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Lesson

Squirreling Around for Science: Observing Sciurid Rodents to Investigate Animal Behavior

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Abstract

Hands-on research experiences are important opportunities for students to learn about the nature of inquiry and gain confidence in solving problems. Here, we present an inquiry-based lesson plan that investigates the foraging behavior of sciurid rodents (squirrels) in local habitats. Squirrels are an ideal study system for student research projects because many species are diurnal, easy to watch, and inhabit a range of habitats including college campuses. In this activity, instructors identify appropriate field sites and focal species, while students generate questions and brainstorm predictions in small groups regarding factors that might influence behavioral trade-offs in sciurids. Students conduct observational surveys of local squirrels in pairs using a standardized protocol and upload their data to a national database as part of the multi-institutional Squirrel-Net (http://squirrel-net.org). Instructors access the nationwide dataset through the Squirrel-Net website and provide students with data for independent analysis. Students across the country observe and record a range of squirrel species, including behaviors and habitat characteristics. The national dataset can be used to answer student questions about why squirrels behave in the way they do and for students to learn about authentic analyses regarding behavior trade-offs. Additionally, the lesson is designed to be modified across a range of inquiry levels, from a single two-hour laboratory activity to a unit- or semester-long student-driven course-based research experience. Our activity highlights the value of using observational data to conduct research, makes use of the Squirrel-Net infrastructure for collaboration, and provides students equitable access to field-based projects with small mammals.

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Supporting Materials: S1. Squirreling Around for Science – Resources for identifying focal species and field sites; S2. Squirreling Around for Science – Squirrel behavior observation datasheet; S3. Squirreling Around for Science – Supplies for introductory majors or lower division majors course; S4. Squirreling Around for Science – Supplies for non-majors course; S5. Squirreling Around for Science – Supplies for upper division course; S6. Squirreling Around for Science – Squirrel behavior student directions; S7. Squirreling Around for Science – Squirrel behavior ethogram table; S8. Squirreling Around for Science – Example of national database; and S9. Squirreling Around for Science – Lecture slides with background information.

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Learning Goal(s)

Students will:

- develop a basic understanding of the scientific process.
- gain confidence in their ability to conduct scientific research.
- understand that observing animal behavior is an important tool to investigate species interactions.
- analyze data and learn about behavioral trade-offs in local wildlife.
- value the diversity of ecological roles and adaptations found within the mammalian family Sciuridae (squirrels).
- create a connection with nature by leaving the classroom to visit field sites and observe species in their habitats.

Learning Objective(s)

Students will:

- conduct animal behavior surveys with peers.
- input data into an online database for focal behavior observations.
- develop and test hypotheses concerning trade-offs among squirrel behaviors.
- analyze data from the national Squirrel-Net database for focal behavior observations.

INTRODUCTION

What, how, and why an animal eats are some of the most fundamental questions in animal behavior. Coming from the Greek word trophē, meaning nourishment, the trophic biology of an animal provides valuable information about its diet, as well as its role in cycling nutrients and transferring energy through ecosystems. Such information is crucial for management and conservation of endangered or threatened species (1). Multiple theories in biology explain the dietary decision-making of animals (2). For instance, optimal foraging theory suggests that animals maximize their caloric intake over time (3). Animals balance many factors when foraging, such as time spent actively searching for food and total calories gained per meal. This balance of multiple factors is one of the many trade-offs studied in behavioral ecology. Trade-offs in biology imply that time or energy spent on one task, such as foraging, is time or energy that is not spent on another task, such as avoiding predators or finding a mate.

Studies of animal foraging behavior provide an opportunity to engage students in authentic, classroom-based research projects (4,5). Lesson plans that use camera traps, for example, offer a great opportunity for students to conduct data analyses, but lack the direct connection with wildlife (6). In contrast, *in situ* observations are the oldest and most direct way to record animal feeding activities. Observational surveys have answered questions regarding foraging decisions and trade-offs in species ranging from songbirds and birds of prey (7,8) to hippopotamuses and chipmunks (9,10). Moreover, observing live animals can foster personal connections with science and nature, particularly for students from urban settings who may be less familiar with wildlife (11). Behavioral surveys therefore provide unique opportunities to engage students in science (12).

