# 6. Radio Telemetry and $G_0$ Protocols

Across the Mojave Desert, several small groups of 8-12 tortoises each have been equipped with radio transmitters and are used to estimate the proportion of tortoises in the local area that are active/visible. Individuals are observed repeatedly throughout the day using a VHF radio receiver and a directional antenna. Each time a tortoise is located, data are recorded indicating its visibility on the surface, in a burrow, or in vegetation. These data allow us to calibrate distance sampling results to account for the proportion of the population that eludes sampling due to fossorial or cryptic behavior. The radio-equipped tortoises are called $G_0$ tortoises ("gee-sub-zero") for the mathematical term in the density equation that represents tortoise availability.

The primary goal of $G_0$ training is successful implementation of the $G_0$ protocol by telemetry crews. This includes correct use of telemetry equipment, understanding $G_0$ data collection fields, observation of as many radio-equipped tortoises as possible during the day, observing the appropriate focal population for the transects being sampled, and a window of observation that overlaps the day's transect time window for each sampling area. An additional goal is to make related work on transects more understandable to line distance crews.

**Objective 1:** Locate tortoises and collect activity data.

Standard: $G_0$ monitors will be proficient in using telemetry equipment to locate tortoises.
Standard: $G_0$ monitors will be proficient at collecting appropriate data.

**Metric:** $G_0$ monitors will use telemetry equipment to locate radio-equipped tortoises and will complete site-day and observation forms correctly. They will demonstrate correct operation of VHF radio receivers. When a tortoise is not immediately detected with a receiver, they will apply appropriate troubleshooting procedures to locate the tortoise.

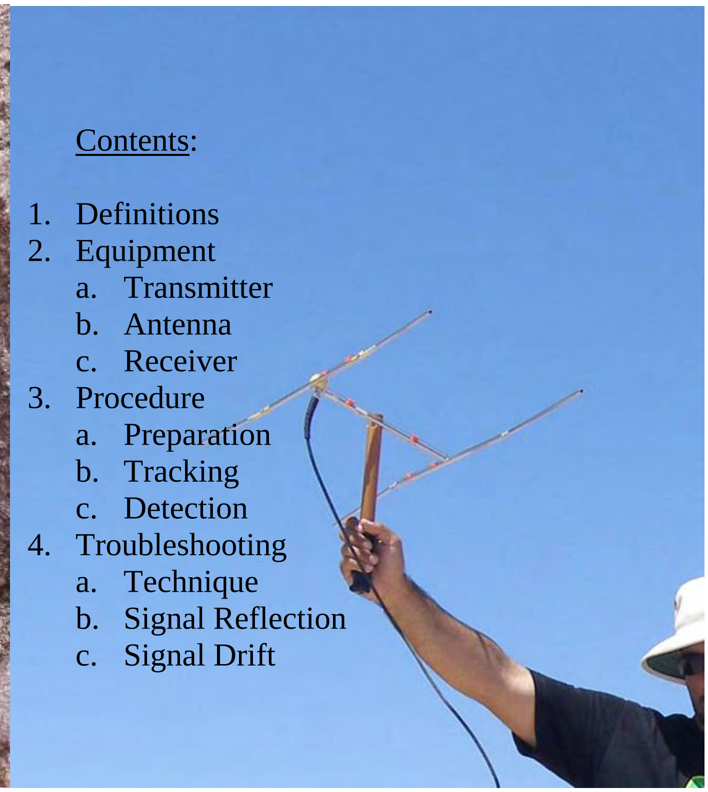
Refer to **Appendix I** for paper data sheets.

**Objective 2:** Implement the daily $G_0$ protocol.

Standard: $G_0$ monitors will successfully complete daily monitoring activities related to schedule coordination with line distance crews and with one another to collect sufficient daily observations on each tortoise.

