Tropical Ecology Assessment and Monitoring Network

TEAM Network Sampling Design Guidelines

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Example of a TEAM Sampling Design for Nam Kading National Park, Laos, where the black pins represent camera trap locations, the green squares indicate vegetation plots, the blue circle symbolizes the location of a climate station, and the red outline designates the core study area.

1. SCOPE

The Tropical Ecology Assessment and Monitoring Network (TEAM) is designed to understand the effects of global drivers of change (climate, land use change) on biodiversity and ecosystem services by collecting standardized data throughout a network of tropical forest sites at several spatial and temporal scales (Andelman, et al. *in prep*). In order to be a successful enterprise and maximize the rigor of the data collected, TEAM implements standardized and detailed documented methods that span the workflows of data collection, data management and data/metadata distribution. A crucial component of this standardization is that all sites in the network follow a consistent and rigorous methodology to place all sampling units (e.g. vegetation plots, camera trap points and climate station points) in the field.

This document is a general overview of the procedures utilized for generating a sampling design that follow TEAM's three main field protocols: Terrestrial Vertebrates, Vegetation and Climate. The individual protocols explicitly detail the processes needed for placing in the sampling units in the field. These guidelines however will focus on outlining the relevant spatial (GIS) layers needed, the selection of the core study area, and ensuring that the sampling design meets the spatial requirements of each TEAM protocol. The sampling design produced from this process for a new TEAM site will be approached as a collaborative effort between site personnel and TEAM technical staff.

The main requirements to be considered during the generation of the sampling design are:

- **Study area standardization:** all TEAM sites follow the same standards in selecting the study area and generating the sampling design
- **Consistency with protocol sampling design:** the placement of sampling units for a given protocol at each TEAM site is consistent with the underlying sampling design guidelines outlined in this document (a spatial scale that is suitable for the organisms being sampled)
- **Disturbance minimization:** disturbance of the site, as a result of opening trails is minimized by using existing trails or establishing additional trails that can be used simultaneously by multiple protocols
- **High quality spatial data:** all the spatial data at a site, including the locations of sampling units, is consistently reviewed to ensure the highest possible standards required by the global scientific and conservation communities

The *TEAM Network Sampling Design Guidelines* delineates the preferred GIS data layers required to begin the process, the minimum steps and strategy for selecting a core sampling area at a TEAM site, and the procedures required for placing the sampling units in the field. In this document the sampling units discussed are one of two types: 1) points (e.g., camera trap points, climate station points), which can be grouped into blocks and/or arrays of points, and 2) areas (e.g. vegetation plots of 1ha). After the proposed location for all sampling units has been generated, they will be reviewed and approved by TEAM technical staff. This must be completed before the sampling units can be deployed in the field. **The final spatial location and coordinate information for all of the units will first be submitted to the TEAM technical staff before any scientific data is collected or can be uploaded to the TEAM Network portal.**

The sampling unit placement design (henceforth sampling design) generated from these guidelines must be approved by the TEAM Technical Director, Jorge A. Ahumada, (j.ahumada@conservation.org) prior to any installation of the physical sampling devices (e.g.

vegetation plots, camera traps, climate station, etc.). Costs of installation will not be reimbursed or covered by TEAM unless the design has been authorized by the TEAM Network Office. For general questions or for more specific questions about the data layers and/or products required to generate an appropriate sampling design contact the TEAM Remote Sensing Analyst (RSA), Melissa Rosa (m.rosa@conservation.org).

2. STEPS TO DEVELOP THE SAMPLING DESIGN

Figure 1 illustrates the main steps involved in generating the sampling design for a TEAM site. The Site Manager and/or designated site personnel will coordinate with the TEAM RSA to generate the Sampling Design. It is the responsibility of the TEAM RSA to design the layout of the sampling units within the previously designated core study area and this process is to be completed in direct collaboration with site personnel.

Using the essential spatial layers (next section), the following steps will be employed in the process of generating the TEAM sampling units with the assistance of GIS analysis. These steps will be carried out by the TEAM RSA, along with the assistance of participating site personnel once all of the essential layers have been compiled for review and analysis.

2.1. Selection of the core study area

All sampling units and/or blocks/arrays will be located within the core study area (CSA). It is required that the CSA be representative of the overall site. The actual size of the CSA will be determined by the total area requirements of the Terrestrial Vertebrate Protocol and the Vegetation Protocol. If there is a major altitudinal gradient at the site (> 1000 m difference between lowest and highest point within the CSA), all sampling units should be placed along this gradient in at least three strata: low elevation, mid elevation and high elevation. If there is no major altitudinal gradient, the core study area will be selected based on (1) the area needed to satisfy the requirements of the three TEAM protocols, (2) access considerations, and (3) distance to the field station. Initially, a proposed CSA should be hand digitized in GIS to capture the general area where sampling units will be placed. Once field GPS data is collected for all sampling units, the TEAM RSA will utilize a series of tools in GIS to create the final, computer-generated CSA. Please refer to the section *Designating the Core Study Area* and *Appendix 3* for a full explanation of the methods used for determining the proposed and final core study area.

2.2. Terrestrial vertebrates

Camera trap points need to be placed at a density of 1 camera trap point per 2 km^2 (or 1.4 km distance between points) and located near game trails and/or places used regularly by wildlife. Camera traps points should initially be positioned regularly in sets of two or three blocks/arrays of 30 or 20 cameras each, located at least 100m, but not more than 500m, from any existing trails or roads, and distributed equally along any significant elevation gradient. Camera traps arrays will be deployed sequentially rather than simultaneously within the same dry season to complete at least 30

days of sampling for each point. The proposed camera trap point locations will be selected to satisfy the stratification criteria, if an elevation gradient exists, or will be positioned based on accessibility. In addition, it is important to verify that the blocks/arrays will be accessible year round and are not situated in areas of sudden elevation change that will preclude access. The specific guidelines for placement of the camera traps are covered in much further detail in the TEAM Terrestrial Vertebrate protocol (http://www.teamnetwork.org/en/protocols/bio/terrestrial-vertebrate).

2.3. Placement of vegetation plots

Each of at least six 1-ha vegetation plots are randomly located within the core study area and at a minimum distance of 2 km between plots. The plots will be located at least 100m, but not more than 500m, from any existing trails or roads and distributed equally along any significant elevation gradient. If a minor access route travels directly from a trail, then it is acceptable to locate the vegetation plot near this minor route, but not within 100m of it. This is recommended to limit the construction of unnecessary additional trails. See details on the TEAM Vegetation Protocol (http://www.teamnetwork.org/en/protocols/bio/vegetation)

2.4. Climate Station

If there is a climate station/tower already at the site, this will be considered for the climate monitoring protocol. However, if a climate station/tower does not currently exist, the Site Manager should locate a candidate site following the guidelines in the TEAM Climate Protocol (http://www.teamnetwork.org/en/protocols/bio/climate) and submit to the TEAM Technical Director for approval.

3. SPATIAL DATA NEEDED TO PREPARE THE DESIGN

Both the TEAM RSA and site personnel are to compile the essential GIS spatial layers prior to the development of the Sampling Design. These layers will contribute to an accurate assessment of optimal placement of the sampling units within the core study area at the TEAM site. It is important to note that all spatial data layers submitted should be in geographic projection, Datum WGS84. This is required to maintain consistency and transferability among the TEAM Network Office and participating TEAM Network sites.

The following data layers are essential to generate a base map of the study area for determining the placement of the sampling units. Any GIS layers compiled by site personnel need to meet certain technical requirements that include a complete description (or metadata) of the spatial data layer. Please refer to the *Appendix 1* for the minimum spatial data requirements for the essential GIS layers.

Required:

Spatial Data Layer	Format
Landsat image, or similar mid-level resolution satellite imagery, covering the study area	Raster
Digital Elevation Model (DEM) and with a spatial resolution ≤ 90m	Raster
Administrative boundaries including managed/park boundaries	Vector
Major/minor access roads within and around the managed and/or protected area	Vector
Existing trails system within and around the managed and/or protected area	Vector
Major/minor rivers within and around the managed and/or protected area	Vector
Location of the field station (lat/long coordinate)	Vector
Extent of the Core Study Area (if available and/or already created)	Vector
Existing or historical land cover (vegetation/forest/agricultural areas)	Raster or Vector

