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FACTORS THAT AFFECT SOUND IN THE FIELD

In field situations, sound is propagated into a heterogeneous physical environment. Topography and atmospheric conditions can affect how far and to where sound carries. Ambient noise from natural sources such as streams, wind, and rain, or from mechanical sources such as vehicle traffic or aircraft, can affect how well sound is heard. An understanding of how sound behaves, and the environmental factors that attenuate (reduce the intensity of) or mask sound, is useful in setting up surveys, adjusting to field conditions, and interpreting results.

MASKING NOISE

As sound propagates from a source, such as from an owl or a surveyor broadcasting owl calls, it decreases in loudness at a constant rate under normal conditions. Sound loses its energy mostly through geometric spreading – as sound radiates away from the source, the energy is spread within an increasingly large area .If the intensity of a sound at the source (amplitude) is known, the distance to which the sound can be heard can be calculated. In terms of what we hear, sound is half as loud for every doubling of distance. An owl heard at 100 meters distance would be half as loud at 200 meters, one-quarter as loud at 400 meters.

The amplitude of a sound decreases rapidly as it propagates from the source but can carry a long ways at a much reduced level. Because of this, it doesn’t take much distance for an owl call to be masked by loud creek noise, but at the same time, an owl call can be heard at long distances under ideal conditions. Whenever the masking noise, such as from a creek or wind, is approximately as loud as an owl calling from it’s location, chances are the owl won’t be heard.

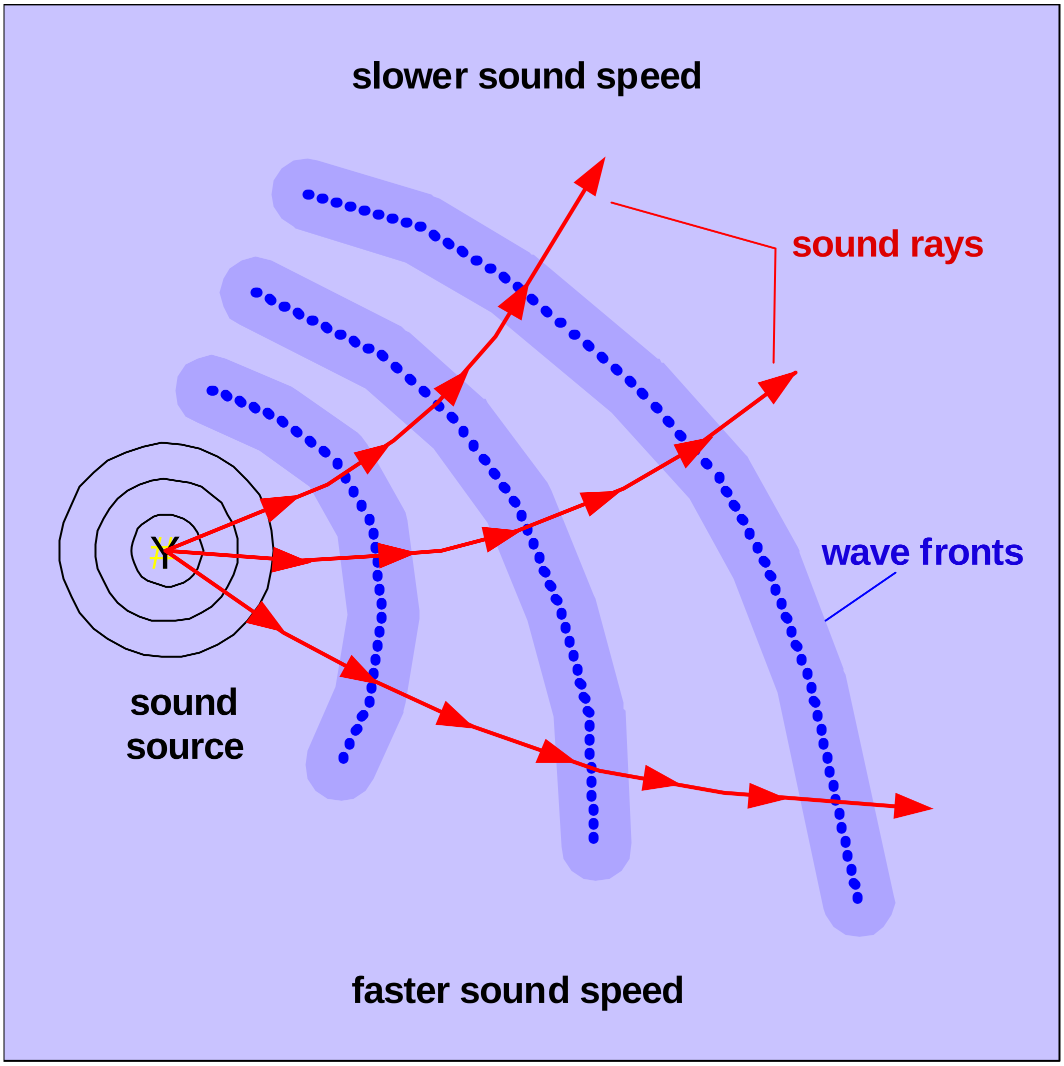
For an owl call to be masked by interfering noise, it shouldn’t be thought of hearing an owl as if it were right next to you, but rather at a distance with reduced volume. Maybe the best way to appreciate this effect is by having someone talk in a normal voice beside a creek, then have them move away, still talking until they can’t be heard any longer. The same thing happens with owls calling from a distance: close in they can be heard, but further away, they may not be, depending on their distance, the reduced amplitude of their call, and the loudness of the interfering noise.

ACOUSTIC SHADOWS

Environmental conditions can create acoustic shadows, or areas where a sound cannot be heard, even though the same sound could be heard without those conditions. Air temperature, wind (beyond noise), and topographical features can all inhibit what can be heard.

REFRACTION OF SOUND WAVES

Refraction occurs when sound waves are transmitted from one medium to another medium, with the second medium having different properties affecting the speed of the sound waves. The speed of the sound waves changes in the second medium, and this alters the direction of (refracts) the sound waves. The waves will refract toward the medium with slower speed, changing the direction of the sound wave. This can be represented graphically by sound rays, lines drawn perpendicular to the direction of the wave front. Both temperature and wind have conditions which affect sound in this manner.