**Metrics:** At an actual $G_0$ site, monitors will locate and record $G_0$ data at a rate equivalent to that required to sample 10 tortoises at least 3 times a day (the length of which is defined by the time between typical start and end times for transect monitoring), and bounding the transect sample period as assigned by trainers. $G_0$ monitors will coordinate with their team leaders to schedule their activities while data are collected on transects.

## Objective 1: Locate Tortoises and Collect Activity Data



Contents:

## 1. Definitions

● **Radio Telemetry** involves data transmission over a distance. In this case, the observer uses a receiver to detect a signal emitted from a transmitter attached to a desert tortoise.

● A **Radio Transmitter** radiates a regularly timed signal at a very specific frequency.

● The **Frequency** is built into the battery-powered transmitter and is a specific band within the electro-magnetic spectrum (in this situation 164-168 MHz).

● Approximately once per second, the transmitter emits a "beep" at one precise frequency; this **Signal** travels in a wave over a specific distance (its **Range**). To detect this signal, the observer needs to be within this range (generally 500 - 900 meters).

● The transmitter signal's frequency is not auditory to humans. Thus a radio **Receiver** is used, allowing the observer to hear the signal when s/he sets the correct frequency into the receiving unit.

● The **Directional Antenna** boosts the receiving power and, because it is tuned to be loudest in only one direction, allows the observer to follow the sound to the signal's source.

● Increasing **Gain** increases the receiving unit's amplification of the signal, but sometimes also increases noise. The gain differs from **Volume**, which only changes the noise intensity coming from the receiver's speaker.

## 2. Equipment

The equipment used to conduct radio telemetry on desert tortoises is typical of that used on many types of animals. The distance from which a signal can be detected is a result of many interacting factors involving the power of the transmitter, the quality of the receiver and the specificity and gain of the receiving antenna. In addition, your ability to track will be influenced by outside factors such as climate, terrain, and obstructions or interfering structures (e.g. power lines).

### Transmitter:

Many tortoises in the Mojave Desert are subjects of research or monitoring programs and carry a radio transmitter. Comprising the transmitter are a battery, a frequency emitter, and a whip antenna. While size, design and location on the tortoise may vary, the transmitter's basic operation remains the same.

Epoxy binds the transmitter to a scute (segment) on the tortoise's carapace (shell). The whip antenna is affixed to one or more scutes as an additional measure to prevent the transmitter's accidental removal. In the event that this antenna is damaged or severed, the tracking range becomes severely limited, typically less than 50 meters. While this antenna may be completely attached, more commonly it extends loosely behind the tortoise, reducing the epoxy mass and making the unit less cumbersome (see Figure 1).

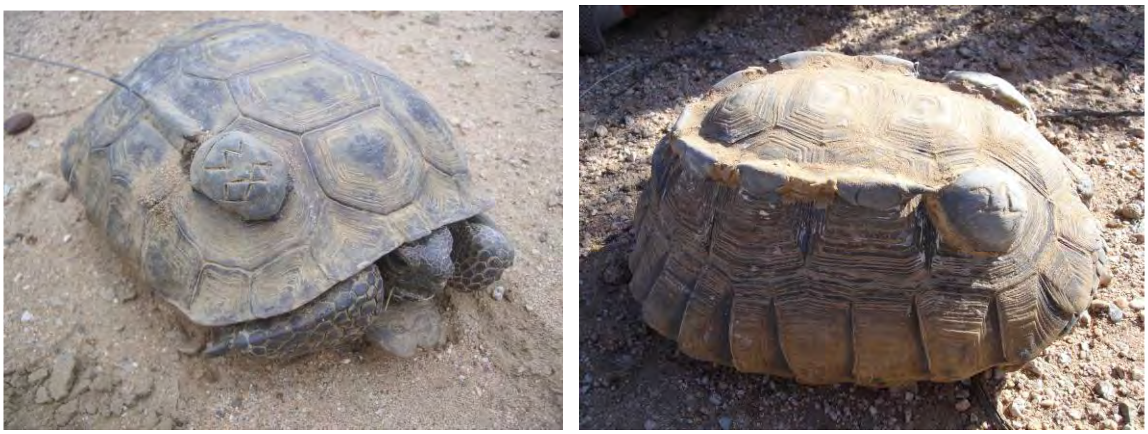


Figure 1. Examples of typical VHF transmitter attachment to desert tortoises.

