



## FIELD MANUAL:

Sampling and analysis  
of data for large  
terrestrial mammals  
during short-term  
volunteer expeditions





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# **SAMPLING AND ANALYSIS OF DATA FOR LARGE TERRESTRIAL MAMMALS DURING SHORT-TERM VOLUNTEER EXPEDITIONS**

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## Foreword

Voluntourism is on a steep rise, but it is too often driven by profit, rather than the desire to make a genuine difference. This applies to social and teaching projects, as well as to wildlife conservation research. There are few standard methodologies in wildlife biology designed for volunteers. The marine research methodology called Reef Check ([www.reefcheck.org](http://www.reefcheck.org)) is a notable exception and as such is used on all Biosphere Expeditions coral reef projects. But there is no equivalent for terrestrial research projects. These by and large concentrate on charismatic megafauna, because megafauna inspires people to volunteer their labour and money. We as wildlife conservationists have a duty to ensure that this willingness is utilised properly, rather than exploited, yielding the best possible results and outcomes. Proper utilisation hinges around good project design and robust methodology. This manual is designed to help field biologists achieve both.

This manual is a product of several years of sampling mammals during short-term expeditions, all over the world and in particular in Brazil, Peru and the Middle East. The procedures adopted here, by maximising sample sizes and sampling effort, are meant to enable scientists to make sound ecological inferences even during short sampling periods. Furthermore, sampling is designed in such a way that a group of laypeople may be trained in a few days accurately to record genuinely useful field data. At the same time analysis requires a very short learning curve, so that it can be performed by a dedicated novice researcher, assistant researcher or student.

This manual focuses on mammal sampling, but the procedures may also be applied to other animal groups. Part 1 discusses the various sampling techniques commonly used to collect data on wildlife during short-term expeditions. Part 2 is a practical guide aimed at using the spatial data collected with any combination of the techniques discussed in Part 1. The methods and software programs discussed in Part 3 were chosen for their simplicity so that they can be rapidly mastered by a dedicated biologist.

We hope you will find this manual useful and invite questions, comments and suggestions



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# **PART 1:**

## **Basic concepts on sampling techniques and design**

### **1.1. A word on ecological inferences**

Ecological inferences are interpretations of natural systems made by scientists. The broad disciplines of ecology, environmental management or environmental sciences, for instance, will be interested in every aspect of the natural system. The disciplines of wildlife management, animal ecology and zoology, i.e. those that are dealt with directly in this manual, should not overlook the disciplines mentioned above, or focus only on the species of interest. There are many aspects that may be thought of as concerning only other disciplines, not directly related to a species of interest, such as water, climate change, human demography and waste management, which may in fact relate or interfere with the focal community, species or population.

Building up a large dataset is a good first step towards solid results, but only as long as it is of good quality and can lead into a framework of ecological inferences. Scientists that study rare species are thus faced with a tough task – the rarer the species, the harder it is to obtain data points. The main concern regarding rare species is their status, so that density and distribution generally become central topics of research. Descriptions of the current density or distribution of a species or its population within a given area are valid ecological interpretations. Detect trends in either distribution and/or density of the species and the result will be excellent and can form part of biological monitoring.

### **1.2. Sampling species that occur at low densities: rare, cryptic and iconic species**

Sampling species that occur at low densities is a tough task, but it is also a task that will inspire volunteers. Sound, relevant and highly useful studies can be conducted on termites, ants, crows, cows and other common species with volunteers, but it will be the tigers, (snow) leopards, pandas and other flagship species of this world that will inspire and attract most of the manpower and funding. A quick glance at the plethora of volunteer offerings will confirm this.

Wildlife scientists the world over wishing to tap into the volunteer resource thus face the same problem: it may be difficult to gather enough information on a rare and ‘exciting’ species to make sound ecological inferences, or at least to have the satisfaction of the project being ‘successful’. When research has its focus on a single species, field scientists will usually choose areas with high densities so that their study will be ‘productive’ (Robinson & Redford 1991, Smallwood & Schonewald 1996). If everybody does that, then the ecological inferences for that particular species will be applicable only to the areas where they have been found at higher densities, not to all landscapes. Ultimately, this bias may affect predictions of populations and their survival.