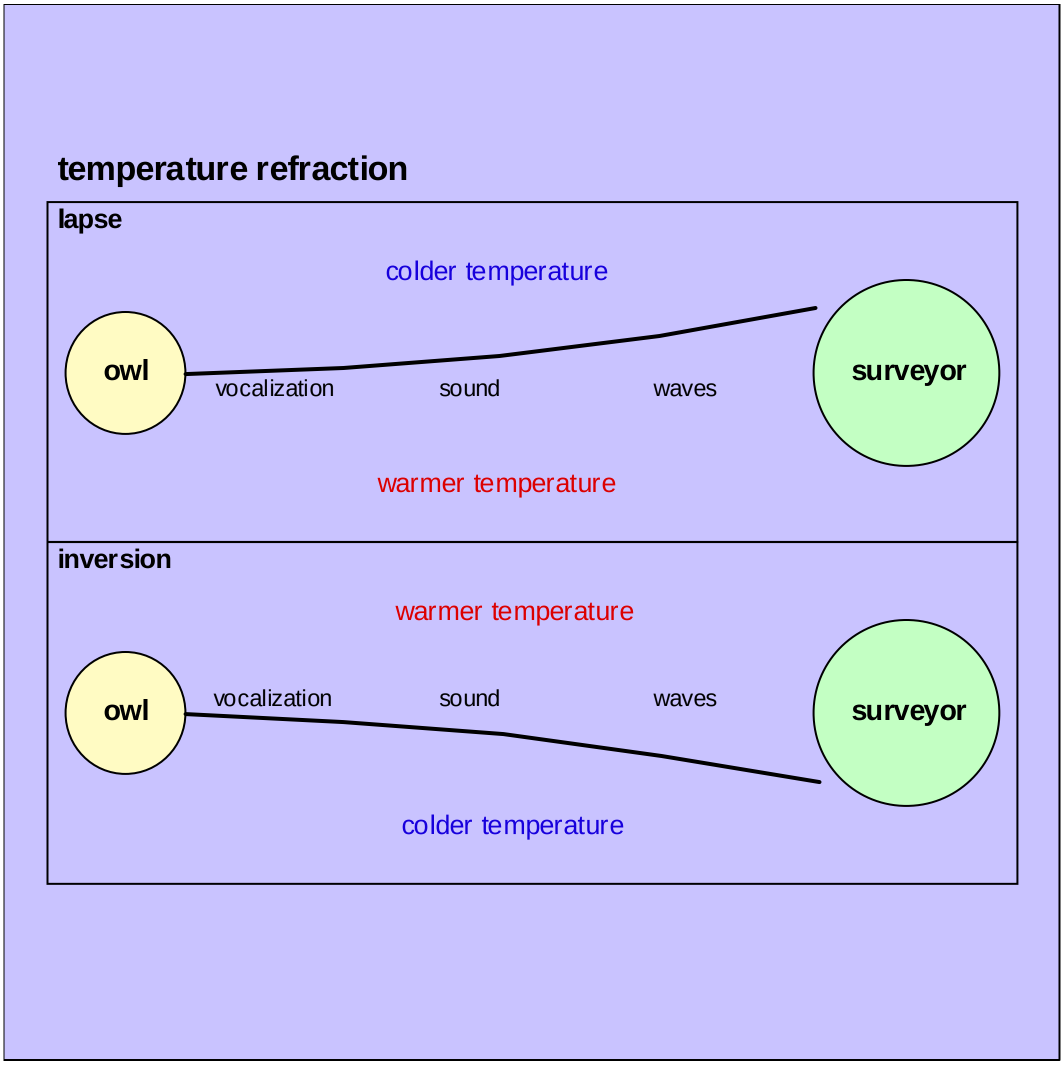


Temperature

Sound travels slower in cooler air. Air temperature during the day is warmer closer to the ground and gradually gets cooler away from the ground. This is called a temperature lapse, and causes sound waves to refract upward away from the ground toward the area of slower sound speed. Whenever there is a mass of air that is cooler than the air above it, it is called a temperature inversion, causing sound waves to refract downward, increasing audibility at ground level.

Temperature inversions, which generally create the best conditions for hearing, occur most often in summer when there is a rapid cooling at ground level, and require very little to no wind and lack of cloud cover. A similar effect can be noticed many times at a body of water, where the air next to the water is cooled compared to the air aloft, and sounds can seem near and loud. Inversions start when it gets dark and dissipate when the sun begins to warm the earth after sunrise.

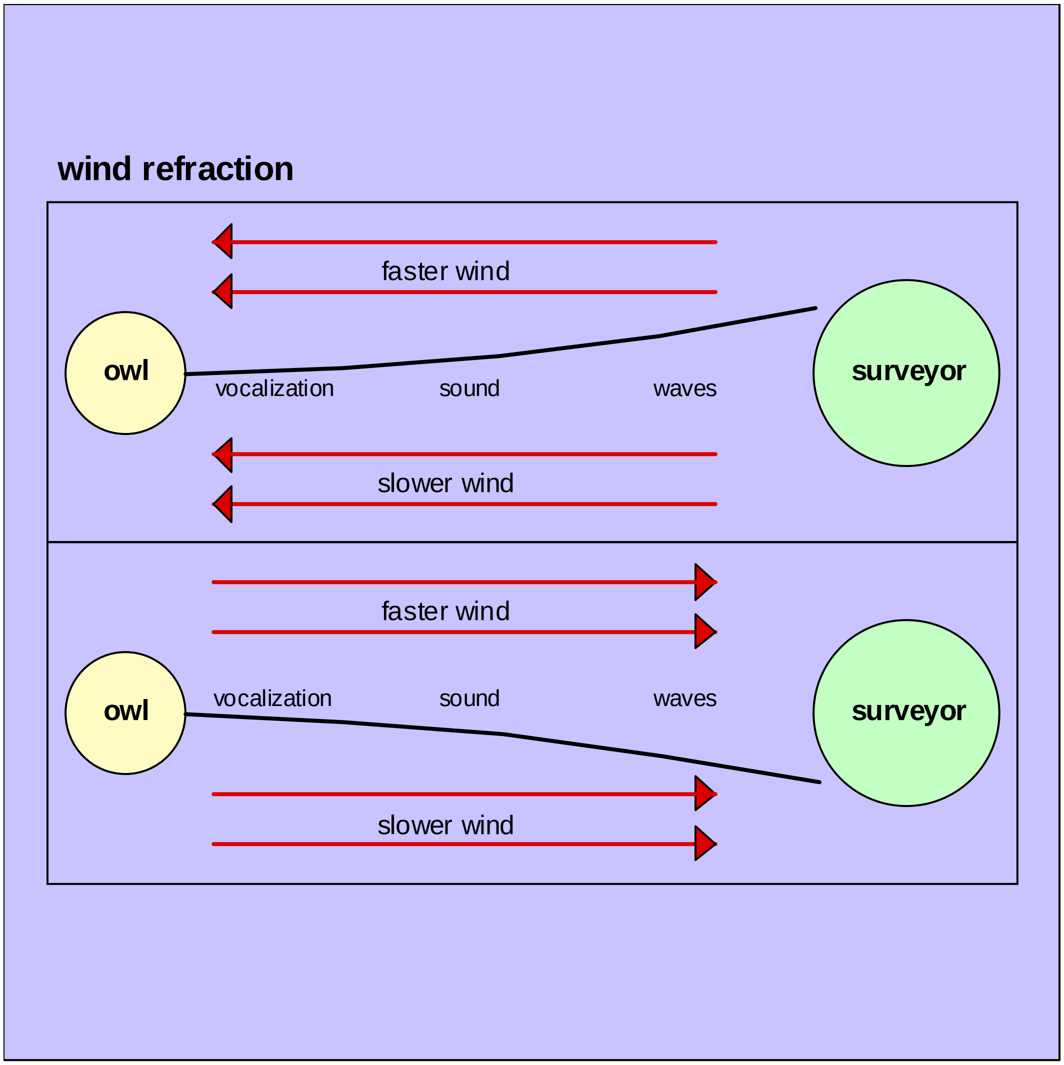
During temperature lapses, sound refracts away from the ground, so that over a distance sounds may pass completely over an observer without being heard. This is one reason night surveys can be more effective than daytime surveys. The following graphic illustrates this effect.