Transmitters currently in use for LDS broadcast in the VHF frequency range, between 164-168 megahertz (MHz). Each tortoise has a unique frequency, for example, one tortoise may have the frequency 164.236. Yet the signal will "bleed" into neighboring frequencies, so this tortoise may be heard at 164.234 or even 164.238 depending on the transmitter's accuracy and the receiver type. Nearby tortoises must possess sufficiently dispersed frequencies (i.e. 20 or more Hz) to ensure the ability to track the correct tortoise.

**Antenna:**

A directional antenna amplifies the signal from a transmitter and allows the observer to aim toward the source. Commonly, the "H" shaped 2- element Yagi antenna (Telonics RA-2AK) is used, but other multi-element Yagi antennas exist. Each antenna is specifically tuned to a 2K MHz range of frequencies (e.g. 164-166 for the antenna in Figure 2), but may also receive frequencies outside of this range, albeit with lower efficiency.

*These fragile antennas are costly and should be treated with care.*

The two-element Yagi depicted in Figure 2 requires assembly, while other models may unfold into the correct operating configuration. For the H-style Yagi, each "kit" should include the main body (A), the arms (B and C) and the handle (D). The arms vary in length and must connect into the correct port on the antenna body. The yellow colored tape on the arms matches that on the body. When assembled, the shorter arms screw into the antenna's forward portion.

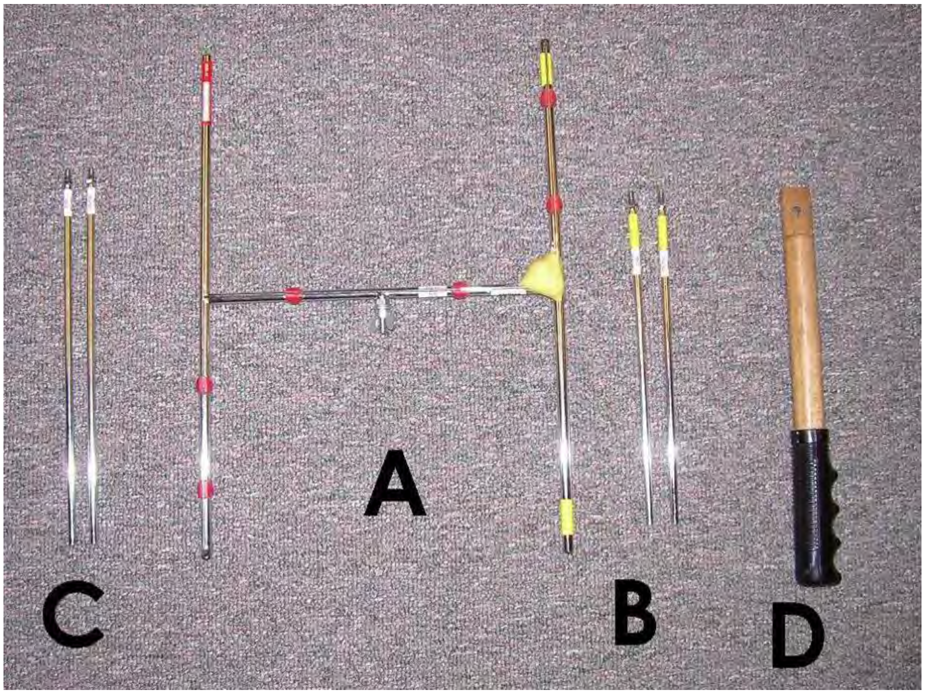


Figure 2. Telonics RA-2AK VHF 2 element Yagi antenna.

A small sticker on the antenna body indicates the “front” (the part to point toward the transmitter) and generally is where the antenna cable attaches. A coaxial cable with BNC connectors on both ends connects the telemetry receiver to the antenna.

