trying to contextualize this diversity within the urban environment is challenging (1). Beyond the causal observation of the common organisms that students may encounter in the city, there is much biodiversity in terms of insects, amphibians, birds, and spiders that also reside in the urban environment. Urban plant biodiversity is more complicated to evaluate since many species are intentionally planted and actively maintained, but those cultivated plants still provide important habitats for other resident species (2). In the city, there are also limited areas for species recruitment – settling and reproducing – that may affect urban biodiversity. However, there is often a strong initiative to be better stewards of urban nature, such as projects that increase trees and plants in urban settings (for example, the MillionTreesNYC project, (3)) and ultimately that can increase the biodiversity of the system(4,5).

Within an urban environment defined by buildings and concrete, there are often open green or less developed spaces. These spaces still harbor diverse organisms even though they are embedded in and heavily influenced by the urban environment (6). For example, New York City's Jamaica Bay ecosystem (a 9,000-acre National Wildlife Refuge) is recognized as a critical habitat for local and migrating animals, with over 313 bird species recorded, including the endangered piping plover (7). Biodiversity in cities is supported through parks and green spaces, even providing refuges for key species of plants as well as other animals such as bats and insects (8-11). Cities have been incorporating more green infrastructure, such as green roofs and bioswales, into their plans, and there is evidence that these interventions can support biodiversity better than conventional infrastructure (2,12).

In general, community science (formerly "citizen science") refers to a scientific endeavor where anyone can participate, regardless of whether or not they have professional scientific credentials. There are a variety of different types of these participatory scientific efforts (13); many of them ask the community to act as guides to their local area and to collect data from their built environment. Since high human population density defines an urban environment, then there is also the potential for a large number of people to act as local collaborations to collect data in the urban environment for community science projects. A dense network of collaborators facilitates finely detailed datasets for the city with frequent data collection. Some datasets compile years of community observations of urban ecosystems through regular monitoring projects. Examples include the daily rain gauge readings by the Community Collaborative Rain Hail and Snow (CoCoRaHS) Network (14) as well as massive yearly events such as the Audubon Society hosting the annual Christmas bird count (15). Incorporating the community, especially students, through community science projects is a growing trend amongst university researchers (e.g., 16,17). Overall, these projects benefit both the participants and the lead scientists of the projects. The participants become more aware and engaged in learning about their environment, while the researchers can utilize the greater volume of data collected that more comprehensively represents the urban study area.

*Biodiversity*

Anthropogenic degradation of the environment creates urgency that drives biodiversity research and assessment of local and global species' presence. Biodiversity can be assessed on several levels, from population genetics to ecosystems. This lesson will focus on community level biodiversity as represented by the diversity of living organisms in a particular location. The variety and abundance of flora and fauna contribute to species diversity observed in a region; the different sensitivities of these species to disturbances can impact the overall assessment of biodiversity (18). Understanding biodiversity, and how it is altered by human actions, is critical to understanding some of the global challenges our society faces today. When ecosystems have a rich biodiversity, there is greater redundancy in ecosystem functions, which contributes to a greater resiliency to disturbances (19,20).

While protecting biodiversity and minimizing human damage to the environment might be a moral imperative, there is also merit in promoting and preserving biodiversity to preserve existing ecosystem services that humans value (21). Ecosystem services can be classified in four interlinked categories: provisioning (food and other products from the ecosystem), regulating (such as pollination and water filtration), cultural (sense of place, aesthetics, etc.) and supporting (longer timescale services that support the others, such as soil formation) (22). Regardless of high or low biodiversity, there can still be important contributions to ecosystem services. Classically, the highest biodiversity is documented in tropical rainforests and coral reefs, which provide a variety of essential ecosystem services – provisioning, regulating, supporting, and cultural services. For example, ecotourism has become an important economic resource for biodiverse countries like Costa Rica. There are also many regions of the world where new species are regularly being discovered, representing unrecognized ecosystem services. One unknown potential is in discovering novel chemicals associated with new species; if there is a continued loss in biodiversity, there is a subsequent loss of discovering new chemicals that may serve as pharmaceuticals (23,24). Even areas traditionally considered less biodiverse, like urban ecosystems, provide essential ecosystem services to city residents and others. For example, urban biodiversity has been shown to contribute to residents psychological and physical well-being (25).

