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GALAPAGOS VERDE 2050

Manual for Personnel, Collaborators and Volunteers

Protocols and Technologies

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SECTION 1 - INTRODUCTION TO GALAPAGOS VERDE 2050

WELCOME TO GALAPAGOS VERDE 2050

You are joining a team of dedicated and energetic staff and volunteers in GV2050. You will undertake many tasks while you are with us and this manual will serve as your guide as you join us in our work. Please read **Section One** on the history and plan for our work as these will help you understand who we are and what we do. Most volunteers will go on field trips so you should read all about this in **Section Two**. Much of the work with plants is done in the CDF labs and offices, so read the Protocol for Plant Care in **Section Three**. In **Section Four** you can read some extra information regarding other aspects and features of the project. **Section Five** will give you some extra resources to look at. Study the addition appendix on plant identification and become familiar with the species with which we work. The manual is here to help you be an effective and knowledgeable volunteer, and we are always happy to answer questions you may have.

You are also encouraged to acquaint yourself thoroughly with the CDF website, especially the section on GV2050 and the GV2050 book 'The Galapagos Verde Project (Volume 1)'.

HISTORY OF GV2050

The Galapagos archipelago is renowned for the abundance of unique flora and fauna, of which more than 30% of the species are endemic to the islands. Sadly, this amazing diversity of native species are threatened by growing human populations, tourism, and introduced species. While numerous large-scale and arduous efforts have been undertaken to address these threats, populations of many keystone endemic plant species remain low and may not recover without intervention.

Galapagos Verde 2050 (GV2050), a Charles Darwin Foundation project, was initiated in 2014 as a means to address this ecosystem degradation and the continued threats to endemic plant species through ecological restoration and. GV2050 also works to establish sustainable agricultural practices that support local biodiversity. By working with local farmers, we hope to reduce dependency on imported products and maximize the efficient use of limited fresh water resources.

Prior to GV2050, vegetation replanting efforts were too sporadic and small-scale to made the impact needed for successful ecosystem restoration and endemic population recovery. GV2050 is working at a larger scale, with 88 study sites on seven of the Galapagos islands. Over 12,000 plants of 79 species have been planted and are monitored regularly.

Further difficulties for restoration in these arid islands are created by periods of drought and lack of freshwater sources.
To combat these water challenges, GV2050 is introducing recently developed water saving technologies: Groasis Waterboxx®, the Groasis Growboxx®, the Cocoon, and Hydrogel, that have been used successfully around the world to increase the survival and growth of native species in arid environments. Use of these technologies can accelerate ecological restoration efforts and reduce the watering costs. The lack of fresh water is also a problem for Galapagos agriculture, making it difficult to have year-round production and creating increasing dependence on imports. Using water-saving technologies can increase the productivity of crops while minimizing wasteful use of traditional irrigation.

GV2050 PLAN

After the successful start of a pilot project in 2013, Galapagos Verde 2050 was officially structured as a three-phased long-term initiative of applied science, restoration, adaptive management, and conservation beginning in 2014 and planned until 2050. It focuses on two primary components 1) ecological restoration of urban, rural and protected areas, and 2) sustainable agriculture.

PHASE 1: June 2014 – November 2017

Ecological restoration began in Santa Cruz, Baltra, Plaza Sur and Floreana Islands. The project worked to restore keystone species on these islands, including *Opuntia echios* on Plaza Sur, and emblematic species such as *Scalesia affinis* on Santa Cruz.

Furthermore, restoration began in 'special use zones', such as waste landfills on Floreana and Baltra Islands, and a black gravel mine and cemetery on Floreana. In urban areas, the project worked with the local community to create ecological gardens in the towns on Santa Cruz and Floreana Islands. In rural areas, the project worked in the restoration of agricultural areas invaded by introduced plant species, removing and replacing them with endemic species. The first example of this was a farm on Floreana where *Scalesia pedunculata* was planted with other native and endemic species from that vegetation zone.

Within the sustainable agriculture component, the project worked with the water-saving technologies in farms on Floreana and Santa Cruz, growing plantain, papaya, tomato, cucumber, watermelon, bell pepper and others. The plants grown with the water-saving technology had increased net production compared to those grown with traditional irrigation techniques, providing an overall positive monetary return. This reduces dependence on imported products, reduces the risk of introducing invasive species, and saves water.

PHASE 2: November 2017 - July 2027

The project is currently in phase 2 and continues to work on the sites selected during phase 1, monitoring the plants, planting new plants, updating the technologies and removing invasive species. The results obtained from phase 1 are being analyzed to prioritize study sites and to identify which technologies should be used for which sites, terrain types and with which plant species. For example, the subproject of 'Baltra Verde 2050' is being developed to test which technologies and plant species are best for restoring ecosystems under highly arid conditions.

The project currently has more than 15 gardens located in the towns on Santa Cruz, Floreana and the Ecological Airport of Baltra, contributing to the recovery of the ecosystems and their ability to generate ecological services such as increased pollination. These gardens also improve the general landscape enjoyment for local people and provide opportunities to educate locals about the endemic and native flora of the archipelago. Within this second phase, ecological gardens have also been created in the towns of San Cristobal and Isabela.

Restoration has been extended to Isabela and Española Islands. In Isabela, the restoration of the threatened endemic subspecies *Galvezia leucantha* sp. *leucantha* has begun, and in Española, the project is working to restore the population of the keystone species *Opuntia megasperma* var. *orientalis* and *Lecocarpus lecocarpoides.* In the sustainable agriculture component, the work of phase 1 is being continued on farms in Santa Cruz and Floreana. Based on the successful results thus far, the project plans to increase the participation of farmers on inhabited islands.