*Each crew should carry an operational spare cable in the event that the first fails.*

**Receiver:**

Telemetry receivers are radios capable of receiving in the VHF bandwidth. Several companies manufacture receivers specifically used for telemetry (e.g. Telonics, ATS, Lotek, etc.), but other multi-band receivers can be used as well (e.g. Icom). Technical specifications and control layout differ among various receivers, but similar concepts govern their operation.

The tracker enters the tortoise's individual frequency into either a number pad or a series of dials. Some models require entry of all six digits (XXX.XXX) to enter the frequency, while others require the entry of only a portion of the whole frequency (e.g. X.XX) where another knob or button adjusts the frequency by small increments (usually 0.001 MHz, or 1 KHz).
In multi-band receivers, the "Band" or "Mode" button alternates the various modes to AM, FM, WFM, LSB, USB and CW. For tracking, CW mode is often used, but you should track using the band that allows for the best auditory clarity of the signal. The "best" mode for use may change while tracking a tortoise as the distance to the source decreases.

All receivers allow manipulation of both "Volume" and/or "Gain" to tune the directionality and auditory expression of the transmitter signal during tracking. As the tracker approaches the animal or requires additional directionality, reduction in the Gain (and/or the combined Gain and Volume control) aids in the signal's attenuation.

> **Volume** on a receiver matches that on any radio; it simply adjusts the signal's amplification to the speaker. The tracker need only set the Volume at a comfortable level.
>
> **Gain** refers to the receiver's amplification of the signal. Increasing Gain increases the distance from which the observer can detect the signal, but it also increases background noise and reduces directionality. Lowering the Gain reduces noise and increases directionality, but also diminishes the signal's detection range.


Figure 3. Examples of three typical VHF receivers used in radio telemetry. The Icom IC-R10 (top left) is a multi-band VHF receiver, while the Telonics TR-5 (top right) and Telonics TR-2 (bottom) operate in more limited frequency ranges.

Table 1. Comparison of three typical VHF receivers used in radio telemetry: the Icom IC-R10/R20, the Telonics TR-2, and the Telonics TR-5. Information collected from: www.icomamerica.com, www.telonics.com.

| **Comparison** | **Icom IC-R10/R20** | **Telonics TR-2** | **Telonics TR-5** |
|---|---|---|---|
| Control Panel | Digital, clear | Dials, intuitive | LCD, Digital, often difficult to read |
| Frequency entry | Enter every digit, including the decimal | The 16 is assumed, the four other numbers are then entered in sequence. For the frequency 164.236, you would see 423 on the dials, and the frequency knob would be turned to 6. | Enter every digit including the decimal, and then press enter. |
| Knobs / Controls | R-10: The Volume and Gain knob are the same: R-20: The Volume and frequency knob are the same.<br>For both, hold down the button labeled "RF GAIN" until the screen reads "Set RF Gain," use the knob to adjust Gain. When it says "max" or "10", press the "RF GAIN" button a second time to return it to Volume or frequency control. | A single knob combines both Gain and Volume, and they cannot be changed separately. | Up/Down arrows allow Gain and frequency changes with a separate knob for Volume. |
| Receiving Power | Low<br>(Often need to be within 300-500 meters) | Medium- High<br>(Often need to be within 500-900 meters) | High<br>(Often need to be within 700-900 meters) |
| Charge | 11 hours | 10 hours | >16 hours |
| Size | Small<br>0.32 kg<br>6 x 14.2 x 3.48 cm | Medium<br>0.86 kg<br>11.7 x 5.1 x 18.0 cm | Large<br>1.2 kg<br>17.8 x 11.1 x 6.2 cm |
| Portability | Handheld or shirt clip | Leather case with shoulder strap | Blue cloth case with shoulder strap |
| Recharge | Wall charger | Wall charger | 8 AA batteries |
| Frequency Band | Extensive, multi-band VHF receiver: SSB, CW, AM, FM, and WFM.<br>0.150-3304.999 MHz<br>CW: 118.000-146.999 MHz | Limited: SSB and CW<br>2K or 4K MHz range: set at factory<br>e.g. 164.000-166.999 | Limited<br>4K MHz range:set at factory<br>163.000-167.999 |
| Pros | Light, easy to use, relatively inexpensive changeable or rechargeable batteries | Intuitive to use, lightweight, manual frequency scanning accomplished easily | Powerful, water resistant, changeable batteries<br>Freqs can be programmed |
| Cons | Limited range, less effective under powerlines, wrong buttons easily pressed , modes confusing | Batteries cannot be changed, recharge only, non-programmable. Gain and volume coupled. | Heavy, difficult to use, display difficult to read, Gain change takes time, frequency adjustment awkward. |