*Data Literacy*

While there are many pedagogical methods for students to learn about biodiversity, this lesson emphasizes data analysis and its critical role in the scientific process. Students generate their own independent questions and analyze large datasets to create tables and figures that address their unique questions. Students employ data-wrangling skills (organization, sorting, cleaning, etc.) when they first access the massive observation lists from the iNaturalist database (www.inaturalist.org). They then apply data analysis and visualization skills to create their tables and figures. Finally, they practice data communication skills to present their work to their peers orally and in writing a lab report.

*Intended Audience*

This lesson in its fullest implementation is intended for science majors at a college or university, fitting within the curricula of typical Biology, Ecology, Conservation, or Sustainability courses. It is also appropriate for science or data skills-focused general education courses, although additional ecological context might be needed, such as an explanation of the scales of ecological study (populations, communities, ecosystems, etc.).

With additional modifications, advanced high school students could complete the lesson and participate in the community science. A main consideration would be adult supervision and following school guidelines for minor students accessing online resources. iNaturalist Terms of Service dictate that a person must be at least 13 years of age to create an account, but it offers a separate app, Seek, that does not require creating an account and does not share precise user location or other user data with the iNaturalist database (26). Seek can be used in the field to identify species and then that information can be collected on paper data sheets. For assistance with lesson modifications for other student audiences and for adjustments related to device access issues, see the additional resources in iNaturalist's Teacher's Guide (26) and lesson suggestions for different grade levels featured in the City Nature Challenge Education Toolkit (27).

*Required Learning Time*

This lesson is set up as multiple stages to be accomplished over approximately 3 days, with 2 days in class (75-minute class sessions). On the day when class does not meet, students should spend at least an hour outside making independent observations of organisms living in their city, recording observations through the iNaturalist app, or taking photographs and uploading them on iNaturalist via the website. These observations may be made as a part of the annual City Nature Challenge (mid- to late April), during a locally organized BioBlitz, as a part of an instructor-organized class event, or independent of a project or event.

*Prerequisite Student Knowledge*

Students should be aware of the basic process of science through the framework of the scientific method (observations, question, hypothesis, experiment, results, conclusions). Additionally, students should have an understanding of the natural environment, including the definition(s) of a species and basic ecological definitions of populations and communities. They should also be familiar with the concepts of species ranges and human impacts on ranges. They should also have experience with computer operation, including word processing and spreadsheets. To reinforce student background knowledge, we recommend viewing the Urban Ecology Science Forward video (28) and reading Chapter 44: Ecology and the Biosphere of the OpenStax Biology textbook (29).

*Prerequisite Teacher Knowledge*

Instructors should be able to define a species and describe populations and communities of species and have a general knowledge about species ranges and human impacts on ranges. It is helpful if this knowledge also regards the local ecological dynamics and species. Analytical knowledge is helpful but should not preclude using lesson with the proper preparation. It is beneficial to have an understanding of biodiversity and various contributions to how it is measured, as well as environmental drivers for high/low biodiversity in different systems. Technology is heavily utilized; therefore, it is important that the instructor is familiar with the use of smartphone devices to photograph and document the animal and plant observations using iNaturalist; a digital camera may be substituted to make observations and upload images to the website at a later time. Instructors will also be combining their analytical and technical skills while guiding students through data organization and computation using data management programs (such as MS Office Excel), so they should have or develop a familiarity for how to download entries from website databases and open text files (tab- or comma-delimited) in spreadsheets.