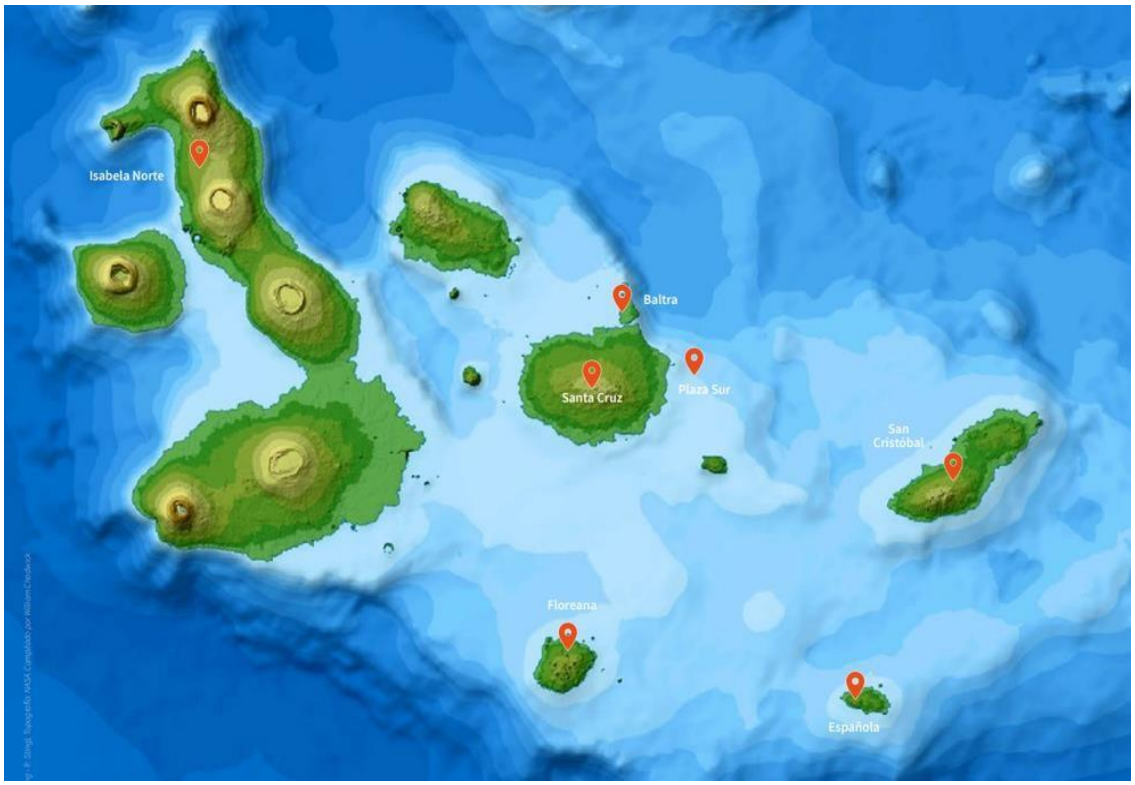


Figure 1- The islands where GV2050 is working in Phase 2

PHASE 3: 2027 – 2050

In the final phase, all results from the data generated through Phases 1 and 2 will be used to optimize all remaining planting efforts. This informed planting work will continue on the islands of Phases 1 and 2, while adding restoration work on San Cristobal and Santiago, and sustainable agricultural practices on Isabela island.

SECTION 2 - WORKING IN THE FIELD

GETTING PREPARED FOR FIELD WORK

Most GV2050 volunteers will go on field trips for planting and monitoring of plants. Field trips give you an opportunity to know Galapagos as no tourist will ever know it and you will be part of the critical work being done by GV2050. Some field trips will be day trips to the highlands or other areas of Santa Cruz, while other field trips may be multiple day trips to other islands. On field trips, you may be working up to 12 hours a day, often in the hot sun with no relief in the shade. You may be asked to carry 50-pound containers of water, hike over rough terrain, climb steep slopes, and work with skin puncturing cacti. You might be sleeping in tents on lava rocks or in bunkhouses on inhabited islands. Wherever you go, the work will be physically strenuous and demanding so it will be good to come prepared both mentally and physically.

Clothing and personal items, bring a change of clothing for multiple day trips as you get very dirty.

- Long sleeve shirts

- Long pants, light weight and not too tight
- A hat that covers the back of your neck, some people like to have a Buff to cover the neck and face
- Boots, hiking boots are good and wearing taller socks can help if you are working in highland areas with lots of ants
- Flip flops or sandals to wear on the boat trip as your field gear will be packed for quarantine
- Sun glasses are optional and will depend on what type of work you are doing
- Sunscreen
- Items for personal hygiene, a flashlight and any medicines and medical supplies you might want, like band aids or lotion for sore muscles

Food will be provided but you will most likely need to bring your own tupper as a bowl, a cup, and eating utensils. You will need a large water bottle to take with you each day, probably 2 liters or more. A large plastic coke bottle can work well. Otherwise you will need more than 1 smaller water bottle. If you bring snacks they cannot contain any seeds. You must also not eat any foods with seeds, like tomatoes, within 48 hours before the trip. We do not want to leave exotic seeds wherever we go.

Sleeping gear will vary depending on whether we will be staying in tents or a building. On Baltra, Floreana and San Cristobal we might stay in bunkhouses, in which case you may need to bring sheets.

Quarantine When we go to work on other islands you will need to pack your field gear for the trip in a backpack and have it ready 48 hours before departing on the trip. It will be put into quarantine before and after the trip for 2 days. This will include freezing, so do not put anything that cannot be frozen into your backpack. You may have a smaller bag of personal items that are not put into quarantine. This can include your phone, your medications, binoculars and items you will need before your pack is unloaded at the work site.

Safety While we are in the field it is important that you work to stay safe and uninjured. Do not wander off alone as it is possible to become lost in some of the landscapes where we work. Do not bring alcohol or drugs to the field. Your belongings may be searched as you leave and arrive back on the island. Each field trip we will be accompanied by a national park ranger, any misconduct will be reported by them to the national park and this will jeopardize any future work.

PLANTING WITH WATER-SAVING TECHNOLOGIES

Water-saving technologies are an efficient tool used in ecological restoration and sustainable agriculture where water is scare or costly, and they are a critical tool in the work of Galapagos Verde 2050. In arid regions of the archipelago, the heat and strong winds create very dry planting conditions and the benefits gained by using these technologies can give the young plants a head start in the critical early months. In agricultural situations, they can increase productivity and decrease the reliance on unreliable and costly water supplies or irrigation.

This section will introduce you to the four water saving technologies used by GV2050, fencing methods and materials, and data recording in the field.

MATERIALS NEEDED FOR PLANTING WITH THESE TECHNOLOGIES

1. Shovel
2. Larger shovels or picks depending on soil type
3. Containers of 20L of water (‘Chimbuzos’)
4. All parts of the Waterboxxes, Cocoons, Growboxxes and the Hydrogel

5. Brush to clean away debris from Waterboxxes
6. Sheets for registering the plants
7. GPS
8. Pencil and eraser

GROASIS WATERBOXX® TECHNOLOGY

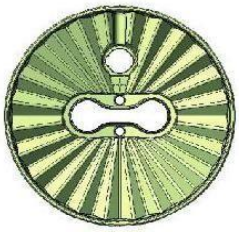
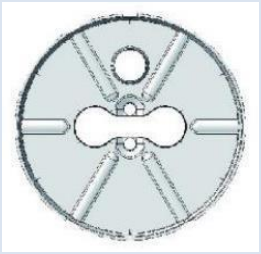
The Waterboxx is a donut-shaped polypropylene tub with a lid designed to collect rainwater and store it inside the tub (Figure 2). The bottom of the tub has a string or wick that feeds water to the area around the plant roots via capillary action (Jaramillo et al 2015, Hoff 2014). Furthermore, the Waterboxx prevents the evaporation of surface water and the growth of weeds around the plant.