Sciurid rodents (squirrels) are great candidates for student research activities in behavioral ecology for several reasons. Sciurids are charismatic and diurnal, and over 60 species are found across North America in habitats from natural areas to urban settings like college campuses (13–15). Like many prey species, squirrels display distinct foraging and vigilance behaviors, and must balance the time they spend eating versus watching for predators (16,17). Therefore, students can conduct behavioral surveys of local squirrel species and test predictions regarding trade-offs between foraging and other behaviors. Factors that can influence these behaviors include the presence of other species, habitat type, the degree of urbanization (18), social patterns of the focal species (19), and abiotic factors like temperature and precipitation (20). For instance, habitat structure could affect vulnerability and exposure to predation (e.g., a reduced understory could expose squirrels to aerial predators), which could in turn increase vigilance behavior in squirrels (21,22).

Here, we present a lesson plan that uses behavioral surveys to provide undergraduate students authentic research experiences in the classroom. To prepare for the activity, instructors identify local species and field sites, and students generate hypotheses and predictions concerning trade-offs between foraging and other behaviors in squirrels. During the lesson, students investigate these trade-offs by conducting behavioral surveys of local squirrels using a standardized protocol, and then input their data into a national database. Instructors can access the national dataset and provide students with a dataset that was compiled by students across the country. Students create graphs to test their hypotheses, ultimately leading to new knowledge and insights regarding animal behavior. Alternatively, instructors could extend the activity by teaching data analyses and interpretation in a successive lab period.

The present lesson has been tested with over 800 students across multiple institutions and in many different course types. Consequently, we have standardized the collection of behavior data while allowing flexibility in the level of inquiry. We believe these attributes strengthen this lesson plan and make it a valuable, highly adaptable tool to provide research experiences to students in the fields of ecology, animal behavior and mammalogy.

Rationale and Origin of Lesson

Squirrel-Net is a group of teacher-scholars that share a common goal of promoting authentic course-based research experiences (CUREs) for undergraduate students. We are mammalogists that hold research and teaching positions at higher educational institutions across the United States. Our goals are to create inquiry-based lesson plans that take students out of the classroom and engage them in research on locally relevant and widely distributed mammals, while also collecting data with standardized protocols to test a wide array of ecological questions across multiple spatial and temporal scales.

This lesson is part of the Squirrel-Net module series (http://squirrel-net.org). All of the Squirrel-Net modules are designed for adaptation to diverse educational contexts, from a single two-hour laboratory period (basic skills acquisition with structured inquiry) to a unit- or semester-long student-driven research project (open inquiry CURE). In each module, students submit data to a national dataset that aggregates observations from multiple institutions. Instructors can access the freely available national database, thereby allowing students to explore and analyze focal questions of the module across a broader variety of habitats and species than would be possible at a single institution. Finally, the four Squirrel-Net modules published in this set (23–25) are designed to be scaffolded into multiple levels in a curriculum, allowing students to return to a similar taxon and themes as well as uniting inquiry across different courses (26).

Intended Audience

Squirreling Around for Science is intended for undergraduate level courses in the sciences at any type of institution. From 2017-2019, this lesson was implemented at nine colleges and universities in the United States, which include small private primarily undergraduate institutions, mid-sized public institutions serving local, under-represented and non-traditional populations, and large public research institutions. This lesson is highly adaptable and has been taught in numerous course types, ranging from non-biology majors to introductory major courses, to upper division electives, with class sizes from 15 to 80 students.

Required Learning Time

One laboratory period (1 hour 50 minutes), at a minimum.