Wind

A similar effect is caused by a condition of wind called wind shear. Wind close to the ground is slower in speed compared to wind further above the ground because of friction with the ground. When a sound wave is propagated in the same direction as the wind, it will refract toward the slower wind speed near the ground; when a sound wave moves in the opposite direction as the wind, the faster wind speed aloft slows the speed more than the slower wind at the ground, and it will refract toward the slower wind speed aloft, decreasing audibility at a distance.

Wind moving in the direction from the surveyor to an owl will refract the owl’s calls upward away from the ground until, at a certain distance, the owl won’t be heard. Wind from the owl to the surveyor will increase the distance an owl can be heard, but at the same time will lessen the distance that an owl can hear a surveyor's calls. The following graphic illustrates this effect.

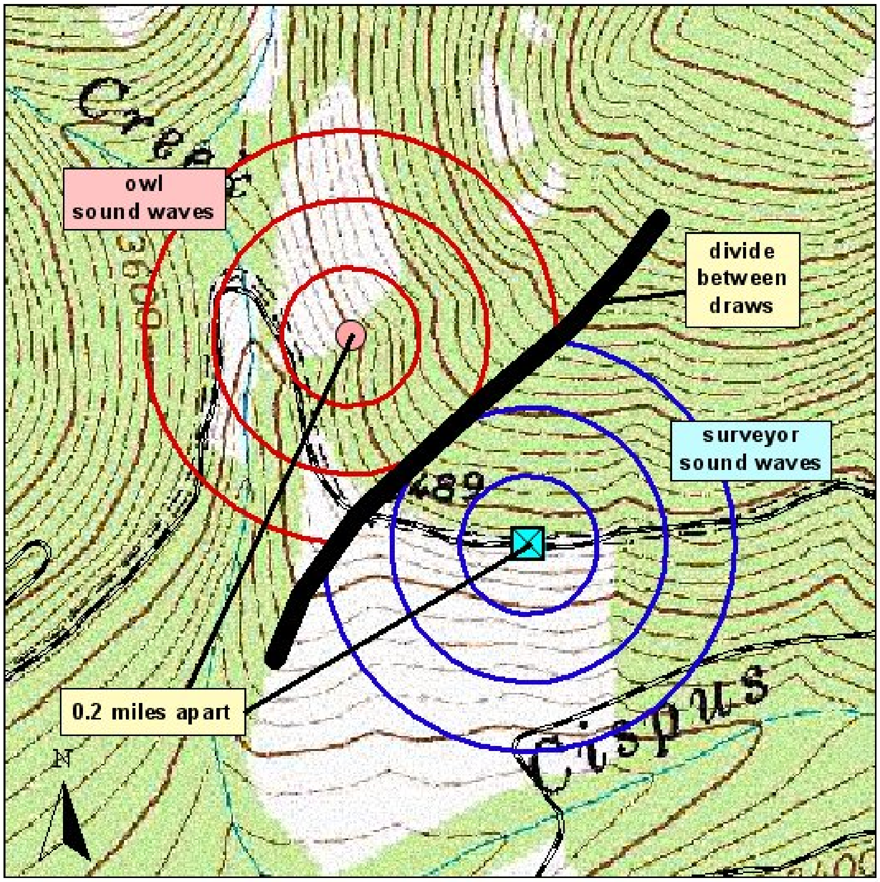


Another effect of this condition is that over long distances (or sometimes even relatively short distances) sound will get louder and softer, depending on local wind shear differences.