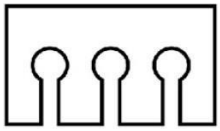
The Waterboxxes are removed from plants once the plants have reached sufficient size to survive on their own, and may be reused.

Figure 2- The Waterboxx technology installed with a Lecocarpus plant

Waterboxx Components

Table 1- The individual components of the Waterboxx technology and their functions

	The **cover** is designed to collect and drain as much rainwater and condensation as possible. It is made of a water-repellent material that has 1000s of tiny pyramids that reduce adhesion and encourage the condensation and capture of valuable moisture from the surrounding area.
	The black **anti-evaporation plate** is placed inside the box to decrease sun exposure, the growth of algae, and evaporation.

	The **box** protects the plant and stores the collected water. The box acts as a shield for the water in the upper ground, and this water then spreads down and out instead of being drawn to the surface and evaporated.
	The water stored in the basin is fed to the area surrounding the plant roots by capillary action through the **wick** and stimulates root growth. The wick releases around 50ml of water per day.
	A **plastic evaporative plaque** is placed around the plant, on or just below the surface of the soil, to reduce the evaporation of water in the soil.
	The water collected on the lid is drained into the basin through 2 blue **siphons** (drain tubes). The **cap** may be opened to add water to the box.

Planting with the GroasisWaterboxx

You can find more information about the Waterboxx on the Groasis website.

1. In order to use the Waterboxx, the ground under the box must be as level and free from rocks as possib le. A hole of approximately 15 cm deep and 60 cm wide should be dug. Place 10 liters of water in the ground (Figure 3).

2. Sometimes the Waterboxxes are planted with Hydrogel, if this is the case, hydrogel is used instead of water. Instructions for hydrogel use are found on page 14.

Figure 3- The hole ready for the Waterboxx, filled with 10L of water

3. Plant the seedling from the nursery by removing the plastic cover on the bottom of the plant and placing the seedling in the ground. The roots of the seedling should be carefully arranged in a vertical position. The base of the seedling should be fixed with soil to ensure its stability and erect growth over time (Figure 4).

Figure 4- A planted Opuntia individual

4. Place the white evaporation plaque on the moist ground around the base of the plant (Figure 5). The plaque has a small compass figure, and its direction should align northwards-facing. When planting *Opuntia* cladodes they will not fit in the spaces for the plants, so the middle two flaps must be folded over to create one large space for the cladode. This plaque must then be completed covered with a layer of soil.

Figure 5- The evaporation plaque with an Opuntia individual, before it is covered in soil

5. Place the bottom green box of the Waterboxx over the plant. It must be positioned firmly in or on the ground. When lowering the box, ensure the wick is slotted underneath the evaporation plate so there is direct movement of water to the plant roots (Figure 6). Place the box delicately over the plant and be certain not to damage the plant.

6. The small hole on the upper rim of the box should point to the north. The plant should not be in the center of the box, but in one of the round openings so it many have room to grow.

7. Fill any area around the edge of the box with soil to help hold it in place (Figure 7).

8. Fill the box up to the inner rim (~20L) (Figure 7).

Figure 6-Diagram of Waterboxx showing wick positioning near plant roots

Figure 7- Waterboxx filled with water and with surrounding soil pushed around its edge

9. Set the black anti-evaporation plate over the water and resting on the small rim inside of the box. The large hole must correspond with the small hole of the green box, both facing north (Figure 8).

Figure 8- Anti-evaporation lid being placed

10. Place the white collector lid, ensuring the hole aligns with the hole of the black lid, both facing north. Ensure that the lid is clicked into place, including the little tabs of the green box are slotted into the slits in the white lid (Figure 9).

11. Insert the siphons, making sure they click into place (Figure 9), and the small blue cap over the hole, twisting it to lock it in place.

Figure 9- The small tabs slotted into the slits of the white lid and the siphons also inserted correctly.

12. Sometimes the Waterboxx is used for two individual plants, the planting process is the same, except the box may have two wicks to place near the roots of each plant (Figure 10).

13. Once the individual has been planted with the technology, write with a pencil, the assigned code for the plant on the white lid.

Figure 10- A Waterboxx with two Opuntia individuals

Removing the Waterboxx

1. Remove both lids (white and black) separately (Figure 11). It will be easier to remove the siphons. Sometimes the plant is large, so this must be done with a lot of care and maneuvering to not damage the plant.

2. Remove the green box with care (Figure 11) and then remove the white evaporation plaque that is beneath the soil.

3. If two plants were planted in a single Waterboxx then one of them must be transplanted to another place as the as they are now too large to grow so closely together (Figure 12).

Figure 11- Careful removal of the anti-evaporation plate (left) and green box (right)

Figure 12- The removal of one of the plants to be planted elsewhere

4. Cover/fill the area where the box has removed with surrounding soil, and surround the plant with small rocks.

5. Rewrite plant code written on the white lid on a metal plaque. On the platform the 'Remove technology' box must be checked.

COCOON TECHNOLOGY

Cocoon Technology is a biodegradable basin and lid designed to support a young plant during its first critical year, providing water and shelter while encouraging it to produce a healthy and deep root system. It is composed of paper, cardboard, nylon, and wax (Land Life Company, 2015) and made up of 3 parts, the basin, the cover and the wicks. It is left in place to degrade around the growing plant.

Planting with Cocoon Technology

1. Dig a hole wide and deep enough for the Cocoon to eventually be completely buried underground and add 10L to the hole. Sometimes the Cocoons are planted with Hydrogel, if this is the case, hydrogel is used instead of water. Instructions for hydrogel use are found on page 14.

2. Create a small mound in the center of the hole using the moist soil.

3. Plant the plant at the top of this mound, this is so when the Cocoon is placed, the plant is positioned at the upper part of its middle section.

4. Place the Cocoon over the top of the plant, ensuring that the wicks are running up and then inside of the central hole (Figure 13).

5. Add extra soil into the middle hole to until it is level with the lip and the plant is sticking out of it (Figure 14).

6. Fill the box with water until the indicated line.

7. Place the lid on the filled box (Figure 15), sometimes the water causes the box to use its shape so it may be useful to use wedged stones down its side to reshape it.

8. Place the cardboard protector (if used), that will provide shade to the plant and deter animals.

Figure 13- Cocoon being lowered onto the plant with the wicks running inside the

Figure 14- The Cocoon basin with the planted individual in the central hole

9. Bury the Cocoon box completely (Figure 16), and place stones around the edge to avoid people from stepping on the lid.