Prerequisite Student Knowledge

Students should be acquainted with the ecological concepts of species interactions and activity budgets. Specifically, students should be familiar with predator-prey relationships and the

adaptations associated with each species (i.e., faster running or ambush speeds of predators, camouflage or physical defenses of prey). Trade-offs occur in activity budgets because there is only a set amount of time or energy available for all of an animal's activities. Animals are constantly making decisions about the amount of time or energy to spend on one activity such as foraging, thereby limiting the amount of time or energy available for another activity such as watching for predators. We also suggest that students be familiar with science process skills, including asking a question, developing a testable hypothesis and prediction based on prior knowledge, and using a standardized protocol to collect data. Additionally, students should have experience with reading and making graphs, either by hand and with computer software such as Microsoft Excel or R. Alternatively, this lesson is great for teaching about data analysis and graphing, but would necessitate at least one additional laboratory period.

Prerequisite Teacher Knowledge

Instructors need to identify a location to observe local squirrel species (Supporting File S1: Squirreling Around for Science – Resources for identifying focal species and field sites). We also suggest that instructors practice observing squirrels and filling out the squirrel behavior datasheet (Supporting File S2: Squirreling Around for Science – Squirrel behavior observation datasheet) before the lesson. It would be beneficial for instructors to have a basic knowledge of animal behavior (e.g., see resources in (27–32).

SCIENTIFIC TEACHING THEMES

Active Learning

During the lesson, we conduct small group and classroom-wide discussions for students to make predictions about foraging behavior. Discussions are facilitated with think-pair-share. Students collaborate to record behavior of local squirrels outside the classroom and analyze data collected across the country. Students also draw conclusions from those analyses in small groups and in classroom-wide discussions.

Assessment

Basic lesson assessment for this activity includes the creation of a graph and a one-page written summary. Rubrics are provided to students during the lesson, which include evidence of student participation in group discussions and data collection. We provide assessment examples (Supporting File S3: Squirreling Around for Science – Supplies for introductory majors or lower division majors course, Supporting File S4: Squirreling Around for Science – Supplies for non-majors course and Supporting File S5: Squirreling Around for Science – Supplies for upper division course) and modifications to the assessments (see Teaching Discussion and Table 2).

Inclusive Teaching

Squirrel-Net modules are designed to provide all students in a class with the opportunity to engage in authentic research experiences. Participation in traditional research experiences can be limited to a select group of students, either because few opportunities exist or because students have other commitments outside of their education (33). By bringing research into the classroom, it can more seamlessly become part of the educational experience for all students. Furthermore, participating in a CURE has significant impacts on students' sense of self-efficacy as a scientist and may promote retention in science, particularly for students from under-represented groups (34). One strength of the Squirrel-Net modules is the use of a national network, which will further help students feel they are making important contributions and belong to a broader scientific community beyond their classroom or institution (35).

This lesson supports multiple modes of learning. Students have the opportunity to work independently and/or collaboratively as they complete each step of the lesson. For instance, students engage in active inquiry and work together to collect their own behavior data. This activity is unique because it physically takes students outside the classroom and connects students with animals in their local environment. Students also work in small groups to generate their own hypotheses and predictions about foraging behavior trade-offs. Lastly, this lesson is not a "cookbook" lab activity with known outcomes, but instead guides students through the scientific process, encouraging and celebrating novel discoveries regarding animal behavior.

LESSON PLAN

Pre-Class Preparation

Before conducting the lesson, instructors should determine their focal squirrel species and field site location(s). There are multiple, open-access resources available online to help instructors correctly identify their local sciurid species (Supporting File S1: Squirreling Around for Science – Resources for identifying focal species and field sites). We also provide important tips when identifying a species and study site close to the classroom. For example, when visiting a potential site, instructors should record the time it takes to travel from the classroom to the field site and back, to ensure that students can successfully conduct their observational surveys within the class timeframe. Many college campuses provide suitable habitat for squirrels, and some institutions may have natural areas on their campus specifically for ecological research and hands-on education. Local parks and public lands are other options for finding sciurids.