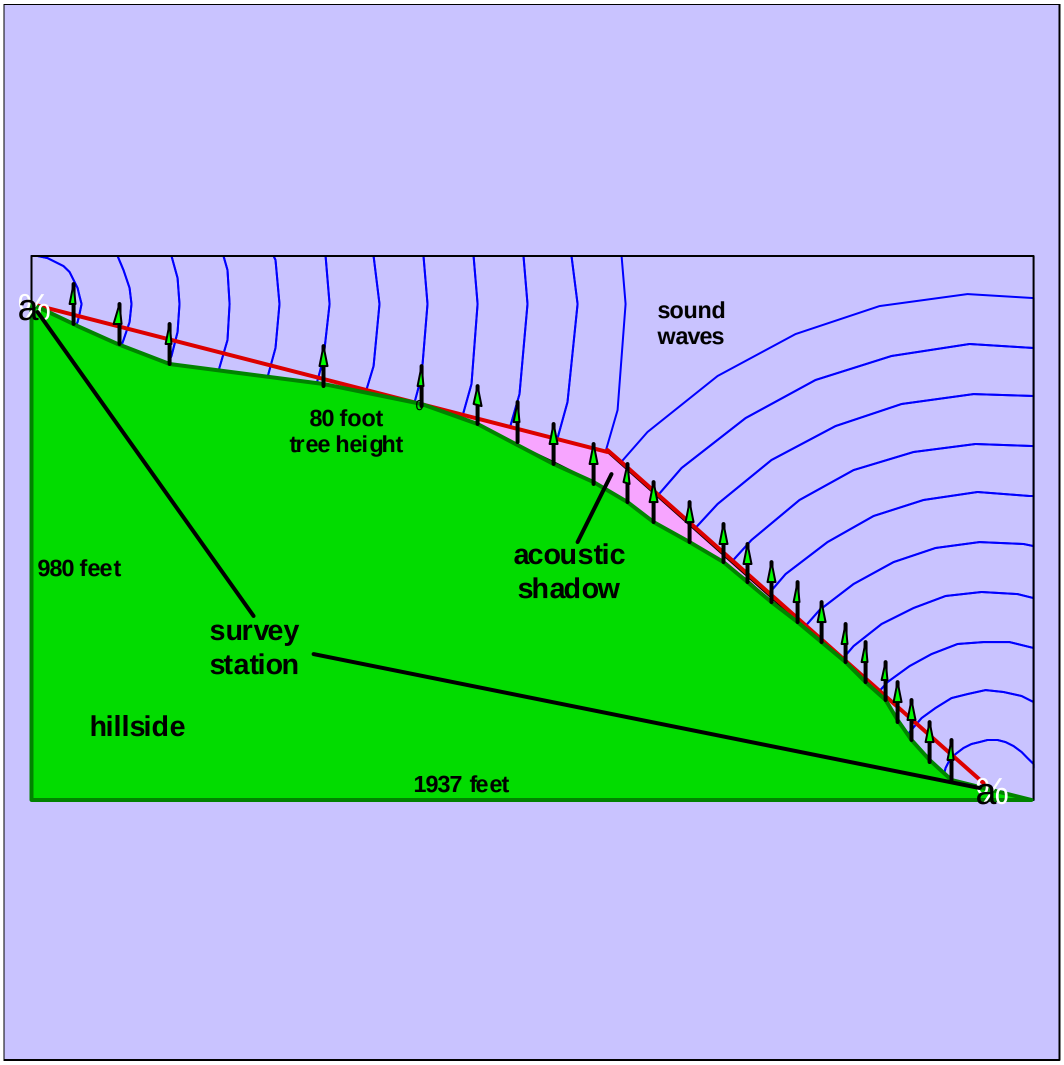
PHYSICAL BARRIERS

When sound meets a physical barrier, such as the ground, it is either absorbed, reflected, or diffused by that barrier. There are many different field situations where this occurs, with varying levels of effect. Following are two of the most common forms of topographical barriers that create acoustic shadows.

Example 1. The surveyor and owl are on either side of divide between two adjacent draws. Sound does not penetrate the higher ground between the two draws, is absorbed or reflected upward, and even though surveyor and owl may be quite close in terms of distance, neither is audible to the other.



Example 2. In this example, there is a survey station positioned at the top and bottom of a steep hillside, with the survey stations being 0.41 miles apart. On flat ground, this distance between stations would provide for overlap of coverage. However, in this situation, because of changes in slope on the hillside, there is an area in the middle of the slope that is an acoustical shadow where the survey calling from either station would not reach, and for which an owl could not be heard from either station. Even though there is an acoustical shadow in this area, in this example an owl could still be heard if it was high enough in the treetops. (See also example 2, *Interpretation of owl detections related to topographical features*).



COMBINATION EFFECTS

Probably the worst field situation typically encountered is to have survey stations along a road above a noisy creek with a steep, incised ridge above, the road curving in and out of the gullies, and then surveying on a night with a variable breeze. The loud creek noise inhibits what can be heard to begin with. Changes in slope on the ascending ridge-side and the incised gullies make for local acoustic shadows. The wind can change what can be heard in any direction from minute to minute. Altogether, a much-reduced potential to detect owls or, if detected, to determine their location.

In these kinds of situations the effect on survey is that effective survey coverage is much less than under good conditions, and survey set-up should be adjusted to try and compensate. Survey stations should be set up closer together than normal, and possibly survey time at each station should be extended. In this circumstance, it may be more effective to survey from across the valley, even though it is further away from the habitat being surveyed (as long as it is not too far away) as the creek noise may not be as loud and it would eliminate the topographical acoustic shadows.

INTERPRETATION OF OWL DETECTIONS FROM SURVEYS

Determining the location of owls heard during survey at night can be difficult. An understanding of the properties of sound and the environmental conditions that may affect sound can help make these determinations. An understanding of owl behavior can also aid in making these determinations.

Compass

One of the better ways to determine owl location based on a vocal response is to take a compass bearing (or azimuth) from the position of the surveyor to the owl (with the compass first having been adjusted for declination, or, with no declination set, the bearing adjusted later). While this accounts for direction, it leaves distance as an estimate of the surveyor. However, as seen above, acoustic factors can alter how loud a sound is, and can cause a surveyor to under- or over-estimate distance.

By moving to a different location and getting a second compass bearing from that location to the owl, a more precise estimate of distance is achieved where the bearings intersect. A third compass bearing from a third location is even better, as it describes an area rather than a point.

A problem is that this does not account for the possibility of owl movement, which can change the perceived location of the owl by quite a bit. The best solution is to take multiple compass bearings from different locations at the same time. This, of course, cannot be accomplished by a single surveyor, so it is included here as the best option when there is more than one surveyor present.

Faint owl responses

While distance is the main factor that would cause an owl response to be faint, there are other factors that should be considered when determining the location of an owl. An owl can sometimes be out of a direct line of hearing but still heard as an echo (example 1). If there is a surface that might be reflective, such as a nearby cliff, this should be considered. Another condition that can sometimes occur is for the owl's response to be mostly blocked by a barrier (example 2). In this circumstance, the main energy of the owl's call would go over the surveyor's head while some reflection and diffusion might occur, making a relatively close owl seem far away.

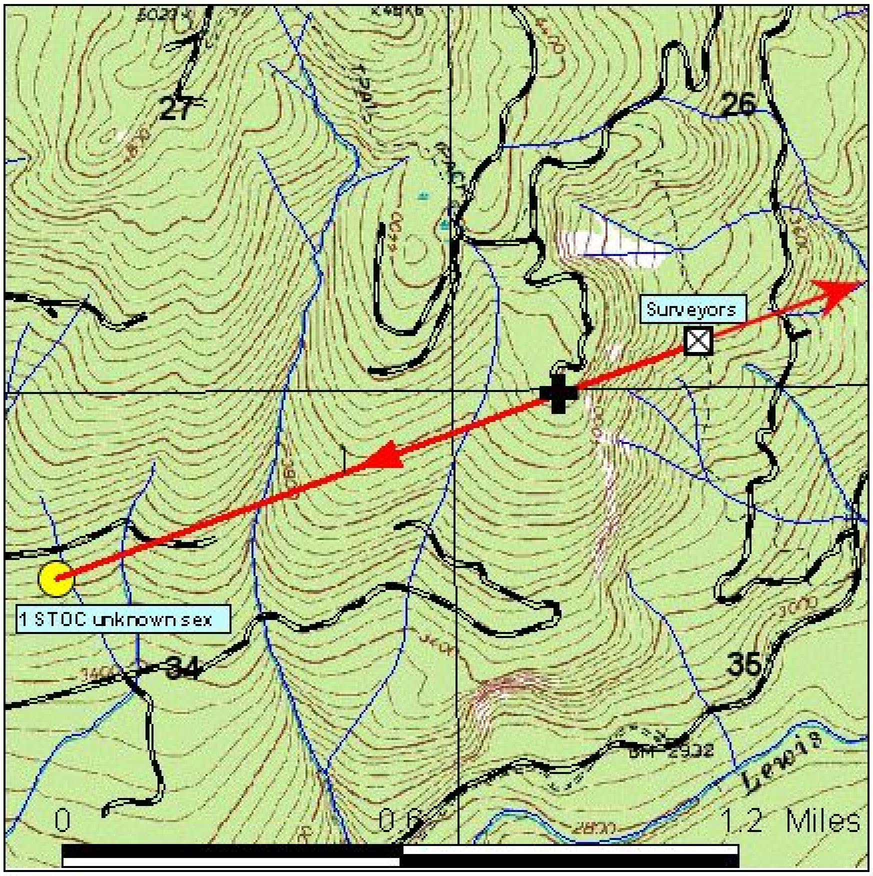
A feature of faint responses that takes some practice to recognize is that faint calls without any intervening obstructions sound soft, but clear and distinct. A soft call due to obstruction may sound the same in terms of loudness, but will sound "fuzzy" or indistinct.

