

# Protocol for Ecological Monitoring on Santa Fe Island, Galapagos

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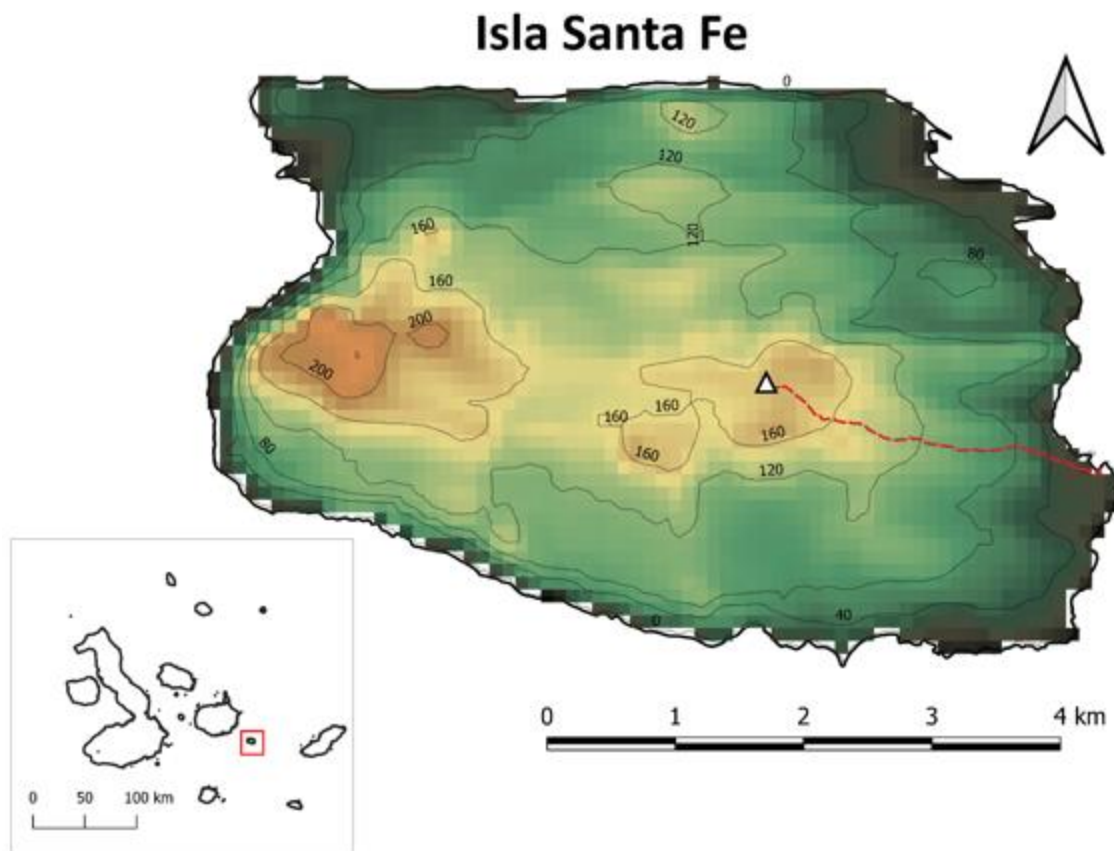
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## Overview

Santa Fe Island (Figure 1) is one of the oldest islands in the Galapagos archipelago. Once hosting an endemic and now extinct species of giant tortoise, Santa Fe Island (hereafter “Santa Fe”) is under active ecological restoration program initiated by the removal of goats and subsequent introduction of Española tortoises (*Chelonoidis hoodensis*) in 2015. As of March 2021, a total of 732 captively reared tortoises have been released on Santa Fe Island.



**Figure 1.** Map of Santa Fe Island in the Galapagos archipelago. Color gradient and contour lines shows elevation in meters. The trail to the main campsite (triangle) is shown as a dashed red line.

With the closing of the Española tortoise captive breeding program and final introductions of tortoises to Santa Fe in 2021, routine ecological monitoring is necessary to assess the long-term status of the tortoise population and its impact on the Santa Fe Island ecosystem. Several long-term monitoring programs have been established on Santa Fe to examine trends in (1) tortoises, (2) iguanas, (3) cactus, (4) plant communities, and (5) other native fauna. Of particular importance are the potential interactions between tortoises and pallid land iguanas (*Conolophus pallidus*), the latter being a species endemic to Santa Fe. The continuation of these monitoring programs is essential to ensure successful ecological restoration and guide future management on Santa Fe.

This document provides a general overview of ecological monitoring activities on Santa Fe, with detailed maps and protocols for expedition planning and data collection. Each section features a full description and instructions for different monitoring activities, including a list of necessary equipment, personnel requirements, data collection procedures, data sheets, and maps.

**Table 1.** List of all relevant data forms and GPS files for Santa Fe expeditions. Facsimiles of the data sheets can be found in the appendices.

	Description
1	Form for mark-recapture surveys
2	Form for transect surveys
3	Form for iguana/tortoise/cactus plot surveys
4	Form for behavior/microhabitat sampling
5	Form for cactus plot surveys
6	Form for cactus census
7	Form for plant exclosure plots
8	Form for camera trap maintenance
9	Notice for field work with participant list
10	Notice for taking samples from the field
11	Trail from camp to boat launch on Santa Fe
12	Mark-recapture search zones
13	Transects for distance sampling
14	Plots for iguanas, tortoises, and cactus
15	Cactus monitoring plots
16	Cactus census points
17	Plant community plots
18	Camera trap locations

While these protocols are described for Santa Fe Island, many of the monitoring resources provided here, can be potentially adapted to other islands in Galapagos with active ecological restoration initiatives and common species of interest.

All questions regarding these protocols, including requests for digital files for GPS navigation as well as data forms and baseline data collected to date, can be obtained by contacting Washington Tapia ([wtapia@galapagos.org](mailto:wtapia@galapagos.org)) or James Gibbs ([jpgibbs@esf.edu](mailto:jpgibbs@esf.edu)) managers of Giant Tortoise Restoration Initiative.

## Pre-trip preparations

### Setting objectives

Expeditions on Santa Fe typically include multiple forms of data collection for meeting different long-term monitoring objectives. The recommended frequency and seasonality of monitoring depends on the specific activity and is subject to change as restoration progress continues on Santa Fe. General plant and tortoise monitoring should be performed at least once per year and ideally once in the wet season and once in the dry season each year if resources permit. Some monitoring methods (e.g., iguana surveys) can be performed less frequently than other methods (e.g., mark-recapture surveys for tortoises, plot and census-based cactus surveys, camera trapping).



Trip leaders should review what data were collected on the last visit to Santa Fe and consider what financial and human resources are available when planning an expedition, to maximize the amount of data collected. The following table is a rough guideline for trip planning and integrating different monitoring activities in single expeditions:

**Table 2.** Overview of recommended monitoring activities on Santa Fe Island.

Activity	Frequency	Min. days per survey*	Notes
Tortoise mark-recapture	Seasonal/Annual	14	Highest priority for annual monitoring
Iguana/tortoise transects	Every 2–5 years	6 for central zone, 15–20 for island	Always perform transects and plots together
Iguana/tortoise/cactus plots	Every 2–5 years	6 for central zone, 15–20 for island	Always perform transects and plots together
Camera traps	Annual	1–2	Must perform least once per year
Cactus plots	Annual	2–3	Should perform concurrent with census and vegetation plots
Cactus census	Annual	1–2	Should perform concurrent with cactus plots and vegetation plots
Vegetation plots	Annual	2–3	Should perform concurrent with cactus census and plots

\* Minimum days required for two-person team to complete task (divide 14 days by total number of two-person teams assigned to task to estimate minimum time requirement)

### Datasheet preparation

All data collection on Santa Fe is standardized according to different data sheets for each type of monitoring activity (see Data Sheets section). As of July 2020, only paper forms of these data sheets are used in the field. Prior to an expedition, data sheets must be printed and included with all other necessary field equipment. One clipboard with relevant data sheets and writing equipment must be allocated for each team on the expedition. Extra data sheets should be printed for each type of monitoring activity. For expeditions taking place from January to May, waterproof Rite in the Rain paper is recommended (if available). Always account for unused data sheets from previous expeditions before printing more copies. The recommended number of copies of each form to have on a trip is as follows:

**Table 3.** Data sheet requirements for monitoring activities on Santa Fe Island.

Activity	Data form(s)	Number of copies
Tortoise mark-recapture	(a) Mark recapture form	(a) 50
	(b) Behavior / microhabitat form	(b) 50
Iguana/tortoise transects	(a) Distance sampling form	(a) 10 (central zone)
	(b) Behavior / microhabitat form	(b) 30 (whole island)

Iguana/tortoise/cactus plots	(a) Iguana plot (b) Behavior / microhabitat form	(a) 10 (central zone) (b) 30 (whole island)
Camera traps	Camera trap form	3
Cactus plots	Cactus plot form	10
Cactus census	Census form	5
Vegetation plots	Plant community plot form	20

## Permits

Ecological monitoring on Santa Fe needs to be conducted under an annually approved permit for investigation granted by the Galapagos National Park Directorate (DPNG). Prior to each expedition, a travel notice must be submitted to the DPNG detailing the objectives of the trip, the names of participants and their associations, and contact information for the organizing parties. Additionally, if any physical specimens are to be collected (e.g., tortoise or iguana feces for diet studies), notice must be given to the Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos (ABG). Examples of these permitting forms can be found in the Appendix.

## GPS data

GPS navigation is necessary for all forms on monitoring on Santa Fe Island. Handheld GPS devices provide the name and location of all transects and plots on the island. Tortoise mark-recapture surveys are guided by daily search zones that can be preloaded onto GPS devices. Additionally, many monitoring activities include some form of spatial data collection (e.g., GPS points for new plant and animal observations; tracks from mark-recapture surveys) that inform data analyses and future monitoring.

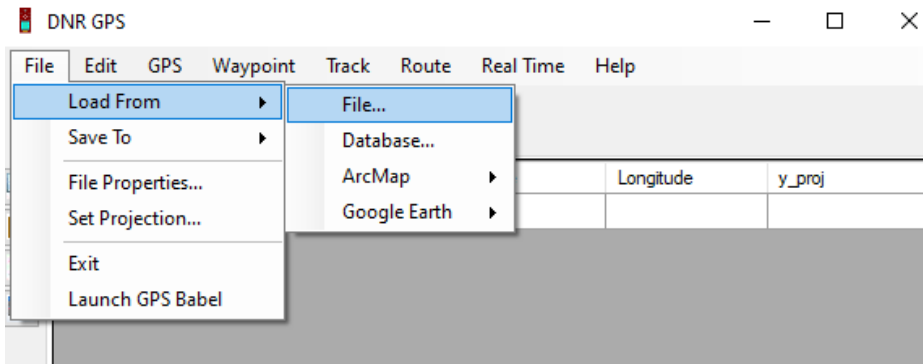
Prior to any expedition, all GPS units should be loaded with point and track files necessary for each planned monitoring activity. At least two GPS units should be prepared for each field team, each given a specific alphabetical label unique to the team to assist with data management. GPS data (tracks and waypoints) should always be saved with file names that include the label of the GPS unit, e.g., “GPS-A\_tracks.kml” and “GPS-A\_waypoints.kml”. Prior to uploading files to GPS units, each device should be turned on and fully cleared of all previous data (points and tracks) to prevent confusion in the field (confirm these files have already been downloaded from the last expedition before deleting).

Files can be uploaded to and downloaded from GPS devices with various transfer software. Currently, we recommend the open source program DNRGPS (<https://www.dnr.state.mn.us/mis/gis/DNRGPS/DNRGPS.html>) for this purpose.

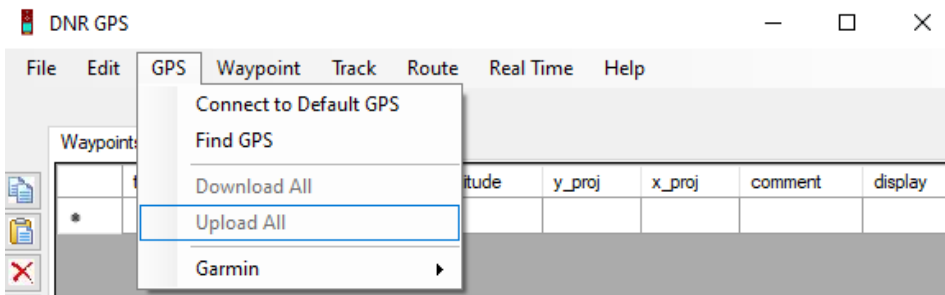
The following steps can be taken to **upload** points and tracks to GPS devices:

1. Open the DNRGPS software.
2. Connect the blank GPS device to the computer. It should automatically be recognized.
3. Click on **File -> Load From -> File...**, which will pop-up your Documents. Locate the point and/or line shapefiles on your computer and click **Open** to load to DNRGPS.