If available:

| Spatial Data Layer	Format
Human settlements (and population size) within and around the managed and/or protected area.	Vector
Buildings, other field stations, and potential overnight camp facility points that are located within the vicinity of the field station	Vector
Soils and/or geology	Raster or Vector
Historical disturbance (i.e. deforestation) in the managed and/or protected area	Raster or Vector
Other data on hydrology, topography, landcover, key species, human activities (e.g. industrial areas)	Raster or Vector
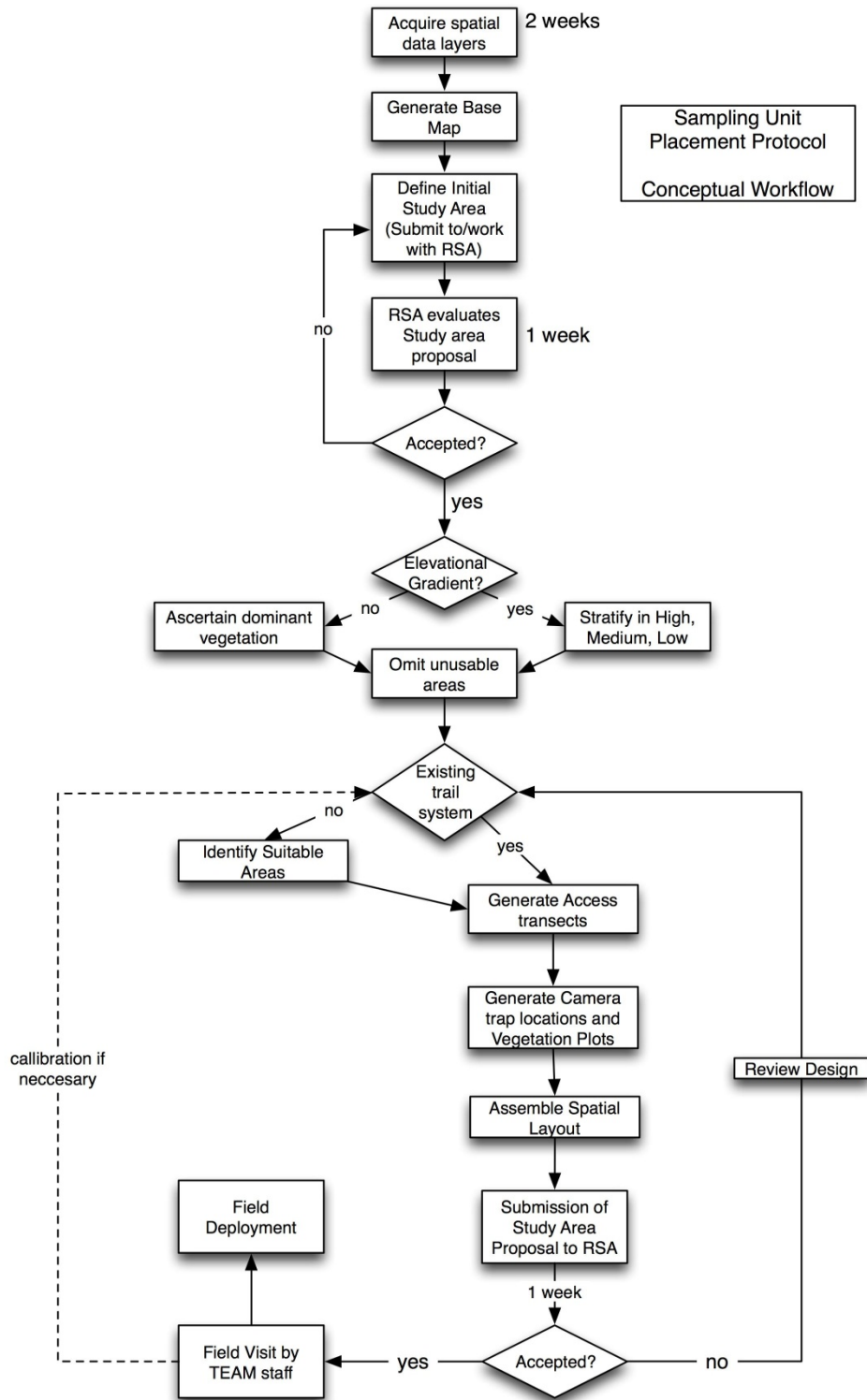
Figure 1. Workflow illustrating the main steps in the Sampling Unit Placement Protocol design set-up.

4. DESIGNATING THE CORE STUDY AREA

The core study area (CSA) represents the area within which the sampling units will be located. There are multiple variables that need to be considered when choosing the CSA and defining this area can be an iterative process. When delineating the CSA, it is first necessary to calculate the total minimum area needed based on the terrestrial vertebrates protocol. The reason that terrestrial vertebrates' protocol is the first to be considered is because this protocol requires a more extensive area than is required for the other two protocols: vegetation and climate (refer to Table 1 for minimum area requirements for each of the three protocols).

The following steps are to be followed when identifying the core study area to meet the spatial requirements for all three of TEAM's protocols:

- **Obtain a background source image:** This will typically be a Landsat satellite image and will be the earliest date freely available. The satellite image will be the first building block in determining the extent of spatially appropriate areas for the designation of the core study area.
- **Identify major access routes:** These should include a good quality road or track along which a vehicle can travel; a permanent river that is easily navigable by boat throughout the year (the navigability of a river should already have been identified from the input hydrology layers used to generate the site map); a major trail within the trail network of the Protected Area (PA). A buffer of at least 100m is created to avoid sampling units of being placed within this designated proximity of a major access routes and/or roads.
- **Identify minor access routes:** These can include the walking trail system within the PA, specifically those within the vicinity of the field station and adjacent or located along the major access routes identified above. If a spatial data layer of the minor trails does not exist, a GPS unit can be used to visit the trails for collecting line feature data, which can then be converted into an additional spatial data layer. A buffer of at least 100m is created to avoid the sampling units being placed within this designated proximity to existing minor access routes and/or trail systems.
- **If no minor trail system exists:** In very exceptional cases (e.g. where no minor routes exist) trails may be created off the major access route. These trails will be referred to as the *Access Transects* and will be used to gain entrance to the Terrestrial Vertebrates camera trap points. These transects will be generated after the Terrestrial Vertebrates protocol sampling units have been created and need to also be included in the current buffered extent.
- **Overlay topographic data:** For the majority of sites the most readily available product will be a coarse SRTM-derived Digital Elevation Model (DEM) with a spatial resolution of 90m. These data will provide an idea of significant changes in elevation. For some sites, local topography maps may have been digitized or generated from other sources and may be available for the analysis.

Protocol	Unit Type	Unit Size	Units per Array	Number of Arrays	Total Number of Units	Minimum Distance/Density	Placement Conditions
Terrestrial Vertebrates	Point	-	20-30	2-3	60-90	1 point/2 km^2	• Initial points placed regularly at required density • If elevation gradient exists, arrays are placed in a stratified random pattern at high, medium, low elevation. • Place within 100m, but no more than 500m, of access routes • Final field points must be located in suitable location within 100m of original location
Vegetation	Area	1 ha	1	6	6	2 km	• If elevation gradient exists, plots are placed in a stratified random pattern at high, medium, low elevation. • If no elevation gradient, place in dominant vegetation type. • Place within 100m, but no more than 500m, of access routes
Climate	Point	-	1	1	1	N/A	• Suitable clearing (ground-based placement)

Table 1. Sampling Unit Specifications for Each Protocol

Determine if there is an elevation gradient: By analyzing the DEM, it can be ascertained if there are any significant elevation gradients evident. An elevation gradient exists if there is a difference of ≥1000m between lowest and highest elevations within the area being examined. If an elevation gradient does indeed exist, stratify the core study area into the following three broad elevation gradients: low, medium, high (each spanning about 1/3 of the total gradient). A polygon spatial data layer may be generated that highlights these three divisions, or recode the DEM such that one (1) represents low elevation, two (2) represents medium elevation, and three (3) represents high elevation.

- **Overlay a land cover/vegetation map:** It is helpful to be aware of a general distribution of vegetation types and these can been delineated from either a land cover map or satellite image and/or with local expertise. Verify that the core study area captures the dominant vegetation type. If it does not, edit the extent of the core study area to include as close to a general distribution of vegetation types as possible. It may be impractical to include an extensive assortment of vegetation types in the CSA, for logistical reasons, but this should be attempted and assessed by TEAM technical staff.

- **Identify impenetrable areas and topographic boundaries:**
  - *Identify rocky outcroppings* by interpreting a satellite image. These areas may be digitized and then clipped out of the extent of the CSA before the sampling design is generated.
  - *Identify steep slopes* that would prohibit traversing or sampling. To identify the slopes:
    - i. A slope map is derived from a DEM
    - ii. Areas that are > 45 degrees are masked out
    - iii. This mask layer will be used to omit those areas from the CSA
  - *Identify seasonally inundated areas, big ponds, or streams that* may be impassable during certain seasons and would preclude sampling throughout the year. If these areas are easily identifiable, they can be digitized directly from an up-to-date satellite image. It should be noted that identifying inundated areas, especially seasonally inundated areas, can be very difficult and that consulting an expert with local knowledge of the area is highly recommended.
  - *Identify open areas, or large gaps* that are unsuitable for sampling. These may be digitized directly from an up-to-date satellite image also or from assistance of local expert who has knowledge of the area. Also, it should be noted that some gaps, for example, may represent senescent vegetation and not gaps.

5. REVIEW OF PROPOSED SAMPLING DESIGN

Once all of above steps have been followed, the Site Manager will review the design and work with the TEAM RSA to reach a consensus for a plausible implementation. This process may take several iterations depending on the quality and quantity of spatial information available for the site. Once the design is agreed upon between the RSA and the Site Manager, it will be sent to the TEAM Technical Director for final approval.

The *Three* Sampling Unit shapefiles presented for review and approval are:

- Proposed locations of the *camera trap points* (60 points)

- Proposed locations of the six *vegetation plots* (SW 0,0 corner point of each the proposed vegetation plot locations – 6 points)
- Proposed location of the *climate station* (1 point)

6. DATA NAMING STANDARDS FOR SAMPLING DESIGN

Post approval of the sampling design, the finalized sampling unit points are generated and labeled with a standardized naming convention. Sampling units are named using the standard **TEAM protocol code** it refers to, a **three letter site identifier code** (e.g. NAK for Nam Kading; UDZ for Udzungwas), an **array number** (if applicable – this normally pertains only to the Terrestrial Vertebrate protocol) and a **unit number**.