## SCIENTIFIC TEACHING THEMES

*Active Learning*

Students will work in small groups inside and outside of class. Scientific communication will be implemented through class discussions and presentations as groups or individuals. Students will collect and contribute data independently via iNaturalist; through their participation they are part of a larger digital community of scientists. The class will conduct data analysis on theirs as well as the broader community observations using a guided computer lab process.

*Assessment*

This lesson is assessed through production of a key figure to address the specific student question and hypothesis, and then a complete lab report in the format of a scientific paper (example sections: introduction, methods, results, discussion). The guiding questions for students at each stage of the project (Supporting File 6. Data Literacy Through Biodiversity Projects – Overall Student Instructions) should be incorporated into the final report (e.g., the background questions included in the introduction, the questions about conclusions part of the final discussion). No assessment should be applied to the observations made through iNaturalist, in order to preserve the process of iNaturalist community scientist review of observations and to refrain from public discussion of student grades.

*Inclusive Teaching*

This lesson strives to address inclusive teaching by shifting the learning environment to a computer lab rather than requiring students to have personal computers already loaded with the required programs (a web browser and data management software such as MS Office Excel or Google Sheets). Contact the department's instructional technology specialist for any recommendations for specific accommodations available in the computer labs. If personal computers are available or preferred, an internet connection and any program that manages data through spreadsheets will work to complete the lesson.

Access to a device that can take a photograph outside is a key component of this lesson. Ideally, a mobile device (such as a smartphone or tablet with satellite connection) with the iNaturalist application would be used. Accounts are free to create on iNaturalist. If mobile devices are prohibited or otherwise unavailable, observations may be made with digital cameras and uploaded through the iNaturalist website. Some colleges have cameras that can be loaned to the students, so it may be useful to check with departments whether these resources are available. The one important difference when using a digital camera to make observations is that students must record where they were when the photo was taken so that the observations can have associated geolocations (a process that is automatic with a mobile phone). A simplified data sheet can be created to encourage students to record this information while they are making observations (columns would include time of observation, photo file number, and location information). Students could also be encouraged to meet up with a partner for making the observations, which will reduce the burden for every student to have a device as well as promote collaboration and safety for work outside of class. Instructors can submit their students' observations as a compiled effort to maintain student anonymity and fulfill the goal of contributing to a public biodiversity database.

Schools may have restrictions on what applications and data students are allowed to share with respect to their coursework. If there are concerns, particularly about location sharing, there are some alternatives that allow students to participate without revealing identifying information. For example, the instructor might choose to create a single class iNaturalist account with their email address; the account would then be controlled by the instructor, but all students would be granted access to contribute observations. Instructors should monitor the account and change passwords if improper behavior is observed. More information on this adjustment can be found in the iNaturalist Teacher's Guide (26).

If possible, we encourage students to create their own accounts on iNaturalist so they may continue to be lifelong observers of nature and be more mindful of the natural world around them. Instructors should make no assessment-related comments on student observations within the iNaturalist platform, as that may be a violation of FERPA regulations. Students will always have the option of deleting their iNaturalist accounts (and all of the data they created) after the lesson is complete, if they choose to do so.

Utilizing data collected by local and global communities demonstrates to students the scale and scope of who participates and contributes to scientific data. Reciprocally, the students' efforts to record their observations extends beyond the classroom and into the broader community that can learn from and use their data for other projects. This activity also illustrates cultural diversity across neighborhoods, as different communities may support or cultivate different habitat types or species that influence the local diversity. Students collect independent data where they are or want to go; thus, the data represents the local areas and communities that students identify most with, rather than just the typical parks or recreation areas. Overall, the students are provided the opportunity to experience how science is accomplished through diverse participants and how through their contributions of observations, they become a part of that community of scientists.

## LESSON PLAN

### *Overview*

This lesson guides students through biodiversity data collection and analysis, and encourages participation in contributing data through recording their own nature observations. Students will export data from a biodiversity repository, iNaturalist, associated with a biodiversity assessment event, such as City Nature Challenge. Students work with the large datasets in spreadsheets to evaluate biodiversity and parse the data along the context of their own questions. Therefore, they will also gain data literacy skills as they manage the dataset and make decisions on the specific elements of the data that pertain to their hypotheses.