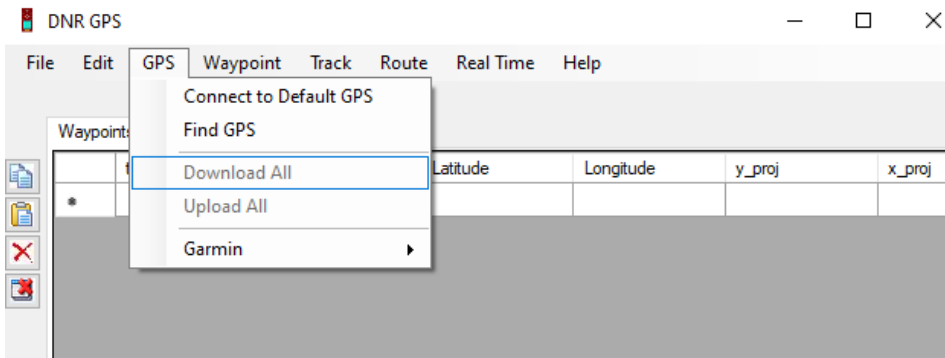
4. Once all of your points and tracks from Step 3 are loaded to DNRGPS, click on **GPS -> Upload All** to upload all spatial files to the GPS.



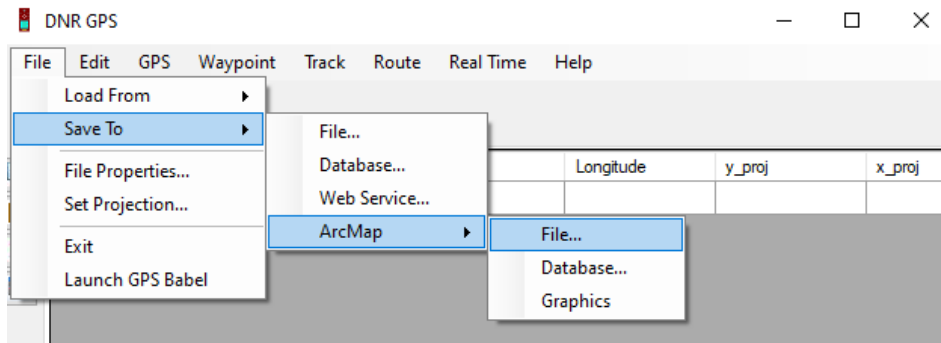
5. Disconnect GPS device. Turn on GPS device to verify the files were successfully uploaded and appearing on the map.
6. Repeat Steps 2–5 for every GPS device you are bringing to the field.

To **download** points and tracks from GPS devices after an expedition:

1. Open the DNRGPS software.
2. Connect the GPS device to the computer. It should automatically be recognized.
3. Click on **GPS -> Download All**. Select all files that appear in the pop-up window.



4. Save all points and tracks, separately, as shapefiles via **File -> Save To -> ArcMap -> File...** Store all point and track files in a unique folder for each GPS device. Put the GPS number, month, and year in the folder name.



5. Repeat Steps 2–4 for every GPS device used in the field.

## Equipment

All field work on Santa Fe requires specific equipment for data collection and establishing camp. Trip organizers should review equipment requirements well in advance of the expedition. All equipment and camp items (including food) must be assembled and put into quarantine **at least 72 hours** before departure. Temperature-sensitive items (e.g., electronics, medical kits) must be put in a separate box labelled “SIN CONGELACION.”

Equipment lists will vary depending on the type of monitoring and the number of individuals participating in expeditions. Specific items for each type of monitoring can be found in later sections of this document. A general inventory of equipment, medicine, and food for Santa Fe expeditions can be found in the Appendix.

Some basic items are helpful for any multiday expedition on Santa Fe. These include:

- Campground equipment, such as:
  - Plastic tarp for creating camp kitchen / dining area (poles are available at the main campsite)
  - Rope for assembling kitchen and drying lines
  - Alcohol and stoves for cooking, lighters, additional pots and pans
  - Bowls, cups, and cutlery for eating
  - Black, blue, and green plastic bags for trash, recycling, and organic waste
  - Tents, sleeping bags, and mattress pads (one set for each person)
  - Lights
  - Aluminum boxes to store all food and equipment and protect items from endemic rice rats
  - Coolers with ice to maintain perishable foods during first days of expedition (e.g., chicken, yogurt)
- Drinking water (5L per person per day) and a reserve amount for 2–3 additional days
- Clipboards to hold data sheets, writing utensils, and sharpeners
- Day packs (one for each person)
- Extra batteries for GPS devices (these devices usually use up one pair of AA batteries every 1.5 days of continual operation so plan accordingly) and flashlights
- Headlamps (*should always have on hand in the field, for emergencies*)
- Sunscreen and other protective clothing
- Toilet paper, moist towelettes and sanitary products for each person, as needed.
- Food (see recommended food list in Appendix)
- Medical kits (see recommended medical list in Appendix)

- Personal medications

## Personnel

Well-prepared field crews are essential for successful monitoring on Santa Fe. Participants must be respectful of monitoring protocols and physically capable of carrying out all field tasks. Furthermore, participants must be able to work cooperatively and contribute to communal activities in camp (e.g., cooking and cleaning). Trip organizers should take these prerequisites into consideration when selecting participants for expeditions and creating groups for specific tasks.

Groups of two to three people should be assigned to each monitoring activity. **No one, under any circumstances, should work alone.** Groups are necessary both as a safety precaution and to promote efficient and accurate data collection. Trip organizers should consider designating certain individuals with more experience on Santa Fe and specific monitoring techniques as “Group Leaders.” Regardless of field experience, all trip participants must receive an overview of the expedition details and monitoring plan prior to departure. Trip organizers should host a “training” session for trip members at least one day before the beginning of quarantine, during which survey protocols are fully explained, medical kits are explained, and personal packing lists are distributed. Trip participants are welcome to use their own camping equipment (e.g., tent, sleeping bag, mattress pad) and expected to provide their own field clothing and footwear, including hats and other items for sun protection, sunglasses, and hiking boots, all approved by the trip leader.

The final list of trip participants with their personal information and associations (e.g., DNPG, Galapagos Conservancy) should be included in the Aviso de Viaje form.

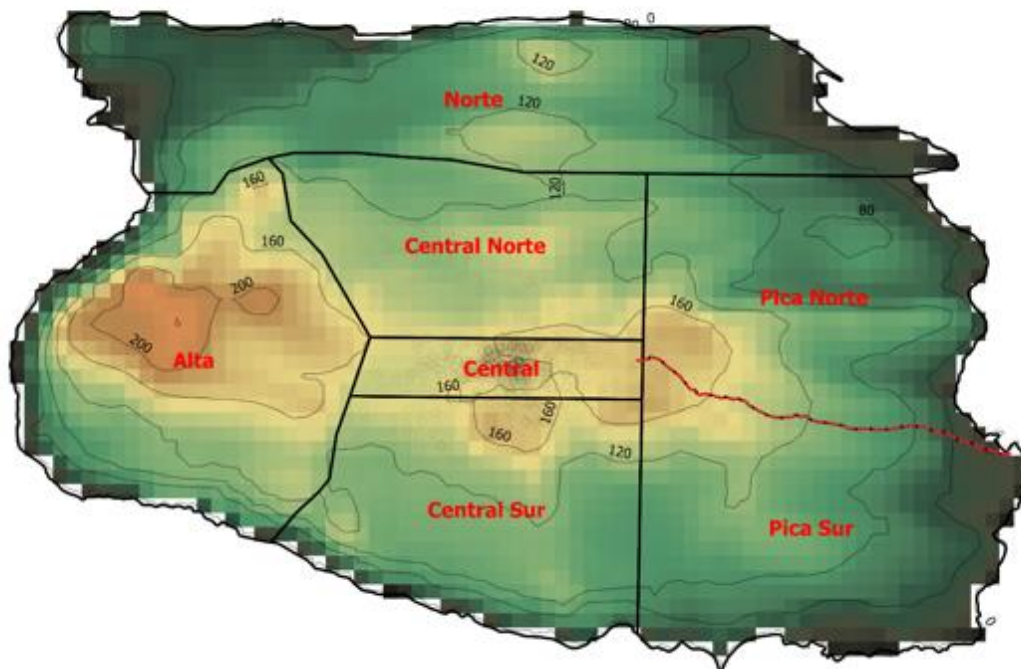
## Mark-recapture surveys for tortoises

### Summary

Mark-recapture (MR) surveys are a vital monitoring tool for assessing tortoise populations in Galapagos. This intensive method, which consists of repeated large-scale surveys with temporary and permanent markings, has been used since the beginning of the restoration program on Santa Fe Island to track tortoise growth, survival, distribution, and abundance over time. MR surveys of tortoises on Santa Fe should be conducted at least once per year during the initial phase of tortoise population restoration.

The basic procedure for MR surveys is as follows:

1. Thoroughly search a defined area (guided by GPS devices) for tortoises (Figure 2).
2. When encountering a tortoise:
  - a. Scan and record PIT tag and other markings
  - b. Record tortoise weight and shell measurements
  - c. Create a new waypoint on the survey team’s GPS unit
  - d. Paint tortoise with new temporary ID
3. Resurvey areas and when encountering new tortoises (individuals without paint IDs), repeat step 2. Note all recaptures (individuals with paint IDs) in the data sheet.
4. Use the Lincoln-Peterson equation to obtain quick estimate of population size from the number of captures and recaptures made in steps 1–3. (This equation is provided later in this section).



**Figure 2.** Map of mark-recapture survey zones for Santa Fe Island. As of March 2020, tortoises are most concentrated in the central zones.

### Equipment

All tortoise monitoring on Santa Fe Island (except for camera traps) requires the same basic equipment for scanning, measuring, and weighing tortoises, GPS navigation, and data recording (Table 3). Mark-recapture surveys additionally require paint for making temporary marks that allow researchers to easily distinguish among previously captured tortoises and new captures.

**Table 4.** Equipment for tortoise mark-recapture surveys.

Item	Description / Comments
PIT scanner	Handheld AVID or BioMark PIT tag reader
PIT tags	Rice-sized electronic tags installed under inner left leg of tortoises
PIT pistol and needles	Plastic pressure gun and needles to install new PITs
Paint	Small bottles of paint for giving tortoises temporary marks
Measuring tape (1.5 m)	For measuring tortoise shell dimensions
Digital scale with small rope	For weighing tortoises
GPS device	For recording survey tracks and saving coordinates of tortoise observations
Batteries	AA and 9 Volt batteries for PIT readers, electronic scales, and GPS devices
MR data sheet	Form for recording all tortoise observations, marks, and measurements
Clipboard	To assist data collection and store data sheets, maps, and protocols
Pencils	
Sharpener	

## Capture and measurement protocol

For every first capture of a tortoise during mark-recapture surveys, the following protocol is employed for data collection. All of this information will be on the data sheet. One or two persons will make and relay the physical measurements and observations while the other person records the data. The basic order of actions upon capturing an unmarked tortoise is to:

1. Record physical measurements (in centimeters) with measuring tape:
  - a. Curved carapace length
  - b. Curved carapace width
  - c. Plastron length
  - d. Aperture
2. Record weight with electronic scale in kilograms



These basic measurement steps are described in greater detail below:

1. **Physical shell dimensions.** Using the metric tape, **measure** the length of the curved surface of the carapace and plastron (as shown in the photos below). The specific measurements are:
  - a. **Curved carapace length:** This reading is measured from the apical end of the supracaudal (behind) plate at the tail end of the carapace to the terminus of the nuchal plates at the head end of the carapace. Please, do not forget to measure from back to front, and not in reverse. Thus, the reading should be made according to the following images:
  - b. **Curved carapace width:** This reading is measured from the junction between the carapace and the plastron on the left side of the animal, passing through the center of the third vertebral plate, to the junction of the carapace and the plastron on the right side



of the carapace.

Measurement of curved carapace length

Position of Curved carapace length (front end of measurement at nuchal plate)



Measurement of curved carapace width



Orientation of curved carapace width

- c. **Curved length of plastron:** This reading is measured from the front to the back of the center of the plastron, as indicated below.



Measurement of curved plastron length

- d. **Carapace opening (aperture):** This reading is measured as the distance between the front end of the carapace to the front end of the plastron (i.e., the head opening of the shell).



Measurement of carapace opening

## 2. Weight

- a. **Juveniles:** One hind leg can be tied with the thin rope provided to each group suspended by an electronic or spring scale, like shown below.



- b. **Adults:** Once the physical measurements have been made and the tortoise is on its back, use the 2.5 meter rope (provided to each group) and loop the line around the rear protrusions of the plastron, creating a secure and simple knot at the center of the plastron from which to suspend the turtle with the scale. For large tortoises, if necessary, the tortoise should be suspended between two people from a small, durable branch or pole and a third person records the weight on the scale.