PROTOCOL_CODE – SITE_CODE – ARRAY – UNIT_NUMBER

For example the sampling unit with name CT-UDZ-1-15, refers to camera trap point (CT) number 15 on array 1 at the Udzungwa TEAM Site (UDZ). Proposed sampling unit points will have the same naming convention plus a "P", for proposed, at the end (e.g. CT-UDZ-1-15P) to differentiate the proposed sampling design from the final design placed in the field. This format was chosen to reduce error in the management of the spatial files transmitted between the TEAM RSA, all TEAM site personnel, and the TEAM portal that houses all of the proposed and field collected sampling unit points.

Codes for TEAM protocols are shown in Table 2. If you have not been given a code for your site, contact the TEAM Director of Information Systems (e.fegraus@conservation.org) to obtain a site code.

PROTOCOL NAME	Protocol Code
Climate	CL
Terrestrial Vertebrates	CT
Vegetation	VG

Table 2. Protocol Codes used through the TEAM Network.

7. IMPLEMENTATION OF THE PROPOSED SAMPLING DESIGN

Once the design has been approved in writing, then the installation and placement of sampling units in the field can begin. All sampling units will be placed in the field according to TEAM protocols and need to be georeferenced with the assistance of GPS technology. Final field locations should be stored within a GPS file (with .gpx extension) and then uploaded to the TEAM portal in a standard geographic format (latitude/longitude coordinates, WGS84 datum) for approval from the TEAM RSA.

The format for submission has been standardized and is fully outlined below. These guidelines provide in explicit detail all of the procedures regarding how to download and upload points to and from the GPS unit, collection of spatial data in the field, naming conventions of sampling units, submission process and management of all collected spatial data. Further detailed instructions on how to setup and calibrate the GPS unit before field data collection can be found in *Appendix 2*.

7.1. Transfer the Proposed Sampling Unit Points to the GPS Unit

The proposed files will be sent with the standardized naming convention format (examples: *CL-NAK-1P*; *CT-NAK-1-30P*; *VG-NAK-1P*) by the TEAM RSA as a .gpx file for transfer to the GPS unit using Garmin's *MapSource* software. This computer software comes with the Garmin device and allows for transfer of waypoints (another word for point), routes and tracks between the device and your computer. It is also referred to as the Trip & Waypoint Manager. The software provides general worldwide maps that include major and minor roads, political boundaries, principal cities and towns, oceans and other general reference details to give the GPS data geographical context.

7.1.1. Download MapSource

- Download the software to the computer from the CD that accompanies the Garmin GPS unit. If there are any issues with downloading the software, please contact the TEAM Remote Sensing Analyst
- Before opening the Sampling Design's "proposed" files into MapSource, be sure to *Edit* the *Preferences* in MapSource. This can be done from the Menu Bar, under *Edit*
- Scroll all the way down to *Preferences*
- Go to the Units tab and change everything to Meters
- Also, go to the *Position* tab and change grid to "Lat/Lon hddd.ddddd°" and Datum to "WGS 84."
- Select okay and then proceed to transfer the "Proposed" points to the unit

7.1.2. Transfer Points from MapSource

- Connect your GPS unit to the computer using the enclosed USB cable
- Open the software and under file, select open and navigate to the location of the .gpx file for each of the protocol "proposed" files
- Once the file is open, select all with Ctrl and A. Then right click and scroll down to *Show Selected Waypoints on Map*. (This will ensure that the proposed points are appearing in the correct geographical area on the map.)
- Next select *Transfer* on the menu bar
- From the drop down, select *Send to Device*. This will transfer the "Proposed" points to the GPS unit. Be sure to open and transfer each of the separate sampling design files (one for each protocol) to the unit individually.
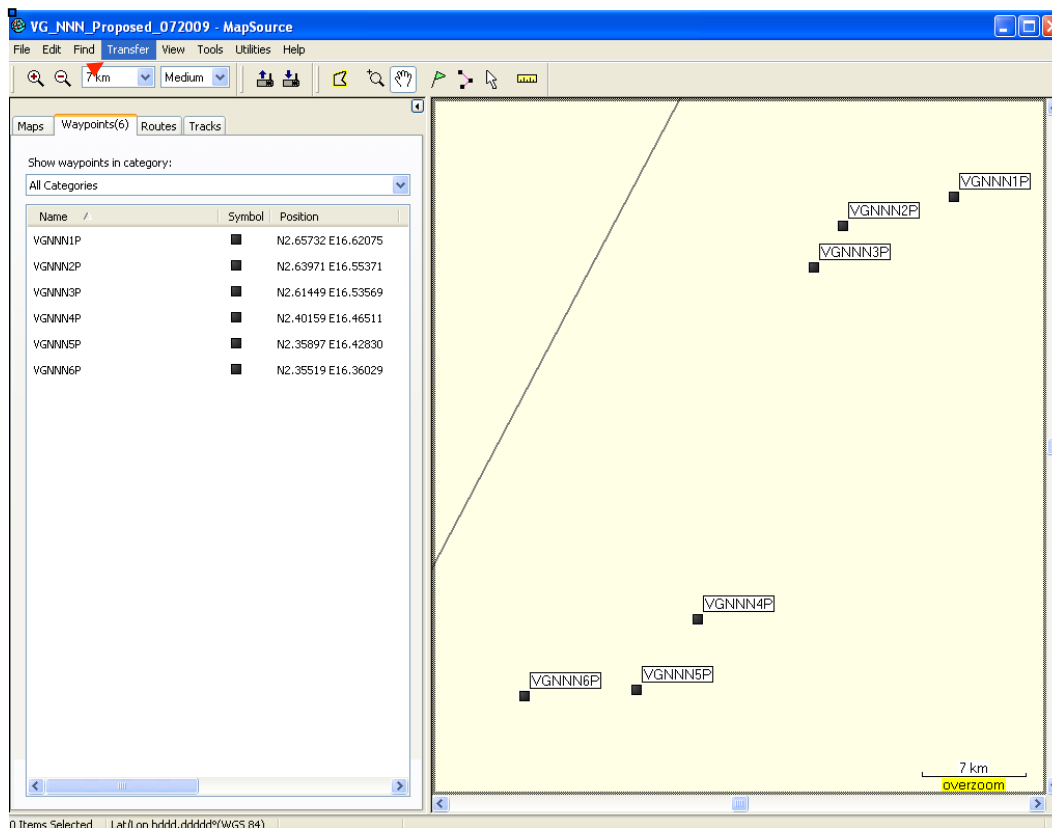- Please refer to Figure 2 to view the MapSource user interface screen.

Figure 2: MapSource open for transferring points to GPS unit.

7.2. Navigate to the Proposed Sampling Unit Points in the Field

Once all of the sampling unit points have been transferred to the GPS unit, the next steps involved are navigating to the proposed points in the field. There are several things to keep in mind when using the GPS compass in the field. The positional reading on the unit will continually shift, along with the compass-bearing arrow, due to the satellite signal strength in the field. Depending on the location and local topography where the GPS unit is being used and the density of the canopy and/or brush, these factors will likely affect the positional accuracy of the latitude/longitude readings. Please refer to *Appendix 2* to make sure your GPS unit is properly setup and calibrated before navigating to proposed sampling unit points in the field.

7.3. Collect New Points in the Field

The proposed points uploaded to the GPS units are merely a navigational guide to arrive within the general vicinity of the computer generated sampling design unit points. It is

required that the field waypoint (being the actual location of the sampling unit at the time of setup) be collected by *Marking* a new waypoint within reasonable proximity to the original proposed point. Also, when collecting a new waypoint in the field, it is crucial to maintain the TEAM naming convention standards for the three TEAM protocols and remove the "P" to signify a field point.

7.3.1. Mark New "Waypoints"

The *MARK* key on the GPS unit provides the function of marking the current location, at any time, by adding a new waypoint to the unit's memory

Once within the vicinity of the proposed point, select the *MARK* button, and name the field point based on the naming convention of the original proposed waypoint name minus the "P" (Figure 3). For example, if the original waypoint's name is "CTCSN101P", then the field waypoint should be named "CTCSNR101**"**
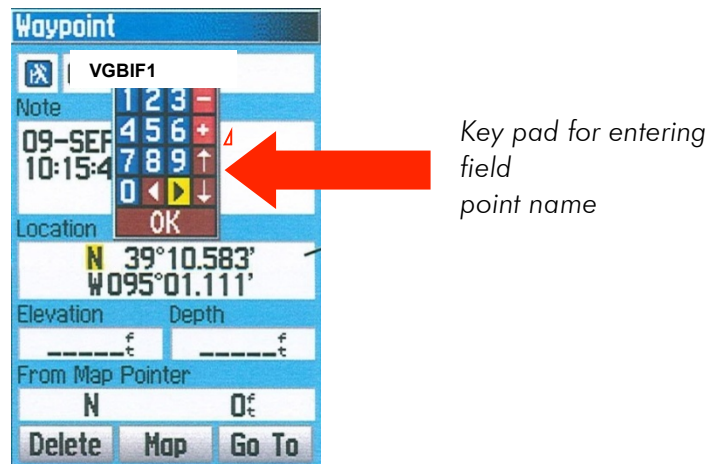

Key pad for entering field
point name

Figure 3: New waypoint screen

7.3.2. Minimum Spatial Accuracy

It is required that the *AVG* button **ALWAYS** be selected before pressing *OK* in order to allow for increased positional accuracy of any sampling unit point taken in the field (Figure 4). This option essentially averages a new waypoint location over time to produce a more accurate lat/long measurement. **_The minimum spatial error of the point recorded should be 5m_**. This typically occurs after the count reaches at least 300, but it is not always the case. Therefore, only record the point when the minimum spatial distance is at least 5m, select *Save*, and the new waypoint is recorded with an average positional reading. Be sure to save it in the GPS unit under the correct naming convention and write down the number of points (or readings) it took to reach 5m spatial accuracy in the appropriate TEAM field form for whichever protocol the points are being collected (e.g. for Terrestrial Vertebrates use the Camera

Trap Point Form). This same procedure must be applied every time a new point is marked in the proposed sampling unit location.