### *Biodiversity Assessment*

iNaturalist facilitates documenting the flora and fauna in an environment and allows observers to get crowd-sourced species identification from an engaged community of amateur and professional naturalists (30). The records ("observations") are based on time-stamped, geotagged photographs of organisms submitted through a mobile application or via a web browser interface. Once observations are submitted, the identity of the organism can be suggested or confirmed by other members of the iNaturalist community. Once at least 2/3 of the identifications agree on a species, the observation becomes what iNaturalist classifies as "Research Grade" and the observation is shared with the Global Biodiversity Information Facility (GBIF), where scientists can download relevant datasets for their research (31). The strength of the data is in the volume of information (observations and identifications) collected from globally dispersed community of scientists who are independent of research institutions. Student observations created during this lesson will add to this global biodiversity data resource.

Many conservation or academic programs recognize the need to know biodiversity in a region and the benefit of inviting local volunteers to contribute observations as community scientists. These observations are becoming more valuable for monitoring local species as museum collections have declined (32). Some groups conduct concentrated biodiversity assessments by inviting local participants to a specific place to observe in a specific timeframe (typically 24 hours). These efforts are known as BioBlitzes and many of them use iNaturalist as the data collection tool.

This lesson focuses on a subset of the data that is generated during the annual City Nature Challenge (http://citynaturechallenge.org/), a 4-day urban BioBlitz globally organized by the Natural History Museum of Los Angeles County and the California Academy of Sciences to document urban biodiversity that has been occurring since 2016. Hundreds of cities and thousands of people have participated in this massive data collection event, whose main goal is to connect people with all of the other species that coexist with them in the city. Anyone using iNaturalist during the four days of the challenge, while located in their participating city, will have their observations automatically added to their city's total observations for the challenge.

### *Instructional Planning*

An introductory lecture regarding urban ecology and biodiversity is recommended (Supporting File S1. Data Literacy Through Biodiversity Projects – Urban Biodiversity Presentation). If the activity is not part of an ecology course, then additional content should be shared regarding some key ecological concepts to facilitate understanding the system more (e.g., edge habitats, invasive species, disturbances, and niches). Following this lecture or discussion, students create or access their iNaturalist accounts and are encouraged to make practice observations around campus (33). By the end of Class Session 1, students should understand these basic ecological concepts and have proficiency in making and uploading iNaturalist observations.

### *In the Field – Making Observations*

Students should be encouraged to make independent observations of flora and fauna in their local neighborhood, park, or even campus using the iNaturalist application from a mobile device (such as a cell phone or tablet with satellite connection). If a mobile device is not available to use the iNaturalist application, observations can be made with a digital camera with location recorded through camera GPS or by hand using a map or other location information available to the students (street signs) then uploaded through the iNaturalist website by the student or instructor. This activity is completed outside of class time, so it can occur any time after orientation to iNaturalist. If class time permits or groups of students make observations together, the same individual organism should not be documented by more than one student in order to spread out observation effort among the students. For example, if one student notices a squirrel and records the observation in iNaturalist, when that same squirrel moves towards another student it should not be recorded. Students should be reminded to focus on wild organisms as much as possible. If captive animals or cultivated plants are included, they should be marked as such in the observation details feature of iNaturalist (34). Students do not need to be able to precisely identify the organism for recording their observations. iNaturalist will prompt potential identifications based on the photo submitted or following submitting the observation, the broader community using iNaturalist will review observations recorded and update the record based on their collective knowledge.

