Chapter 14

Birdsong Playback as a Tool for Teaching Animal Behavior

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Introduction for Instructors

These laboratory and field exercises are designed to introduce students to the general topic of animal communication, and to the biology of birdsong specifically. The objectives of these exercises are threefold:

1. Provide basic background information on animal communication and the role of song in bird behavior;

2. Introduce the acoustic structure of birdsong and use computer software to explore some aspects of this structure; and

3. Show students how animal behavior can be studied in the field.

Instructors have options for where these exercises can fit profitably into the course syllabus. In a general biology course, the birdsong lab can serve to illustrate not only the topic of animal behavior, but also sensory physiology and certain aspects of ecology. If the course is animal behavior, then the topics of physiology, development, genetics, territoriality, or communication all offer conceptual links between lectures and the birdsong lab. While this lab is inquiry-based and can serve as a good test of a student's ability to design and carry out scientific investigations, there is a fair amount of background knowledge needed to understand the role of song in bird communication. This limitation therefore makes the birdsong lab inappropriate as an initial exposure to scientific inquiry at the start of an introductory lab course.

The birdsong lab and field exercises described in this document can be done either as isolated activities, or as an integrated whole. If the entire lab is performed, then ample time must be allowed for the field component, which also has seasonal limitations in terms of songbird availability and acoustic activity. Field exercises that do not require actively singing birds are possible, including mapping the acoustic characteristics of habitats, or measuring how these characteristics affect the sound quality of specific songs. Other examples of possible field or lab studies using the acoustic behavior of birds and other animals include:

1. Examining the role of alarm calls in vocal communication;

2. Studying the vocal interactions of birds at artificial feeding stations (This is especially useful in winter.);

3. Assessing vocal characteristics associated with social dominance (e.g., chicken flocks); and

4. Testing acoustic communication in non-bird species (e.g., amphibians and insects).

Equipment needs for the birdsong lab are relatively minor, but do require some advance planning. The computer program *Canary* (for Macintosh computers only) is easy to master and available at a modest cost from the Cornell Laboratory of Ornithology. A Windows-based version of this software (called *Raven*) is scheduled for release by the Lab of Ornithology in late summer 2001. Other, and typically more expensive, DOS-based acoustic analysis software packages are available as indicated below in the Notes for Instructors section. The field playback equipment (e.g., portable tape recorder, field speaker, batteries, and cassette tapes) is readily available from commercial electronics stores or specialty research suppliers. If properly cared for, this equipment can last a long time, thus spreading the cost of outfitting this lab over many years. Audio CDs of recorded bird vocalizations are also available commercially, or can be obtained through actual field recordings given the proper equipment and planning. If the instructor has a basic understanding of the role of song in avian communication and knows fundamental methods of field biology, then no additional training beyond mastery of the acoustic analysis software is required to teach these exercises.

Materials

The following materials are needed if the entire birdsong playback lab is to be taught:

- Macintosh or Windows computer(s) with graphics capability and at least 10 Mb free memory. The faster the CPU processing speed, the better the performance. Refer to the program developer's specific hardware specifications for each software option.

- Acoustic analysis computer software. Options include:
  - *Canary* (Macintosh)
  - *Raven* (Windows; scheduled for release in summer 2001)
  - *Avisoft* (Windows)

- Field playback equipment, including:
  - Portable cassette deck and/or CD player
  - Portable speaker and 35 m of cable
  - Batteries, tapes, and birdsong CDs
  - Recording microphone (optional)

- General field equipment (e.g., binoculars, field identification guides, stopwatches, measuring tapes, etc.).

Notes for Instructors

The birdsong playback lab does not require that students have a detailed understanding of the acoustic structure of animal communication signals. However, if students are to fully appreciate the ecological reasons why certain birds use specific vocalizations in the ways that they do, it is necessary to provide some background about the physical structure of birdsong. This can be done during a preparatory lecture, or as part of the lab itself. The former usually takes on a more traditional, one-way presentation of acoustic theory. The latter is a more hands-on approach that can be greatly facilitated by the use of acoustic analysis computer software like the commercial products described below. The computer approach can be made more enjoyable for your students by letting them analyze sounds of interest, such as their own voices, or non-animal acoustic signals (e.g., traffic noises, musical instruments, pure tones, etc.). By gaining a basic understanding of the physical features of sounds (i.e., frequency, intensity, modulation), students will have a much richer understanding of the role played by song in the behavior and ecology of birds.