Average Spatial Accuracy Option

Figure 4: Location of *AVG* option.

7.3.3. Delete a Point (if necessary)

In the instance that a waypoint needs to be deleted from the uploaded sampling unit points, follow the steps below:

- There are two ways to delete waypoints. One is individually and the other way is to delete all or clear the memory in the GPS unit
- To delete a waypoint individually, hit FIND, select Waypoints, and scroll down to whichever waypoint needs to be deleted
- Once that waypoint is selected, hit ENTR and move down to the bottom of the page to highlight *Delete* in yellow. A sub-menu will pop-up asking again if the point should be deleted. Select *Yes*
- To delete all waypoints, hit the Menu button from the *All Symbols List* page for Waypoints
- The options given here are for finding symbol by name, nearest, selecting a symbol, changing a reference and delete
- Scroll down to highlight *Delete* in yellow and it will then ask to delete all Once this has been selected, all existing waypoints will be deleted from the unit
- It is important to delete any unnecessary points from the GPS unit before field deployment of the approved and final Sampling Design begins

7.4. Transfer Collected Field Data to Computer

After the geographical positions for all the new sampling unit points have been collected in the field, post production of the data includes downloading the collected points to a computer for transmission to the TEAM Portal for approval. The following steps outline the required procedure for downloading and saving field data on a computer.

- Connect the GPS unit to the computer where the data can be transferred into MapSource
- Once the Garmin GPS unit has been connected to the computer and MapSource is open, locate *Transfer* on the menu bar and select *Receive From Device*. This will transfer all the points collected in the GPS unit from the field into the MapSource software (Figure 5)
- Select and Save the collected points as a .gpx file under *File*, *Save As* (Figure 6)
- Be sure to follow the naming convention for saved field points coming from different protocols on a .gpx file (replace *SiteCode* by the appropriate three letter code for your site):

  Terrestrial Vertebrates Protocol -- CT_*SiteCode*_Field_ddmmyyyy.gpx
  Vegetation Protocol -- VG_*SiteCode*_Field_ddmmyyyy.gpx
  Climate Protocol -- CL_*SiteCode*_Field_ddmmyyyy.gpx
- This file can then be uploaded directly to the TEAM website data interface portal.
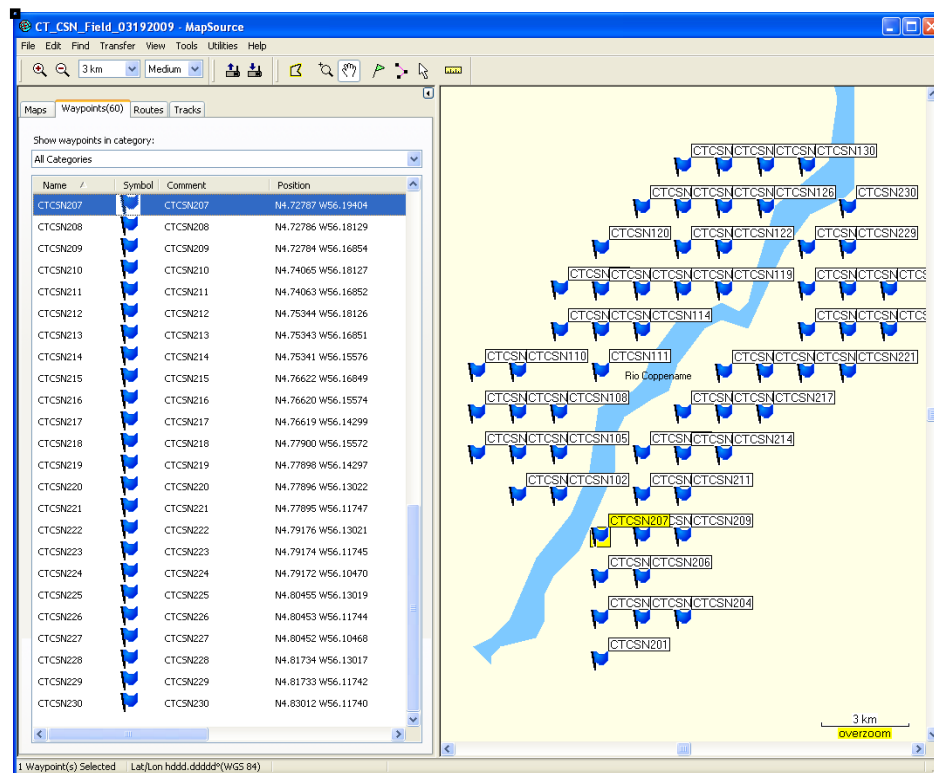

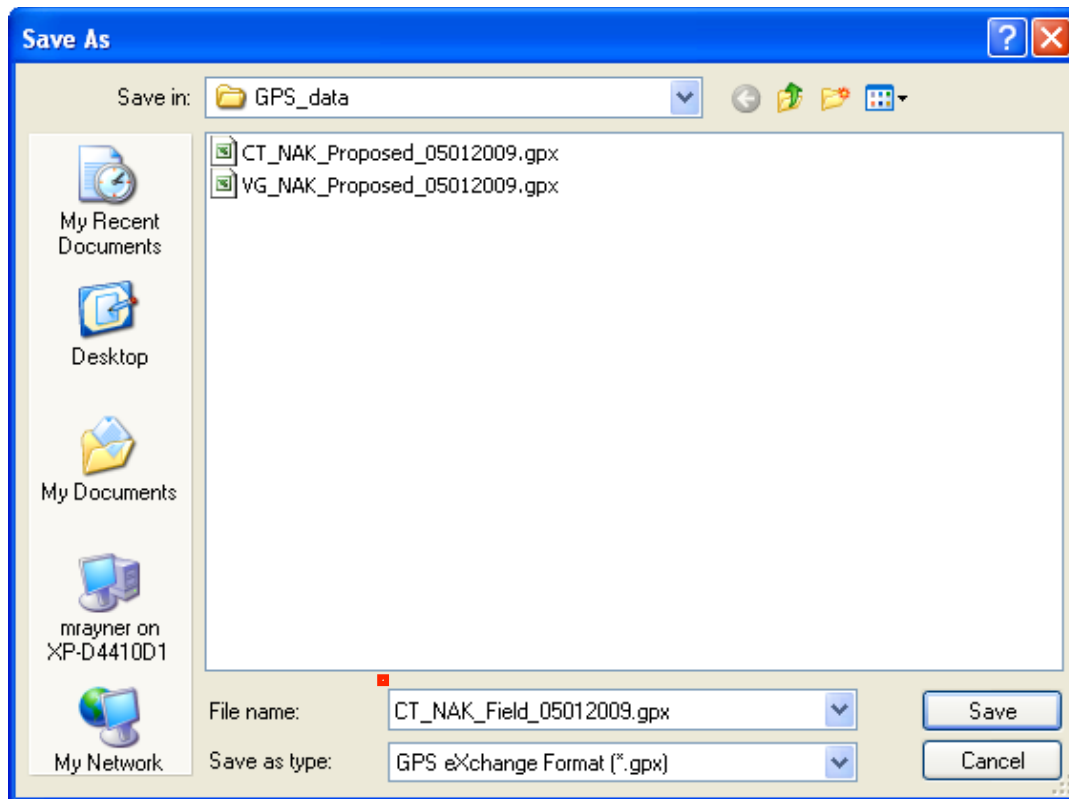Figure 5. MapSource showing collected field points.

Figure 6. Save as option within MapSource and naming convention

7.5. Upload the Field Data to the TEAM Portal

Once the field data has been successfully transferred from the GPS unit to the computer and saved, the next steps involve uploading the individual protocol files to the TEAM portal.