Once the physical measurements and weight have been recorded, the remaining protocol is followed:

3. Classify stage / sex as either juvenile (J), male (M), or female (F)



4. Make any additional comments about physical condition (e.g., cracked shell)
5. Scan for PIT tag and record number on data sheet
  - a. If no PIT tag, implant a new one (and record on data sheet with comment: "New PIT")
6. Mark rear of shell with a unique paint ID corresponding to your field group and the observation number (e.g., A3 = the third tortoise marked for group A)
7. Create new waypoint on GPS, using the paint ID for the waypoint name, and write down the coordinates on the data sheet.
8. If also recording behavior and microhabitat characteristics, fill out all of the fields on that data sheet (see Appendix).
9. Enter the date and time for all observations on the data sheet.

**Recaptures:** For recaptures (encountering a tortoise that already has paint during the recapture survey), simply write the letter "R" next to the original entry for that tortoise on the MR data sheet. Also, paint a small period on the shell of the animal to prevent create a duplicate entry in the data sheet.

**Dead tortoises / remains:** Recently deceased tortoises that are encountered in the field should be noted on the data sheet. Measurements are not necessary for dead tortoises, but a waypoint should be created with an appropriate comment. Researchers should scan the body and immediate surroundings, including the underlying soil, for a PIT tag and recover any information on shell markings and sex.

### Summarizing data

Before departing the island, trip and group leaders should consolidate and organize all data sheets from mark-recapture surveys, resolve any uncertainties about specific data recordings, and make some basic summaries of the data to share with the DPNG. Care should be taken to transport the data sheets such that they are well-protected during outward trip. A post-survey summary form can be found for MR surveys in the Appendix of this document and as an Excel spreadsheet in the Protocol file archive.

## Transect- and Plot-based Surveys for Iguanas, Tortoises, and Cactus

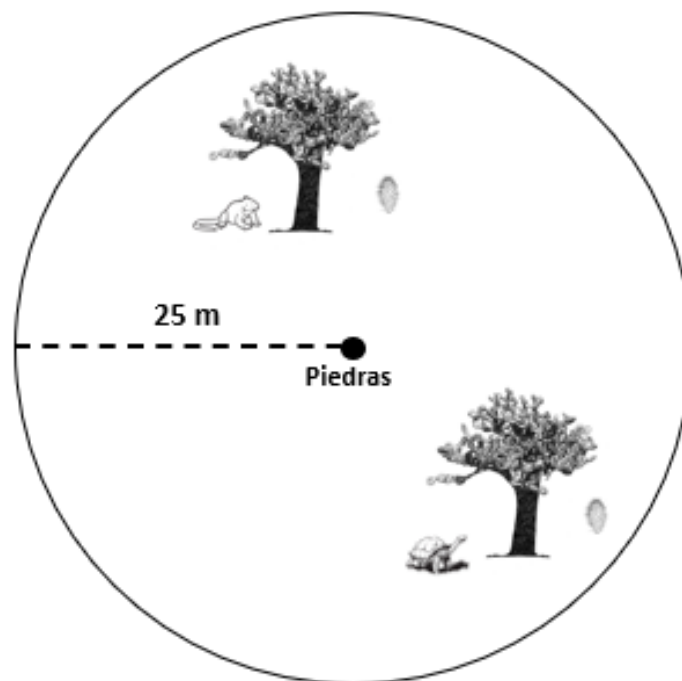
### Summary

Santa Fe Island is well known for its large populations of endemic land iguanas (*Conolophus pallidus*), rice rats (*Oryzomys bauri*), and cactus (*Opuntia echios* var. *barringtonensis*), the latter constituting one of the largest cactus populations in Galapagos both in terms of abundance and physical stature. Cactus is an important resource for both land iguanas and tortoises, which occupy similar spaces on Santa Fe. A grid of long-term monitoring plots (N = 178) and transects (N = 296) were established throughout the Santa Fe in 2011 to assess cactus and iguana populations prior to tortoise reintroduction (cactus are not surveyed along transects). Unlike tortoise mark-recapture surveys, plot and transect surveys allow us to better understand how tortoise and iguana densities are interconnected and driven by other environmental factors. Routine monitoring of these plots and transects provides a clear method for estimating trends in tortoise, iguana, and cactus populations over time and understanding how tortoises might restructure ecological communities on Santa Fe.

### Survey methods

Plots and transects are surveyed simultaneously, providing two independent estimates of tortoise and iguana density at given points in time. Plot surveys also include total counts of cactus and animal feces. Prior to conducting plot and transect surveys, plots and transect lines must be loaded to GPS devices.

**Plot surveys:** Plots are circular, with a radius of 25 meters from the center (Figure 3). The center of every plot is marked by a pile of rocks. Researchers should use either the GPS or a tape measure as guides for conducting plot surveys until they feel confident approximating 25 meters by sight. The objective of plot surveys is to complete a thorough search of the entire area, counting all tortoises, iguanas, and cactus by stage and/or sex. Tortoise and iguana feces are also counted. For all tortoise encounters, the observation protocol described in the previous section (Mark-recapture surveys for tortoises) is followed (i.e., obtaining PIT tags, physical measurements, etc.). Additional activity and microhabitat assessments may be conducted for tortoises and iguanas, if time permits.

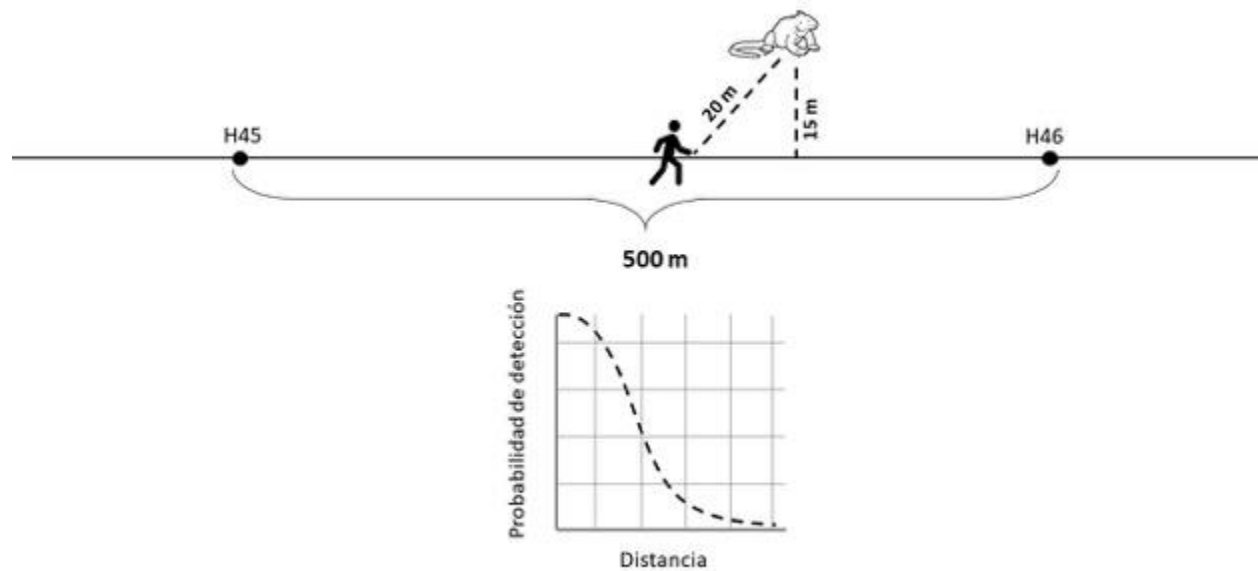


**Figure 3.** Long-term monitoring plots for tortoises, iguanas, and cactus (N = 178). Plots have a radius of 25 meters, with the plot center marked by a pile of rocks.

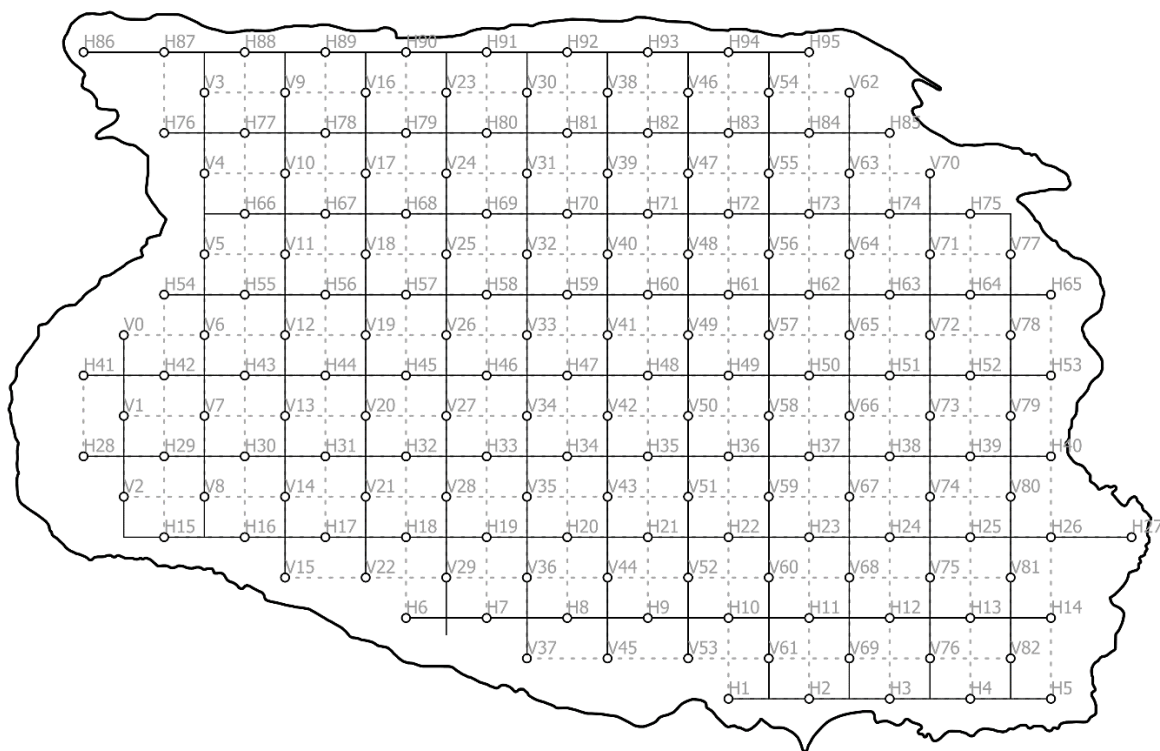
**Transect surveys:** In between all plots are transects of 500 m in length (Figure 4). Transects are horizontal (east/west) or vertical (north/south), as indicated by the name of each transect (e.g., H58-H57 is horizontal; V11-V10 is vertical). The primary goal of transect surveys is to make observations of iguanas and tortoises and estimate their distance from the transect line. Animals are typically harder to detect with greater distance from the transect, allowing us to estimate animal density and abundance using a technique called “distance sampling.”

Using a GPS and/or compass, researchers will follow these lines, taking care to not deviate from the path on the map. With two persons, a good approach is to have one person in front, navigating the line, and one person behind, recording all data on the data sheets and a GPS. As they walk along the transect line, both individuals will thoroughly scan the surrounding area next to the transect for iguanas and tortoises. Upon sighting an iguana or tortoise, they will measure its direct (from the point of observation) and perpendicular (from a 90° angle with the transect line) distance from the transect, determine its stage or

sex, make an entry in the transect data sheet, and record a new waypoint on the GPS. Tortoises should be scanned and measured, unless already marked from a mark-recapture survey during the same expedition. Activity and microhabitat assessments may be performed for each individual, if time permits.



**Figure 4.** Transects for distance sampling (N = 296) are 500 m long and in between plots. (Diagram not to scale.)



**Figure 5.** Map of all transects and long-term monitoring plots for iguanas, tortoises, and cactus on Santa Fe Island. Plots are labelled with specific names and connected by transects 500 m in length. Dashed lines are additional (optional) transects that can be surveyed if time permits. A list of plots and transects with associated coordinates can be found in the Appendix.

## Equipment

Materials for plot and transect surveys of tortoises, iguanas, and cactus (Table 5) are similar to those used in mark-recapture, with the addition of a long measuring tape (at least 50 m) for calculating plot dimensions and distances to animals from transects, a compass for additional guidance along transect lines, and several data sheets (found in Appendix).