## 3. Procedure

**Preparation:**

Assemble the necessary equipment:

- GPS
- PDA
- Two-way radio
- Charged receiver
- Yagi antenna
- 2 Coaxial cables
- Sufficient replacement batteries
- A list of past known locations and frequencies for each tortoise
- Mirror
- Compass
- Paper datasheets
- Writing implements
- Safety equipment
- Water

Check the tortoise frequencies and bring the appropriate receiver and antenna prior to heading into the field.

*Never track when lightning may strike*.

**Tracking:**

1. Follow the provided GPS coordinates to the tortoise's last known location; start as close as possible to that site.
   (Note: Listening to the tortoise's frequency while traveling to its last location, and even scanning for other nearby tortoises as well, is recommended. Tortoises move frequently during the activity season, increasing the likelihood that the tortoise you seek will be found in a different location than the last. You will save time if you listen for each animal while traveling between locations.)
2. Assemble the antenna and connect it to the receiver using the coaxial cable.
3. Turn on the receiver and enter the correct frequency.
4. Set Gain to maximum.
5. Listen for the signal:
   a. Stand a few meters away from vehicles or structures.
   b. Hold the antenna high at arm's length.
   c. Orient the antenna in a Vertical position (see Figure 4). The Vertical orientation provides more range but less directionality.
   d. Listening for the transmitter beep, rotate your body in a slow, *complete* circle.
   e. Determine the direction from which the signal sounds strongest.

Figure 4. The Vertical antenna position on the left (handle parallel to the ground) provides more range but less directionality in detecting the signal, while the Horizontal antenna position on the right (handle perpendicular to the ground) allows better directionality while lessening range.

6. Follow the signal and adjust:
    a. Walk toward the loudest sound.
    b. Continue listening while walking, sweeping the antenna from side to side to confirm a strong signal directly forward.
    c. If the signal weakens, repeat Step 5 and continue in the new direction.
    d. Reducing Gain while approaching the source also aids in narrowing the loudest signals direction.
7. Improving Directionality:
    a. When you hear the signal clearly (about 300 meters or so), orient the antenna in a Horizontal position (see Figure 4). This provides less range, but better directional certainty. Once you hear the signal using this orientation, the Vertical position becomes unnecessary.
    b. Repeat Step 5 using the Horizontal orientation.
    c. Continue lowering the Gain as you approach the tortoise until the signal sounds loud at minimum Gain.

**Detection:**

1. Final Location:
    a. When very close, the beeping becomes loud enough to sound distorted and omnidirectional. Continue walking and sweeping until the signal weakens or sounds louder behind you to triangulate to the correct location.
    b. Upon determining a small area with the strongest signal, point the antenna perpendicular to that area and walk in a circle around it to confirm the correct location; this may take time. At close range the signal may sound equally strong directly behind as well as in front of you.
    c. At this point, begin scanning visually for the tortoise or burrows.
2. Burrow:
    a. If the signal seems to emanate from a burrow, make a visual inspection to locate the tortoise. The tortoise may be deep inside; you should use a mirror to reflect sunlight into the burrow.
    b. If the tortoise cannot be seen, two things can be done to detect its exact location:

*Be careful: do not step on or collapse the burrow while performing these.*

1) Remove the cable and antenna from the receiver. If beeps can still be heard, the tortoise is very close.
2) You may "fish" for the tortoise. Remove the cable from the antenna, but leave it connected to the receiver. Dangle the antenna over the burrow and move it around to the loudest point – the tortoise's most likely location. To avoid getting dirt in the BNC connector, do not let the cable bottom touch the ground.