Following are two examples of interpreting owl detections related to topographic features and four examples of interpreting owl detections related to owl behavior. All of these examples were taken from actual field situations from past surveys.

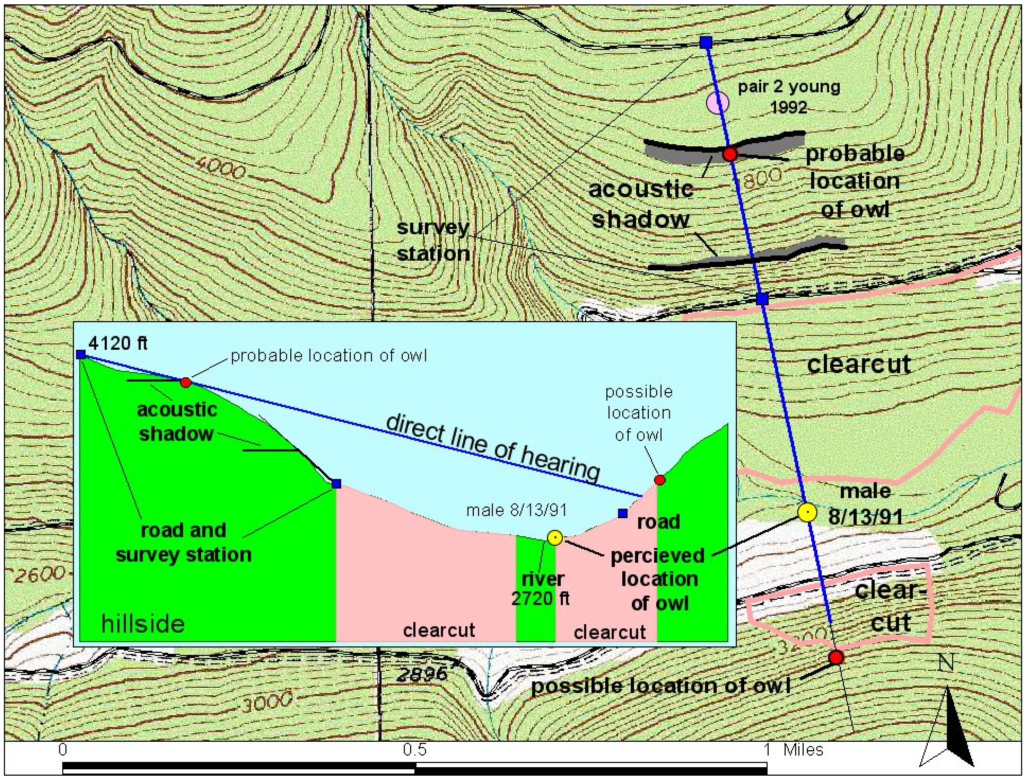
INTERPRETATION OF OWL DETECTIONS RELATED TO TOPOGRAPHICAL FEATURES.

Example 1. Surveyors were with a pair of spotted owls on a daytime follow-up and heard another faint spotted owl call. They equated the faintness of the call to distance, and they placed the location of the owl over a mile away along the compass bearing they took. The problem was that there was a ridge between them and their perceived location of the owl, making it impossible to hear an owl in that location.

In this example, it is much more likely that the owl was just beyond the ridge break, as indicated by the black cross, or that they heard an echo off the steep ridge-side next to their location, with the owl actually located along a ~~back-bearing~~ [note: this should be “along a reflected bearing” and the graphic needs to be changed]. The result of examples like this is that the surveyors will be looking for the owl in the wrong location.

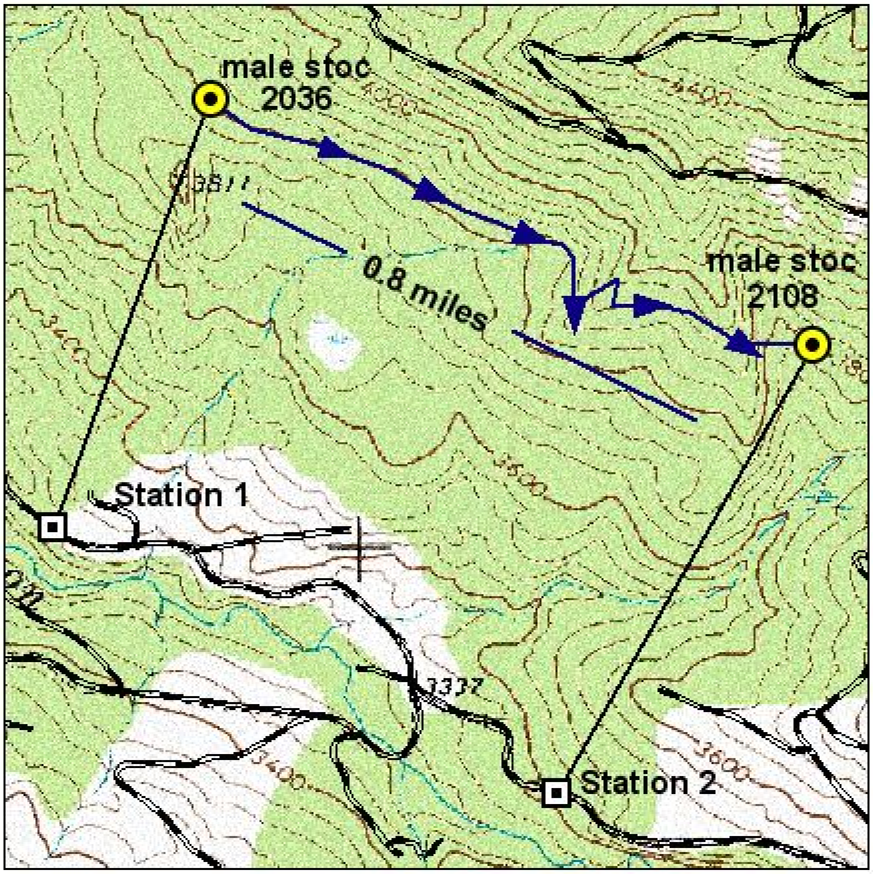


Example 2. Surveyors heard an owl faintly, seeming to be downhill and distant from their location. As in example 1, the surveyors equated a faint response with distance. However, due to the acoustical shadow inherent to their survey station, their perceived location of the owl was impossible. It is much more likely that the owl was just beyond the break of the steep downhill portion of the slope where the acoustical shadow begins. Another possibility is that the owl was even further away, on the slope across the river; however, this seems less likely with the distance involved combined with competing noise from the river. A second clue to the actual location of the owl was that no owl was heard from the survey station lower on the hillside, which would have been in direct line of hearing with an owl at the perceived location, but would have had the owl within the acoustical shadow in the probable location.