If instructors are unfamiliar with collecting focal animal observations using an ethogram, we suggest they practice recording data prior to the lesson, using the datasheet (Supporting File S2: Squirreling Around for Science – Squirrel behavior observation datasheet), student instructions (Supporting File S6: Squirreling Around for Science – Squirrel behavior student directions), and squirrel behavior ethogram (Supporting File S7: Squirreling Around for Science – Squirrel behavior ethogram table). Instructors can practice filling out the datasheet by watching a freely-available video clip of uninterrupted squirrel behavior, such as those available on our website (http://squirrel-net.org). The completed sample datasheet can serve as an example for students during the lesson.

Prior to the lesson, instructors should familiarize themselves with the national database, which is available by request through our website. This dataset may be manipulated to produce a graph for assessment and/or potentially edit or cleaned for student analyses (see Teaching Discussion for modifications). An example datasheet with both original data from the database and a cleaned data set specific to answering student questions is provided (Supporting File S8: Squirreling Around for Science – Example of national database). Finally Squirrel-Net has also developed several videos introducing the network and the protocols for

this lesson; these videos are available via our website (http://www.squirrel-net.org).

Handouts and materials to be prepared before the lesson include the datasheet (Supporting File S2: Squirreling Around for Science – Squirrel behavior observation datasheet), student instructions (Supporting File S6: Squirreling Around for Science – Squirrel behavior student directions), and ethogram (Supporting File S7: Squirreling Around for Science – Squirrel behavior ethogram table). Optional documents include any additional worksheets pertaining to specific focal species and rubrics for assessments (e.g., Supporting Files S3: Squirreling Around for Science – Supplies for introductory majors or lower division majors course, S4: Squirreling Around for Science – Supplies for non-majors course and S5: Squirreling Around for Science – Supplies for upper division course). Required materials for surveys include a writing surface (e.g., clipboard), a GPS device (or a smartphone), and a timepiece (e.g., a watch, phone timer, or stopwatch). Most students can provide these items themselves, especially since they will be collecting data in groups. For instance, modern smartphones include a stopwatch and mapping capabilities that provide GPS coordinates in decimal degrees (either by dropping a pin at the current location in Google Maps or by using a free GPS app, such as GAIA GPS or HandyGPS). Depending on focal species and its distance from observers, students should also bring binoculars.

Progressing Through the Lesson

Interactive lecture (~15 minutes).

We begin the lesson with a short, interactive lecture about squirrels and foraging behaviors (Supporting File S9: Squirreling Around for Science – Lecture slides with background information). Instructors can focus on background material appropriate to the course. For example, in a non-majors biology course that broadly covers animal biology, we focus on squirrel biology and emphasize locally occurring species. In upper division courses, we focus on broader theories of foraging behavior (e.g., optimal foraging theory). Some instructors use short video clips to introduce topics to students. We also introduce Squirrel-Net, highlighting the fact that students like themselves across the country are collecting data and contributing to the dataset. We end the lecture by describing the behavior observation surveys. Specifically, we hand out instructions (Supporting File S6: Squirreling Around for Science – Squirrel behavior student directions), datasheets (Supporting File S2: Squirreling Around for Science – Squirrel behavior observation datasheet) and ethograms (Supporting File S7: Squirreling Around for Science – Squirrel behavior ethogram table), explain specific squirrel behaviors outlined in the ethogram (Supporting File S9: Squirreling Around for Science – Lecture slides with background information, slide 9), and walk through the instructions for completing the datasheet.

Practice data collection (<10 minutes).

Once students have all the handouts, instructors usually lead a practice recording observational data. We play a practice video (available on our website: http://squirrel-net.org) and prompt students to categorize the squirrel's behavior based on the ethogram at 20-second intervals. We allow students to record for a full five minutes to simulate how long the procedure should last. After students record their data, we review the behaviors as a whole class and clarify any questions or confusion about the protocol.