A good way to introduce students to the computer analysis of sound is to make up a worksheet that leads your students through the basic steps of using whichever software program you decide to purchase. This exercise can be as simple or extensive as you care to make it, depending on the level of the course and the depth at which you want the students to explore. The key is to not get lost in the details of complex acoustic analysis, but rather to use the program to demonstrate the key parameters of acoustic structure, and how these parameters can be analyzed or manipulated.

Instructors must also realize that birdsong is typically a seasonal behavior. If wild songbirds are to be used as the study subjects for courses taught in northern temperate climates, this lab should be done only in spring or early summer. However, if captive species are to be used, or non-singing vocalizations such as alarm calls or contact notes are to be studied, then this seasonal limitation may not apply. Moreover, if non-avian subjects are studied, then any field or lab conditions (independent of season) that can reliably result in vocalizations by the animal under investigation are appropriate for this teaching exercise.

Another important point to make to students is the relative difficulty of conducting field studies versus basic laboratory science. The inability to control variables precisely, combined with the inherent unpredictability of animals in their natural habitats, can be significant sources of frustration for students. Be sure to clearly inform your students that fieldwork takes time, and frequently lots of it. Time management and careful planning of research activities are therefore critical to success in the field.

Specialty equipment for the birdsong playback lab can be obtained from the following suppliers:

- For information on the *Canary* and *Raven* acoustic analysis software programs, contact:
  Bioacoustics Research Program
  Cornell Laboratory of Ornithology
  159 Sapsucker Woods Road
  Ithaca, NY 14850
  607-254-2408
  http://birds.cornell.edu/brp/CanaryInfo.html

- For information on the *Avisoft* acoustic analysis software, contact its programmer Raimund Specht directly at:
  http://home.t-online.de/home/raimund.specht/avisoft_.htm

- Pre-recorded birdsong CDs may be purchased from the Lab of Ornithology, or from any good local or on-line CD store.

- Mineroff Electronics, Inc. is an excellent source for field playback and recording equipment. They sell a wide variety of reasonably priced equipment that is very reliable and durable. Contact them at:
  Mineroff Electronics, Inc.
  574 Meacham Avenue
  Elmont, NY 11003
  516-775-1370
  http://www.mineroff.com

  Less professional and durable, but nevertheless effective, playback equipment can also be obtained from local vendors such as Radio Shack and other commercial electronics stores.

Student Outline

General Principles of Animal Communication

One of the behavioral hallmarks of the human species is our aptitude for complex communication. Many biologists and anthropologists consider the sophisticated nature of human communication as the single most significant factor that separates us from other animals. But what exactly is communication, and is it unique to humans? To help us answer these questions, imagine each of the following situations:

1. You are about to take the biggest exam of your life and you are very nervous. A friend sitting next to you reaches over and reassuringly pats your arm. Almost immediately you start to relax.

2. Your mother invites you home for a holiday dinner. A bouquet of wonderfully familiar smells greets you at the door, causing you to salivate in anticipation of a delicious meal.

3. A female firefly of the genus *Photinus* blinks a repeating pattern of flashing light, which she creates through chemical reactions in her abdomen. Soon a male of her species arrives, and the two proceed to mate.

4. A male Black-capped Chickadee (*Parus atricapillus*) gives his namesake "chicka-dee-dee-dee" vocalization as he interacts at a winter bird feeder with members of his flock. Other chickadees stay away from the feeder when the male vocalizes.