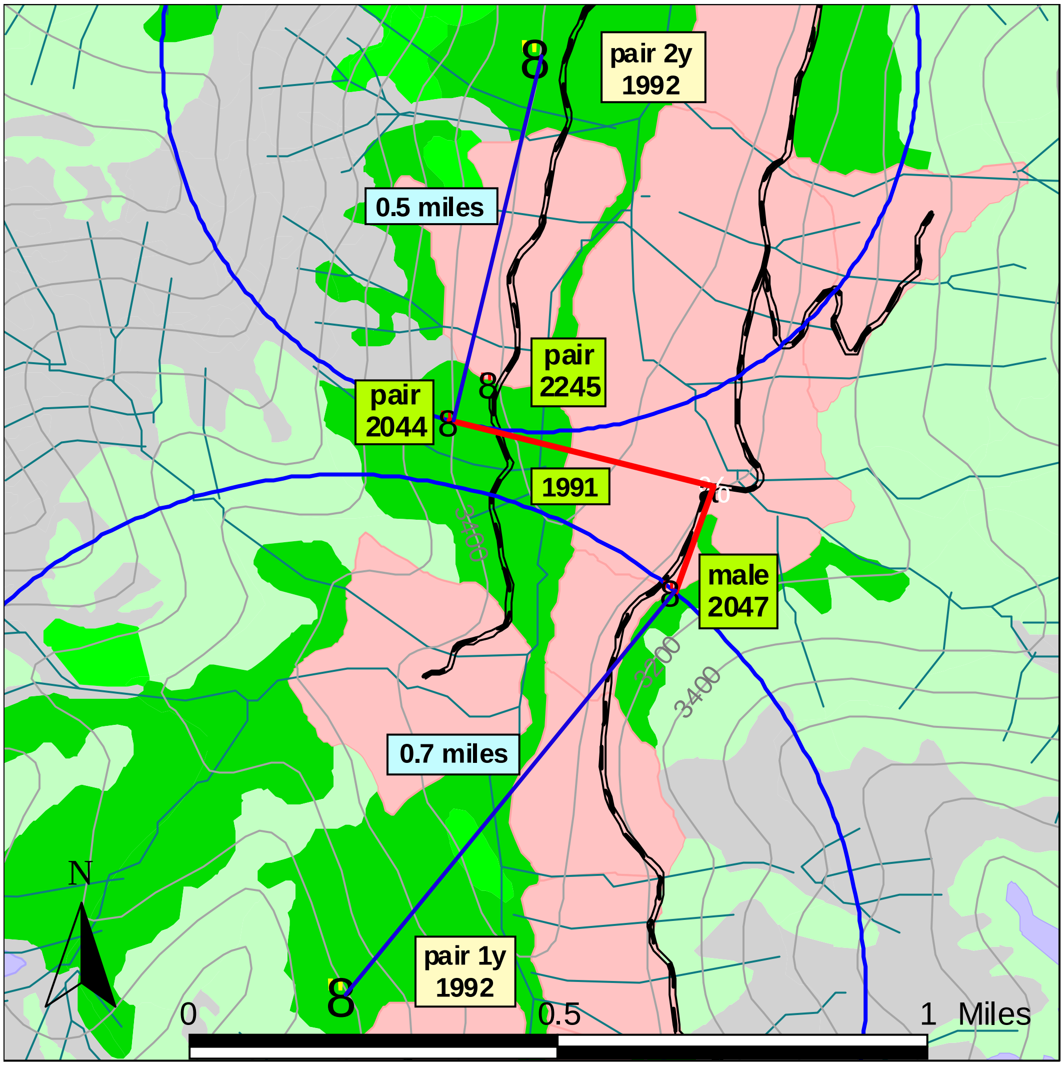


INTERPRETATION OF OWL DETECTIONS RELATED TO OWL BEHAVIOR

Example 1: owl movement. It's a fairly common mistake to attribute multiple detections of owls from different stations to the same owl. Unless an owl is triangulated to the same location, a response in two different locations could be either the same owl that moved or two different owls. In the following example, the surveyors considered the responses from two stations to be the same owl. However, considering the distance the owl would have had to travel, taking into account that Spotted Owls travel in short flights from perch to perch rather than one long, quick flight, and that this would have included some uphill flight, where the owls will zigzag up the slope from perch to perch, it is more likely that this was two owls.