**Table 5.** Equipment for plot and transect surveys of tortoises, iguanas, and cactus.

Item	Description / Comments
PIT scanner	Handheld AVID or BioMark PIT tag reader
PIT tags	Rice-sized electronic tags installed under inner left leg of tortoises
PIT pistol and needles	Plastic pressure gun and needles to install new PITs
Measuring tape (1.5 m)	For measuring tortoise shell dimensions
Measuring tape (50 - 100 m)	For measuring plot dimensions and animal encounters from transects
Digital scale with small rope	For weighing tortoises
GPS device	For navigating to plots and along transects and recording animal locations
Compass	For maintaining the correct bearing along transects
Batteries	AA and 9 volt batteries for PIT readers, electronic scales, and GPS devices
MR data sheet	Form for recording all tortoise observations, marks, and measurements
Transect data sheet	Form for recording all iguana and tortoise observations along transects

Plot data sheet  
Clipboard  
Pencils  
Sharpener

Form for recording all iguana, tortoise, and cactus observations in plots  
To assist data collection and store data sheets, maps, and protocols

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## Observation protocol

### Plots

1. Navigate to plot center with GPS. Plot center is marked by rock pile.
2. Establish plot boundaries (25 m radius from plot center) with GPS and/or tape measure.
3. Follow the columns on the data sheet and count all tortoises, iguanas, cactus, and tortoise and iguana feces within the circular plot.
  - a. For all tortoises and iguanas, record the stage / sex (juvenile, male, female)
  - b. For all tortoises, obtain PIT tag, coordinates, and follow the measurement protocol described in the previous section (Mark-recapture surveys for tortoises), unless the tortoise was already recorded during a mark-recapture survey in the same expedition.
  - c. For all tortoises and iguanas, record activity and microhabitat information, if time permits.
  - d. For all cactus, record the stage (juvenile, subadult, adult).
    - i. Juvenile: Small (typically less than 1 m) and fully green under needles. No sign of bark formation.
    - ii. Subadults: Bark formation. Needles are still present on bark.
    - iii. Adults: No needles on bark.

### Transects

1. Walk length of transect and visually scan surroundings for iguanas and tortoises.
2. Upon an animal (tortoise or iguana) encounter, measure the distance between the observer and the animal upon observation (direct distance) and the perpendicular distance between the transect and animal (perpendicular distance) in meters.
3. Walk to animal for further data collection:
  - a. Create GPS waypoint.
  - b. Classify stage / sex of animal.
  - c. Scan for PIT, measure, and weigh animal (for tortoises).
  - d. Describe animal activity and microhabitat if time permits.
4. Continue on transect, repeating steps 2–3 for every tortoise or iguana encounter.

**Dead animals / remains:** Recently deceased tortoises or iguanas that are encountered in the field should be noted on the data sheet but not counted in official plot counts or for distance sampling along transects. Measurements are not necessary for dead tortoises, but a waypoint should be created with an appropriate comment. Researchers should scan the body and immediate surroundings for a PIT tag and recover any information on shell markings and sex.

## Diet Study

### Summary

Tortoises and land iguanas are both prolific herbivores and play important roles in shaping island plant communities through their plant consumption and seed dispersal activities. Regeneration of native plant communities is an important objective of tortoise restoration. Studying the diet of tortoises and iguanas through fecal sampling provides a more detailed profile of their ongoing roles in the ecosystem and highlights any potential competition between the two herbivores. Diet can be examined via fecal content sampling and may be undertaken on some monitoring trips. Tortoise and iguana feces typically contain large quantities of seeds which can be counted and taxonomically identified to determine tortoise and iguana dietary preferences and seed dispersal potential. Post-processing of samples is time consuming.

### Equipment

Prior to transporting fecal samples, an official notice must be submitted to ABG for approval (see Appendix). Few materials are required for fecal sampling in the field.

**Table 6.** Field equipment for fecal sampling of tortoises and iguanas.

Item	Description / Comments
GPS device	For marking where samples are taken from on the island
Batteries	AA and 9 volt batteries for PIT readers, electronic scales, and GPS devices
Plastic Ziploc bags	For collecting individual samples
Marker	To label sample bags

### Collection and processing protocol

#### Collection of feces

Typically, fecal samples are collected haphazardly throughout an expedition. Each field team should aim to collect minimum 5–10 samples per species across their monitoring zone. This is generally done concurrently with mark-recapture surveys or other monitoring activities when field teams come across fresh feces. Feces sampled for diet studies must be relatively fresh (i.e., still moist) and collected whole.

1. Select fresh feces for collection.
2. Store entire feces in an individual plastic Ziploc bag.
3. Record new GPS waypoint for sample with unique ID beginning with the letter “H” (e.g., H1A for the first feces sample of group A).
4. Label plastic bag with the date, group number, island name, species, and sample ID.
5. All samples are aggregated at the end of the expedition and placed in a large plastic bag for later processing.

#### Drying and separation of seeds

Each sample should be preserved according to the biosafety policies established by the Directorate of Galapagos National Park:

1. Once samples arrive to Santa Cruz and complete their respective quarantine, they should be disinfected, transferred to paper bags and moved to a drying station at the Charles Darwin Foundation where samples are dried in a stove to 45 degrees centigrade.

2. Subsequently, each sample must be disaggregated, using water and a five-level sieve with a mesh size of 5, 4, 3, 1.5 and 0.5 mm.
3. The material collected at each level should be weighed and using criteria for color, texture, and shape of the remains of stems, leaves, roots, seeds and flowers found in the feces, components should be categorized into one of the the following groups: herbaceous, cactus , woody material, and unidentified material.

#### **Identification and data entry of seeds**

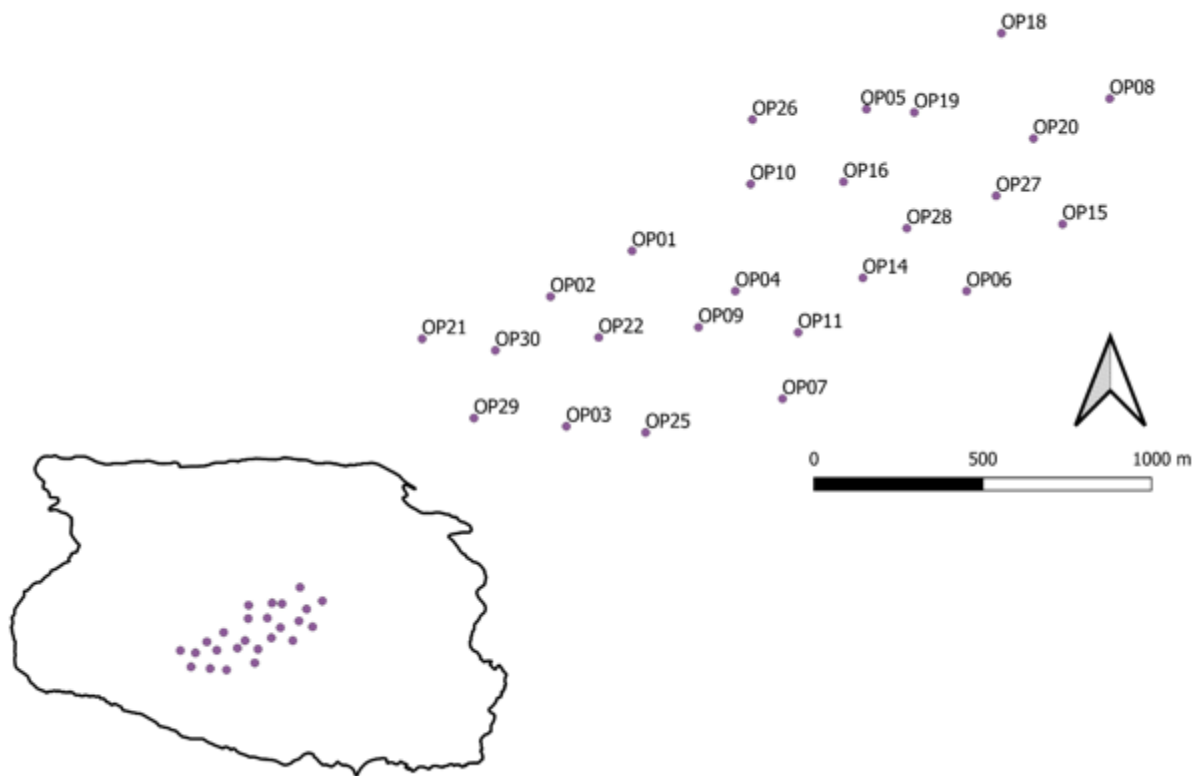
1. First, the seeds retained in the different levels of the sieve must be removed and counted and they must be separated according to their characteristics of color, shape and size.
2. Then, using a Leica model EZ4W stereoscope, which magnifies the image 32 times, photographs should be taken with the greatest possible detail of the morphotype of the seed for later identification.
3. Finally, each element found in the feces should be compared with the photographic guide of seeds of the Galapagos plants (Jaramillo and Heleno in prep), with the book of taxonomic keys of the flora of Galapagos (Wiggins & Porter, 1971), and the Galapagos Islands seed and plant collections from the Charles Darwin Foundation herbarium.

## **Plot-based cactus population surveys in Central Zone**

### **Summary**

Several techniques have been implemented on Santa Fe Island to monitor cactus populations, including long-term monitoring plots and a large scale census. In addition to the island-wide plots that are surveyed for iguanas, tortoises, and cactus, a set of long-term plots (N = 26, see table in Appendix) in the central zone of Santa Fe focus exclusively on cactus populations. The purpose of these plots, which are located in proximity to the tortoise release point, is to study how cactus populations are affected by tortoise reintroduction. Plots are 25 m in radius and unmarked (no rock pile in center). Using a GPS device, researchers will navigate to these points and perform a complete survey of the plot dimensions, counting and measuring the height of every cactus within 25 m of the plot center guided by a measuring tape as needed.





**Figure 6.** Map of all cactus plots (N = 26) on Santa Fe island. Plots are labelled with specific names starting with the letters “OP.”

### Equipment

The equipment for plot-based cactus population surveys is minimal, as no data are collected on tortoises (thus, there is no need for PIT scanners, paint, etc.). The required list is as follows:

**Table 7.** Equipment for plot-based cactus population surveys.

Item	Description / Comments
Measuring tape (< 1 m)	For measuring juvenile cactus heights
Measuring tape (25 m)	For measuring plot dimensions
GPS device	For navigating to plots and estimating plot dimensions
Collapsible pole (~ 3 m)	A collapsible metal pole for measuring heights of tall cactus
Batteries	AA batteries for GPS devices
Parcela data sheet	Form for recording all cactus observations and measurements in plots
Clipboard	To assist data collection and store data sheets, maps, and protocols
Pencils	
Sharpener	

### Survey protocol

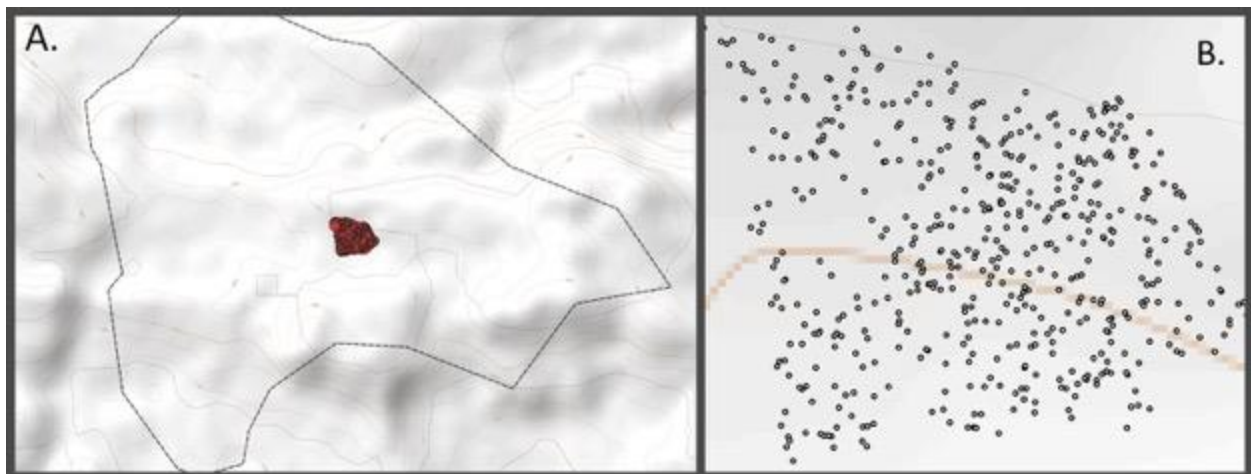
1. Find plot name in GPS and navigate to exact point.

2. Using the GPS device or, better, a tape measure, mark out the circular plot dimensions (25 m radius).
3. Conduct a thorough search of the plot for all cactus. With a group of two persons, one person should conduct the survey and relay data to the other person to enter on the data sheet. For every individual encountered:
  - a. Identify the stage (juvenile, subadult, or adult):
    - i. Juvenile: Small (typically less than 1 m) and fully green under needles. No sign of bark formation.
    - ii. Subadults: Bark formation. Needles are still present on bark.
    - iii. Adults: No needles on bark.
  - b. Measure the height of the cactus.
    - i. For juveniles, a small tape measure will be most accurate.
    - ii. For larger subadults and adults, a collapsible metal pole that is pre-labeled with measurement units will be necessary.
    - iii. For very large cactus (> 2 m), the surveyor will hold up the fully extended pole parallel to the tree for the data recorder to estimate height visually from a distance. In the event that a tree is taller than the full extent of the pole, the surveyor will elevate the pole upwards until it reaches the top of the crown. In such a circumstance, the total height will be the full extent of the pole plus the displaced height from the ground to the bottom of the pole.