The common link among these situations is that they are all examples of animal communication. When animals communicate, at least two individuals must be involved in the sending and receiving of a physical signal. That signal can be in the form of light, sound, chemicals, or pressure changes associated with touch. Biologists say that true communication occurs between animals when one individual (*signaler*) sends a message (*signal*) to another individual (*receiver*), thereby causing a change in the behavior or physiology of the receiver.

Based on this definition, explain how the four situations described above are examples of true communication. Be sure to identify the signal, the signaler, the receiver, and the end result of the communication effort.

As these examples show, communication is a regular occurrence in many animal species. Effective communication systems allow individuals to find more food and better shelter, to defend themselves or their resources, and to obtain mates. Since good communicators tend to survive longer, they also increase their lifetime reproductive output compared to individuals that do not communicate effectively. Because of its direct effect on reproduction, the quality of a communication system is very important in determining the overall evolutionary success of a species.

One factor that helps determine the effectiveness of a communication system is the nature of the sensory channel used to communicate. Several possible channels can be employed, each with its own set of strengths and weaknesses as a communication signal. Table 14.1 compares the four most common sensory channels used in animal communication systems.

Table 14.1. A comparison of four common sensory channels and their usefulness as communication signals. *

	Hearing	**Vision**	**Chemical**	**Touch**
Can be used at night	Yes	Rarely	Yes	Yes
Flows around objects	Yes	No	Yes	No
Range	Long	Medium	Long	Short
Information content	High	High	Low	Medium
Locatability of signaler	Medium	Good	Poor	Good
Cost to produce	High	High	Low	Low

* Modified from Alcock (1989).

The information in Table 14.1 reveals that some sensory channels are better suited for short-range communication (touch), while others work best at longer distances (hearing and chemical). Some channels work equally well during day or night (hearing, chemicals, touch), while others are limited to daytime use (vision) except under very special circumstances (e.g., fireflies that can generate their own light). Sensory channels such as sound and vision also make possible complex, information-rich signals, whereas the chemical channel is limited to communicating relatively simple signals. Note that the channels with the richest potential for complex signaling (hearing and vision) are also the most energetically expensive channels to maintain. This is because hearing and vision require specialized anatomical structures such as vocal organs and brightly colored body parts to generate a signal, as well as ears and eyes to detect that signal.

Now use the information in Table 14.1 to rank these four sensory channels in order of their importance to *human* communication. In the space that follows, suggest some physiological, ecological, and evolutionary benefits that are gained by humans when they communicate using each channel.

	Sensory channel	**Benefits to humans**
Most important		
Least important		

Birdsong is a Type of Animal Communication

Birds can communicate using all four of the sensory channels described above. However, bird communication is primarily accomplished using vision and hearing. Of these, sound signals are the more flexible and effective communication tools given the biology of birds. Let's examine why.

Consider a small bird moving through its habitat. If it relies primarily on vision for signals, then whether or not a receiver can detect a visual signal depends on several factors. These include the amount of light available, objects in the environment that create visual obstructions between the signaler and receiver, and weather-related factors such as precipitation that can influence visibility. Indeed, *watching* birds in their natural habitat can often be a matter of "now you see it, now you don't". If, however, a bird uses sound as its primary signaling method, then it can almost always be heard, sometimes long after it moves out of visual range for a potential receiver. This is why accomplished birders often first note the presence of birds by their vocalizations, rather than by actually seeing them.

Referring back to Table 14.1, we see that acoustic signals have the advantage of traveling longer distances than light-based signals. They can also flow around most environmental obstructions. Since sound travels very rapidly in air, acoustic signals are typically short-lived. This transient feature of sound means that a great deal of information can be conveyed in a relatively short amount of time. Overall, sound is clearly the best communication mechanism for the highly mobile and active lifestyle of birds. The only significant costs to using acoustic signals are the high-energy demands of sound generation, and the maintenance of necessary anatomical structures to produce and detect signals.

Having established that sound is the best way for birds to communicate, we now turn our attention to the behavioral functions of bird vocalization. Begin by taking a few minutes to list all of the possible *biological functions* you can think of for bird sounds.