7.5.1. Upload to TEAM Portal

- Go to TEAM portal via the TEAM Network website http://www.teamnetwork.org
- Login under username and password
- Go to myTEAM ➔ data management tool under 'Data Management' (Figure 7)
- Select Site from Upload Spatial Data tab (Figure 8)
- Select the Protocol (Terrestrial Vertebrates, Vegetation, or Climate) from same tab
- Navigate to where the field collected gpx file is located on your computer and open it under *File*
- Finally click on the Submit button to upload the points into the system
- Figure 9 illustrates a successful upload of the field collected points into the system
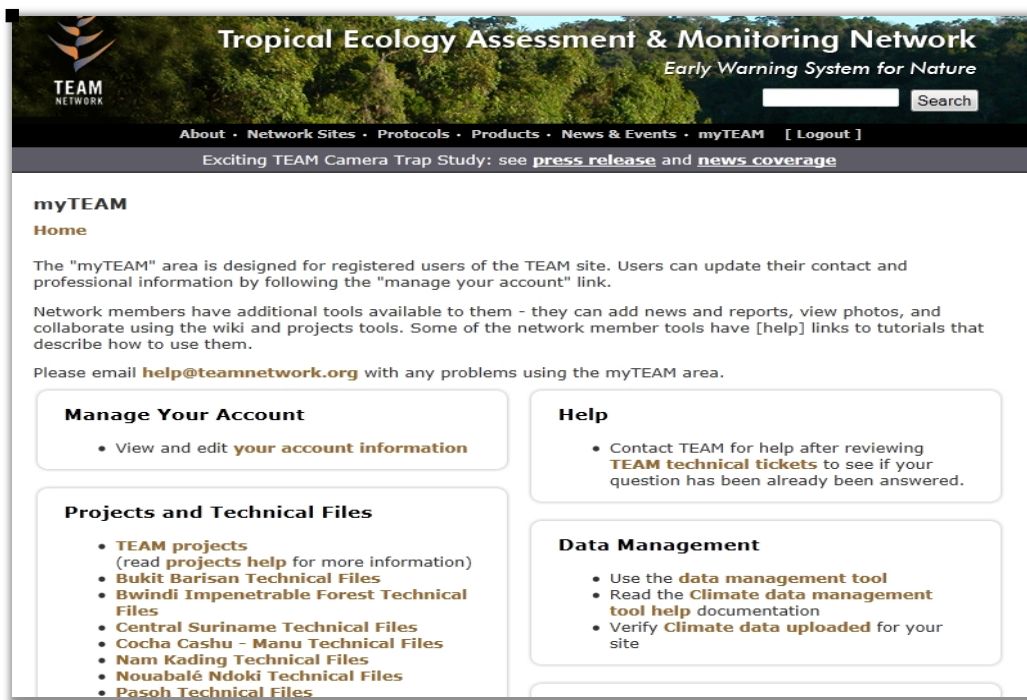
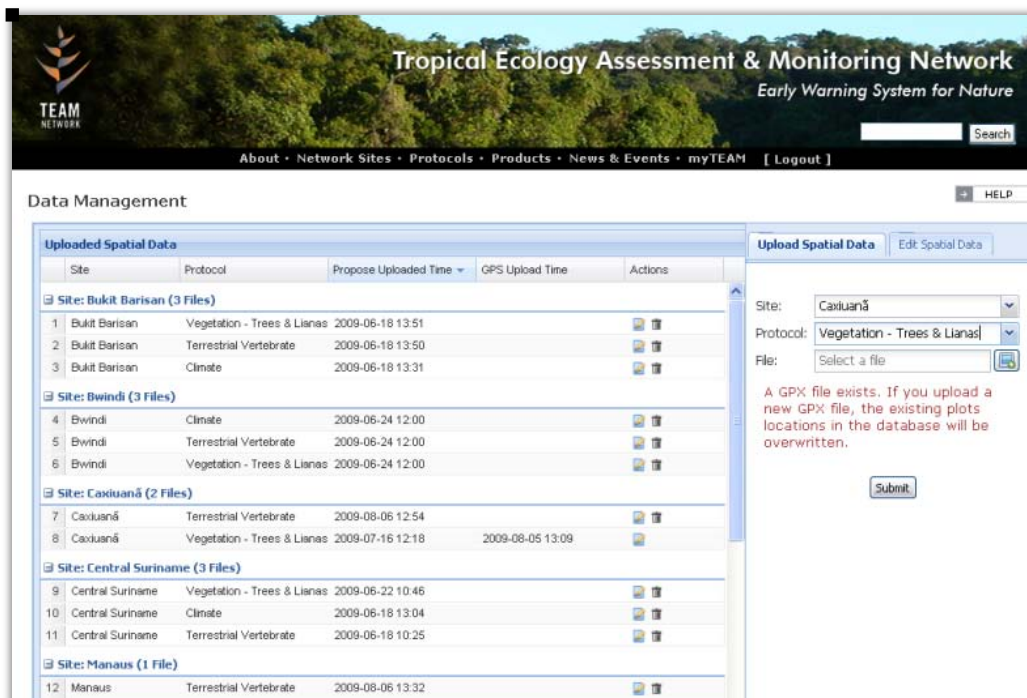Figure 7. TEAM portal menu options for data upload

Figure 8. Selecting the site and protocol for uploading points.

Figure 9. Data Management Table on the TEAM portal.

7.5.2. Enter Field Metadata in Data Table

After field .gpx files have been uploaded to the TEAM portal for each protocol, it is necessary and the responsibility of TEAM site personnel to manually enter the required metadata from field forms into the data table (Figure 10). This includes the following information:

- Date of Field Reading
- Person Name for GPS Reading (who collected the field data)
- GPS Make and Model
- Number of Points (to reach 5m minimum spatial accuracy for each point, e.g. 300 – 500 points)
- For the *Vegetation Protocol* only:
  - Bearing from (0, 0) to (0, 100)
  - Bearing from (0, 0) to (100, 0)
  - Start Date of Installation
  - End Date of Installation
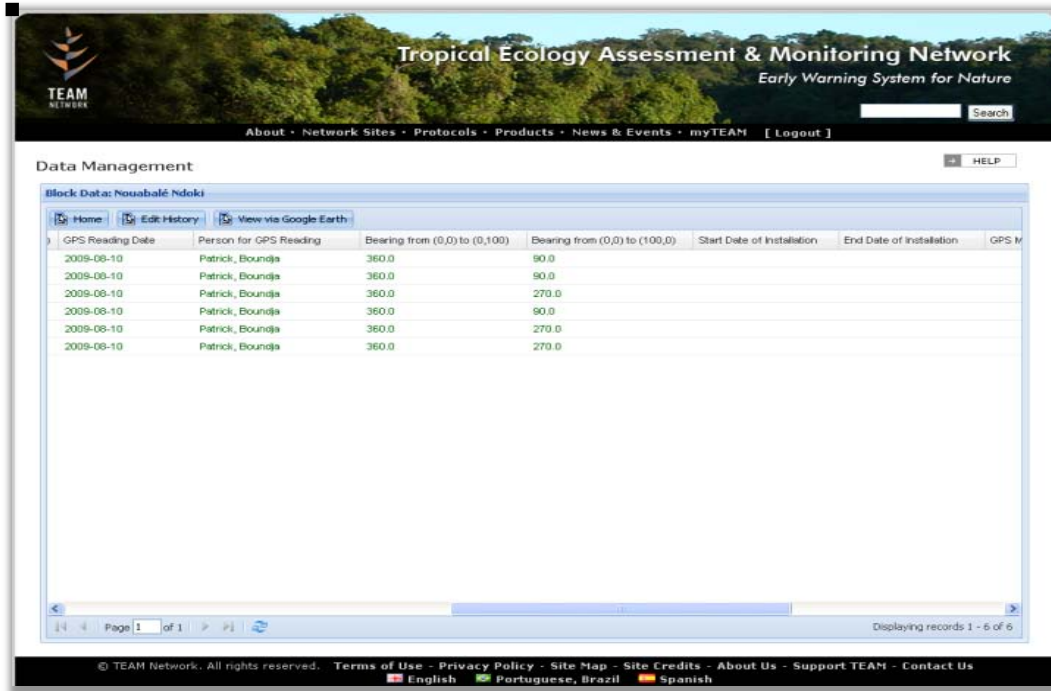
Figure 10. Data Management table ready for editing

7.5.3.   View in Google Earth (optional)

After the points have been successfully uploaded to the TEAM portal, it is also possible to view them within the data portal. The data management table has a "View via Google Earth" button (Figure 11). Clicking on this button allows the user to view the uploaded GPS data, along with the already entered proposed points, in Google Earth.   This should be done to ensure the spatial relevance and accuracy of the newly uploaded field data.

Figure 11: Google Earth view of the data with sampling unit description label.