The literature that deals with methods to study species that occur at low densities make, in fact, reference to species that are declining in numbers. These species are usually threatened with extinction, but may still be locally abundant, or they may be cryptic species that are not easily seen. In both cases, however, employing modern methods for indirect observation such as camera traps, DNA scatology and tracks recording, will yield a good dataset.

But what if your target species is all of the above, as well as locally rare? In other words, with all the available tools, your species is recorded at such a low rates that ecological inferences become a distant dream? Unless you have the facilities to jump to another level and, for example, have dogs specially trained to find scats of specific species (and then use DNA scatology to identify them), you should look at alternatives. For instance, at habitat features that may provide information on the status of your study species. This requires the incorporation of such disciplines as community ecology, spatial ecology, conservation biology and the broader biological conservation approaches. While you may not often get direct information on the species you are interested in, you will not be wasting your time in the field running after a ghost. Instead you will be collecting systematic and relevant information on the habitat, threats, competition and the availability of food sources that relate directly to the survival of your species of interest.

### **1.3. Case study of jaguars in the Atlantic Forest of Brazil**

In a study of jaguars in the Serra do Mar mountain range on the southern Atlantic coast of Brazil that lasted five years, evidence of jaguar was found in only three instances. The study site was not chosen based on a presumed high density of jaguars, but because it was the southernmost population of jaguars in the Atlantic Forest that was thought could be a source of dispersing individuals for natural repopulation of adjoining, more impoverished habitats. Camera traps and tracking were employed with no success and no scat for DNA analysis was found despite intensive efforts by volunteers. By looking at several other indirect management aspects such as human interference (poaching and illegal harvesting of palm-heart), lack of protection policies (reserves lacking rangers) and indirect biological aspects, namely the geographic restriction of a key prey species (white-lipped peccaries), the conclusion was that the jaguar population was heading for local extinction if the same conditions were maintained.

The biological aspects of the geographical restriction of prey species was very important in inferring that the habitat was not homogeneous for jaguars in terms of prey. Thus, and this is not rocket science, prey availability was found to be an important variable that had a direct influence over the distribution of jaguars and their densities. This is an intuitive, simple, key - but usually overlooked - piece of information, which may be obtained during short sampling periods. As we will see later in this manual, distribution and geographic restriction of a species may be a suitable substitute to densities in wildlife management. With such information lacking or very hard and cumbersome to obtain, a species management plan may, for instance, erroneously overestimate population numbers by calculating densities based on the assumption that all habitat is equally suitable or occupied homogeneously by the study species, rather than correctly assigning different weights to different sections of the habitat.

### **1.4. Scientific foundation of sampling methods**

The disciplines of wildlife management, animal ecology and zoology are often interested only in pieces of information shared by other disciplines (such as water management and pollution or climate change) that will help them to understand conditions for wildlife populations. In the same way our method will take relevant pieces of information from spatial ecology, GIS and community ecology to fulfil its purpose. This purpose, to remind ourselves, is fast sampling and analysis on a level that is detailed enough to describe aspects of wildlife communities and habitat features. We do this with the ultimate aim of making inferences about our target species' population status.

#### 1.4.1. Geographic scope (extent of study area/scale)

The first step in this methodology is to select a study area large enough to be representative of your population. A common mistake is to select an area the size of a single home range of the species of interest. In such an area, you run the risk of collecting information mainly of a single or at most very few individuals of the population, in a single habitat, usually not representative of the population or the habitat of the study area. For a large wild cat, for example, that is known to have a home range of 10,000 hectares or larger, select a sampling area of about 10 times that or more. The larger the study area, the more you can capture habitat heterogeneity and how species respond to different aspects of the landscape. For the same reason, make sure your sampling effort is not confined to just a few kilometres around your volunteer base.