Generate questions and predictions (15-20 minutes).

In pairs or small groups, students brainstorm factors that influence the foraging behaviors of squirrels. They then work together to determine possible questions and hypotheses that could be tested with the data. The data include squirrel behavior, date, time, weather, habitat and GPS location. Thus, students are able to learn and ask questions about the effects of urbanization, abiotic factors, and presence of other animals on activity budgets. Possible questions include: "Will squirrels spend more time being vigilant on college campuses compared to natural environments?", "Do different species of squirrels show similar behaviors on college campuses across the United States?", or "What is the effect of season on the behavior of squirrels found on college campuses?" We have students share their questions with the whole class and discuss how the data can be used to answer each question. We allow each pair or group of students to test a different question, but some instructors may choose to have only one question that the whole class will test (see Teaching Discussion for modifications). Students also brainstorm predictions in small groups or in pairs. In classes with a quantitative/statistical component, we challenge students to sketch a figure of their expected results; this provides practice in graph-making skills and prepares students to interpret data later. Students often create bar graphs to clearly compare average behavioral trends in categories such as location, habitat type, behavior type or species.

Conduct surveys (~45 minutes).

Prior to conducting outside surveys, we recommend reviewing the instructions, then leading students to a predetermined field site. The protocol requires students to work in pairs: one student watches the focal animal and classifies its behavior, while a second student calls out 20-second intervals and records observations on the datasheet. Groups of three students are possible for larger classes or those with odd numbers; in this case, there will be one observer, one data recorder, and one timekeeper. However, student groups of four or more are not recommended because there are not enough roles to keep all students engaged in the activity. We ask students to rotate roles such that every student has an opportunity to be the recorder and the observer. Once at the field site, students should find a squirrel before filling out the datasheet. Instructors should ensure that students are not recording the same animal at the same time. One pair of students can record the same squirrel at different times if the animal remains in the study site for the entire length of the observational time (i.e., more than 10 minutes).

Database input (<10 minutes per student).

Upon returning to the classroom, we provide time for students to enter their data into the national database. Instructors can request access to the national dataset and the data entry links via our website (http://www.squirrel-net.org). We suggest that students complete this task in class using their own mobile devices in case questions arise. Instructors can also collect hard copy datasheets from students after data entry for back-up, quality control, and/or attendance.

Lesson wrap-up (<10 minutes).

We conclude the lesson by summarizing the activity, introducing the assignment, and providing a rubric (examples in Supporting Files S3: Squirreling Around for Science – Supplies for introductory majors or lower division majors course, S4: Squirreling Around for Science – Supplies for non-majors course and S5: Squirreling Around for Science – Supplies for

upper division course). For an introductory or lower-division course, we assign a short, one-page written report that asks students to state the question, explain a hypothesis, and use the class' data or the national database to make a graph and interpret data to determine if the results support the hypothesis. Rubrics can also require summary statistics, such as means and standard deviations.

Outside of Class Activities

Instructors can request access to the national database for this module through our website (http://www.squirrel-net.org). Data are available in Excel spreadsheets and can easily be manipulated in Excel (i.e., for data cleaning or streamlining). We suggest instructors download data soon after their class submits their data to provide time for cleaning, or the removal of certain fields based on student questions and data quality (example sheets in Supporting File S8: Squirreling Around for Science – Example of national database). For example, instructors may restrict the dataset to a single squirrel species or habitat, or remove extraneous variables before sharing the dataset with students. In lower-division courses, we removed incomplete observations and only provided students with the data necessary to test their hypotheses, thereby reducing confusion about data analysis. Instructors are encouraged to tailor data cleaning to the appropriate inquiry level for their course.

