TheCornellLab of Ornithology

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Instructor Guide: Sound Trees

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Introduction

Purpose

Learning how to construct and interpret phylogenetic trees is one of the most important skills for students studying biodiversity and evolution. Most trees that students encounter are based on DNA sequences or morphological traits, but there are other characters that can be useful for studying relatedness. In this investigation, students study bird calls and songs, and use them to infer relationships and to think about the function of calls in the life history of birds.

Overview

This investigation is composed of three semi-independent parts, which escalate in complexity and in the independence of thought required from the students. Parts 1 ("What you see is what you hear") and 2 ("Owls in trees") teach students skills that they can apply to fully inquiry-based projects in Part 3. Instructors can choose to omit Part 3 if time does not permit the entire investigation. Part 1 equips students with the skills required for independent navigation of the Macaulay Library, so it can be used as a stand-alone lesson to prepare them for other projects that use the library's resources.

The Macaulay Library is an ideal place for students to explore natural history and make their own observations and measurements. It is large enough that students can find their own topic or taxon of interest within it, allowing them an authentic scientific experience as they use its data to test their hypotheses. From the Library website (http://macaulaylibrary.org):

"The Macaulay Library at the Cornell Lab of Ornithology is the world's largest natural sound and video archive of animal behavior. Its mission is to collect and preserve recordings of each species behavior and natural history and to make them available for research, education, conservation, zoos and aquaria, wildlife managers, publishers, the arts, and both public and commercial media. Since 1930, recordists of all backgrounds have contributed their recordings, which now number to several hundred thousand in total. A large percentage of the recordings can be searched and played online."

Essential Questions

- Which traits are useful in classifying organisms, and when would one type of trait be more useful than another?

Learning Objectives

Students will:

- Learn how to use and explore the Macaulay Library at the Cornell Lab of Ornithology (Part 1)
- Analyze owl calls to define phylogenetic characters, and use these characters to build a phylogenetic tree (Part 2)
- Compare the calls tree to morphological and DNA trees, and discuss the reasons for their similarities and differences (Part 2)
- Develop hypotheses about how bird calls relate to bird life history traits, and test their hypotheses via independent research using the Library (Part 3).

Materials

- Computers (one per pair of students, plus computers available for students to use outside class) with Internet access, and QuickTime and RavenViewer installed. Computers must be able to play sound, either through speakers or through headphones.
- A similarly configured computer for the instructor, with a projector for demonstration. This computer should be audible, so the instructor can demonstrate sounds for the class.
- Optional (useful in a large class): headphones for the computers, one per student. It would be helpful if two students could listen at the same time.
- Student worksheets
- Scratch paper
- For Part 1: prizes for the highest score on day 2 (optional)
- For Part 2: printouts (preferably in color) of the owl morphology sheets

Preparation

This investigation is designed for undergraduate or high school students who are familiar with the idea of phylogenetic trees. The tree-building exercise may be made more or less sophisticated, depending on the prior experience of the students. As written, it requires only an intuitive approach to grouping by similarity, but it is easily adapted to require students to apply formal algorithms of parsimony (for example) to the character matrices.

This investigation would be appropriate for a general biology class (perhaps in the behavior, ecology, or evolution curriculum), an introductory course on evolution, or a course on animal behavior.

See Materials for specific computer requirements to conduct the investigation. Information on installing the free QuickTime plug-in for RavenViewer can be found at: http://macaulaylibrary.org/help/ravenViewer/index.do.

Part 1: What You See is What You Hear

Learning Objectives

Students will:
- Understand what a spectrogram is and how to interpret it
- Be able to navigate and explore the Macaulay Library

Duration

30 minutes in the first class, then 30 minutes in the second class after the students have completed the at-home assignment.

Procedure

Day 1

Let students know that they will need to be able to use the Macaulay Library for a homework assignment.

Begin by giving students a tour of the Library (http://macaulaylibrary.org). Take requests from students, typing in the names of birds or other animals that they'd like to hear examples of. This is a way of letting students bring in their own knowledge of birds. It would also be a good way to recall organisms that you have studied earlier in the class (Galapagos finches, for example).

Introduce students to the idea of a visual representation of sound by demonstrating a RavenViewer spectrogram. Entries with triangles/wings on the playback symbol lead to RavenViewer. There is a guide to the viewer here:
http://macaulaylibrary.org/help/ravenViewer/details.do

Show students how to use the waveforms and spectrograms and, optionally, the power spectrum.