8. REVIEW OF FIELD SAMPLING DESIGN

Once the final field coordinates and required information is available on the TEAM portal, the RSA will review the georeferenced points and compare them to the proposed points. The RSA will contact and work with the Site Manager regarding any discrepancies that violate the Sampling Design Guidelines. After issues are resolved, if any, the final core study area can be determined by using a GIS to create a convex hull around each camera trap array, a convex hull around vegetation plots, buffer each hull according to the minimum distance requirement for that protocol, then merge all polygons together. See *Appendix 3* for further technical GIS details regarding this process. See Figures 12 and 13 for examples of implemented designs at two current TEAM sites.
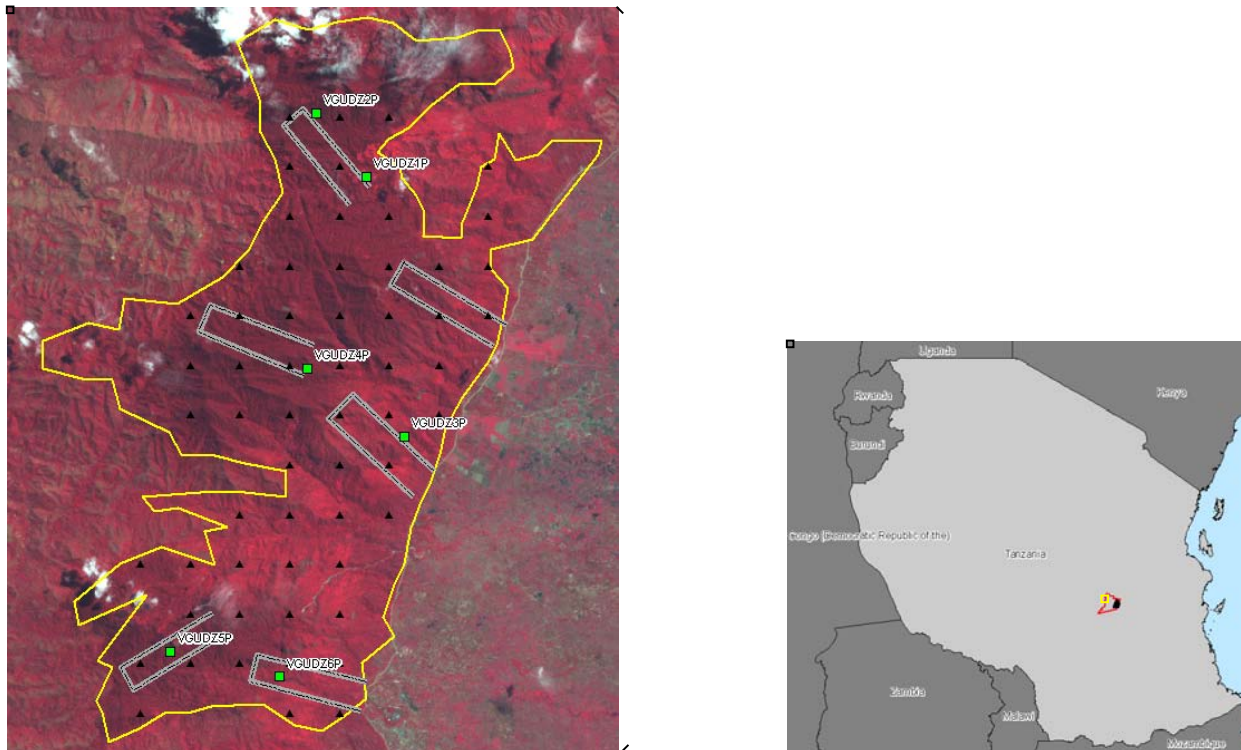

Figure 12. Example Sampling Design for the Udzungwas (Tanzania): Core Study Area boundary is represented by the yellow polygon. Total of 60 camera trap points (black triangles) are divided up into 3 groups of 20. Vegetation plots (green squares) are randomly placed and access transects (gray "U" shaped lines) were generated to easily arrive at the proposed locations.
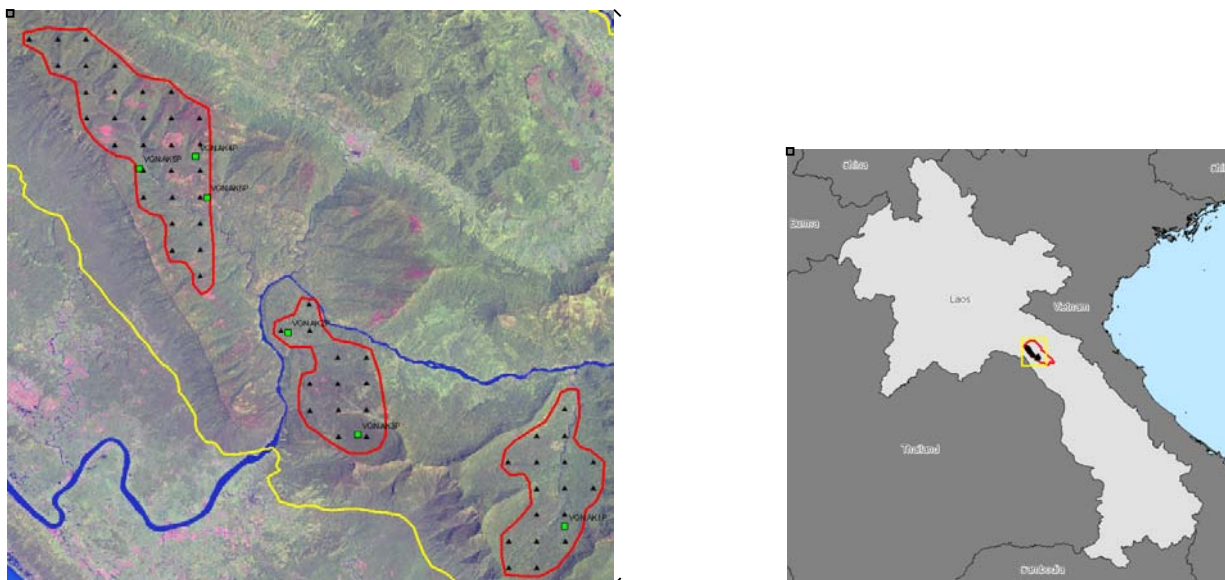
Figure 13. Example Sampling Design for Nam Kading (Laos): Core Study Area boundaries / 3 arrays (red polygons) ➔ 30 + 15 + 15 = 60 Camera traps divided up in three arrays (black triangles); 6 vegetation plots (green squares). Entry to sampling units is dependent on existing satellite camp locations and river access in some areas. Access transects were not generated for this site due to recommendations by site personnel.

9. MODIFICATIONS TO THE FIELD SAMPLING DESIGN

For subsequent seasons, if a sampling unit needs to be moved from its original field location, then the process of collecting a new waypoint in the field and uploading the spatial data (.gpx file) to the TEAM portal as outlined in Section 7 needs to be followed. It is important to refer to the specific field TEAM protocol to ensure the relocated sampling unit will be placed within the guidelines of that protocol. Follow these main steps if a sampling unit needs to be moved from its original location:

- Establish and mark the new point in the field. Find a new location as close as possible to the original location and georeference the point. Follow all steps in Section 3 and be sure to adhere to the minimum spatial accuracy requirement (see Section 3.2) when collecting the new waypoint.
- Mark the new point using the same naming convention, followed by a dot, and a sequential number. For example, if the name of a camera trap point that needs to be moved is CT-UDZ-1-15, then the new camera trap point name would be CT-UDZ-1-15.1. If a sampling unit needs to be moved again in the future, then keep increasing the number after the dot (e.g. CT-UDZ-1-15.2)
- Fill in relevant field information. Use the TEAM protocol field form for the sampling unit that needs to be relocated to write down necessary field data information, which should be transcribed to the TEAM portal.
- Transfer and upload the .gpx file containing the new location to the TEAM portal. Then manually enter field information in the data table (see Sections 4 and 5).

The TEAM Remote Sensing Analyst should be notified if the location of a sampling unit needs to be changed at any time.

10. GLOSSARY

Camera Trap Array – A set of camera trap points (usually 20-30) distributed at a density of 1 camera trap every 2 km². All camera traps in the array sample during the same 30-day period.

Climate Station – The set of sensors, data logger, power supplies, and physical base (tower/tripod) that is assembled to continuously monitor climatological variables at a fixed point in space.

Core Study Area – This refers to the sub-area within the site where TEAM sampling units will be located.

Datum – A model of the shape of the earth that defines a geographic coordinate system. The datum used for TEAM spatial data is WGS84.

DEM – Digital Elevation Model; a model describing changes in elevation across an area.

Geographic Information System (GIS) – A computer system for capturing, storing, querying, analyzing, and displaying geographically referenced data.

Global Positioning System (GPS) – A space-based satellite navigation system that provides information on location and time. By capturing the signals from three or more satellites, GPS receivers are able to triangulate data and pinpoint a location.

GPX – The GPS Exchange Format, or light-weight XML data format, for transferring GPS data (waypoints, routes, and tracks) between the GPS receiver and a computer, application, or the Internet.

Map Projection – The representation of the Earth's surface (sphere) or other three-dimensional body on a plane. All map projections distort the surface in some way and there is no limit to the number of possible map projections. The map projections commonly used for TEAM spatial data is Geographic (unprojected) or UTM-Universal Transverse Mercator (projected).

Raster – A data structure that uses a grid and cells to represent the spatial variation of a feature. Some examples of raster datasets are satellite imagery, Digital Elevation Models (DEM), and digital photos or maps. Examples of raster data formats include TIFF, IMG, Bitmap (BMP), PNG, GIF, and JPEG.

Sampling Design – Refers to the locations (spatial distribution) of sampling units, the time of year and frequency of successive sampling periods (temporal distribution), and the length of time the sampling units are deployed in the field during each sampling period (effort)

Sampling Period – The specified time (e.g., week, month, climatic season) when data is collected for each protocol.

Sampling Unit – The equipment placed in the field that collects data for each protocol (camera traps, vegetation plots, and climate stations).

Sampling Unit ID – A unique identification that includes the two-letter code for the TEAM protocol, the three-letter site code, and the unit number.

Site – This refers to the entire spatial area within which TEAM takes measurements and carries out monitoring activities.

SRTM – Shuttle Radar Topography Mission DEM, or elevation raster data, obtained on a near-global scale at 3-arc second (approximately 90 m) resolution.

Vector – A map data structure using the point or node and the connecting segment as the basic building block for representing geographic features.

Vegetation Plot – The 1-ha (100 x 100 m) plot where the DBH of all stems of a ≥ 10 cm DBH are measured annually.