10. Once the individual has been planted with the technology, write down the assigned code for the plant on a metallic plaque and secure it with a wooden stick.

11. Unlike the Waterboxx technology, this is left in the ground and will degrade (Figure 17).

Figure 17-Placing the lid on the filled Cocoon box

Figure 16- The Cocoon box with the protector in place

Figure 15- the Cocoon box completely buried

GROWBOXX TECHNOLOGY

The Growboxx technology (Figure 18) is also produced by Groasis, and was introduced to the project October 2020. It is a square box with a hole in the middle, made from recycled paper pulp and can be used to plant once. It is placed around a young tree but has four small holes in the lid where seeds and soil can be placed to germinate and grow hydroponically in the water which is stored inside the Growboxx.

Planting with Growboxx Technology

1. Dig a 50cm^2 hole and 18cm deep, and fill it with 10L of water and mix well. Sometimes the Growboxxes are planted with Hydrogel, if this is the case, hydrogel is used instead of water. Instructions for hydrogel use are found on page 14.

2. Plant the individual in the center of the hole.

3. Place the evaporation cover around the plant (Figure 19) and cover with soil.

Figure 19-The evaporation cover around the planted individual

4. Place the Growboxx base around the plant and insert the biodegradable Growsafe around the plant in the central hole (Figure 20).

5. Fill the Growboxx (Figure 21) up to 3 cm from the edge of the box and then put the lid in place. To add the water, a hose can be inserted into the small hole that is in the corner of the lid. However sometimes water may be added using chimbuzos, in which case you will need to fill the box before placing the lid.

Figure 20- The Growboxx and Growsafe placed around the plant

6. Place the small clay ball in the corner hole of the lid (Figure 22).

7. Fill any space by the sides of the box with soil, so only the lid is visible, making sure to fill the seed holes with soil (Figure 23).

8. Once the individual has been planted with the technology, write down the assigned code for the plant on a metallic plaque and secure it with a wooden stick.

Figure 21- Growboxx filled with surrounding soil

HYDROGEL TECHONOLOGY

Figure 23- The Growboxx filled to the correct level of water, with the lid placed and the clay ball being placed to plug the water-entry hole

Figure 22- An installed Growboxx technology

Hydrogel is an absorbent substance that can be used to retain water around the roots of plants. Hydrogel products are composed of a group of polymeric materials (Potassium polyacrylate) and its hydrophilic structure makes it capable of retaining large amounts of water. It can hold up to 1000 times its volume in water and will slowly release the water to the root system as the surrounding ground dries out (Figure 24).

Figure 24- Hydrogel powder mixed in with the soil about the roots around the planted plant

1. More often than not, in GV2050 we use mix the hydrogel powder with water prior to planting. The general method of application is 8.75 grams of hydrogel per 5 liters od water. Make sure the water is being constantly stirred as the power is being added to avoid coagulation. Figure 25 shows the consistency of mixed hydrogel.
2. Mix the hydrogel well with the soil before planting the plant.
3. Plant the plant ensuring the soil mixed with hydrogel is surrounding the plant roots.
4. Make sure the top layer is normal soil and the hydrogel is not showing at the surface as sunlight will decompose in the exposure to ultraviolet rays.
5. Once the individual has been planted with the technology, write down the assigned code for the plant on a metallic plaque and secure it with a wooden stick.

Figure 25- A tub of mixed hydrogel

PLANTING CONTROL PLANTS

As part of the experimental design, we need to plant control individuals which does not use the water saving technologies described above.

1. Dig a small hole and fill it with 10L of water and mix well.
2. Plant the seedling from the nursery by removing the plastic cover on the bottom of the plant and placing the seedling in the ground. The roots of the seedling should be carefully arranged in a vertical position. The base of the seedling should be fixed with soil to ensure its stability and erect growth over time.
3. Once the individual has been planted, write down the assigned code for the plant on a metallic plaque and secure it with a wooden stick.

DATA COLLECTION AND DATA PADS

ANDROID APPLICATION

We use an online virtual platform specifically designed for GV2050, that can be found at www.galapagosverde.com/admin. It is used to register all the plants of the project, all the data collected from each of these plants, and information about species and study sites. It is where all the data collected on the project can be exported to be analyzed. Each staff member, or sometimes volunteer, has their own passcode to enter the platform and to schedule work at each site, along with their name and job title.
Connected to the virtual platform, GV2050 has an Android App used for data collection in the field. Prior to any fieldtrip, a study site can be put in the agenda, allowing all the data for plants of the site to be inputted offline.

MONITORING THE FIRST TIME

The first monitoring is usually done when planting, by manually recording the data of each plant. It is important to fill all the fields in each sheet of paper and do it orderly, even though the date and site are the same (Figure 26). This practice can prevent future misunderstandings when entering the data to the system after the field trip. If there are any errors, it is better to cross out and rewrite the data instead of trying to erase it or correct it. This will allow to have clear and legible data.