#### 1.4.2. Calculating densities or distribution and occupancy?

Do not be fooled. The calculation of animal population densities is a tall order and requires not just count data, but also the calculation of detection probabilities ( $p$ ). For example, if you count 10 animals in your study area, it does not mean that there are only 10 individuals in that area. If that count represents half of the total population, then  $p=0.5$  and your total population will be 20, rather than 10.

To calculate detection probabilities for individual species, you must use capture-recapture sampling methods. Data should be collected either by physically capturing and recapturing individuals in live traps, capturing and recapturing known individuals using camera traps or by employing line transect sampling. When using either live or camera traps, you need at least two sampling occasions, one of capture and a second of recapture. To have an idea of how the system works, if you recapture, during your second sampling, most of the individuals that you captured during your first sampling effort, then you are near to having captured the whole population. If instead you recapture just a fraction of what you first captured, your population is highly likely to be much larger than the (small) sample you have captured. In line transect sampling, you need at least 40 counts (of individuals or groups) to support strong inferences on population densities.

Usually you will only want to employ physical capture and recapture techniques to estimate population parameters (such as density) when your data recording does not cease with the end of a short volunteer expedition. It takes time to install and check traps and during a short volunteer expedition the capture rate is by and large too low to yield enough data for sound ecological inferences. The same applies to radio telemetry.

However, all is not lost if you cannot calculate densities. MacKenzie et al. (2002) argue that the presence-absence of a species in cells of its habitat may often be a viable substitute for density. They demonstrated how to apply capture-recapture theory to occupancy data. The result comes out as a percentage of the area sampled that is occupied by the species. It works just like the example given above for live and camera trap captures and recaptures. Suppose you are sampling 50 cells and you always 'recapture' individuals (regardless of their individual identities), either by tracks, sighting, or whatever other method, in 25 cells every time you sample those cells. Then the occupancy of the species will be 50% of the sampled area. Now suppose that you captured individuals during just one out of the three occasions in those 25 cells. The statistic specifically allows for the fact that the animal is not always detected when present, assuming that you are failing to record once again (i.e. recapture) species in cells in which they had previously been detected, and 'believes' that the other 25 cells you sampled with zero records may also be part of the range of the species; it is just that it was not detected.

This inflates the occupancy for species that are less easily detected. In the example given above, on the jaguars in the Atlantic Forest, the doomed population was calculated as occupying 100% of its territory (Mazzolli & Hammer 2008a). So care must be taken when applying occupancy calculations. Once again, and this is critical, the methodology assumes that low detections are a function of the shyness of the animal, not of its actual rareness.

Also of advantage for short-term volunteer expeditions with relatively few data points is the fact that you do not necessarily need to apply calculations to find occupancy. You can instead map the distribution and aggregation of species in your study area - the procedure is the same! That means that with your data collected, you can calculate occupancy if you wish. We therefore recommend the maintenance of the resampling procedures as a general rule, as the species may not always be detected during the initial sampling. But, as is so often the case in field biology, there are exceptions. In dry and essentially rain-free Oman (Mazzolli 2009, Mazzolli & Hammer 2008 and 2012), resampling was not really necessary, because tracks and scats of species remained in the cells for a long time, so there was a long 'history' of the species that crossed the cells. It was like resampling every day for many consecutive weeks in areas where signs are washed away every other day, such as in rainforests or other highly variable habitats. In Oman tracks were not seen to be erased by the wind and rain was essentially absent. Further, more than one group often sampled the same cell, and that is also resampling. The other point that is worth mentioning here is that sampling in Oman was not restricted to narrow trails as the habitat was quite open and accessible. This allowed access to several corners in each sampling cell (see below for a description of sampling cells). Resampling becomes even more imperative when sampling areas are confined to narrow trails.

#### 1.4.3. Capture history (capture/recapture information)

A capture history should always be built, even if you do not intend to analyse it statistically. In case you decide to do it later, then you already have the data. In any case, tabulating a capture history also demonstrates that you are adopting the recommended resampling procedures. Capture history can be used to calculate two parameters. Either density via the individual's history of capture or occupancy via records of species inside sampling cells.