11.   DATA SOFTWARE AND SOURCES

11.1.   Open Source GIS Software

Quantum GIS (QGIS) – www.qgis.org
GRASS (Geographic Resources Analysis Support System) GIS – http://grass.fbk.eu/

11.2.   Satellite Imagery and Derived Datasets

USGS (Landsat, ASTER, MODIS) – http://glovis.usgs.gov
SRTM DEM (Hole-Filled) – http://srtm.csi.cgiar.org

12. APPENDIX 1: MINIMUM SPATIAL DATA CONDITIONS FOR ESSENTIAL GIS LAYERS

Description of Layers *(These must be in digital format for transmission and in geographic projection, datum WGS84)*

1. Landsat (or similar mid-level resolution) Satellite Imagery

A spatial description should include the following:
* Date of acquisition of the image
* Scene parameters (example: Landsat - 185km by 185km)
* Pixel resolution
* Name, title, and qualifications of the individual who processed the image, if pre-processing techniques were applied (e.g. atmospheric correction, georeferencing, etc.)

Any background data source image must include a metadata file or header file. This file will include all of the necessary information if processing techniques need to be applied to enhance the image for interpretation purposes.

Other background data sources to be considered:
* Quickbird
* Ikonos
* Aster
* CBERS

2. Boundary Information (including both the spatial extent of the site area and protected area, if applicable)

A spatial description should include the following:
* Latitude and longitude of the perimeters of the site area and protected area
* Name, title, and qualifications of the individual who created the data and current email address

A digital boundaries layer should be accompanied by the following:
* A description of the method used to collect the data and date(s) of collection (and when revised, if applicable)
* A description of ancillary data sources used – examples include, vegetation maps, historical burn data, topographic layers, infrastructure and network layers
* Projection information including:
  * Projection name
  * Projection specific parameters (e.g. zone number, central meridian, standard parallels, false easting, false northing etc.)
  * Datum information
* Publication information – name and title of the organization/individual creating the data and current email address
* Data sharing limitations including restrictions on use, circulation, and re-circulation

3. Buildings and Infrastructure Information

A spatial description should include the following:
- Latitude and longitude of each building and related structures
- Brief description of each building or infrastructure feature including whether it has:
  - Electricity
  - Cooking facilities
- Name, title, and qualifications of the individual who created the data and current email address

A digital building and infrastructure layer should be accompanied by the following:
- A description of the methodology used to collect the data and date(s) of collection (and when revised, if applicable)
- A description of ancillary data sources used – examples include historical building maps
- Projection information including:
  - Projection name
  - Projection specific parameters (e.g. zone number, central meridian, standard parallels, false easting, false northing etc.)
  - Datum information
- Publication information – name and title of the organization/individual creating the data and current email address
- Distribution limitations including restrictions on use, circulation, and re-circulation

4. Existing Trail (Paths) Information
A spatial description should include the following:
- Latitude and longitude of the trail start and end points
- Spatial information including length, direction, etc.
- Brief description of the trail quality – examples include single track, unpaved, uneven, ease of navigation
- A digital trail system layer should be accompanied by the following:
  - A description of the method used to collect the data and date(s) of collection (and when revised, if applicable)
  - A description of ancillary data sources used – examples include, vegetation maps, historical burn data, topographic layers, infrastructure and network layers
- Projection information including:
  - Projection name
  - Projection specific parameters (e.g. zone number, central meridian, standard parallels, false easting, false northing etc.)
  - Datum information
- Publication information – name and title of the organization/individual creating the data and current email address
- Data sharing limitations including restrictions on use, circulation, and re-circulation

5. Hydrological Information (including lakes, rivers, streams, ponds, swamps, inundated areas, watersheds, drainage patterns)

A spatial description should include the following:
- Latitude and longitude of each hydrologic feature (start/end points if a linear feature, such as a river, or simple point location if a point/polygon feature, such as a pond)

- Brief description of the spatial extent of each feature (examples include length, direction, spatial extent)
- Brief description of the characteristics of each feature (e.g. seasonal)

A digital hydrologic layer should be accompanied by the following:
- A description of the method used to collect the data and date(s) of collection (and when revised, if applicable)
- A description of ancillary data sources used – examples include, vegetation maps, topographic layers
- Projection information including:
    - Projection name
    - Projection specific parameters (e.g. zone number, central meridian, standard parallels, false easting, false northing etc.)
    - Datum information
- Publication information – name and title of the organization/individual creating the data and current email address
- Data sharing limitations including restrictions on use, circulation, and re-circulation

6. Land Cover information

A spatial description should include the following:
- Spatial extent of each vegetation type
- Vegetation type name
- Brief description of vegetation type
- A description of the process used to collect the data and date(s) of collection

A digital land cover product should be accompanied by the following:
- Information regarding the classification scheme (an explanation of the classes included in the legend)
- A description of the classification method used if derived from remote sensing data – examples include maximum likelihood classifier, Isodata, decision tree classifier
- A description of the remotely sensed input imagery used – examples include Landsat, CBERS, ASTER, IKONOS
- The acquisition date of the input imagery in month/day/year format (mm/dd/yyyy)
- The spatial resolution (m) and number of rows and columns if a raster product
- Projection information including:
    - Projection name
    - Projection specific parameters (e.g. zone number, central meridian, standard parallels, false easting, false northing etc.)
    - Datum information
- Publication information – name and title of the organization/individual/collaborators creating the data and current email address
- Data sharing limitations including restrictions on use, circulation, and re-circulation

13. APPENDIX 2: GPS GUIDELINES

The deployment and georeferencing of the sampling units in the field is a crucial component of every TEAM protocol. The *GPS Guidelines* provide detailed criteria for proper setup of the GPS unit before carrying out this process in the field. These instructions are standardized and should be followed with the intention of maintaining a high level of consistency with data collected among all TEAM Network sites.

13.1. GPS Technology for Field Deployment of Sampling Units

Once the TEAM technical staff has approved the sampling design proposal, the next steps involve the actual set-up/deployment of the sampling units in the field. However, prior to field deployment of the sampling units, there is some GPS preparation required. First it is necessary to have a basic understanding of the GPS technology involved and comfortable awareness of the GPS unit recommended by TEAM for any and all of the georeferencing of the sampling units to be collected.

13.2. Introduction to Garmin Model 60CSx

The GPSMAP 60CSx has special performance-enhancing features that include a removable microSD™ card, a high-sensitivity GPS receiver, barometric altimeter and electronic compass. The Garmin 60CSx boasts a high-sensitivity GPS receiver that gives the user improved satellite reception even in heavy tree cover or deep canyons. The barometric altimeter provides extremely accurate elevation data and the electronic compass can determine heading and direction, even when maintaining a stationary position. The unit has a large, color TFT display that makes viewing the screen easy, day or night.
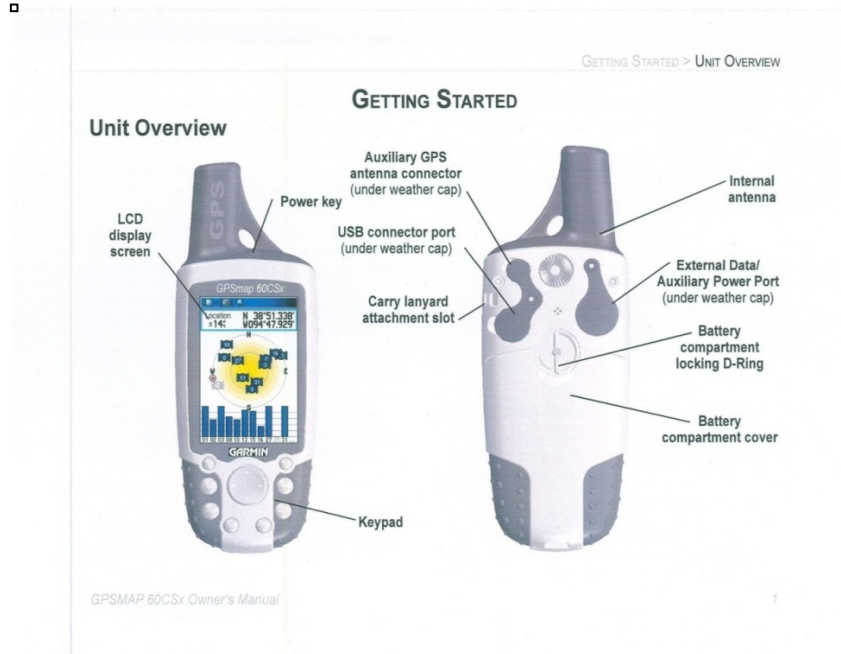
Figure 1.1: Garmin 60CSx Unit Overview

13.2.1. Satellite Display Screen

This is the first page that appears once the unit has been turned on.   It identifies the GPS satellites within range and the strength of their signal.   The GPS unit attempts to attain a 3D fix (which means that the unit is receiving a signal from at least four or more satellites). This will be shown with a small satellite looking symbol on the very top of the display screen and is illustrated with the letters "3D" in the center.
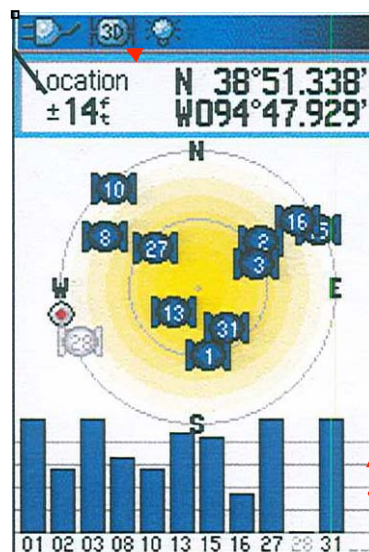
3D Satellite fix indicator

Number of satellites within range and satellite signal strength

Figure 1.2: Satellite display screen

13.3. Setup of GPS Unit Prior to Field Deployment

After general familiarity with the Garmin GPS unit has been attained, the next steps involved are the technical set-up of the GPS unit for use in the field. It is required that the unit collects data in the correct time zone, projection and units of measurement. Also, prior to begin collecting data in the field, it is vitally important to calibrate the compass in order to ensure that navigation to the designated location of the sampling units is accurate. These steps (described below) can be completed in the field station or an open area with good satellite coverage.
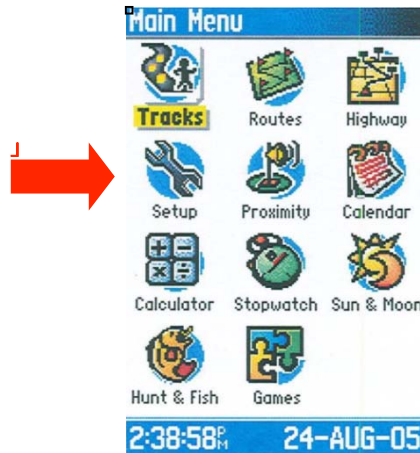

Figure 1.3. Main menu screen

13.3.1. Time Zone Set-up

- From the Main menu page, go to *Setup*
- Once on the Setup page, select *Time*
- The unit needs to be powered on in the correct time zone where the points are being collected
- Also, note that the unit must be in an area where it is able to pick up significant satellite signal to be able to select the correct time zone.