The City Nature Challenge (CNC) occurs annually in the Spring, so ideally this lesson would be implemented concurrent with the Challenge. Each participating city will have its own "collection" project page on iNaturalist (example: City Nature Challenge 2019: New York City (35)) and leaderboards for all the cities together are displayed in an "umbrella" project (example: City Nature Challenge 2019 (36)). A collection project automatically aggregates all observations that satisfy a set of iNaturalist criteria (e.g., location and time observed), so participants do not have to do anything more than upload their observations (30). For the CNC, observations are automatically collated when (1) the observation was made during the dates of the CNC and (2) the observation was made in the city's designated place boundary (37) . An umbrella project is how general project statistics, including leaderboards of top species observed and observers, for several collection projects are displayed so they can be compared. For CNC, hundreds of cities' results are displayed in the main umbrella project and the individual collection projects for each city can be accessed from this project page.

Students should be encouraged to join the local community on iNaturalist and contribute time to record observations during the CNC window. However, if this lesson occurs outside the dates of the CNC, students can be assigned a specific time window to make observations. This time window can be of the instructor's choosing or it can coincide with a local BioBlitz event if one will be occurring. If accommodations for working with students who cannot make iNaturalist accounts (see Inclusive Teaching above) are not feasible, this lesson can be adjusted to only include the "In the Computer Lab" components detailed below. However, this adjustment does eliminate some of the learning goals related to collecting data and connecting with the community. The instructor can choose the dataset to use for the third part of this lesson. Because of the volume of observations made during the CNC and the structure of the projects in iNaturalist, the CNC data are an ideal dataset to use, even if this lesson occurs at a different time. Students can easily find and download individual city data from the project pages.

### *In the Computer Lab – Data Management*

The key to the data literacy learning goals of this lesson is time spent in a computer lab working with the iNaturalist data. Students can accomplish this lesson on a personal computer if they have access to one; however, we recommend using computers with the same hardware, software, and file organization to limit time spent troubleshooting. In the computer lab, students should be oriented to the City Nature Challenge project (or another iNaturalist biodiversity project) on iNaturalist website (30) and introductory spreadsheet operations. We have described this lesson working with MS Excel software, but any program that can access .xlsx formatted files could be used (Open Office, Google Sheets, etc.). Following general overview and resources orientation, students should be guided through the process to locate and download data from iNaturalist for a city that was a part of a City Nature Challenge (Supporting File S2. Data Literacy Through Biodiversity Projects – Guide to iNaturalist and Downloading Data). Selection of data fields can be kept at a minimum for introducing the process: common name, scientific name, GPS coordinates, date and time observed (Supporting File S3. Data Literacy Through Biodiversity Projects – Dataset1 - 2017 City Nature Challenge). Then the data should be decompressed and opened using MS Excel (or other spreadsheet software) to facilitate further steps that summarize the data in tables and graphs. This process will emphasize the common and key formulas in Excel that facilitate summarizing the data, such as sum, average, countif, and sumif, as well as the formula for Shannon Diversity Index (Supporting File S4. Data Literacy Through Biodiversity Projects – Prepared Data Analysis Template).

The second class meeting in the computer lab should be focused on students accessing the iNaturalist data specific to their question. Student questions have generally been comparisons of biodiversity and most observed organisms across two cities. Student projects can involve surveying to initially describe the biodiversity of their local city, or applying their personal observations or independent research for city background or environmental conditions to generate hypotheses. Alternatively, they can go more in-depth and utilize the global network of biodiversity data that the iNaturalist repository contains. To remove some variability in identifications as well as improve confidence in the data reported, the genus of the scientific names is used to represent the organisms present. Other student questions could involve a comparison between cities, while identifying key differences in the environment (coastal or mid-west plains), population, or geographic size of the city (e.g., New York compared to Boston or Los Angeles), which may influence biodiversity or specific organisms present. For a population ecology perspective, ranges of the flora and fauna can be used to select cities and make predictions for presence in the built environments as subsets of their potential habitats based on historical data defining the expected ranges. Project pages in iNaturalist are formatted the same and the process to export data follows the same process followed previously (Supporting File S2. Data Literacy Through Biodiversity Projects – Guide to iNaturalist and Download Data).