**Table 1.** Capture history for pumas, obtained by camera traps and aiming for the calculation of densities. Presence (1) or absence (0) of individuals in each capture occasion, categorised by age and sex classes as adult males (AM), adult females (AF), sub-adult males (SM), sub-adult females (SF) and sub-adult of unknown sex (S). Each capture occasion corresponds to a period of a month from June 1998 to August 1999.

Individual	Capture occasions													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
AM1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AM2	0	0	0	1	0	1	1	0	1	0	0	0	0	1
AM3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
AF1	1	1	0	0	0	1	0	0	0	1	1	1	0	0
AF2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
AF3	0	0	0	1	0	1	0	0	0	0	0	0	0	0
AF4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
SM1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
SM2	0	0	0	1	0	0	0	0	0	1	0	1	0	0
S3	0	0	0	0	0	0	0	0	0	0	0	1	0	0



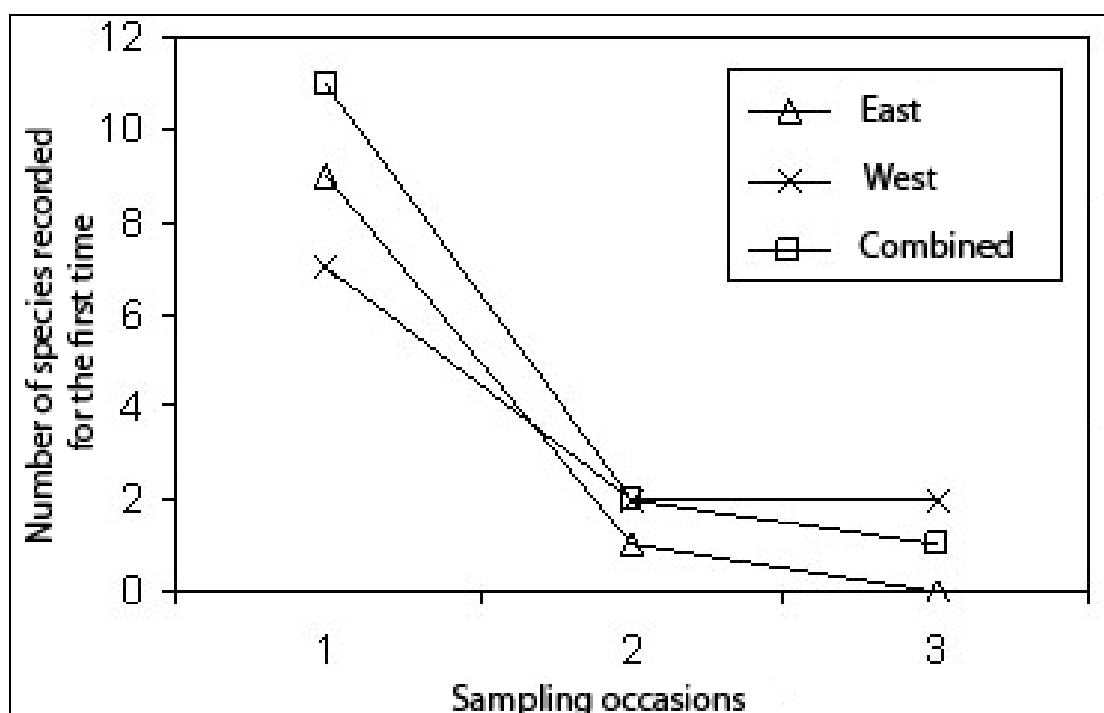
Two examples are given here, one for camera trap data that were later analysed for density of pumas using the software program CAPTURE (White et al. 1982, Mazzolli 2010a) (table 1), and the other for presence-absence later analysed for occupancy with the software program PRESENCE (Mazzolli & Hammer 2008) (table 2). You may not need to go into that at first, but if you wish to do so, you can find more on this topic in Otis et al. (1978), White et al. (1982), Rexstad & Burnham (1991) for CAPTURE and MacKenzie et al. (2002, 2003) for PRESENCE.