The sounds that birds make serve many purposes. Key among them are maintaining contact between members of a social group, warning of danger, establishing and holding feeding or breeding territories, and attracting mates. The members of one large taxonomic group of birds called the oscines, or songbirds, are especially talented at using complex sounds for these purposes.

Bird vocalizations can be divided into two categories: *songs* and *calls*. Songs tend to be long, complex sounds produced by male birds during the breeding season. They are used to establish territorial boundaries and advertise ownership, as well as to attract females. Calls tend to be shorter, simpler sounds produced by both sexes throughout the year. These vocalizations are used for keeping contact between individuals that are out of sight, as short-range communication signals between adults or between parents and their young, or to sound an alarm.

Songbirds have well-developed vocal abilities, to the point that they possess special brain pathways (absent in other bird groups) to deal specifically with vocalizations. Individual songbirds may sing only one to a few versions of their species-specific song, or they may sing a wide variety of slightly different versions. Each version is called a *song type*, and individual singers will frequently switch between song types while engaged in long bouts of vocalization. The complete collection of song types for any individual singer is known as his *song repertoire*, which may number in the hundreds or even thousands of song types for some especially vocal species.

Acoustic Structure of Birdsong

Odd as it might seem, sounds can be "observed" as well as heard. Since sound is acoustic energy that results from the vibration of air molecules, it can be graphically represented as a plot of vibrational frequency (what we perceive as sound pitch) versus time. Figure 14.1 shows such a *sonagram* for two simple sounds: a pure tone that maintains a constant frequency through time, and a fluctuating signal that changes its frequency over time.

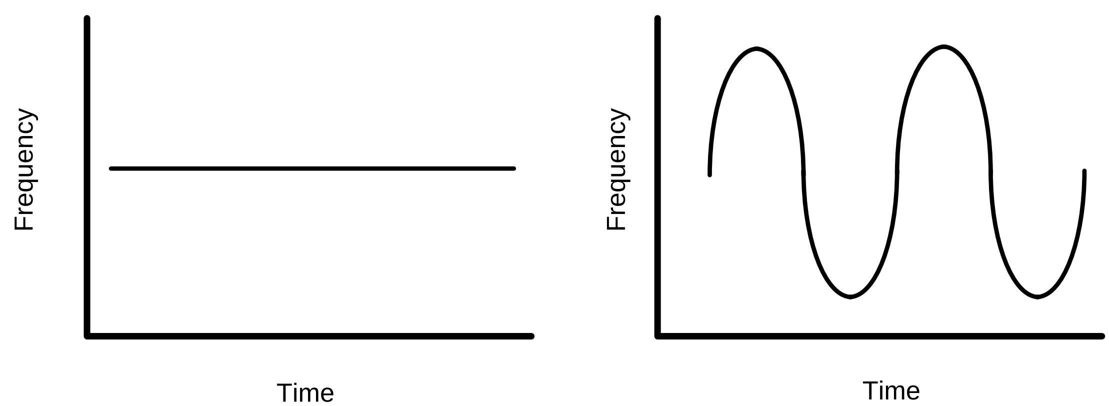

Figure 14.1. Idealized graphical representations of two simple sounds. A pure tone is shown on the left, and a fluctuating tone on the right.

Describe what you think these two acoustic signals would sound like to the human ear.

Pure tone:

Fluctuating tone:

Birdsong can also be illustrated using the sonagram method, as shown in Figure 14.2. The sonagram reveals that songs from different species, or even song types from the repertoire of a single individual, have different acoustic substructures. Each song can be divided into distinct sections called *phrases*, which in turn are composed of smaller acoustic units known as *syllables* and *elements*. This structure is somewhat analogous to a human language sentence, where individual words combine to make up identifiable parts of grammar that give the sentence linguistic meaning.