### *Guiding Student Projects*

To orient students to exploring the biodiversity data, students were tasked to answer a few questions in the first computer lab class, based on the iNaturalist project pages and exploring the downloaded datasets. The theme to the questions was a scaffold for students be able to predict the top identified organisms and where the most species were described. Overall, a good summary is for students to identify the top 10 organisms they would expect and subsequently the top 10 they observed.

Small group discussions help refine the student's perspective and focus for their hypotheses (Supporting File S5. Data Literacy Through Biodiversity Projects – Overall Student Instructions). A few key considerations:

- What are characteristics of cities contribute to biodiversity?
- What are general differences in abiotic, environmental factors for the cities participating? How could this influence the potential for biodiversity?

Then students repeated this process with their own selected data during the second lab class.

*Biodiversity Analysis*

The iNaturalist data can be sorted and filtered, using MS Excel or similar program, to facilitate calculating biodiversity. Specifically, the data should be filtered to include just the 'Research Grade' observations, though this does not guarantee complete accuracy in all the organisms identified since it is relying on community driven identifications. Therefore, to improve confidence in the data reported, the genus of the scientific names is used to represent the organisms present. This is a more general level of classification and can control for some of the variation or error in species identification. The biodiversity metrics for students to calculate are species richness (the number of unique organisms present) and the Shannon Index (H'). The Shannon Index accounts for the species richness and evenness of their abundance within the sample. Data analysis skills will develop while working through this large dataset and learning the importance for making quality records for data analysis and being explicit about underlying assumptions (Supporting File S6. Data Literacy Through Biodiversity Projects – Detailed Instructions to Calculate Biodiversity).

This iNaturalist data include all recorded observations regardless of quality; therefore, a majority of the student experience will consist of filtering information into a usable dataset. Selecting only "Research Grade" observations (mentioned above) is one important filter. Looking for patterns in the data that may indicate bias is another. It is important for the students to recognize that humans of varying familiarity with the local flora and fauna create these records. There is also potential bias for where observations were recorded that may influence any trends in the dataset. Since this is part of a community science initiative, there can be uneven distribution of observations, there can be data clusters near participating schools or organized BioBlitz efforts for a specific park. One option to manage this bias in data collection is to focus the project on different areas that have similar bias. For example, students may choose to compare CNC cities that had a similar number of participants and total observations. There are minimal adjustments to be made while analyzing the data, except for reducing the strength of conclusions when evaluating trends in the analysis. It is part of the learning experience to acknowledge when our assumptions alter the strength of our conclusions.

## TEACHING DISCUSSION

Students were able to produce simple charts that summarized the biodiversity across the survey areas selected. Some of the students within the classes struggled to navigate the steps for spreadsheet data processing, while other students took initiative to produce more than the required summary figure. During both computer sessions, it was observed that students with more advanced computer skills were able to assist their peers. Having the students work on computers in a campus technology lab made resolving issues less complicated and leveraged the ability to share solutions between students.

The required outside observations were completed by most students, though the quality of many observations was poor. Some did not take the wild focus seriously, rather they documented most of the landscaping that neighbored their homes, producing many captive/cultivated observations. Therefore, the learning objective for students to contribute to a community science project was only moderately achieved. Subsequently, the benefit to the broader community of enhancing the observations recorded was not fully realized. Through discussions in class, students did apply their personal observations of their daily urban environment and evaluate which component would be of greater interest for their project. For some students, it was an effort to recognize the plants and animals around them; therefore, any observation quality and interest can be regarded as a successful challenge for the students to regard their daily environment in a more biological lens.

Students partnering and going to an open space together to explicitly focus on non-human supported organisms would be a key update to the student experience. This would also enhance the safety of the students while making observations, reinforce the learning objective that the students learn more about biodiversity in their local urban environment, and improve the inclusive practices by reducing the obligation of students owning a mobile device to make observations.

This lesson can be adapted to include many other cities now participating; in the first iteration of the CNC was in 2016 when only two US cities participated and since then the CNC network has now grown globally with hundreds of cities participating and tens of thousands of people logging observations (37). This growth and scale of participation allows students to be a part of a global community of scientists and nature observers. The data that community scientists, including the students, collect is invaluable because of the volume of data collection and the geographic reach of so many distributed participants.