Demonstrate how to "zoom in" on a spectrogram for fast and detailed calls (e.g., warblers) in RavenViewer:
--Increase the "timeline zoom"
--Decrease the "speed"
--Click the "Waveform" button and enable "Hide;" repeat with the "Power Spectrum" button so only the spectrogram window remains (enlarged).
Demonstrate that this is very useful for fast calls (e.g., golden-cheeked warbler), and less useful for slow/simple calls (e.g., red-tailed hawk).

If time permits, have students explore the library and the viewer in pairs on their own computers. You may wish to suggest some birds for them to look up, or you may prefer to simply let them explore on their own. Circulate and help students who are stuck.

Finally, give students the homework assignment. Decide on the best way for them to turn it in (email, a web drop-box, etc.) and give them this information.

Day 2

Before class, prepare a sound-matching game based on student explorations of the database, as follows.

Look up each URL chosen by a student, adjust the playback settings according to the student specifications, and advance the recording to the start time requested by the student. Hide the "Power Spectrum" pane and, if you wish, the "Waveform" pane. Then make a screen-shot of the RavenViewer playback image.
--To do this on a Macintosh running MacOS X, press the Cmd, Shift, and 4 keys, and the cursor will turn into cross-hairs. Click and drag to demarcate the area you wish to save, and then let go of the mouse. A file called "Picture 1.jpg" will appear on the desktop. Repeat as necessary until you are happy with the image.

Repeat to get screen shots of each recording. Then assemble the pictures into a printout that you can give to the students in class. Give each picture a letter (A, B, C, ...) and record for yourself which recordings correspond to which letters.

Before class begins, on the instructor computer, cue up each recording in a separate RavenViewer window, with the settings and start time specified by the students. Organize the windows into recording 1, recording 2, etc. DO NOT project the screen for students to see, but DO make sure that students can hear what you play on the computer.

When the students arrive:

Hand out the copies of the recording pictures. Explain the game to the students:

"Each one of these is the spectrogram of a recording chosen by one of you. I will play each recording on my computer in a random order, and your job is to guess which spectrogram goes with each sound."

Play recording 1, recording 2, etc., and have students quietly assign it to the spectrogram they think it fits best.

When you have finished, go over the game sheets as a class and give a prize to the student(s) with the highest score. If you're concerned about cheating, have students score one another's papers instead of their own.

Assignment: What you see is what you hear

You have been shown how to use RavenViewer and how to explore the Macaulay Library (http://macaulaylibrary.org). Your assignment is to explore it on your own, and find your favorite sound. Your sound may be a bird, a mammal, or any other animal in the Library. The recording must be playable in RavenViewer.

When you have found it, decide on the best way to display it. Choose a moment in the recording that you feel is a particularly good example of the sound. Adjust the "Speed" and "Timeline zoom" playback settings so they display the features of the sound clearly.

Then give this information to your instructor:

- The URL of the recording
- The start time of the moment in the recording that you chose
- The "Speed" and "Timeline zoom" settings you chose

Your instructor will tell you when this is due and how to turn it in.

Part 2: Owls in Trees

Introduction

This part of the investigation is meant to give students practice in building and using phylogenetic trees, using an unusual set of character traits (owl calls). More broadly, it invites discussion of the important question of what constitutes a good phylogenetic character for a particular group of species. Owl morphology is often convergent or invariant, making it a problematic trait for phylogenetic reconstruction (see Wink et al. 2009). DNA sequences for owl species are not yet easily available, so the data molecular phylogenies have thus far been restricted to a single mitochondrial and a single nuclear gene (Wink et al. 2009). Since individual gene trees do not always correspond to species trees, it is useful to consider other characters as well.

In some birds, such as the yellow-naped amazon parrot *Amazona auropalliata,* calls are learned socially, making them unsuitable as phylogenetic characters (Wright et al. 2001). In owls, however, calls are inherited (Wink et al. 2009). As a result, students can reliably group some owl species together by call (e.g., the screech owls). Other owl calls are harder to categorize, meaning that different groups of students tend to come up with different trees, providing useful fodder for discussion.

One factor that contributes to the success of this investigation is the appeal of the owls themselves. In trials, students found them charismatic, using words like "adorable" to describe the screech and Northern saw-whet owls. Some students spontaneously made a connection to the Harry Potter books and movies, which feature a snowy owl as the hero's pet. Many were surprised and delighted by the unexpected sounds, such as the screech owl whinnies. The classroom atmosphere was happy and talkative, and students eagerly engaged with the investigation as a result. Owls, it seems, are inherently entertaining.