## Census-based cactus population survey in the Central Zone

### Summary

Census-based cactus surveys focus on a single population of over 500 cactuses in the central zone of Santa Fe Island, proximate to the tortoise release point. The census-based survey is a complete inventory of all cactuses in a defined area (see map below). As with the plot-based cactus surveys, cactuses are staged, counted, and measured. Additionally, in the census-based survey all cactuses are individually marked with permanent metal tags and monitored over time, providing detailed information on cactus growth and survival on Santa Fe.



**Figure 7.** Location of the cactus census megaplot (A.) where 525 cacti of all sizes and ages are permanently marked (B.) with metal tags to measure growth, survival and population change.

## Equipment

The equipment for census-based cactus population surveys is minimal, as no data are collected on tortoises (thus, there is no need for PIT scanners, paint, etc.). The required list is as follows:

**Table 8.** Equipment for census-based cactus population surveys.

Item	Description / Comments
Measuring tape (< 1 m)	For measuring juvenile cactus heights
Measuring tape (25 m)	For measuring plot dimensions
GPS device	For navigating to plots and estimating plot dimensions
Collapsible pole (~ 3 m)	A collapsible metal pole for measuring heights of tall cactus
Batteries	AA batteries for GPS devices
Metal tags	For assigning to new cactuses in the census area
Census data sheet	Form for recording all cactus observations and measurements in plots
Clipboard	To assist data collection and store data sheets, maps, and protocols
Pencils	
Sharpener	

## Survey protocol

1. Find census area and navigate to individually marked cactus manually or with GPS. Cactuses should be located in order according to the numbers on the metal tags.
  - a. With one group of two to three people, it is easiest for one or two persons to navigate and announce cactus measurements while the other person enters data into the data sheet.
  - b. With two groups of two to three people each, the cactus population should be divided, and each group should focus their efforts on one half.
  - c. The work can be done with just two people but three is very helpful – one finding the cactus, one measuring them, one recording the data.
2. Identify the stage (juvenile, subadult, or adult):
  - a. Juvenile: Small (typically less than 1 m) and fully green under needles. No sign of bark formation.
  - b. Subadults: Bark formation. Needles are still present on bark.
  - c. Adults: No needles on bark.
3. Measure the height of the cactus.
  - a. For juveniles, a small tape measure will be most accurate.
  - b. For larger subadults and adults, a collapsible metal pole that is pre-labeled with measurement units will be necessary.
  - c. For very large cactus (> 2 m), the surveyor will hold up the fully extended pole parallel to the tree for the data recorder to estimate height visually from a distance. In the event that a tree is taller than the full extent of the pole, the surveyor will elevate the pole upwards until it reaches the top of the crown. In such a circumstance, the total height

will be the full extent of the pole plus the displaced height from the ground to the bottom of the pole.

4. For juveniles only, count the total number of cladodes (cactus pads).
5. Occasionally cactus assume atypical forms (broken limbs, collapsed and re-rooted): for these height represents the highest part above ground – make notes about the form of these atypical individuals.
6. Add any additional comments about cactus condition.
7. Repeat steps 2–5 for all cactuses marked in the census zone. Any new unmarked (juvenile) cactuses will be (1) assigned a tag (the next sequential tag in the population, e.g., if the last marked cactus in the population is 545, use tag 546), (2) measured, and (3) recorded as a new waypoint in the GPS. Waypoints IDs should match the tag number.

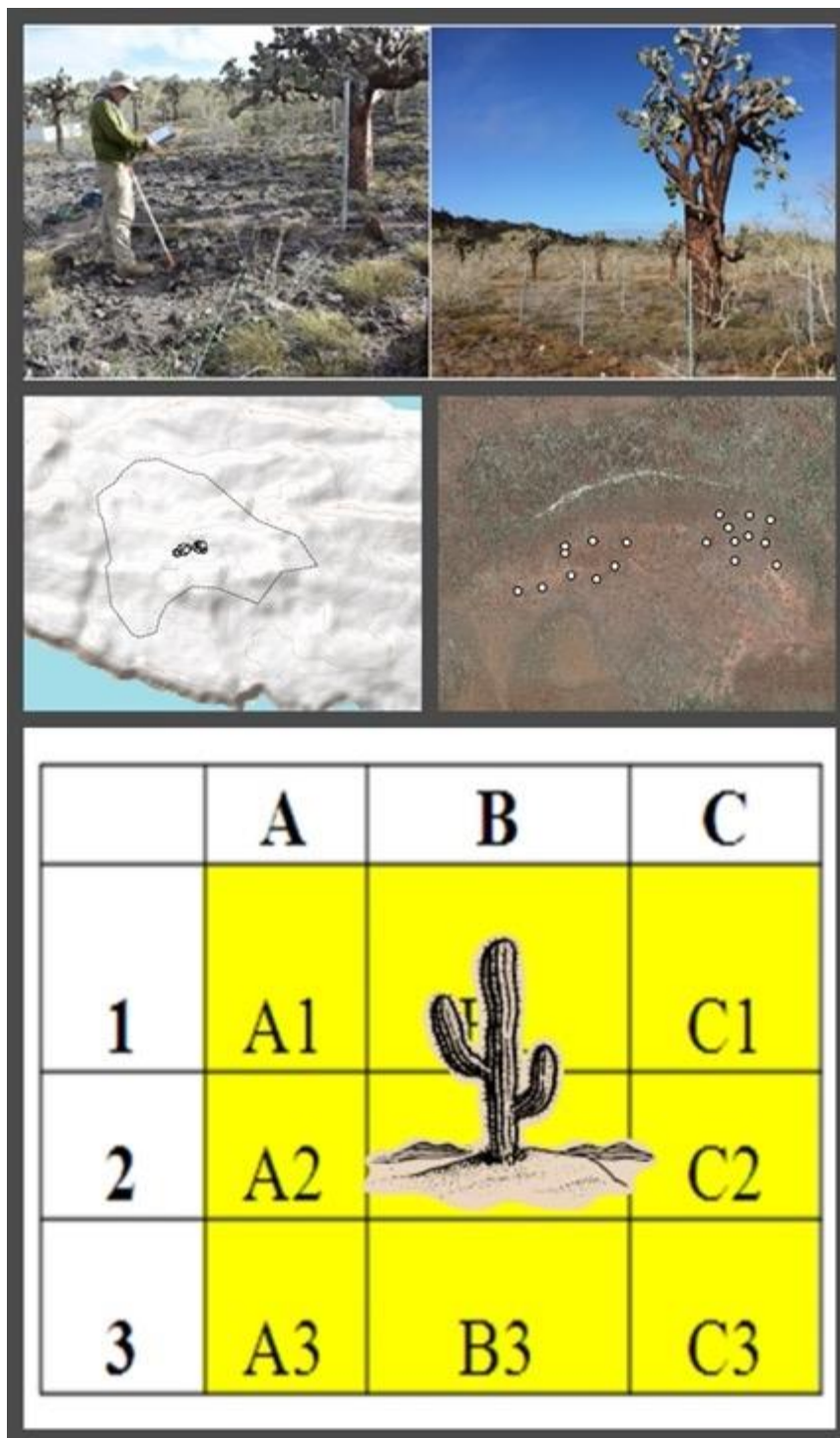
**Dead cactus:** All dead cactuses must be noted in the data sheet. Cactuses are considered dead if they have fallen (as adults) or have no green pigment on the cladodes. Dead cactuses do not need to be measured. Recover the metal tags of all dead cactuses.

## Plant community change: Exclosure Plots and Controls

### Summary

Monitoring plant community profiles helps measure the impact that tortoises have on Santa Fe ecosystems. Through their grazing and seed dispersal, tortoises are thought to be important ecosystem engineers by limiting plant cover and encouraging recruitment of certain species; therefore, the reintroduction of tortoises to Santa Fe Island should fundamentally affect plant communities on Santa Fe and hopefully encourage restoration of native plants impacted by legacies of introduced goats. Monitoring plant communities over time will also help reveal the trophic niches of tortoises relative to those of land iguanas and determine ecological overlap between these two important herbivores.

We study plant community change on Santa Fe Island with an array of paired quadrats in the central zone. Each quadrat features a cactus tree at the plot center and is broken into nine subquadrats. For each pair of quadrats, one plot is “closed” using barriers to exclude tortoises and/or iguanas, and one plot is “open,” without any barriers, and thus considered a control. In total there are 10 pairs of plots (N = 20 plots), each plot 6 by 6 m in dimension. Within each plot, tortoise and iguana feces are counted, ground cover by various plant species is estimated, and individual woody plants are documented and measured. *Be very careful to walk only on rocks when measuring inside each plot so as not to disturb the vegetation.* Generally an observer enters each plot to make measurements and call them out to a data recorder waiting just outside the plot perimeter.



**Figure 8.** Plant community monitoring: : general exclosure design (top tier) which includes areas fenced to exclude herbivores and unfenced, location of plots within the island (left, middle tier) and in relation

to one another (right, middle tier), and subplot design for measuring vegetation parameters in each plot (bottom tier).

## Equipment

**Table 9.** Equipment for plant community monitoring.

Item	Description / Comments
Thin ropes (4 in total) 8 m long, each with a stake (can be cut from dead wood on site outside of plot)	For delineating the 9 2x2 subquadrants within each study plot
Measuring tape (< 1 m)	For measuring juvenile cactus heights and small woody plants
Measuring tape (25 m)	For measuring plot dimensions
GPS device	For navigating to plots
Collapsible pole (~ 3 m)	A collapsible metal pole for measuring heights of tall cactus
Batteries	AA batteries for GPS devices
Metal tags	For assigning to any new cacti encountered in plots
Exclosure data sheet	Form for recording all plant observations and measurements in plots
Clipboard	To assist data collection and store data sheets, maps, and protocols
Pencils	
Sharpener	

## Survey protocol

1. Navigate to plot using GPS and/or physical map.
2. Record plot number, date, and type (exclosure or control).
3. Delineate the outer limit of each plot with a metric tape (wrap tape around base of plot at fence base (fences) or around corner stone (controls))
4. Delineate each 2x2 subquadrant by stretching a thin rope (4 total) each attached to stakes at each 2 m section along plot sides (controls) or to fence links at each 2 m section and extending across plots.
5. In each subquadrant (9 total):
  - a. Estimate % of substrate that is rock/soil.
  - b. Estimate % of ground cover that is (a) forbs, (b) grasses, and (c) without vegetation.
  - c. Estimate % of overhead cover (> 2.5 m in height) that is (a) cactus and (b) woody plants.
  - d. Count the number of entire cactus pads (be careful to not disturb the pads which may have become rooted), partial cactus pads, entire cactus fruits, partial cactus fruits, and tortoise and iguana feces
6. Measure and record the following details for each *woody plant*:
  - a. ID of subquadrant
  - b. Circumference at chest height
  - c. Species (M=muyuyo/Cordia, C=Chala/Croton, A = Algarrobo/Prosopis, PV= Palo Verde/Parkinsonia, PS=Palo Santo/Bursera, T = Tournefortia)
  - d. Individual or in groups
  - e. Live / dead

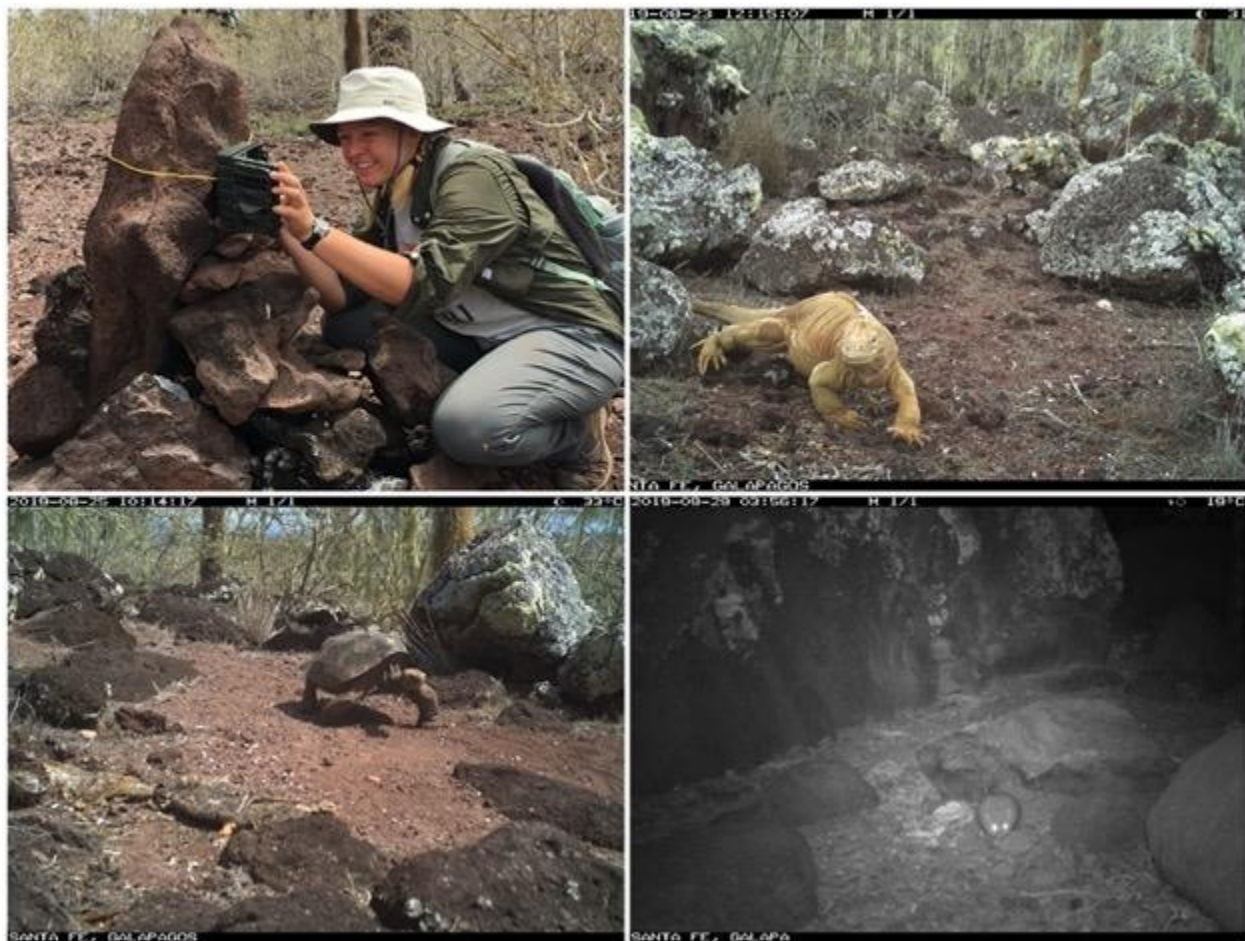


7. Measure the height and record the stage (Juvenile/Subadult/Adult) of every cactus in the plot (including the central one)