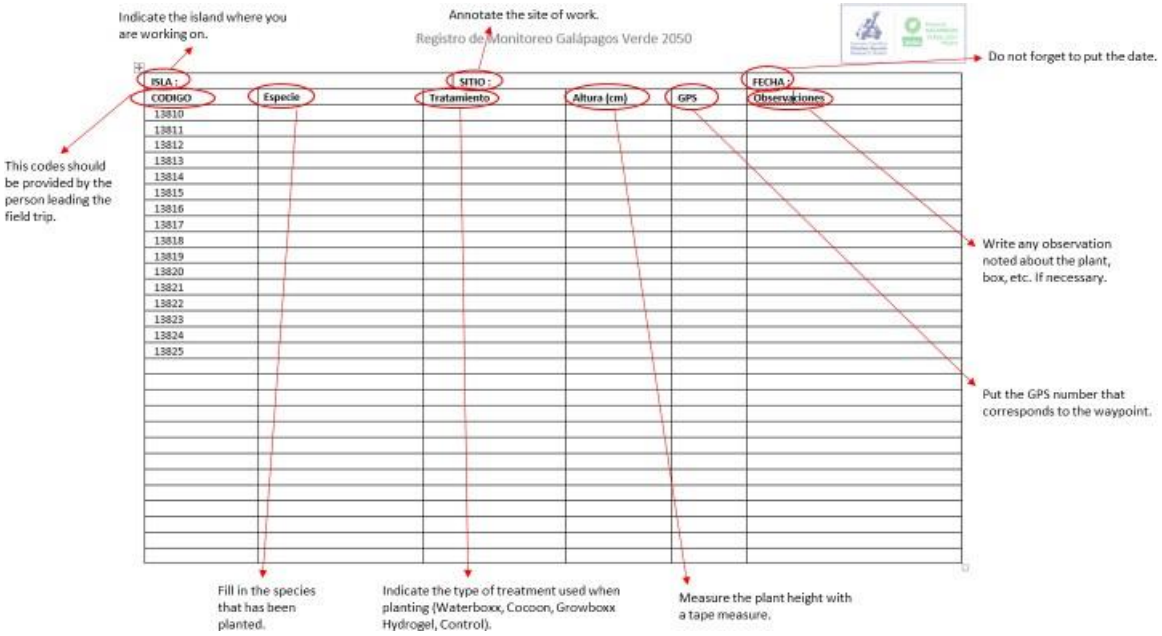


Figure 26. Monitoring recording sheet

MONITORING INSTRUCTIONS

When you are entering data in the field it is important to have clear and accurate exchange of information between people who are working together. Be certain you clearly understand what someone tells you and always ask them to repeat it if you do not understand. Entering data under the wrong plant number or entering the wrong number can cause irritating problems later on.

Figure 27- The app logged into Maria Guerrero's account with the sites that were in the agenda

1. Before leaving for the field trip, the study sites that are planned to monitor must be set in the agenda and someone must sign into all the tablets/mobiles that will be used. Once logged in and out of internet connection you **must not press the *Salir* button** in the top right-hand corner (Figure 26).
2. The page for each study site will look like something similar to Figure 27. Each of the boxes corresponds to the codes written on with the plants. The numbers may be difficult to find. If the numbers are not written clearly you will be need to rewrite them, or replace the metal plaque. The green boxes are those planted with technology, the red ones are controls and the yellowish green ones are plants that have had the Waterboxx removed from them.
3. **<u>Do not hit the *Enviar Monitoreo*</u>** button on this page. This will close out the program and it will not be possible to use the tablet in the field. You will have to resort to tedious methods to record the data. Nobody wants that.
4. On the data entry screen (Figure 28) for each plant, you will have to enter the following data:
   Especie: Verify it is the right plant species. If not, go to the previous step, you might have selected the wrong number.

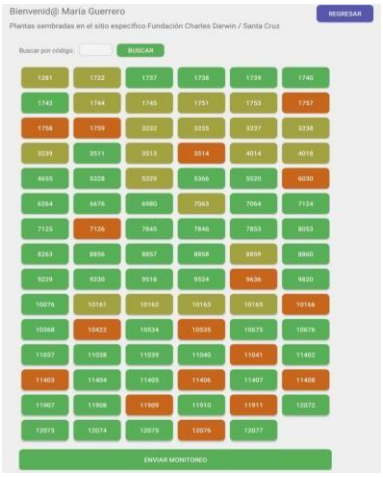


Figure 28- The plants yet to be monitored in the Charles Darwin Foundation site

Altura: Information about how to correctly measure plant height can be found on page 17. You may not enter a height that is less than the previous height. The most recent height measurement can be found in the right-hand corner (***Ultimo monitoreo***). If the plant is now shorter than previously recorded, enter the same number as recorded previously. Then, under ***Observaciones,*** enter the measured height by writing the value followed by '*altura real*'.

Estado Select from *Bueno, Regular, Malo,* and *Muerto*. These are subjective categories and will be determined by an experienced team member. If a plant is dead, *muerto*, for altura you will enter the previous height. You cannot enter *muerto* unless you find the dead plant or the site at which the plant was planted. Not finding a plant does not mean it is dead. You should touch the plants very lightly on the stem or main axis to check if they are alive or dead. If you are not sure you must register the status of the plant in the application as "bad", for the next monitor to verify if it can recover.

Herbivoria If a plant has obvious signs of insect damage select yes.

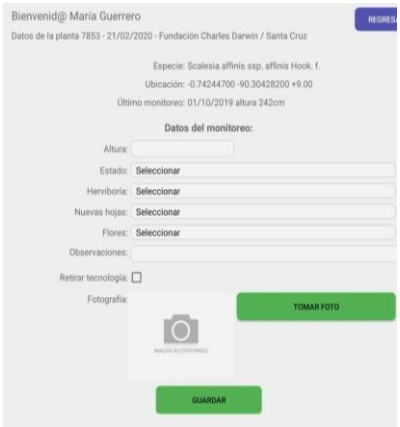


Figure 29- the data entry screen for plant 7853

Nuevas hojas Answer yes if there are new leaves. Remember on Opuntia cacti, new cladodes are not new leaves.

Flores Yes if there are flowers.

Observaciones Use the observation section to mention any irregularities or question about species or measurements. Avoid using the ENTER key when writing the text.

Retirar tecnologia If the Waterboxx box is being removed, you check the box.

Fotografia Take a photograph ***Tomar foto***. If there is a Waterboxx, the blue cap should be at the top of the photo. You will have to practice with the pad to be certain the photo is taken correctly. If not, retake it so it is positioned correctly by selecting ***reintentar*** and then taking another photo.

Guardar When you have done everything correctly, select ***Guardar*** to save the data.

5. After you save the data of a plant, it will be outlined in black so you can tell that plant has been monitored.
6. Any plants that are missed will need to be found using GPS. This can be difficult so be systematic and look carefully as you work to avoid having to search at the end of the day. Any plants that cannot be found with the GPS must be left unmonitored. If after 2 years a plant hasn't been found and monitored, it can be changed to ***'No Monitorear'*** back in the office.

We must conserve the power of recording devices. Once in the field, make sure the tablet does not continue browsing. Turn it off when you are taking breaks for lunch so you conserve energy on the tablet. It is very important that the recording device has sufficient power to keep working throughout the monitoring. Also, clear communication is important when working in the field with two or more people. Whoever reads the codes from the boxes and plants must pronounce them clearly to avoid confusion and incorrect data.

Materials and Equipment

1. Tablet
2. Measuring tape
3. Pencil with thick lead
4. Extra Batteries
6. First Aid Kit
7. Waterboxx spare parts kit (siphons, blue lids)
8. Metal plaques
9. Wooden Sticks
10. Brushes to clean the boxes
11. Pruning shears.
12. GPS with batteries

The codes for each plant are either found on metal plaque on a wooden stick next to the plant, or written on the lid of the Waterboxx (Figure 30). Sometimes on larger individuals, the metal plaque is attached to branches, or the main stem.

Figure 30- The location of the plant codes for all plants (left) with the exception of Waterboxxes (right)

In addition to monitoring, maintenance and cleaning of study sites will often be carried out simultaneously:

Cocoons/Growboxx/Controls- Clean any weeds and general overgrowth. If the Growboxx or Cocoon's lid has fallen in, fill it.