*To avoid stepping on the antenna, place it up high or in a creosote bush.*

   c. If you see a tortoise, make sure it is the one you seek by checking for a transmitter and even a tortoise number on a floy tag glued to the shell.

3. Record Location:
    a. Record the Tortoise Number, Frequency, Northing, Easting, Date, Time, Observer, and any other necessary information.
    b. Use your PDA to record required information as well.

## 4. Troubleshooting

**Technique**:

**Antenna**. Understanding the antenna's performance may assist in tracking the signal. In figure 5, the antenna's listening pattern, the sound intensity appears loudest when the antenna points directly at the signal's origination (0 degrees). **Backfeed** may be heard when the antenna receives a signal from the opposite direction as well. An alternative exists to determine the correct direction when following the loudest signal is not possible. Holding the antenna horizontally, identify the "signal nulls," or the sections in which the beeping disappears completely, as opposed to the "signal peaks," while turning in a complete circle. Walking in the direction exactly opposite to the middle of the null areas forms a viable option.

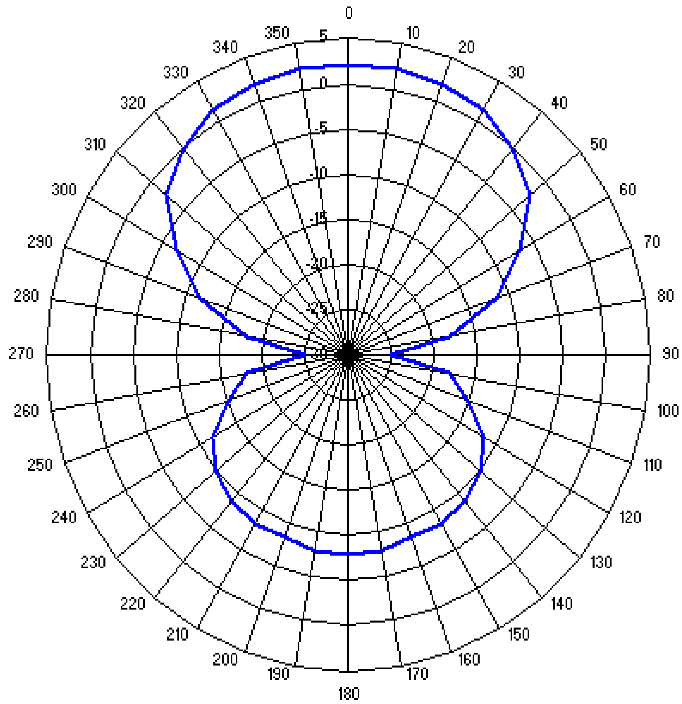


Figure 5. The listening footprint for an antenna held horizontally; northward (0°) sets the signal's source.

**Receiver**. At minimum Gain, the sound may occur at the same intensity from all sides. This phenomenon makes locating the tortoise at close range particularly difficult. Shifting the frequency slightly up or down may provide a difference in beep intensity. Lowering the frequency until a "thump" sounds or raising it until a very high-pitched beep occurs may provide some direction.

**Signal Reflection**:

Many factors may distort the signal's direction including frequencies from other transmitters, complex terrain, powerlines, and even nearby fences or vehicles. In all cases, the tracker should move away from obstructions to allow for open space through which the signal may travel.

**Terrain**. Rocky terrain, hills, washes, cliffs, and even mountains may obscure or redirect signals. Height above the ground, obtained by climbing hills or up to ridge-tops, increases a signal's range. The signal may be lost when dropping into a canyon or wash. If a signal does become lost, a tracker should climb to a high place near the tortoise's last known location to listen for the signal or walk the ridge above a canyon while following the sound.