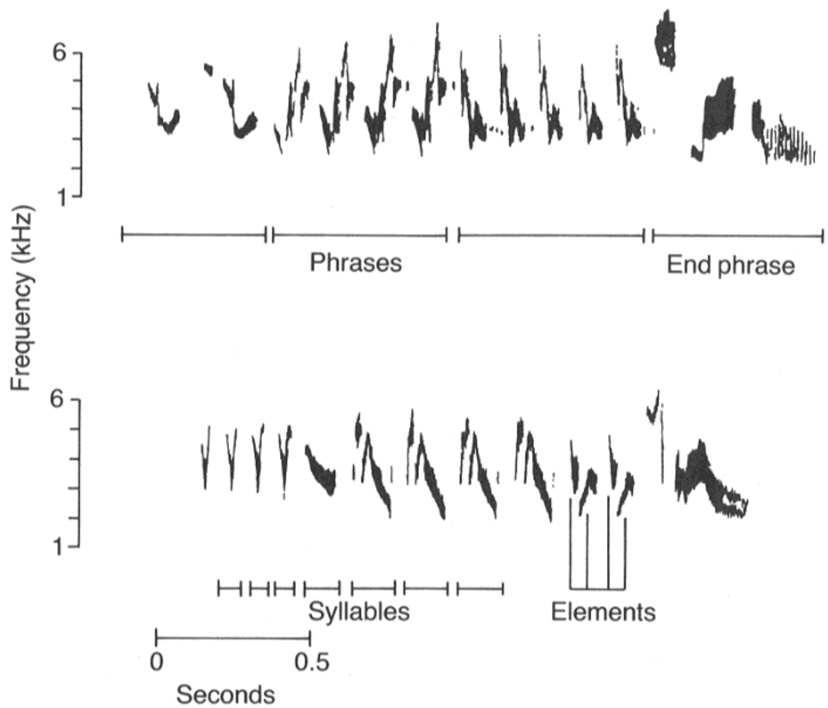

Figure 14.2. Sonagrams showing two different song types from the same male Chaffinch (*Fringilla coelebs*). (Adapted from Catchpole & Slater, 1995).

As with human language, the specific order of elements, syllables and phrases in birdsong is important for proper understanding of the intended message. Suggest some of the biological "messages" that a bird might send via its song.

Development of Birdsong

By recording birdsong in the field and then transforming it into sonagrams for later analysis in the laboratory, biologists have learned much about various aspects of bird communication. We know, for example, that some songbirds hatch with an instinctive knowledge of their songs and calls, but that many others must learn their species-specific vocalizations as part of a *sensitive phase* that they pass through as nestlings and early fledglings. Evidence for this developmental process comes from experiments in which baby songbirds are raised by hand in captivity. When these young birds are given very selective exposure to the songs of their own (and other) species, the result is that proper songs must be learned during the first few weeks of life if individuals are later to sing and recognize the correct vocalizations for their species. For some species, this early acoustic exposure essentially ends the song learning process, thereby fixing repertoire size for the life of the individual. But for other species, new song types may be added throughout adulthood.

Environmental Influences on Birdsong

Although sound offers many advantages as a sensory channel for communication, it also has its limitations. One of these is the fact that sound waves are physically degraded as they pass through the environment, thus altering both the transmission range and information content of the signal. The degradation process occurs when acoustic energy is lost as sound waves bounce off of, or are filtered by, objects in the environment. Atmospheric changes brought on by daytime heating and shifting weather patterns also affect sound transmission.

Birds engage in two interesting behaviors to compensate for these environmental effects on sound. Since the atmosphere is usually most stable in the morning when temperatures are coolest, a maximum of singing activity occurs at sunrise. Hearing this “dawn chorus” can be a very impressive experience for people that live in regions containing numerous breeding songbirds. Another behavior employed by birds to improve acoustic signaling is singing from an exposed perch. This activity minimizes the acoustic obstruction caused by physical barriers to sound transmission, thereby increasing the transmission distance as well as helping to maintain the quality and information content of the song.

Natural selection has also finely matched the acoustic properties of birdsong to the transmission characteristics of the specific habitats where birds live. The characteristics of song thus differ among species partly as a result of the acoustic constraints imposed by their environments. Even individuals of the same species may sing songs with dramatically different acoustic properties if the possible habitat types present within the species’ breeding range vary significantly.