Waterboxx- It is normal that the boxes collect a lot of debris on the lid. To clean it is better to remove the two covers and use the water inside to clean them. Also take out the two blue siphons and uncover them of debris. Clean the plants / weeds that are growing around the box.

GUIDELINES FOR MONITORING AND DIFFERENT GROWTH FORMS

- Know which species will be monitored in each study site and know how to recognize them.
- The measuring tape should be placed in a straight line, parallel to the plant. It should follow the main line of growth. It is not necessary that it is touching the stem or branch.

Below are examples of growth forms and complicating factors along with specific methods to measure each.

Plants with a Principal Axis

In plants that have a well-defined main axis the height should be measured from ground level to the top of the stem (Figure 30). While measuring the axis make sure the measuring device is held straight to avoid errors in measurement. Fruits and inflorescence are not included in measurements of height as they are temporary parts of the plant. Plants in this category include *Opuntia* sp., *Parkinsonia aculeata, Senna pistaciifolia, Maytenus octogona, Bursera* sp., *Vallesia glabra*.

Figure 31- Measuring an Opuntia individual by its principal axis

Multiple Axes

There are many species that generate several primary axes or bifurcations from a young age. This can make it difficult to determine the total height. For these cases, the measurements will be taken on the main axis with the greatest height or length (Figure 31). For species that tend to have crawling habits, it is necessary to mark this axis or branch with tape so that later monitoring can continue to use the same branch for measurements. Some examples of vegetation with multiple axes are, *Lecocarpus* sp., *Prosopis juliflora., Cordia lutea, Waltheria ovata, Clerodendrum molle, Gossypium darwinii.*

Figure 32- Measuring an individual with multiple axes

Figure 34- Measuring an Acacia individual with multiple branches

Multiple branches

Some species generate multiple branches that grow at different rates. This uneven growth can confuse a monitor, so it is important that you always mark and measure the same branch to obtain accurate data (Figure 32). Some examples of this type of vegetation are *Lycium minimum*, *Acacia macracantha*, *Alternanthera filifolia*, The latter is one of the species that has a main axis, but several branches which are very sensitive to touch and tend to break. It is important to take an intermediate or average height where most of the branches have reached their full height (Figure 33).

Figure 33- Measuring an individual of Alternanthera filifolia

Figure 35- A Castela individual with dry stems

Dry stems and sprouts

Some plants in our study sites may enter and leave periods of grown and dormancy; during dormant periods the plants may appear to be dead (Figure 34). Changes in growth periods may be a result of climatic factors such as wind or drought or they may result from pests or disease. These conditions are common in Galapagos and they may kill the plants. Sometimes these changes are confusing to a monitor and they may make it difficult to know if a plant is dead or alive. When this occurs, take measurements of the stem that remains or that has regrown. Species that may exhibit these dilemmas include *Castela, Lycium, Acacia, Senna,* and *Bursera graveolens.*

MAINTENANCE ACTIVITIES

For Cocoon/Growboxx/Hydrogel/Control plants:

- Clear any surrounding weeds and/or invasive plants.
- If the location of the plant is not clear, place rocks around the plant to draw more attention to it.
- If the lid of a Cocoon or Growboxx has fallen in, fill and cover it with surrounding terrain.
- If the metal label is not clear or damaged, replace it.

For Waterboxx plants:

- Clear any surrounding weeds and/or invasive plants.
- Remove both the white and the black lid and clean them with water from the box.
- Clean out the blue siphons
- Rewrite the code on the lid of the box if it has faded.

PROTOCOL FOR PRODUCTIVITY ANALYSIS IN AGRICULTURE

Population growth in the Galapagos archipelago in recent decades has led to the permanent need for the importation of perishable and non-perishable products from the continent. This creates high prices for the consumer and brings in products that were grown without regulations. These imported products bring with them the danger of introducing new pests and diseases. Importing products also disrupts local markets for economically important crops, lowers prices on local products thereby creating a loss of local production, and creates a surplus of some products (GADMSC, 2009).

Figure 36-Locally grown peppers

According to the Galápagos Report 2013-2014 prepared by the Directorate of the Galapagos National Park, new opportunities for the implementation of sustainable agriculture or bioagriculture are topics for immediate discussion (DPNG et al 2015).

Because sustainable food production is important in the archipelago, especially in populated islands, the Galapagos Verde 2050 Project is seeking alternative ways to use scarce water resources for agriculture. By helping to create more sustainable food production and conserve fresh water supplies, we are also contributing to the welfare of the local population. We are using Groasis Waterboxx technology for restoration of degraded ecosystems and to improve agricultural production (Jaramillo 2015).
In 2013, we carried out a pilot project using the Groasis Waterboxx. This project monitored the growth of species in the upper part of Santa Cruz Island and focused exclusively on the functionality of the Groasis Waterboxx. The purpose of the project was to evaluate the use of the Groasis Waterboxx to increase productivity and profitability (Jaramillo et al 2013).

MEASURING PRODUCTIVITY

The process for productivity analysis in agriculture consists of measuring and recording the height of plants and the size and weight of the fruits, such as peppers or tomatoes, on each plant. We compare the data on plants grown using the Waterboxx against those grown as control plants without the Waterboxx.

MATERIALS AND EQUIPMENT

1. Cutting tool
2. Rubbing Alcohol
3. Balance/ Scale
4. Calibrator
5. Ruler or tape measure

METHODOLOGY

1. Record the phenological state (presence of buds, flowers, new leaf growth or fruit) and the presence of insect damage.
2. Harvest the fruits, peppers or tomatoes, using a disinfected trimmer, by cutting on top of the petiole. Harvest only those peppers or tomatoes that have an adequate size and turgor to be sold at the market. These will be delivered to the producer for marketing after analysis so do not damage them.

Figure 37-Measuring the weight (left) and length (right) of a harvested pepper

3. Collect and record data on the size of each fruit, pepper or tomato, by measuring the length and width of each fruit. Weigh each fruit to the nearest kilogram (Figure 35).
4. The productivity data will be statistically analyzed in the platform of the Galápagos Verde 2050 project based on the number of mature fruits per plant and the weight of each fruit.

SECTION 3 -GROWING AND CARING FOR PLANTS AT CDRS

CARING FOR PLANTS IN THE GV2050 LABORATORY AND THE SHADE HOUSE

CARE AND MAINTANENCE FOR PLANTS IN THE LAB

Daily:
- Open the windows in the morning and after lunch. Close them at lunch time and in the afternoon.
- Check that the seedbeds containing cactus species are slightly moist, but never flooded. It is best to water them only every 2 days, unless they are in direct sunlight and the soil is drying out.
- Water with the water obtained from de-humidifiers and stored in the large blue containers. Always be careful not to wet the leaves of delicate species such as *Galvezia*, *Lecocarpus*, *Scalesia*.
- Clean the tables with a damp cloth and keep all surfaces clean.