**Echoes**. As some tortoises do tend to live in washes and cliffside caliche caves, echoes may sound louder than the true direction. For example, a tortoise may be on a mountaintop while the tracker walks below, between mountains; rocks may obscure the signal's source but the echo resonates clearly bouncing off the opposite mountain. In this case, it is best to climb to a higher point and listen.

**Powerlines**. Powerlines distort or mask signals, making them difficult to acquire or follow. The tracker should walk at least 100 m away from the lines to listen. As an aside, some people have received mild electrical shocks while tracking under the lines.

**Burrow Substrate**. The signal may become dampened or distorted if the tortoise rests deep within its burrow. Caliche seems to mask the signal the most, requiring that the tracker be very near to detect the signal or in a direction corresponding with the orientation of the burrow opening. Other substrates may impede the sound as well.

**Signal Drift:**
A transmitter's frequency may "drift" up or down with changes in climate and over time. Other factors affecting the emitted frequency and transmitted signal include terrain, temperature, humidity, wind speed, the receiver, and the antenna.

If, while in the field, a tracker cannot detect the provided frequency, s/he should first check that the inputted frequency matches that of the desired focal tortoise. When the correct frequency does not yield a signal, the tracker should listen in a complete circle while adjusting the frequency up and down at least 6 KHz away from the original incrementally in both directions. If this does not yield results near the last known location, the tracker may choose to listen from an elevated location, such as a mountain or hilltop. While this may seem like extraneous effort, finding the tortoise immediately represents the best option as it may move even further away if already distant.

Finally, if searching for at least 30 minutes yields no signal, the tracker should proceed to the next tortoise and continue searching for the missing animal while moving among the other animals in the observer's tracking schedule. This animal may be encountered associated with another as tortoises seem to aggregate at times.

## Objective 2: Implement the Daily $G_0$ Protocol

### Optimizing monitoring to coincide with tortoise activity
One of the adaptations tortoises have for living in the desert is to restrict surface activity to fairly narrow windows of time during the year. In general, tortoises predictably emerge from deep within shelters (burrows) from mid-March through mid-May and then again (less predictably) in the fall. These periods coincide with flowering of their preferred food plants (in spring) and with annual mating cycles (in fall). Both periods also represent the most likely times to find water in plants or on the surface. The annual range-wide monitoring effort is scheduled to match the spring activity period for tortoises.

During this season, all tortoises are not above ground or visible in burrows. In order to encounter as many tortoises as possible, monitoring is scheduled for early in the day and to be completed before the hottest time of day. Because we are using vision to find tortoises, monitoring is restricted to daylight hours. Based on past experience, we expect tortoises to become most active after 7am at the beginning of April (it is usually too cool before this time), but to emerge earlier and earlier until their optimal activity period is around sunrise by the beginning of May. In May, we also expect daytime temperatures to limit tortoise above-ground activity as the morning progresses to afternoon (see “Line Distance Protocols, Objective 2: Start and Complete Transects to Optimize Tortoise Detections”).

**Coordinating start and end times with transect crews**

Field crews on transects are working to complete transects during this optimal period each day, so crews are likely to arrive at transects at similar times on a given morning. The role of telemetry crews is to provide data to estimate daily tortoise activity during the period when transects are walked. Telemetry and transect crews are responsible for beginning the field day at the scheduled time. However, completion times will be more variable, and will be affected by terrain, air temperature, number of tortoises encountered, etc. Each field group will use their own method to communicate between transect and telemetry crews so that telemetry crews monitor until all transects have been completed for the day. In general, at the end of the day, when each crew has finished their transect and is back at the truck, they make contact with the logistics coordinator for the group. After this coordinator has heard from everyone that day, the telemetry crew is notified. Telemetry crews cease monitoring once they hear from the logistics coordinator or it is 4pm, whichever comes first.