## Camera Traps

### Summary

Between field trips to Santa Fe, animals are continuously monitored by an array of passive camera traps (Reconyx Hyperfire 2, N = 60) installed in the central zone of the island in July 2019. The purpose of these cameras is to reveal activity patterns, distributions, and interactions among tortoises and other wildlife on Santa Fe. Cameras are equipped with sufficient battery power and memory to capture and store up to one year of images. Annual camera maintenance is necessary to save image data and replace batteries and memory cards for continuous operation.



**Figure 9.** Camera installation on Santa Fe Island and sample images captured.

### Equipment

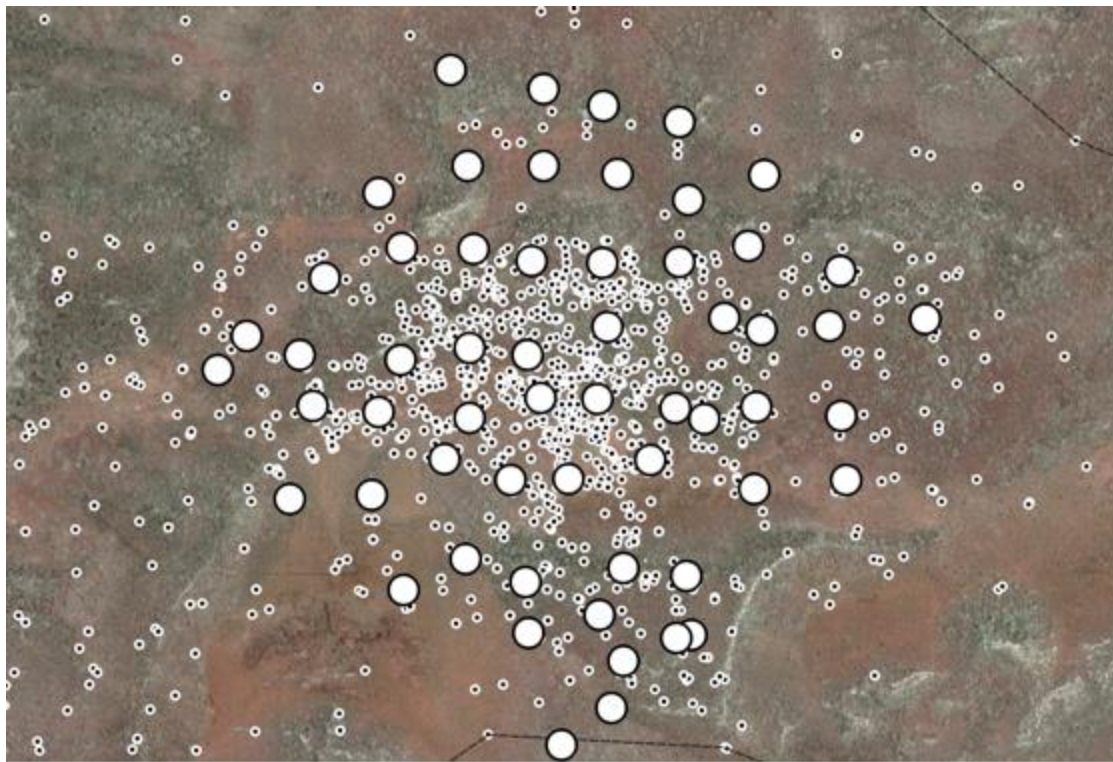
**Table 10.** Equipment for camera trap maintenance.

Item	Description / Comments
GPS device	For navigating to camera traps
Lithium AA batteries	To replace for cameras with low charge



Micro SD memory cards (60 + extras)	SD/XC or SD/HC 64 GB memory cards to replace when memory low
Pliers	For adjusting camera positions / making repairs, if necessary
Metal wire	For adjusting camera positions / making repairs, if necessary
Camera trap data sheet	Form for recording all camera trap battery / memory levels in field
Clipboard	To assist data collection and store data sheets, maps, and protocols
Ziploc bags (2)	One bag for holding new memory cards, one bag for old cards
Fine tipped marker	For writing camera ID on memory cards
Pencils	
Sharpener	

## Map of cameras



**Figure 9.** Map of camera locations (large white dots) arrayed across a gradient of tortoise density (smaller dots) to measure impacts of tortoises on the community of vertebrate fauna on Santa Fe Island.

## Camera formatting

The memory cards used for cameras on Santa Fe are SanDisk Ultra SD/XC with 64 GB of memory (<https://www.reconyx.com/product/64GB-Reconyx-Certified-SDHC-Memory-Card>).



**Figure 10.** Memory cards used for Reconyx cameras on Santa Fe Island.

The Reconyx cameras can be programmed to take photographs according to a variety of settings that control image frequencies, trigger sensitivity, and various other functions. Cameras can be programmed individually in the field; however, this process is very tedious and prone to more errors than programming the settings onto the memory cards directly, which can be done from any computer prior to departure for an expedition. Currently, all cameras in the field are programmed according to these settings:

**Table 11.** Settings for Reconyx Hyperfire 2 cameras on Santa Fe Island.

Type	Function	Setting
Motion	Motion pictures	On
	External trigger pictures	Off
	Number of pictures	5
	Time between pictures	3
	Motion videos	Off
	External trigger videos	Off
	Quiet period	1 minute
	Sensitivity	High
Time Lapse	Time lapse pictures	On
	Number of pictures	1
	Time lapse videos	Off
	Time lapse interval	15 minutes
Day/Night	Take pictures	Both day and night
	Take videos	Both day and night
	Flash output	High
	Minimum shutter speed	1/30th
	Maximum ISO	ISO1600
Display	Label	Santa Fe
	Time format	24 hour
	Temperature units	Celsius

Other	Show logo	Yes
	Use CodeLoc	No
	Resolution	Wide (16:9)
	Loop recording	Off
	Record audio	On
	PIR Type	Long range
	Delay start	Off

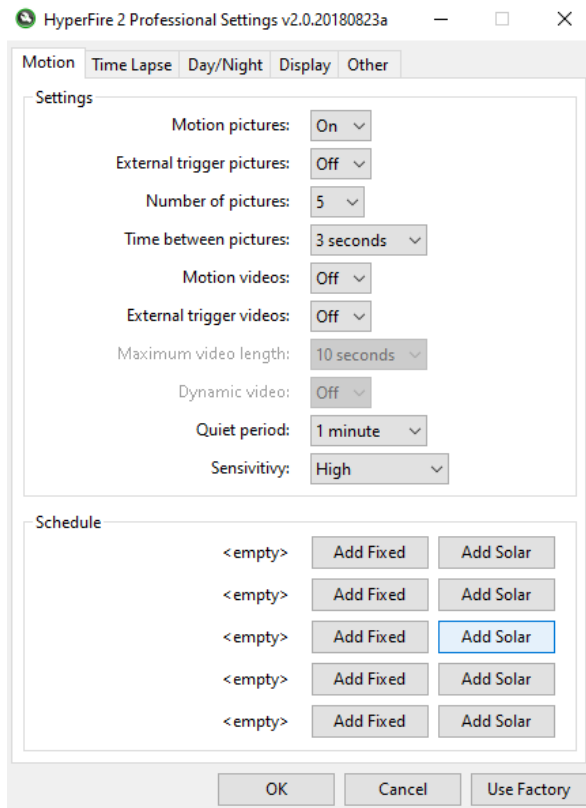
**No action needs to be taken when replacing memory cards to retain camera settings.** Current camera settings will be saved once they are programmed, even if cameras are turned off or memory cards are replaced with blank ones.

To change existing camera settings or for new camera installations, camera settings can be programmed directly onto memory cards using the *Hyperfire 2 Professional Camera Settings Software*, which can be freely downloaded from <https://www.reconyx.com/software/pro-settings-hf2>. You will need to create an account to download the software.

After downloading the software, continue through the installation process to setup the program on your computer.

1. Insert memory card into your computer SD drive or via an adapter. If the memory card already has images on it, copy all existing files onto a new folder on the computer with the same name as that labelled on the memory card. Then delete all files on the memory card so it is empty.

2. Open the Hyperfire 2 software. You should see the following window open:



3. Click on each of the tabs in the window and follow the settings protocol in Table 10 (for new cameras) or a new protocol (for changing existing settings) to program the correct settings onto the memory card.
4. Remove memory card and place into a new bag labelled “New cards.”
5. Repeat steps 1–4 for all memory cards.

**Please consult with James Gibbs ([jpgibbs@esf.edu](mailto:jpgibbs@esf.edu)) or Washington Tapia ([wtapia@galapagos.org](mailto:wtapia@galapagos.org)) before considering making any modifications to camera settings. Any future modifications to existing camera settings must be documented and included in an updated version of this document.**

### Camera maintenance

Prior to any field trip that includes camera maintenance, 60 blank memory cards (plus a few extras) must be prepared to replace existing cards in cameras. Use old cards from Santa Fe, if available, before opening new (still packaged) memory cards. Old cards are labelled with the name “SF” and a camera ID in black marker.

Old memory cards must be **wiped clean** of all images (i.e., images must first be downloaded and saved on a computer and then deleted from the memory card) and removed of its camera ID (with alcohol wipes) before reuse in the field.

The following protocol is used when checking on cameras in the field.

1. Use GPS to navigate to camera traps
2. Open camera and record current memory and battery from screen on data sheet.

3. If remaining battery is low (< 25%), and you have new AA lithium batteries with you, turn off camera, replace batteries, and turn on camera again.
4. Remove old memory card and store in "Old cards" bag.
5. Take out one blank memory card from the "New cards" bag. Label blank card with the two camera IDs (GPS point and metal tag number).
6. Insert new labelled card in camera.
7. Scroll through the screen display until the message "ARM CAMERA" appears and press "OK."
8. Close the camera.
9. Repeat steps 1–8 for each camera on Santa Fe.

### Image downloading

After returning from an expedition, images should be immediately downloaded from memory cards and backed up to prevent data loss.

1. Create new folder to store all images from the most recent trip. Title the folder "Santa\_Fe\_cameras\_DAY\_MONTH\_YEAR"
2. Take out one memory card from the "Old cards" bag.
3. Create new subfolder within the "Santa\_Fe\_cameras\_DAY\_MONTH\_YEAR" trip folder. Title the new subfolder with the camera ID label on the memory card.
4. Insert memory card into SD slot or adapter on computer and open the folder titled "RECONYX."
5. Copy all images on the memory card to the new subfolder on the computer.
6. Repeat steps 2–5 for all memory cards from the field.