Weekly:
- Check if there are herbivorous insects on the plants and, if necessary, apply insecticide suitable for plants.
- Clean the soil from under the planting containers. Clean up dead insects and droppings of finches, geckos, or roaches.
- Check the stability of the plants and add plastic stakes to those that are lying down or leaning more than seems natural.

Monthly:
- Add nutrients to those plants that are in a period of growth (opening new leaves, blooming, fruiting etc.). In delicate species such as *Galvezia*, *Lecocarpus* and *Opuntia*, add only four balls of slow-release organic amendment near the base of the plant. Register the date of fertilization.

Long-term:
- Replant plants that are too large for their containers and move them to containers of an appropriate size. ALWAYS water right after transplanting.

CARE AND MAINTANENCE FOR PLANTS IN THE CDF SHADE HOUSE

Daily:
- Check that the germination beds are kept moist, damp but not flooded, and if necessary, water them with the running water hose that is connected to the front of the building.
- Check that the seedbeds containing cactus species are kept slightly moist, but never flooded.
- Water the seedlings with water obtained from the dehumidifiers stored in the large blue water cans if necessary and always be careful not to wet the leaves of delicate species such as *Galvezia*, *Lecocarpus*, *Scalesia* ...
- Keep the space tidy and do not mix the plants of the different islands.

Be sure to return the keys to lower office, also called the lab, after you work in the shade house.

Weekly:

- Check if there are herbivorous insects on the plants, and if necessary, apply insecticide suitable for plants.
- Clean the soil from under the beds, as well as dead insects and droppings of geckos.
- Check the stability of the plants and add plastic stakes to those that are lying down or where the apex of the plant touches the soil.

Monthly:

- Add nutrients to those plants that are in a period of growth (opening new leaves, blooming, fruiting) In delicate species such as *Galvezia*, *Lecocarpus* and *Opuntia*, add only four balls of slow-release organic amendment near the base of the plant.

Long-term:

- Replant plants that are too large for their containers and move them to containers of an appropriate size.

ALWAYS water right after transplanting.

SECTION 4 – MISCELLANEOUS

GV2050 ELECTRIC CAR

GV2050 has an electric car located on Baltra in order to easily travel and transport materials between the study sites. The car has a detachable trailer. The car is located at **Gate 3** of the airport loading site next to its charging point (Figure 40) however sometimes the FAE allow the car to be stored and charged overnight during our stay there. In order to open Gate 3, William Tirado of ECOGAL may need to be contacted.

Figure 38- The electric car while charging (left) and stored at the end of a trip (right).

BEFORE USE

- Remove the protective cover from the car and roll up the windows of the car.
- If the vehicle has not been used for a long time, connect the battery cables, first connect the red cable (+), followed by the black cable (-).
- Check the content of the brake fluid

- Check the distilled water in the batteries
- Check the wheel pressure, it should be 35 psi
- The vehicle charge must be at 100% before first use
- Check that lights, windshield wipers, etc. work correctly

TO STORE

- Wash the vehicle with a mild soap and fresh water (not under pressure)
- Use the air compressor to clean the brake pads and areas that can't be cleaned with water. (If necessary, remove the wheels with the hydraulic jack).
- Clean the battery connections, and observe if there is sulfur buildup of the poles.
- Spray the electronic cleaner liquid on the electronic connections once the car has been washed.
- Add WD40 oil to the pieces of the car susceptible to corrosion (screws, bolts, batteries).
- Check the level of distilled water in the batteries (Use the hose with the pump, connect it to the battery and place the other end of the hose into the container with distilled water, press the pump, if the pump does not allow more water to enter distilled, it is checked that it is full)
- When leaving the vehicle unused for a long period, disconnect the battery, first remove the black (-) cable, then the red (+).
- Verify that the brake fluid exceeds the minimum mark, but never exceeds the maximum mark.
- The tool box should be left in the back of the vehicle as well as the compressor.
- Close the windows and put on the protector cover.

Figure 39- Cleaning the internal parts of the vehicle with the compressor.

Figure 40- Electronic cleaner product (left) and WD-40 oil for adding to the metallic pieces (right).

OTHER THINGS TO CONSIDER

- Avoid the use of the vehicle if it has less than 20% battery level.
- Always fully charge before use.
- Maximum load capacity: 630kg (including weight of personnel and trailer). Maximum weight in trailer: 408kg.
- Never exceed 16km/h when loaded.
- In areas with rocks and uneven ground, slow down and be careful with the front and rear axle (Knocks on the crown or axles can permanently damage the vehicle).

HOW TO CHANGE A TIRE

- Park in a safe place with a flat solid surface.
- Put on the parking brake
- Release pressure from bolts- With the vehicle on the ground, take the cross wrench and turn the bolts counterclockwise. Caution! It is not about removing them, but just loosening them.
- Raise the car with the hydraulic jack- Place the hydraulic jack under the vehicle (near the flat tire). Now activate it and start taking the car off the ground. Remember! The jack goes under the chassis, not the body.
- Remove the bolts and store your flat tire- After lifting the car, remove the loosened bolts and keep in a safe place. Remove the flat tire and store it in the trunk to take to repair as soon as possible.

- Install new tire - Mount this wheel and place the bolts in the shape of a cross. In this way, it will not wobble and it will be easier for you to finish the operation. Then lightly tighten them with the cross wrench.
- Return the car to the ground with the help of the hydraulic jack, remove it and finish tightening the studs with the cross wrench.