TEACHING DISCUSSION

Collectively, we have successfully implemented this lesson over 20 times during the 2017-2019 academic years in 13 courses at nine institutions across the United States. The courses ranged from non-majors courses to lower and upper division major courses, and we estimate that over 800 students have been engaged in this lesson. As a result, we now have a large national database (available by request via our website), and such datasets tend to be more forgiving of occasional erroneous observations. All instructors, including those not specifically trained in behavioral ecology or mammalogy, provided positive feedback about the procedure and ease of data entry. Student evaluations showed that students enjoyed the outdoors and hands-on aspect of the lesson, contributing to a nationwide study, and asking their own research questions. Informal evaluations from students and instructors alike suggested that some students gained confidence in their ability to conduct scientific research and became more interested in careers in science after participation in the lesson. We believe this evidence suggests that our lesson plan enhances students' research skills and confidence in research.

Extensions and Modifications

The current lesson is written at the controlled level of inquiry (Table 2); however, it can be easily modified to provide a more structured or more student-driven inquiry, depending on the instructor's goals and course context. For example, instructors of non-biology majors courses can use this lesson at the structured inquiry level (Table 2). Here, instructors provide a single research question and students generate hypotheses as a whole class. Instructors take students to a single field site and observe a single focal species during a single 2-hour class period. After data collection, the instructor provides a graph for interpretation and discussion as a whole class, instead of a dataset for student analyses. Other modifications are also possible at this level of inquiry. For instance, the lesson was implemented during a 50-minute lecture period for 30 non-major students. We presented background information and practiced recording behaviors with the class, but students collected data outside of class time (e.g., over the weekend). In a second lecture period, students entered data they collected in a computer lab, generated potential questions they could ask from the data, and then predicted possible responses with a structured worksheet (Supporting File S4: Squirreling Around for Science – Supplies for non-majors course).

To adapt the current lesson plan to meet higher levels of inquiry (Table 2), instructors can provide students with a choice of field sites and/or focal species or encourage students to select their own observation sites outside of class. Instructors can link hypothesis development to background information such as ecological concepts, like trophic levels, or animal behavior theories, like optimal foraging theory. Example research questions at this level of inquiry could include "How does urbanization of habitat affect the perception of risk for sciurids?", "Do changes in perception of risk promote acclimation to urban habitats?", or "Do sciurids adapt to changes in climate by altering phenology of caching?" We often suggest that students in upper division classes collect observational data multiple times. Therefore, this lesson plan requires more than one laboratory period that is at least two hours long or data collection outside of class time. During the additional data collection sessions, instructors can provide feedback to student groups about their specific question and prediction. Students then analyze a cleaned or raw dataset provided by the instructor and create a one-page summary with graphs and simple statistics or a larger lab report with an introduction and conclusion (S5: Supplies for upper division course). Alternatively, instructors can employ an "un-essay" final project format, whereby students are allowed to submit a data-driven artistic expression of their questions and findings (e.g., a painting, rap song, sculpture, or cartoon (36,37)).

A unique strength of the Squirrel-Net modules is that they can be adapted at multiple levels, allowing students to revisit the same research topic at different levels in their education. Specifically, Colorado Mesa University students participated in Squirreling Around for Science in both lower-division required courses at a structured inquiry level and again in upper-division elective courses at an open inquiry level. During the second implementation of the activity, we focused on higher-level research skills, such as more-complex statistical analyses and dealing with messy and/or incomplete data. Far from feeling like the lesson was redundant or duplicative, many students appreciated the opportunity to revisit the activity. Informal conversations with students suggest that they gained an appreciation for the research process by comparing their experience in open inquiry to their previous analysis with a cleaned dataset. Repeated exposure to the same topic is known to promote deeper engagement and long-term gains in skills and content knowledge (38). Finally, if instructors plan to employ multiple Squirrel-Net modules (e.g., (23–25)), we recommend Squirreling Around for Science as an entry-level lesson to the network and to the concepts of animal behavior.