13.3.2. Units of Measurement Set-up

- From *Setup,* select *Units*
- Position format is to be in decimal degrees (hddd.dddd)
- Select Datum: WGS 84
- Change Distance/Speed to metric
- Elevation to meters (m/min)
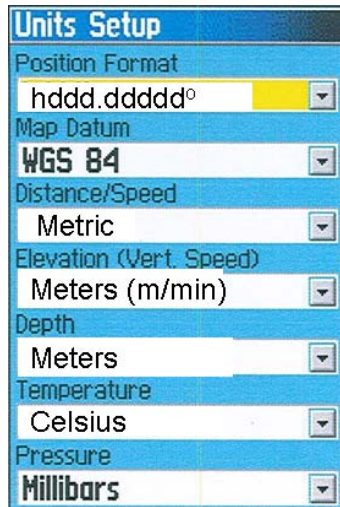- All other units listed below can be left as their defaults

Figure 1.4. Unit setup screen

13.3.3. GPS Compass Setup

- Go to the *Setup* menu page.
- Scroll all the way down to *Calibration*, select and hit *ENTR* while Compass is highlighted
- Follow the instructions displayed on the unit to calibrate the compass. Once the compass has been calibrated by turning it clock-wise, return to the Main Menu page
- From the Main Menu page, hit *QUIT* twice, or as many times as necessary to arrive at the Compass display screen. From this view, it is possible to change the compass display information.   By default, there are four boxes of information that can be used for navigation
- In order to change the information displayed in any of the boxes, hit *MENU*. This will bring up a sub-menu page. Scroll down to *Change Data Fields* and hit *ENTR*
- For every box, it is possible to choose from a list of options to be displayed. It is suggested that the following options be displayed for navigation purposes in the field:
  - Bearing
  - Distance to Next
  - Heading
  - Time to Next
- Please refer to the Figure 1.5 as a reference when selecting compass display information.

The Compass' red arrow is constantly facing straight ahead or perpendicular to the current location of the directional bearing. If it veers to the right or the left, than it is necessary to re-adjust the unit's physical direction in order to return the red arrow to pointing directly ahead of you, in a perpendicular position. See Figure 1.6 for visual reference.
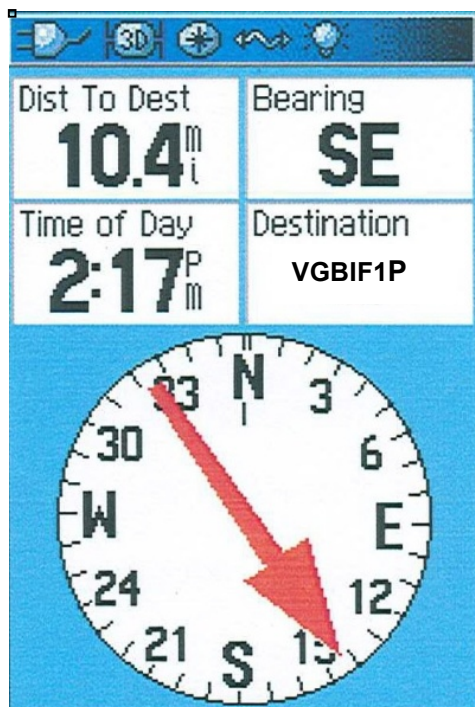
GPS Unit Compass
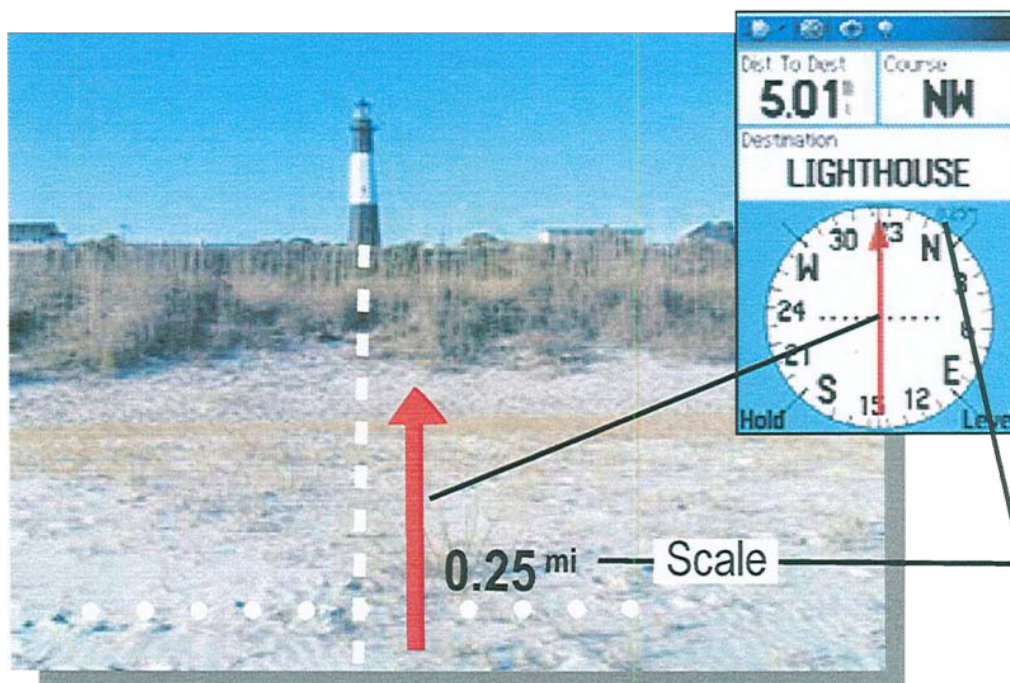
Figure 1.5. GPS Unit Compass display screen

Figure 1.6. GPS Unit Compass display screen

14.   APPENDIX 3: GIS TECHNICAL DETAILS

14.1. INTRODUCTION

The final core study area (CSA) of a site can be computer generated within a GIS to reduce the amount of subjectivity when defining the final CSA boundary. After field locations of all sampling units are uploaded to the TEAM portal and approved by TEAM staff, GIS is used to create a convex hull around each camera trap array, a convex hull around vegetation plots, buffers around each hull according to the minimum distance requirement for that protocol, and merge polygons together as the final CSA. The *GIS Technical Details* provide a detailed methodology for implementing this process using ESRI ArcMap. However, the approach outlined below can also be executed in another GIS software package such as open source GIS (e.g. Q-GIS).

14.2. Create Convex Hulls

o   Open the camera trap and vegetation shapefiles in ArcMap
o   In ArcToolbox, go to *Data Management Tool   Features   Minimum Bounding Geometry*
o   Open the field camera trap shapefile for *Input Features*
o   Name the *Output Feature Class*
o   Select *Convex_Hull* from the drop down menu for *Geometry Type (optional)*
o   Leave other fields at default and hit *OK*
    ▪   *Note: If there is more than one camera trap array and they are close to each other, merge the arrays into one shapefile first; if they are not already (e.g. CAX Sampling Design). If the camera trap arrays are significantly far from each other, then treat them as separate entities and complete the above steps for each array (e.g. MAU Sampling Design). This will exclude any large areas between arrays that are not part of the sampling area, but include areas where sampling units are placed.*
o   Repeat steps 1.2 through 1.6 for the vegetation plot shapefile
    ▪   *Note: In some instances the vegetation plots are located within the camera trap arrays, so it would not be necessary to create a convex hull around vegetation plots. The final CSA in this case would be developed using only the camera trap points. (e.g. COU Sampling Design).*

14.3. Buffer the Convex Hulls

Use the *Buffer* tool in ArcMap to create a FULL *(Side Type)* ROUND *(End Type)* 1.4 km buffer around the camera trap array(s) convex hull(s) and a 2 km buffer around the vegetation plot convex hull (if applicable)

14.4. Merge and Dissolve Polygons

If vegetation plots are within the camera trap array(s), then no further action is needed at this point and the final CSA for the site is complete. If a convex and buffer was performed for both camera trap array(s) and vegetation plots, then use the *Merge* tool followed by the *Dissolve* tool in ArcMap to aggregate polygons into one final CSA polygon.