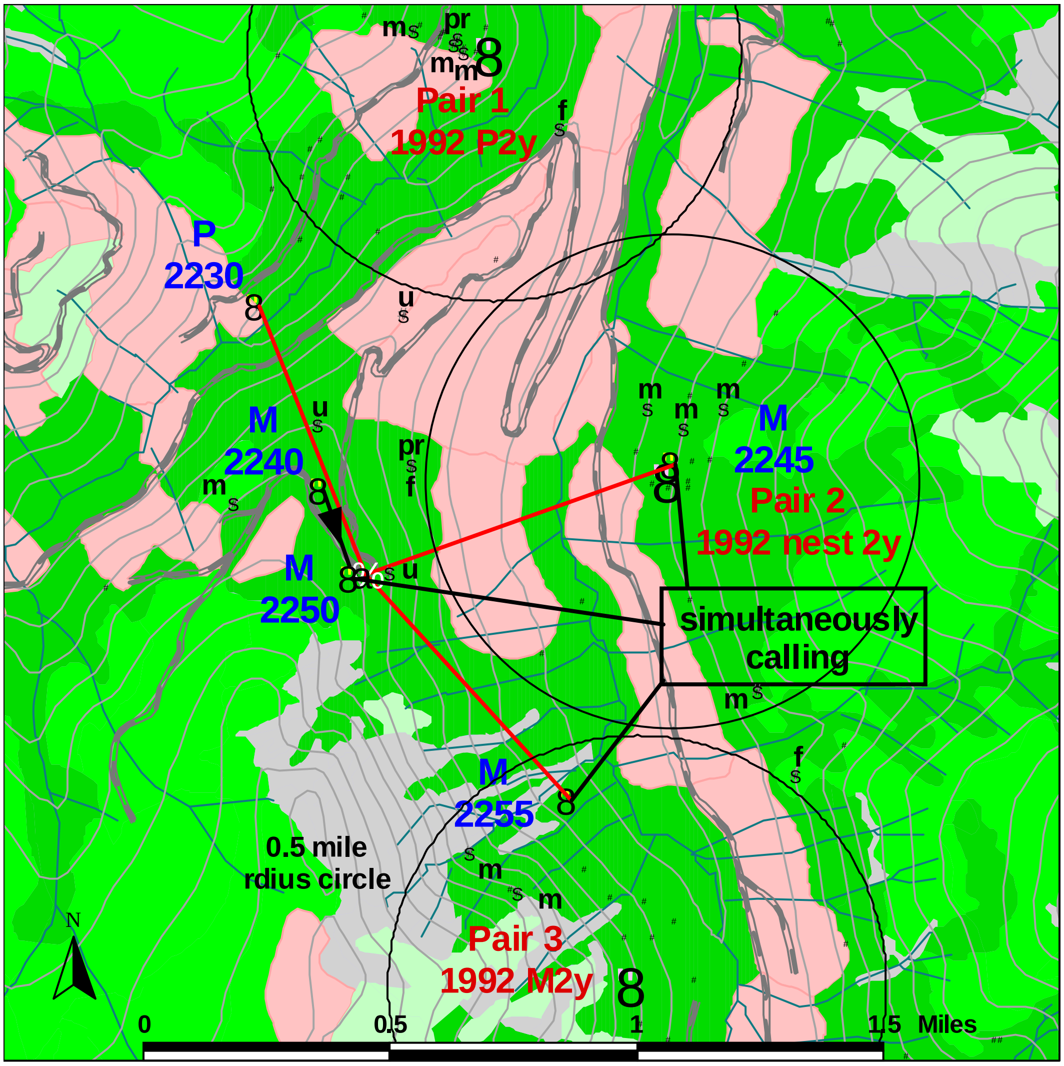


Example 2. **A** spotted owl pair was heard to the west of the survey station across the valley at 2044. At 2047, a male spotted owl was heard to the south of the station on the same side of the valley. Later in the survey, at 2245, they got the pair again from a survey station near to the pair's original location. At the time, the surveyors (two wildlife biologists) came to the conclusion that the male of the pair had flown across the valley near to their location, and then had flown back when they got the pair again at 2245. However, this would have entailed the male spotted owl flying nearly ½ mile in 3 minutes, an unlikely scenario. Because of this interpretation of events, there was only one follow-up in the pair location, and the possibility that the male spotted owl response represented a second pair was not even considered. Surveys in 1992 located a reproducing pair southwest of the male spotted owl's 1991 location, and it is likely that the pair was also there in 1991, but was missed because of misinterpretation.

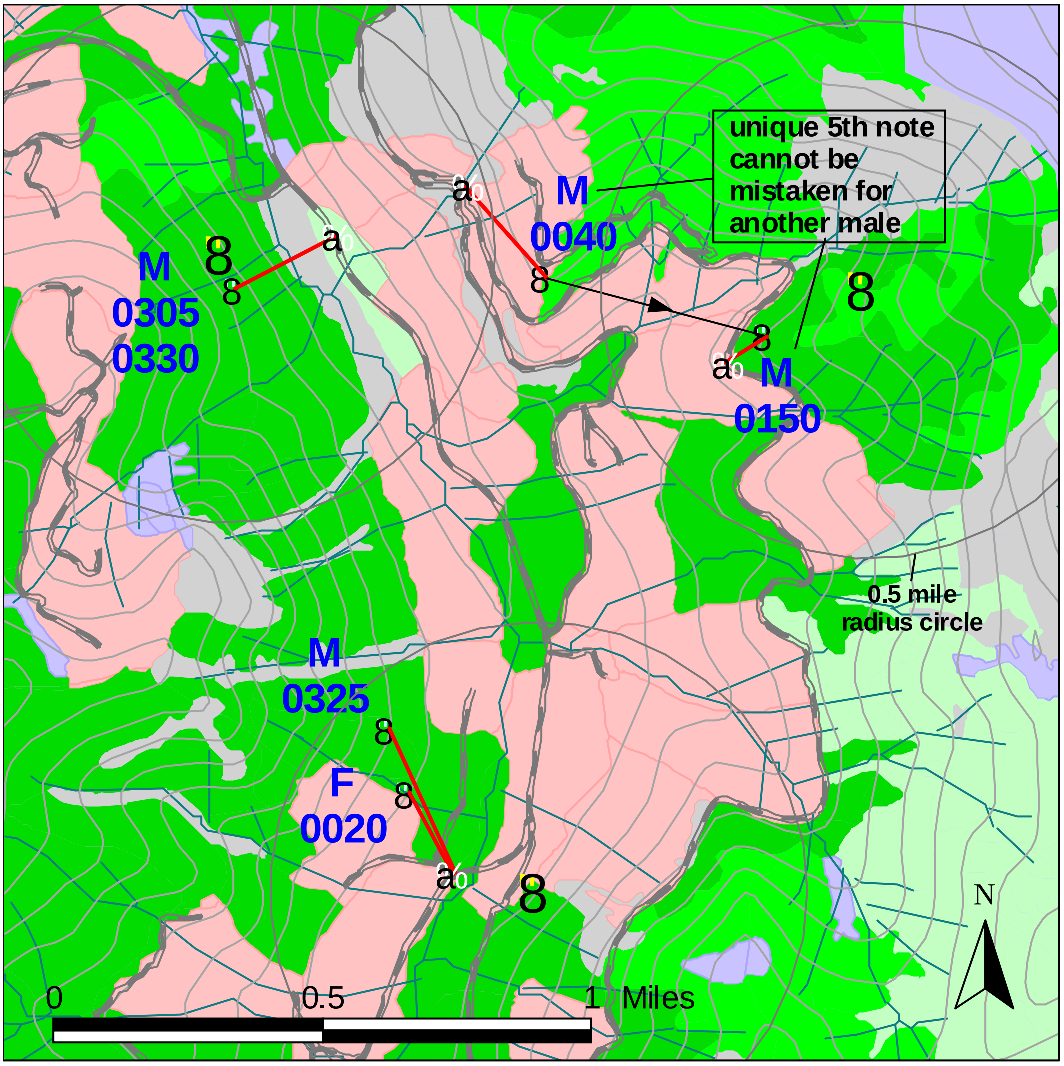


Example 3: simultaneous detections. In 1992, pair of spotted owls was heard to the NNW of the survey station across the valley at 2230. At 2240, a male spotted owl was heard to the NNW that ended up moving adjacent to the station. This male was thought to be the male of the pair, since it was observed moving in the direction from the pair toward the survey station. While this male was at the survey station, a second male spotted owl began calling at 2245 across the valley to the east, and a third male spotted owl began calling at 2250 to the south. In 1992, all 3 of these males were found to be males of reproducing pairs.