Squirreling Around for Science can also be extended into a unit- or semester-long CURE. This free inquiry lesson plan is aimed at senior-level students and can be used as a capstone activity for science majors. Here, instructors create a longer timeline that allows students to perform research of primary literature in order to generate questions and hypotheses about

sciurid foraging behavior across a range of species and habitat types. Students collect observational data multiple times and are provided a raw dataset that includes multiple locations and species across time. Students conduct statistical analyses ranging from t-tests to ANOVAs, and then write a publication-style paper with references or create a conference-style presentation. Opportunities exist within this format to cover more specific topics related to the course, to incorporate other resources on campus such as primary literature research, and to test open-ended and novel questions with the national dataset. Furthermore, student pre- and post-assessment surveys regarding the effectiveness of the CURE can be requested via the Squirrel-Net homepage (http://squirrel-net.org), which are in compliance with the Institutional Review Board for the Protection of Human Subjects in Research (IRB).

Finally, instructors could adapt the current lesson to investigate the behavioral ecology of animals beyond sciurid rodents. We focus on squirrels because of their charismatic behavior, diurnal activity, and ubiquity across habitats, but the observational protocol described here can be easily modified to record behaviors from other mammalian species. Ungulates (e.g., deer) and lagomorphs (e.g., rabbits) are prey species that must also balance foraging with predator surveillance and are common across a range of habitat types. Alternatively, the lesson plan can be adapted to observe bird behaviors. Feeders in urban and suburban habitats offer an opportunity to test predictions about trade-offs associated with foraging behaviors, species interactions (e.g., competition with conspecifics, predator vs. prey), and the influence of migration. In summary, Squirreling Around for Science is designed to be easily modified to meet instructor needs based on time, content, and assessment goals while providing students with authentic research experiences studying local mammals outdoors.

SUPPORTING MATERIALS

- S1. Squirreling Around for Science – Resources for identifying focal species and field sites.
- S2. Squirreling Around for Science – Squirrel behavior observation datasheet.
- S3 Squirreling Around for Science – Supplies for introductory majors or lower division majors course.
- S4. Squirreling Around for Science – Supplies for non-majors course.
- S5. Squirreling Around for Science – Supplies for upper division course.
- S6. Squirreling Around for Science – Squirrel behavior student directions.
- S7. Squirreling Around for Science – Squirrel behavior ethogram table.
- S8. Squirreling Around for Science – Example of national database.
- S9. Squirreling Around for Science – Lecture slides with background information.

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Table 1. Squirreling around for science teaching timeline