## Appendix

### Data sheets

#### Summary of mark-recapture survey with Lincoln-Peterson Index

<b>Day:</b> _____ <b>Month:</b> _____ <b>Year:</b> _____ <b>Trip leader:</b> _____  <b>Total number of survey days:</b> _____ <b>Total number of field participants:</b> _____
--

Total observed counts of tortoises by sex and stage

Group	Juveniles	Males	Females	Total
A				
B				
C				
D				
E				
F				
G				
<b>Total</b>				

Number of  
hatchlings  
(<30 cm LC)


Population estimate with Lincoln-Peterson

Lincoln-Peterson Index:

$$\hat{N} = \frac{M \cdot S}{R}$$

*N* = estimación del tamaño de la población

*M* = número de tortugas marcadas durante la primera búsqueda

*S* = número de todas las tortugas capturada en la segunda búsqueda

*R* = número de tortugas recapturada en la segunda búsqueda

Group	Juvenile				Male				Female				Total
	M	S	R	N	M	S	R	N	M	S	R	N	N
A													
B													
C													
D													
E													
F													
G													
<b>Total</b>													



# List of plots for tortoises, iguanas, and cactus

Parcelas para tortugas, iguanas, y cactus								
<i>Horizontal</i>								
H1-H32			H33-64			H65-H95		
ID	LAT	LONG	ID	LAT	LONG	ID	LAT	LONG
H1	-0.8371	-90.0513	H33	-0.8235	-90.0648	H65	-0.8144	-90.0333
H2	-0.8371	-90.0468	H34	-0.8235	-90.0603	H66	-0.8099	-90.0784
H3	-0.8371	-90.0423	H35	-0.8235	-90.0558	H67	-0.8099	-90.0739
H4	-0.8371	-90.0378	H36	-0.8235	-90.0513	H68	-0.8099	-90.0694
H5	-0.8371	-90.0333	H37	-0.8235	-90.0468	H69	-0.8099	-90.0649
H6	-0.8326	-90.0693	H38	-0.8235	-90.0423	H70	-0.8099	-90.0603
H7	-0.8326	-90.0648	H39	-0.8235	-90.0378	H71	-0.8099	-90.0558
H8	-0.8326	-90.0603	H40	-0.8235	-90.0333	H72	-0.8099	-90.0513
H9	-0.8326	-90.0558	H41	-0.8190	-90.0874	H73	-0.8099	-90.0468
H10	-0.8326	-90.0513	H42	-0.8190	-90.0829	H74	-0.8099	-90.0423
H11	-0.8326	-90.0468	H43	-0.8190	-90.0784	H75	-0.8099	-90.0378
H12	-0.8325	-90.0423	H44	-0.8190	-90.0739	H76	-0.8054	-90.0829
H13	-0.8325	-90.0378	H45	-0.8190	-90.0694	H77	-0.8054	-90.0784
H14	-0.8325	-90.0333	H46	-0.8190	-90.0648	H78	-0.8054	-90.0739
H15	-0.8280	-90.0829	H47	-0.8190	-90.0603	H79	-0.8054	-90.0694
H16	-0.8280	-90.0784	H48	-0.8189	-90.0558	H80	-0.8053	-90.0649
H17	-0.8280	-90.0739	H49	-0.8189	-90.0513	H81	-0.8053	-90.0603
H18	-0.8280	-90.0693	H50	-0.8189	-90.0468	H82	-0.8053	-90.0558
H19	-0.8280	-90.0648	H51	-0.8189	-90.0423	H83	-0.8053	-90.0513
H20	-0.8280	-90.0603	H52	-0.8189	-90.0378	H84	-0.8053	-90.0468
H21	-0.8280	-90.0558	H53	-0.8189	-90.0333	H85	-0.8053	-90.0423
H22	-0.8280	-90.0513	H54	-0.8144	-90.0829	H86	-0.8008	-90.0874
H23	-0.8280	-90.0468	H55	-0.8144	-90.0784	H87	-0.8008	-90.0829
H24	-0.8280	-90.0423	H56	-0.8144	-90.0739	H88	-0.8008	-90.0784
H25	-0.8280	-90.0378	H57	-0.8144	-90.0694	H89	-0.8008	-90.0739
H26	-0.8280	-90.0333	H58	-0.8144	-90.0648	H90	-0.8008	-90.0694
H27	-0.8280	-90.0288	H59	-0.8144	-90.0603	H91	-0.8008	-90.0649
H28	-0.8235	-90.0874	H60	-0.8144	-90.0558	H92	-0.8008	-90.0604
H29	-0.8235	-90.0829	H61	-0.8144	-90.0513	H93	-0.8008	-90.0558
H30	-0.8235	-90.0784	H62	-0.8144	-90.0468	H94	-0.8008	-90.0513
H31	-0.8235	-90.0739	H63	-0.8144	-90.0423	H95	-0.8008	-90.0468
H32	-0.8235	-90.0693	H64	-0.8144	-90.0378			

List of plots for tortoises, iguanas, and cactus (continued)

Parcelas para tortugas, iguanas, y cactus								
V0-V27			<i>Vertical</i> V28-V55			V56-V82		
ID	LAT	LONG	ID	LAT	LONG	ID	LAT	LONG
V0	-0.8167	-90.0851	V28	-0.82576	-90.0671	V56	-0.81214	-90.0491
V1	-0.82124	-90.0851	V29	-0.8303	-90.0671	V57	-0.81668	-90.0491
V2	-0.82578	-90.0851	V30	-0.80308	-90.0626	V58	-0.82121	-90.0491
V3	-0.80309	-90.0806	V31	-0.80761	-90.0626	V59	-0.82575	-90.0491
V4	-0.80763	-90.0806	V32	-0.81215	-90.0626	V60	-0.83029	-90.0491
V5	-0.81216	-90.0806	V33	-0.81669	-90.0626	V61	-0.83482	-90.0491
V6	-0.8167	-90.0806	V34	-0.82122	-90.0626	V62	-0.80307	-90.0446
V7	-0.82124	-90.0806	V35	-0.82576	-90.0626	V63	-0.8076	-90.0446
V8	-0.82577	-90.0806	V36	-0.8303	-90.0626	V64	-0.81214	-90.0446
V9	-0.80309	-90.0761	V37	-0.83483	-90.0626	V65	-0.81667	-90.0446
V10	-0.80762	-90.0761	V38	-0.80308	-90.0581	V66	-0.82121	-90.0446
V11	-0.81216	-90.0761	V39	-0.80761	-90.0581	V67	-0.82575	-90.0446
V12	-0.8167	-90.0761	V40	-0.81215	-90.0581	V68	-0.83028	-90.0446
V13	-0.82123	-90.0761	V41	-0.81668	-90.0581	V69	-0.83482	-90.0446
V14	-0.82577	-90.0761	V42	-0.82122	-90.0581	V70	-0.8076	-90.0401
V15	-0.83031	-90.0761	V43	-0.82576	-90.0581	V71	-0.81213	-90.0401
V16	-0.80308	-90.0716	V44	-0.83029	-90.0581	V72	-0.81667	-90.0401
V17	-0.80762	-90.0716	V45	-0.83483	-90.0581	V73	-0.82121	-90.0401
V18	-0.81216	-90.0716	V46	-0.80307	-90.0536	V74	-0.82574	-90.0401
V19	-0.81669	-90.0716	V47	-0.80761	-90.0536	V75	-0.83028	-90.0401
V20	-0.82123	-90.0716	V48	-0.81214	-90.0536	V76	-0.83481	-90.04
V21	-0.82577	-90.0716	V49	-0.81668	-90.0536	V77	-0.81213	-90.0356
V22	-0.8303	-90.0716	V50	-0.82122	-90.0536	V78	-0.81667	-90.0356
V23	-0.80308	-90.0671	V51	-0.82575	-90.0536	V79	-0.8212	-90.0356
V24	-0.80762	-90.0671	V52	-0.83029	-90.0536	V80	-0.82574	-90.0356
V25	-0.81215	-90.0671	V53	-0.83482	-90.0536	V81	-0.83027	-90.0355
V26	-0.81669	-90.0671	V54	-0.80307	-90.0491	V82	-0.83481	-90.0355
V27	-0.82123	-90.0671	V55	-0.8076	-90.0491			

# List of transects for tortoises and iguanas

Transectos					
Horizontal			Vertical		
H1-H2	H38-H24	H65-H53	V0-V1	V36-V29	V63-V55
H2-H3	H38-H39	H66-H55	V1-V2	V36-V35	V63-V62
H3-H4	H39-H25	H66-H67	V10-V4	V37-V36	V64-V56
H4-H5	H39-H40	H67-H56	V10-V9	V38-V30	V64-V63
H10-H1	H40-H26	H67-H68	V11-V10	V39-V31	V65-V57
H10-H11	H41-H42	H68-H57	V11-V5	V39-V38	V65-V64
H11-H12	H42-H29	H68-H69	V12-V11	V40-V32	V66-V58
H11-H2	H42-H43	H69-H58	V12-V6	V40-V39	V66-V65
H12-H13	H43-H30	H69-H70	V13-V12	V41-V33	V67-V59
H12-H3	H43-H44	H7-H8	V13-V7	V41-V40	V67-V66
H13-H14	H44-H31	H70-H59	V14-V13	V42-V34	V68-V60
H13-H4	H44-H45	H70-H71	V14-V8	V42-V41	V68-V67
H14-H5	H45-H32	H71-H60	V15-V14	V43-V35	V69-V61
H16-H17	H45-H46	H71-H72	V16-V9	V43-V42	V69-V68
H17-H18	H46-H33	H72-H61	V17-V10	V44-V36	V7-V1
H18-H19	H46-H47	H72-H73	V17-V16	V44-V43	V7-V8
H18-H6	H47-H34	H73-H62	V18-V11	V45-V37	V70-V63
H19-H20	H47-H48	H73-H74	V18-V17	V45-V44	V71-V64
H19-H7	H48-H35	H74-H63	V19-V12	V46-V38	V71-V70
H20-H21	H48-H49	H74-H75	V19-V18	V47-V39	V72-V65
H20-H8	H49-H36	H75-H64	V20-V13	V47-V46	V72-V71
H21-H22	H49-H50	H76-H77	V20-V19	V48-V40	V73-V66
H21-H9	H50-H37	H77-H66	V21-V14	V48-V47	V73-V72
H22-H10	H50-H51	H77-H78	V21-V20	V49-V41	V74-V67
H22-H23	H51-H38	H78-H67	V22-V15	V49-V48	V74-V73
H23-H11	H51-H52	H78-H79	V22-V21	V5-V6	V75-V68
H23-H24	H52-H39	H79-H68	V23-V16	V50-V42	V75-V74
H24-H12	H52-H53	H79-H80	V24-V17	V50-V49	V76-V69
H24-H25	H53-H40	H8-H9	V24-V23	V51-V43	V76-V75
H25-H13	H54-H55	H80-H69	V25-V18	V51-V50	V77-V71
H25-H26	H55-H43	H80-H81	V25-V24	V52-V44	V78-V72
H26-H14	H55-H56	H81-H70	V26-V19	V52-V51	V78-V77
H28-H29	H56-H44	H81-H82	V26-V25	V53-V45	V79-V73
H29-H15	H56-H57	H82-H71	V27-V20	V53-V52	V79-V78
H29-H30	H57-H45	H82-H83	V27-V26	V54-V46	V8-V2
H30-H16	H57-H58	H83-H72	V28-V21	V55-V47	V80-V74
H30-H31	H58-H46	H83-H84	V28-V27	V55-V54	V80-V79
H31-H17	H58-H59	H84-H73	V29-V22	V56-V48	V81-V75
H31-H32	H59-H47	H84-H85	V29-V28	V56-V55	V81-V80
H32-H18	H59-H60	H85-H74	V3-V4	V57-V49	V82-V76
H32-H33	H6-H7	H87-H76	V30-V23	V57-V56	V82-V81
H33-H19	H60-H48	H88-H77	V31-V24	V58-V50	V9-V3
H33-H34	H60-H61	H89-H78	V31-V30	V58-V57	
H34-H20	H61-H49	H90-H79	V32-V25	V59-V51	
H34-H35	H61-H62	H91-H80	V32-V31	V59-V58	
H35-H21	H62-H50	H92-H81	V33-V26	V6-V7	
H35-H36	H62-H63	H93-H82	V33-V32	V60-V52	
H36-H22	H63-H51	H94-H83	V34-V27	V60-V59	
H36-H37	H63-H64	H95-H84	V34-V33	V61-V53	
H37-H23	H64-H52	H9-H10	V35-V28	V61-V60	
H37-H38	H64-H65		V35-V34	V62-V54	

**List of long-term monitoring plots for cactus**

ID	Latitud	Longitud	y_proj	x_proj
OP01	-0.82148	-90.06416	9909071	158907
OP02	-0.82271	-90.06634	9908935	158665
OP03	-0.82618	-90.06591	9908551	158712
OP04	-0.82255	-90.06141	9908952	159213
OP05	-0.81768	-90.05793	9909492	159601
OP06	-0.82255	-90.05526	9908953	159899
OP07	-0.82544	-90.06016	9908633	159353
OP08	-0.81740	-90.05145	9909524	160323
OP09	-0.82352	-90.06239	9908845	159104
OP10	-0.81969	-90.06101	9909269	159258
OP11	-0.82366	-90.05974	9908830	159400
OP14	-0.82220	-90.05802	9908992	159591
OP15	-0.82076	-90.05270	9909152	160184
OP16	-0.81963	-90.05854	9909276	159533
OP18	-0.81565	-90.05433	9909717	160001
OP19	-0.81777	-90.05665	9909483	159743
OP20	-0.81846	-90.05348	9909406	160097
OP21	-0.82384	-90.06975	9908809	158284
OP22	-0.82380	-90.06505	9908814	158808
OP25	-0.82634	-90.06380	9908533	158947
OP26	-0.81796	-90.06096	9909460	159263
OP27	-0.82000	-90.05447	9909236	159987
OP28	-0.82087	-90.05685	9909139	159722
OP29	-0.82596	-90.06837	9908575	158438
OP30	-0.82415	-90.06780	9908775	158501