Overall, students gained a broader perspective of their environment, learning that ecological concepts are not constrained to textbooks and pristine environments. Students have improved career competency skills by working in groups and transferable computer skills that build data literacy. The data students collect for urban biodiversity is incredible and will contribute to both urban planning of our daily environments as well as conservation efforts.

## SUPPORTING MATERIALS

- Supporting File S1. Data Literacy Through Biodiversity Projects – Urban Biodiversity Presentation
- Supporting File S2. Data Literacy Through Biodiversity Projects – Guide to iNaturalist and Download Data
- Supporting File S3. Data Literacy Through Biodiversity Projects – Dataset1 - 2017 City Nature Challenge
- Supporting File S4. Data Literacy Through Biodiversity Projects – Prepared Data Analysis Template
- Supporting File S5. Data Literacy Through Biodiversity Projects – Overall Student Instructions
- Supporting File S6. Data Literacy Through Biodiversity Projects – Detailed Instructions to Calculate Biodiversity

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Table 1. Lesson Timeline. The lesson best spans two class sessions as well as outside of class time for preparation and independent student activity. A third class session provides the opportunity to cover the data analysis and context of the activity in greater detail.

| Activity | Description | Estimated Time | Notes |
|---|---|---|---|
| **Preparation for Class** | | | |
| Download iNaturalist App | Have students download the application iNaturalist onto their mobile device and create an account. | 2 minutes | The program can also be run on a computer, but then a digital camera will be needed to upload photos. |
| **Class Session 1** | | | |
| Introductory Lecture | Urban ecology and biodiversity background. | 10 minutes | Lecture slides with notes are in Supporting File S1. Data Literacy Through Biodiversity Projects – Urban Biodiversity Presentation. |
| Practice Observations | Data collection. | 15 minutes | Instructed practice on quality of observations and basic identification. |
| Orientation to iNaturalist Biodiversity Database | Guide students through the process of locating and downloading data from iNaturalist. | 15 minutes | Choose a city that was a part of a City Nature Challenge. Supporting File S2. Data Literacy Through Biodiversity Projects – Guide to iNaturalist and Download Data provides slides to guide the process of downloading data. (If needed as reference, 2017 CNC data is Supporting File S3. Data Literacy Through Biodiversity Projects – Dataset1 - 2017 City Nature Challenge) |
| Laboratory Practice and Report | Set expectations for independent observations for data collection and tenacity for data analysis | 10 minutes | The overall student process is included in Supporting File S5. Data Literacy Through Biodiversity Projects – Overall Student Instructions.<br>This is a good time to review the structure of a lab report, including a discussion regarding student hypotheses about urban biodiversity. |
| **Independent Student Observations** | | | |
| Fieldwork and Data Collection | Students should be encouraged to observe the flora and fauna in their neighborhood or local park using iNaturalist. | 60 minutes | If students make observations together, the same organism should not be counted by more than one student.<br>Plants specific to landscaping, e.g., annual flowers, should be discouraged as observations. |
| **Class Session 2** | | | |
| Data Analysis | Data wrangling: Lab exercise on cleaning and organizing data. | 30 minutes | Students follow the prepared files to compile and summarize CNC biodiversity data from NYC (Supporting File S4. Data Literacy Through Biodiversity Projects – Prepared Data Analysis Template).<br>Instructions are in Supporting File S6. Data Literacy Through Biodiversity Projects – Detailed Instructions to Calculate Biodiversity. |
| Communicating Results | Summarize data in basic statistics and figures. | 15 minutes | Guide students through creating charts, such as the top species abundances |
| **Class Session 3 (optional)** | | | |
| Data Analysis | Focus is on students accessing the iNaturalist data specific to their data collection effort and question. | 45 minutes | This is time specific for the students to work independently or as lab groups while the instructor is available to address questions. |