Computer Analysis of Birdsong

Analyzing the structure of birdsong with the aid of a computer program is a good way to understand the physical properties of song. It can also be a tool for measuring or manipulating songs as part of research into bird communication. Several such acoustic analysis programs exist for use on today’s personal computers. These programs allow you to analyze graphically any sound that can be turned into a digital signal. They will let you display, manipulate, and record new versions of bird songs for use in field studies. They also have a set of statistical functions that can compare songs to determine their acoustic similarities and differences.

If your instructor chooses to have you do this portion of the birdsong laboratory, you will receive a supplemental handout describing the procedure for running your analysis software, along with specific training activities that you should work on with this program.

Using Playback to Study Birdsong in the Field

We can now apply our knowledge about the biology of birdsong to the design of a field study that tests some specific hypothesis about song function or singing behavior. As with all scientific studies, it is best to develop field studies according to an agreed-upon set of procedures that insure the study will provide useful information. These steps are summarized in Table 14.2.

Table 14.2. The steps involved in measuring behavior. *

1. Formulate an initial question and make preliminary observations.
2. Formulate hypotheses and make predictions.
3. Choose behavioral measures and a research design.
4. Define each measure.
5. Select the appropriate data-recording methods.
6. Practice the data-recording methods.
7. Collect and analyze the data.

* After Martin & Bateson (1993)

Field studies of birdsong often involve some kind of playback design in which pre-recorded songs are played to free-flying, wild birds using a portable tape player and field speaker. The birds' responses to these songs are then collected and analyzed. Questions that lend themselves well to playback techniques include studies of species or individual song recognition, the role of song in territorial maintenance and mate acquisition, and how response to song varies over the course of the breeding season. In addition, if actively singing birds are not available, playbacks can also be used to study the acoustic properties of an environment by recording the playback song at various locations within a habitat, or at various times of day and weather conditions. If your study is being done in winter, the vocal signals used by birds at artificial feeders may be a rich source of study, as can the response of birds to alarm calls or predator vocalizations. You may also apply this methodology to the study of the acoustic influences on social structure in domesticated birds such as poultry, or even to non-bird species that communicate acoustically (e.g., frogs and insects).

You will have at your disposal the following equipment for a field playback study:

- Portable tape deck or CD player, speaker, and speaker cable
- Batteries
- Pre-recorded birdsong cassette tapes or CDs
- Stopwatch and measuring tape
- Binoculars

To begin the process of designing a field study, take a few minutes and brainstorm with your classmates about *specific questions* regarding bird behavior, ecology, or physiology that could be addressed utilizing playback.

Now pick one of your questions and develop an appropriate hypothesis.

What are some dependent and independent variables that could be involved in an experimental test of your hypothesis?

What variables need to be standardized or controlled in this test?

Describe the methodology you would use for this study. Be sure to consider important issues such as: 1) exactly how you will present your song stimulus, 2) what aspect of bird behavior you will measure, 3) precisely how you will measure that behavior, 4) at what time of day you will take your measurements, 5) what levels of treatment are appropriate, and 6) how many replicates are needed. If appropriate, also consider what statistical tests you will use to analyze the data you collect.

Using the field methods that you developed above, design a data sheet to help you efficiently record the data that you will obtain in your study.

One final note before you begin your field project. Unlike the laboratory, where experimental circumstances can be fairly precisely controlled and standardized, field work requires investigators to be persistent, flexible, and to plan ahead. Field studies often take longer to complete than does lab work, largely because you are studying organisms who perform many behaviors during their day in addition to the relatively few that you are interested in observing. You should therefore be sure to allow sufficient time to collect your data, and to return for additional field trials if the weather or birds do not cooperate at first!

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I thank my colleagues Hal Weeks, William Kimler, Steve Nowicki, Jeff Podos, and Brandon Kibbe at the Shoals Marine Laboratory for their help in developing this field exercise. I also thank the more than 200 students who have participated in some part of this lab over the past 17 years for their useful comments on how to improve it.

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