## Permit forms

MINISTERIO DEL AMBIENTE



PR.CEI-CEA-P02.R02

### AVISO DE VIAJE

Fecha: xx/xx/20xx

**Actividad:** Monitoreo experimental de las interrelaciones entre herbívoros nativos y vegetación leñosa en Santa Fe

**Institución Responsable:** Galapagos Conservancy y Dirección del Parque Nacional Galápagos

**Nº de Permiso de investigación:** PC-xx-xx

**Nº Contrato Marco:** \_\_\_\_\_

**Convenio:** GC-DPNG

**Proceso:** \_\_\_\_\_

**Componente:** \_\_\_\_\_

**Responsable del proyecto/ actividad:**

Washington Tapia Aguilera y Christian Sevilla

**Lugar/Acampar/Visitar:** El Miedo y zona central

**Isla:** Santa Fe

**Objetivo del viaje:** Monitorear las tortugas liberadas y los cercados temporales para evaluar las interrelaciones entre herbívoros nativos, la vegetación leñosa y cactus

**Responsable del Viaje:** Washington Tapia Aguilera

**Período del viaje:** xx días

**Desde:** xx/xx/20xx

**Hasta:** xx/xx/20xx

**Participantes:** 11

**Nº Personal PNG:** 5

**Nº Personal FCD:** 0

**Nº Científicos Visitantes:** 3

**Nº Otros:** 3

Nº	Nombre	C.I./Pasaporte	Grupo / Área / Universidad / Institución / ONG
1	Harrison Goldspiel	XXXXXXXXXX	GC/GTRI
2	Washington Tapia	XXXXXXXXXX	DPNG
3	James Gibbs	XXXXXXXXXX	GC/GTRI
4	Jeffreys Málaga	XXXXXXXXXX	DPNG
5	Diana Gil	XXXXXXXXXX	DPNG
6	Rafael Chango	XXXXXXXXXX	DPNG
7	Wilson Cabrera	XXXXXXXXXX	DPNG
8	Jean Pierre Cadena	XXXXXXXXXX	DPNG
9	Novarino Castillo	XXXXXXXXXX	Porteador
10	Luis Abad	XXXXXXXXXX	Porteador
11	Ann De Roy	XXXXXXXXXX	Fotógrafa

**Medio de transporte:** Marítimo

**Hora:** 09h30

**Nombre del transporte:** Lancha

**Megalodón** \_\_\_\_\_

**Persona de contacto en PNG/FCD/ONG/** Christian

**Sevilla**

**Días de contacto radial o telefónico:** xx/xx/20xx

**Cargo:** Responsable de Conservación y Restauración de Ecosistemas Insulares

### (F) Responsable del proyecto/ actividad

\*Se recuerda qué está prohibido realizar actividades de manejo y/o investigación combinadas con actividades de turismo y pesca: así como realizar campamentos en más de una isla durante el mismo viaje.



Puerto Ayora, xxxxxxxx xx de 20xx

Señora Doctora  
Marilyn Cruz Bedón  
Directora Ejecutiva  
Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos

De mi consideración:

Por el presente reciba un cordial saludo y mis deseos de éxito en sus funciones, a la vez que aprovecho la oportunidad para solicitarle lo siguiente:

En colaboración entre Galapagos Conservancy y la Dirección del Parque Nacional Galápagos, estamos implementando el proyecto denominado “Iniciativa para la Restauración de las Tortugas Gigantes de Galápagos”, el cual tiene como una de sus actividades el estudio de la dieta y la salud de las diferentes especies de tortugas gigantes. En ese contexto del xx de xxxxxxxx al xx de xxxxxxxxx realizaremos un viaje de campo a la isla Santa Fe con el propósito de realizar un censo poblacional de tortugas gigantes.

Con esos antecedentes, solicito se sirva emitir la respectiva guía de movilización, para trasladar desde la isla Santa Fe hasta el laboratorio Fabricio Valverde de la DPNG en Puerto Ayora las siguientes muestras:

Muestras a Ser Trasladas			Especie
Cantidad*	Tipo	Forma de Preservación	
150	Muestras de heces	Fundas ziploc	<i>Chelonoidis hoodensis</i>
150	Muestras de heces	Fundas ziploc	<i>Conolophus pallidus</i>
Información del Viaje			
Nombre del Científico responsable del		Washington Tapia	
Nombre del Científico que transporta las		Washington Tapia	
Nacionalidad	Ecuatoriana	Nº Pasaporte o Cédula	XXXXXXXXXXXX
Fecha de ida	xx/xx/20xx	Fecha de retorno	xx/xx/20xx
Lugar de embarque	Muelle Municipal	Lugar desembarque	Muelle DPNG

\* = Cantidad de muestras aproximada, pues el número real depende de la cantidad que se encuentre en el campo.

Para su conocimiento y fines pertinentes, adjunto al presente se servirá encontrar copia del respectivo permiso de investigación emitido por la Dirección del Parque Nacional Galápagos con número PC-xx-xx.

Seguro de la favorable acogida que se permitirá dar al presente, lo cual contribuirá al objetivo de mantener la integridad ecológica del archipiélago, me suscribo.

Atentamente,

Washington Tapia Aguilera  
Director  
Giant Tortoise Restoration Initiative  
Adj: Permiso de investigación N° PC-xx-xx



## Food and material inventory

Lista de comida y materiales para viaje a Santa Fe (5 días, 10 personas)				
Producto	Cantidad Requerida		Adquirir	
	Cantidad	Unidad de Medida	Disponible	Total a Comprar
Galletas de dulce	5	Libras		
Galletas de sal	3	Libras		
Queso Crema	2	Unidades		
Menestra de lenteja	6	Latas		
Carne	8	Libras		
Pollo	20	Libras		
Queso fresco	8	Unidades		
Pollo desmechado	8	Latas		
Frejol con tocino	10	Latas		
Ensalada mixta	10	Latas		
Chanco desmechado	8	Latas		
Arveja y zanahoria	5	Latas		
Aji casero	2	Frascos		
Cocoa de 1/2 lb	2	Unidades		
Frasco de aliño	2	Unidades		
Tang o Yupi	3	Libras		
Cubos maggi	5	Unidades		
Salsa de tomate	2	Unidades		
Papel higiénico	1	Paca		
Axión de 250 gr.	2	Unidades		
Vileda	2	Unidades		
Mayonesa Alacena	2	Unidades		
Mermelada (no criolla)	3	Unidades		
Granola del CADE	10	Unidades		
Atún mediano	25	Unidades		
Leche vaquita de 1/2 lb	8	Fundas		
Aromáticas diferentes sabores	2	Cajas		
Arroz	50	Libras		
Azúcar	5	Libras		
Cebolla colorada	5	Libras		
Papa chola	10	Libras		
Encendedor	3	Unidades		
Aceite de girasol	4	1/2 litro		
Café Giardella	2	Libras		
Fideo para sopa	3	Libras		
Tallarín	3	Libras		
Sal	2	Fundas		
Pan	50	Unidades		
Fundas para basura grandes	3	Paquetes		
Barras de chocolates de 1/2 lb	10	Unidades		
Sopas maggi surtidas (no crema)	10	Unidades		
Yogourt	5	Botellas de 2L		
Gelatina	4	Libra		
Pilas AA	24	pares		
Pilas AAA	10	pares		
Quaker	6	Fundas		
Hielo	2	Sacos		
Shampoo	2	Frasco		
Pirola	60	metros		
Gasolina	2	Galón		

## Equipment inventory

<b>Lista de equipos y materiales requeridos para el viaje de monitoreo a Santa Fe</b> <b>(3 grupos y dos porteadores)</b>				
Equipo o Material	Descripción/ Especificaciones	Cantidad		Observaciones
		Grupo	Total	
Palitos para medir cactus	Númerados cada 5 centímetros	1	4	
Fundas para basura común	negras	3	10	
Fundas para basura orgánica	verdes	3	10	
Fundas para basura reciclable	azules	3	10	
Cocinas de alcohol	más una hornilla extra	1	4	
Botellas para alcohol	Rojas tapa hermética	1	4	
Lima triangular	Para afilar machete	3	3	
Olla mediana	con tapa	1	3	
Cuchillo	de cocina	1	3	
Cintas métricas	1,50 metros	3	9	
Lápices	con punta	3	12	
Borrador	para lápiz	1	4	
Sacapuntas	metálico	1	4	
Tablero	Gris con tapa	1	4	solo hay 9 poner uno azul
Pesola electrónica	con baterías	1	4	Si no hay 10 poner manuales
Cabo japonés de 3 metros	Blanco para pesar tortugas grandes	1	4	
Pirola delgada	para templar techo de cocina	60	60	40 metros por grupo
Pistola para poner pits	morada	2	8	
Frascos de pits	frascos con 25 pits cada uno	1	4	
Agujas para pits	Usadas	3	12	Colocarlas en frascos con tapa naranja
Agujas para pits	nuevas incluido PIT	2	8	
Scanner para pits	solo verdes AVID	2	8	
Jeringas con aguja grande	jeringas normales	2	8	
Frasco Falcon	con tapa naranja vacío	1	4	
Frasco Falcon	con tapa naranja con alcohol potable	1	4	
Pintura	Diferentes colores por grupo	1	4	1 botella de medio litro
Machete	afilado	1	4	
Baterías AA	pares	6	24	
Baterías AAA	pares	2	10	
Baterías 9 voltios	Cuadradas	2	8	para los grupos con scanner verde
Torundas	de algodón humedecidas en alcohol	20	80	
Marcador permanente	punta fina	2	8	
Marcador permanente	punta gruesa	2	8	
GPS garmin	etiquetado de la a la d	2	8	
GPS Rino	con 1 batería extra	1	6	Poner a cargar las baterías
Techo azul	para cocina	1	1	
Plástico grande	para cocina	1	1	
Plástico pequeño	para carpas	2	11	
Fundas ziploc grandes	Caja	1	3	
Fundas ziploc medianas	Caja	1	3	
Chimbuza de agua (5 galones)	Chimbuza 5 galones	5	25	
Insecticida para cuarentena	Frasco	1	1	
Extensión con foco		1	1	
Generador		1	1	
Cortapicos		1	1	
Fundas grises grandes	Para cuarentena	1	1	Paquete

## Medical inventory

<b>Botiquin para viaje de monitoreo a Santa Fe (11 personas)</b>				
<b>Producto</b>	<b>Forma</b>	<b>Cantidad</b>	<b>Uso</b>	<b>Dosis</b>
Gasas quirúrgicas	Sobres	20	Para limpiar y cubrir heridas	Cuantas veces sea necesario
Ampicilina 500 mg	Cápsulas	20	Antibiótico (no tiene ningún efecto sobre resfriados, gripe y otras infecciones virales).	Una cápsula cada 8 horas
Agua oxigenada	Frasco 100 ml	1	Para limpiar heridas	Cuantas veces sea necesario
Alcohol	Frasco	4	Para desinfectar heridas	Cuantas veces sea necesario
Linimento olímpico	Frasco	2	Para calambres y dolor muscular	Cuantas veces sea necesario
Yodo	Frasco	1	Para desinfectar heridas	Cuantas veces sea necesario
Curitas	Caja	20	Para cubrir ampollas y heridas menores	Cuantas veces sea necesario
Buscapina 20 mg	Tabletas	10	Para dolores de estómago y cólicos relacionados con el sistema digestivo.	Una tableta cada 8 horas por máximo 2 días
Neogripal	Tabletas	20	Alivio de los síntomas de la gripe y resfriado	Una tableta cada 12 horas
Loratadina 10 mg	Tabletas	10	Antihistamínico para alergias	Una tableta cada vez que haya síntomas, máximo una cada 4 horas
Analgan 1 gramo	Tabletas	20	Analgésico para dolores en general	Una tableta cada 8 horas por máximo 2 días
Sal de Andrews	Sobres efervescentes	10	Para tratar indigestión, malestar estomacal y acidez	Un sobre cada 12 horas
Apranax 500 mg	Tabletas	10	Desinflama golpes y torceduras, alivia el dolor	Una tableta cada 12 horas por máximo 3 días
Tensiflex	Tabletas	10	Relajante muscular	Una tableta cada 12 horas
Esparadrapo (rollo)	Rollo	1	Cubrir heridas con gasa	Cuantas veces sea necesario
Suero Oral	Sobres	7	Rehidratación	Un sobre por día disuelto en un litro de agua