GV2050 VIRTUAL REALITY GOGGLES

The project has created a virtual reality experience video about the restoration of Opuntia species. The equipment for this includes:

- 3x Samsung Gear VR Goggles (Figure 41)
- 3x Samsung Galaxy S7 Phones
- 3x Bluetooth headsets

The video lasts 6.20mins in English and Spanish, and the full charge of the phone lasts around 15 replays of the video. The VR googles should not be used by kids younger than 12 or people with epilepsy.
Gmail and Samsung accounts for the phones:
User: naceuncactus@gmail.com
Password: Cl4d0d10VR
Date of birth: 1 January 1950

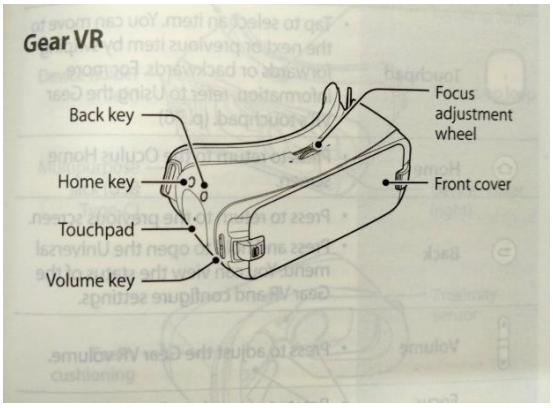


Figure 41- The different components of the VR goggles

SET-UP

1. Charge all phones and headphones
2. Use 3 swivel chairs
3. Support from at least 2 people
4. Enough space for people to move around with the chairs

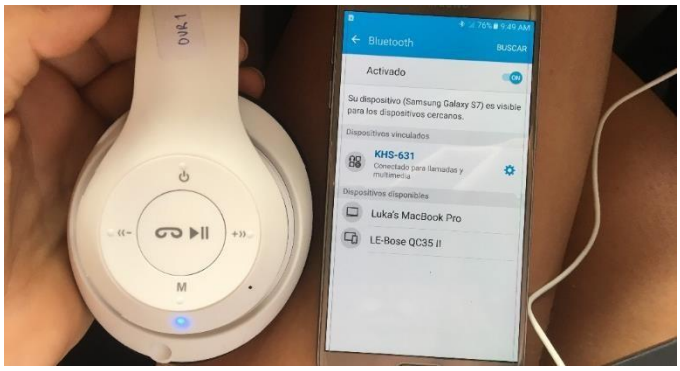


Figure 42- The headphones connected to the Samsung mobile via Bluetooth

INSTRUCTIONS

1. Turn on the Samsung Galaxy Phone
2. Connect to the headphones via Bluetooth (Figure 42)
3. Remove the cover from the VR goggles (Figure 43)

Figure 43- The removal of the cover from the VR goggles

4. Unlock and push the slider on the left to the ‘B’ position (Figure 44)
5. Flip up the slider on the other side

Figure 44- The point that should be slid and lifted

6. Place the phone to the port on the left-hand side slider (Figure 45).

Figure 45-Placement of the phone into the flipped-up port

7. Push the phone down and the right-hand slider should click into place
8. Place the goggles on your head. Movement of the head should move the cursor and tapping the panel on the right-hand side of the goggles is to click (Figure 46)
9. Click to remove the warning message and wait for home screen to load
10. Click on “Library”
11. Click on ‘Oculus video’
12. Choose between English (Opuntia V4 ENG…) or Spanish (Opuntia V4 ESP…) version
13. Adjust the volume and focus to an appropriate level and pause the video
14. Transfer the goggles and headphones to the person to watch the video
15. Instruct them to navigate the cursor over the ‘play’ button and tap the panel to start the video
16. Make sure to also tell them how to adjust volume and focus (Figure 47)
17. If possible, leave the phone to cool after the experience is over.

Figure 46- The phone secured into the goggles

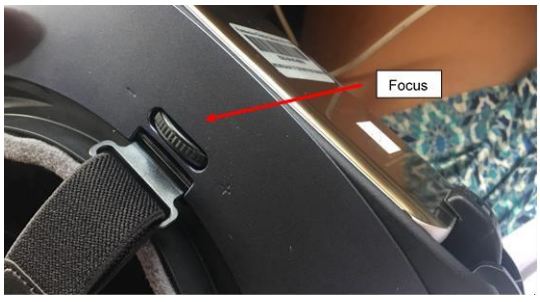


Figure 47- Location of the wheel to adjust focus

GPS UNIT WAYPOINT UPLOAD/DOWNLOAD

UPLOAD COORDINATES WITH CODIGO (PLANTING ID) LABELS ONTO A GPS UNIT

1) First, download the platform data with the Codigos and GPS coordinates.
2) Make a new excel sheet and copy the following columns into it:
    a. Column 1 = Latitude (signed decimal degrees)
    b. Column 2 = Longitude (signed decimal degrees)
    c. Column 3 = Identifier (string)
    d. But don't include any column headings
3) Save this excel file as a *.csv (filename does not matter)
4) Then upload the file into the GPSBabel app to export it as a GPX file
    a. https://www.gpsbabel.org/screenshots.html
5) Connect the Garmin GPS unit to the computer
6) Copy and paste the *.gpx file into the 'GPX' folder on the GPS unit.
7) After disconnecting the GPS unit and turning it on, it may take a few minutes for all the waypoints to appear on the map.

TO CREATE AND UPLOAD POINTS TO A GPS UNIT FROM ARCMAP

1) Create the points in ArcMap the way you can create and/or modify any new shapefiles in ArcMap (e.g., with a random point generator).
2) If you want the waypoints to have labels, make sure there is a text column in the attribute table titled "name."
3) Use the 'FeaturesToGPX' tool that was downloaded. Open it with the Catalog.
4) Connect the Garmin GPS unit to the computer
5) Copy and paste the *.gpx file into the 'GPX' folder on the GPS unit.
6) After disconnecting the GPS unit and turning it on, it may take a few minutes for all the waypoints to appear on the map.

TO DOWNLOAD WAYPOINTS FROM GARMIN GPS UNIT AND UPLOAD INTO ARCMAP

1) Connect the Garmin GPS unit to the computer
2) Copy and paste the *.gpx file from the 'GPX' folder on the GPS unit into a folder on your computer.
3) Then upload the file into the GPSBabel app to export it as an ESRI shapefile
    a. https://www.gpsbabel.org/screenshots.html
    b. https://www.gpsbabel.org/htmldoc-1.6.0/fmt_shape.html
4) Then open the shapefile with ArcMap using the Catalog.

ident	lat	long
10677	-0.742229	-90.303922
10678	-0.891509	-89.48318
10679	-0.893867	-89.479566
10680	-0.893844	-89.479589
10681	-0.893863	-89.479603
10682	-0.893844	-89.479625
10683	-0.893851	-89.47962
10684	-0.893854	-89.479641
10685	-0.893806	-89.479659

SECTION 5 – OTHER RESOURCES

INFOGRAPHIC ON ECOLOGICAL RESTORATION FRAMEWORK

https://www.darwinfoundation.org/en/blog-articles/605-preserving-terrestrial-ecosystems-of-the-galapagos-islands

360º VIRTUAL REALITY VIDEO ON OPUNTIA RESTORATION

https://www.youtube.com/watch?v=PlzJGxT0mxM

'PROTAGNONISTAS' DOCUMENTARY

In 2018, GV2050 won the 'Protagonistas' award at the Latinoamerica Verde Awards. The prize for this was a documentary on DirecTV that you can be found here:
https://www.youtube.com/watch?v=DLLR3T7uJ7A&t=643s

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