Activity	Description	Time	Notes
Preparation for Class			
Research & find local squirrel species	1. Determine potential squirrel species in your area. 2. Choose a single focal species or create a guide to identifying the squirrel species your students are likely to see. Print handouts for students and/or post on course webpage. 3. Find a location with squirrels (e.g., campus trees, town park, local forest or field) and determine how long it takes to get from your classroom to the observation site. 4. Request access to the national dataset & submission forms via our website (http://squirrel-net.org).	Variable; Plan on 30 minutes to research squirrel species; Plan on 30 minutes to 1 hour for finding an observation site (hopefully less!)	• Use websites, state info & mammal guides to find local species, example websites in Supporting File S1. • Tip: Find a location with >10 squirrels.
Practice recording data	1. Print out one copy of the squirrel behavior observation datasheet. 2. Watch an example video and record behaviors in datasheet.	5-10 minutes	• Observation datasheets are in Supporting File S2. • Example videos are on our website (http://squirrel-net.org).
Prepare handouts & supplies	1. Print the following documents for your students: • Squirrel behavior observation datasheet (double sided, 1 per student) • Student instructions (double sided, 1 per pair) • Ethogram (double sided, 1 per pair) • List/description of local species (optional) 2. Collect materials for observations: • Clip-boards/writing surface • GPS-locating device • Watch/time piece/stopwatch • Binoculars (optional) 3. Determine your formative assessment and edit rubrics.	15-30 minutes	• Students can use SmartPhones for GPS coordinates in decimal degrees (drop a pin in Google Maps or use a free GPS app like GAIA GPS or HandyGPS). • Observation documents are in Supporting Files S2, S6 and S7. • Examples of assessments are in Supporting Files S3, S4 and S5.
In-Class Activity			
Interactive lecture and project discussion	1. Interactive lecture introducing topics (sciurid rodents, foraging behaviors, Squirrel-Net, etc.). 2. Practice recording observational data as a group. 3. Discussion: Students generate questions, hypotheses and predictions in small groups.	30-45 minutes	• Lecture slides with notes in Supporting File S9. • Example videos are on our website (http://squirrel-net.org).
Conduct surveys outside	1. Review student instructions. 2. Divide students into pairs or triplets. 3. Travel to observation site. 4. Record squirrel behavior. 5. Return to class room.	40+ minutes, depending on travel to your field site	• Be sure students change roles, so that each student records behavior. • Acclimation time is accounted for as students fill out the top portion of the datasheet.
Data input and lesson wrap-up	1. Students use computers and/or SmartDevices to electronically enter collected data into the Squirrel-Net database. 2. Summarize activity, introduce assignment and provide rubric for assessment materials to students.	15-20 minutes	• Completed in class or outside class, depending on time. • Be sure to request access to the submission forms via our website (http://squirrel-net.org). • Examples of assessments are in Supporting Files S3, S4 and S5.

Activity	Description	Time	Notes
Outside Class Activities			
Data analysis (instructor)	1. Download data from the national database (http://squirrel-net.org). 2. Clean dataset (remove columns and/or rows that do not pertain to student questions). 3. Post/share dataset with students. 4. Provide rubric for assessment materials, if not done previously.	10 minutes	• Example Excel spreadsheets of original and cleaned datasets are in Supporting File S8.
Data analysis (students)	1. Students receive dataset from Instructor. 2. Students complete data analysis on their own or in groups and complete assignments.	~1 week	• Instructors can vary the due date/time of the assignment. • Further modification includes creating graphs as a whole group during class time. Instructors should plan ~20 minutes to create a graph in Excel with an introductory class, or up to an entire class period (50+ minutes) to use R with an upper division class.

Table 2. Examples of extensions and modifications for this lesson. Levels of inquiry are explained in more detail in the companion essay by Dizney et al. (26).

Level	Structured Inquiry	Controlled Inquiry	Guided Inquiry	Free Inquiry
Instructor provides	• Question (e.g., foraging/ vigilance tradeoffs relative to safety) concerning one species at a single field site • Guided discussion to develop hypotheses and predictions • Behavioral observation protocol • Plotted data and/or statistics to students	• Identification for species and field site, and suggests potential questions • Guidance on hypotheses and predictions • Behavioral observation protocol • Cleaned class or national data sets • Statistical analyses and results	• Identification for potential species and field sites, and guides discussion of their selection • Behavioral observation protocol • Cleaned or raw national data sets	• Guidance on field site selection and species identity • Behavioral observation protocol • Raw national dataset • Guidance on statistical techniques
Student activities	• Generate predictions either individually or as a class • Collect data • Input data electronically • Discuss and interpret results	• Generate hypotheses and predictions • Collect data • Input data electronically • Calculate summary statistics • Discuss and interpret results	• Generate question, hypotheses and predictions • Collect data at least once in and/or outside class • Analyze national dataset (either raw or cleaned by instructor) with graphing and simple statistics to test predictions • Discuss and interpret results	• Determine species and select among potential field sites • Generate question, hypotheses and predictions • Collect data throughout the semester • Clean national dataset • Analyze own and national dataset • Plot, data, run statistical analyses, discuss and interpret results
Possible assessment(s)	1-page written report	1-page written report with summary statistics and graph	• Lab report or un-essay presenting results	• Conference-style presentations or written manuscript