In 1990 and 1991, spotted owls were detected in the core areas for these sites (small gray circles). All of these detections were assumed to be owls of the pair 1 site, even though there were sequential detections of same-sex owls during surveys. The tiny black dots represent detections after 1992.



Example 4: unique vocalizations and near-simultaneous detections. A female spotted owl was heard at 0020, then a male at 0040 1 mile to the north. This male had a unique 5-note call where the 4th and 5th notes were the exact same pitch (many spotted owls have a 5th note added to their 4-note call, but the 5th note always descends at least slightly in pitch). Calling directly west of the area where this male was detected previously with a female had no response, but returning later, this same male with the unmistakable 5-note call had flown to this area and responded at 0150. Calling at the known pair site to the west located the male spotted owl for that pair at 0305. Upon returning to the original female response, a male spotted owl responded at 0325, a bit further up the hill than the female had been. Returning to the last male, he was still calling at 0330 in the same place, meaning that the male to the south was different than the male for either of the pairs to the north.



4. Tricks and tips

Moving around in the local area of the survey station

Because owl vocalizations can be reflected by a tree of sufficient diameter, or any other terrain feature that may be present (e.g. a rock outcrop), standing in one place for the duration of the time spent at the station to try to elicit a response from an owl and listen for owl responses could potentially miss owls that are present. Moving to different positions in the local area of the survey station while calling and listening removes some of this potential. In addition, for an owl response that is faint, sometimes moving a short distance can result in a louder response heard, enabling better location of the owl. This can also aid in identification of a species heard calling when the response is very faint.

Cupping the ears

Sound waves radiate outward from the source. The further you are from a sound source, the smaller portion of the total energy of the sound is intercepted by your ear. Cupping the hands behind the ears intercepts a larger portion of the sound and directs it toward the ears, increasing the loudness of the sound. In situations with competing noise, such as from a nearby stream or river, this has the effect of increasing the loudness of the owl call in relation to the competing noise. For very faint, distant calls, this also serves as a directional aid, because the sound of the owl will increase more noticeably when aimed directly at the owl with cupped ears than without cupping the ears.

Using terrain features and the vehicle to block competing noise

In a situation where there is competing noise from a stream that is below a survey station along a road, the stream noise can sometimes be prohibitive to hearing an owl response. One way around this is to use nearby physical features to block out the stream noise while still retaining the capability to hear any owls. If the road has a ditch on the uphill side away from the creek, listening from down in the ditch can block some of the stream noise with the roadbed. However, if there is habitat between the road and the creek, this could also block out an owl in that area, so you would want to spend time away from the ditch listening through the noise as well.

Another way is to use the vehicle to block stream noise, getting positioned behind the vehicle. Many times there is a point along the stream where the noise is the loudest, such as from a small fall or steep section through rock, and the worst noise can be reduced significantly by getting positioned behind the vehicle in line with this source.

Although it is recommended in the protocol to always be outside of the vehicle when doing survey, there are certain situations where being inside the vehicle increases the potential to hear an owl. If, for example, there is loud competing noise from a stream, and all habitat where an owl might be located is above the road away from the stream, sitting inside the vehicle next to an open window facing uphill will block out most of the stream noise while allowing any owl up the hillside to be heard.

Vocalization list?

Sound terms glossary?

The **decibel** (**dB**) is a logarithmic unit of measurement that expresses the magnitude of a physical quantity (usually power or intensity) relative to a specified or implied *reference level*. Since it expresses a ratio of two quantities with the same unit, it is a dimensionless unit.

In physics, **attenuation** (in some contexts also called **extinction**) is the gradual loss in intensity of any kind of flux through a medium.

Appendices

WHY DO OWL VOICES CARRY WELL IN FORESTED CONDITIONS?

Voices of the larger owls encountered on surveys (e.g. Great Horned, Barred, and Spotted owls) are of low frequency (300-700 Hz) and have long wavelengths. A frequency of 300 Hz has a wavelength of about 45 inches while 700 Hz is about 20 inches. When a sound wave approaches a barrier, if the barrier is longer than the wavelength, the sound wave is reflected; if the barrier is shorter than the wavelength, the sound wave refracts around the barrier. In terms of what can be heard, when a sound wave refracts around a barrier, it is as if the barrier was not there.

With the long wavelengths of the larger owls, only the larger trees in a forest will have an effect on their hoots.

TEMPERATURE LAPSES AND INVERSIONS

Temperature lapse. Without outside influences, air temperature decreases as altitude increases, called a **temperature lapse**. In the troposphere, the average environmental **lapse rate** is a drop of about 6.5°C for every 1 km (1000 meters) increase in elevation, typically ranging between 4° and 10° C. This causes sound waves to **refract** upward toward the area of slower sound speed and decreases audibility along the ground at a distance.

Temperature inversion. Under certain conditions, the lapse rate of temperature is reversed and temperatures rise with increasing elevation creating an **inversion** or **inverted lapse rate of temperature**. This causes sound waves to refract toward the ground. There are a number of different types of inversions:

1. **Radiation inversion.** During the day the sun heats the earth (short wave radiation) and the heat is conducted to the air. At night, the ground cools rapidly (long wave radiation). The air in contact with the ground then loses heat by conduction to the ground, and ends up being cooler than the air above, which is not losing temperature as fast because air is a poor conductor. This leads to the configuration of cold air forming a stable air mass with little vertical movement that is colder than the air above. A radiation inversion can range from a few inches to a kilometer in thickness, with 100m an average depth of the inversion. Ground fog often accompanies this type of inversion. In mountains, colder air along the ground on the sides of valleys descends to the valley bottom under the influence of gravity, strengthening the inversion. The inversion breaks up soon after sunrise as the earth begins to warm.
2. A **Subsidence inversion** is caused by descending air over a large area that warms by adiabatic compression. The upper part of the layer sinks farther and warms more than the bottom part, creating the inversion. They sometimes occur at the surface, but more frequently are observed aloft and are often associated with high-pressure areas.

3. **Frontal inversion.** This is commonly associated with both warm and cold fronts. At the leading edge of either, warm air overrides the cold air.
4. **Advection Inversion.** A **warm advection** is warmer air moving horizontally into an area; a cold advection is colder air moving horizontally into an area.. Cold advection: A **Sea-breeze inversion** happens when air is cooled over the ocean and moves inland under a warmer layer of air. Warm advection: In mountain areas, warm air passing over the mountains from the west override a cold air mass on the eastern side of the mountains.

If surrounding sounds seem more loud and clear than usual, there is likely an inversion present. Inversion layers are characterized by calm conditions and sometimes fog. Wind >4 mph can prevent a radiation inversion from forming, or dissipate one already formed. Clouds, because of their insulating effect, can also prevent radiation inversions.