<u>References and further reading:</u>

Wink, M, El-Sayed, A-A, Sauer-Gurth, H, & Gonzalez, J 2009. Molecular phylogeny of owls (Strigiformes) inferred from DNA sequences of the mitochondrial cytochrome *b* and the nuclear *RAG-1* gene. *Ardea* **97(4),** 581-591.

Wright, TF, and Wilkinson, GS 2001. Population genetic structure and vocal dialects in an amazon parrot. *Proc. R. Soc. Lond. B* **268,** 609-616.

The owl descriptions and photos for this part of the lesson (adapted to disguise the identity of the owls) are from the Cornell Lab of Ornithology's "All About Birds" website: http://www.allaboutbirds.org

Learning Objectives

Students will:

- Use the Macaulay Library to listen to the calls of ten North American owls, and decide on characters to use to describe the calls
- Build a phylogenetic tree of the owls based on their calls
- Build an independent tree of the same owls based on morphology
- Compare the two trees and discuss the similarities and differences
- Compare both trees to a DNA sequence tree
- Analyze and write up their findings.

Duration

Variable depending on how rigorous you wish the phylogenetic approach to be, and how detailed you wish to make the discussion. A reasonable estimate would be two hours total for sections 1 and 2 (separable into two class periods), with section 3 assigned as homework.

Procedure

Section One: Calls

Decide in advance how long you want students to take on this part of the investigation, and how many characters you want each group to come up with. Share these expectations with the students. Some students will want to measure calls in great detail, spending time on adjusting playback settings and recording frequency ranges and so forth; other students will be happy with a gestalt approach. As a result, it is useful to give the students a sense of how they should pace themselves. Most students find this activity fun, so if you have the time (e.g., devoting an hour to section 1), it is rewarding for students to be able to take the time to enjoy the sounds and debate the merits of different characters.

Divide students into pairs, one pair per computer, and hand out the Owls in Trees worksheets. If the class is large, it may be useful to have two sets of headphones for each computer so students are not distracted by the noises around them, but this is optional. Have students work through the first section of the worksheet: listening to the ten owl calls, deciding on characters, and scoring the characters in the table provided.

The URLs for the owl calls are anonymous; they do not indicate the species names of the owls, so students will not have clues about which species are in which genus. Enterprising students may try typing the ID number into the search field of the Macaulay Library website, but this can lead them astray because video numbers and audio numbers do not correspond. You may wish to warn them of this pitfall, or (better) simply keep an eye out for especially clever students as you circulate while they work on the investigation!

When students have finished their trees, reunite the class for a discussion. Solicit characters that students used, and write these on the board. Have groups come up and write their trees on the board, indicating the character transition points. Groups with different character choices and/or character weights will produce different trees, and this enables a good discussion of what makes a good character. Ask student groups to explain their reasoning. Ask the class for opinions on which groupings they think are the most likely to be correct, having seen various trees, and which characters they think are the most likely to be informative. If possible, leave the trees on the board while students work on section two.

Section Two: Morphology

Pass out the owl picture/description sheets to the pairs of students.

These owls are lettered rather than numbered, so students will not be able to tell which photo and description corresponds to which call. As before, they are also anonymous, with no species names. Have students develop and score characters in the same pairs as before, and make trees. This will take less time than section one, because they have practiced the skill and because looking at pictures is faster than listening to calls.

Once students have finished, reunite the class again and have them draw the new trees. Discuss differences between trees. Was there more agreement between trees for morphology than there was for calls?

Reveal the number/letter/species-name correspondence at this point, handing out the key. Discuss.

Finally, give out the DNA tree from Wink et al. 2009. Discuss the discrepancies between gene trees (presented in this phylogeny) and species trees, and how ancestral polymorphism can result in misleading results. Students will have a bias toward trusting the DNA tree over the morphological or call trees; discuss this preference and whether it is merited.

Section Three: Discussion Questions

Assign the discussion questions found in the Student Sheets as homework.

Part 3: On Your Own

In section two above, the class discussed whether calls or morphology make better characters for owls. Ask the question: What about owl ecology might make calls a better character than it is in parrots? This discussion should have led to some hypotheses, such as higher heritability of owl calls, higher sociability of parrots, and especially the nocturnal habits of owls. From these ideas, have students develop hypotheses that can be tested in other bird groups using the Library's recordings of songs and calls. Students will work in groups of three to test these hypotheses. Where molecular phylogenies are available, you can help students find and interpret these to help with their investigations of the sounds.