**Table 2.** Presence-absence data of jaguar, puma and ocelot (translated and adapted from the original in Portuguese).

Locality (cells)	Species								
	Puma			Jaguar			Ocelot		
Cell 1	1	1	1	0	1	0	0	0	1
Cell 2	0	0	0	0	0	0	0	0	0
etc									

#### 1.4.4. Sampling sufficiency

Species may not be detected even when present and this is the main issue here. Make sure you have sampled enough before making inferences. Be convincing and explain in the methodology of your report why you believe your cells have been sufficiently sampled. Show that you have performed the resampling scheme described in this manual, thereby avoiding inferences based on a single reading. If you are not sure, then the use of statistical tools is recommended. The use of species curves (White et al. 1982; Rexstad & Burnham, 1991) (figure 1), for example, and/or the calculation of occupancy (MacKenzie et al. 2002, 2003).



**Figure 1.** Species cumulative curve for each region of the study area (east and west), and combined for the entire area, during three sampling occasions. Each sample occasion lasted two weeks.

If you aim to estimate species richness by sampling a large number of species, adopt species curves to verify sampling sufficiency. This may also be statistically tested for precision using CAPTURE using the removal method (Rexstad & Burnham 1991). In the example above, sampling sufficiency was tested for two regions of the study area (Mazzolli & Hammer 2008) (figure 1). The software tests for closeness (or closure) of the population (no significant number of migrations, deaths or births during sampling that may interfere in your results) (Lindberg & Rexstad 2002) and calculates the confidence interval of the estimated richness.

#### 1.4.5. Standardising sampling efforts

One simple but often overlooked procedure is the standardisation of sampling effort. The principle of standardisation is very simple. If you aim to understand species' distribution patterns within your study area, you should not sample in one section of the study area more than in the other; otherwise it may result in bias.

Sampling for tracks is a main issue in some regions, as the substrate may vary depending on the location, which means that detectability will also vary. For example, your target species will be better detected in areas of soft substrate, in contrast to areas of hard substrate. That is why in some experiments researchers build track traps at regular intervals to standardise the sampling procedure. In Peru, for example, we have used track traps at 200 m intervals for jaguar and puma and it worked fine.

#### 1.4.6. Camera traps

Camera traps may be used to identify individuals and derive population densities for species that can be identified by their coat patterns (Karanth and Nichols 1998, Mazzolli 2010a). But this only works if individuals are relatively abundant in the study area. In this case, the utilisation of two cameras for a single camera trap station is recommended (Karanth et al. 2004).

There are situations in which attempting to estimate densities from camera traps may not work. It is better to know in advance in which cases you should not attempt to calculate densities. In the case of rare species, or more specifically, in the case of species that will be photographed only occasionally during your expedition, and of those that cannot be identified by their coat patterns, use single camera traps instead, distributed at different habitats throughout your study area. You can then focus your efforts on finding distribution and occupancy patterns (see below) instead of densities.

We recommend that you select camera traps that have an infrared system, rather than a visible flash, particularly if sampling in locations where people use trails as walking routes. A visible flash attracts attention and people may be tempted to take your cameras.

#### 1.4.7. Scat identification

With very few exceptions, a basic rule is not to attempt to identify scats of carnivores, either macroscopically or microscopically, regardless of what your local (or global, for that matter) guide or scientist says! There are very few people in the world who can identify scats by sight and even established and experienced field workers have error rates of 50% or more (see Perez et al. 2006, Janecka et al. 2008, Harrison 2002, Vanstreels et al. 2010). Relying on volunteers to identify scats by sight is very likely to invalidate your results. Therefore, it is better to loose information than to add misleading information to your sample. Scats of carnivore must, for the sake of precision (and science is based on precision), be sent for DNA analysis wherever

possible. In Oman, for instance, over 30 scats were collected as likely to belong to Arabian leopard. DNA analysis of these scats showed that only one was in fact from a leopard (Mazzolli & Hammer 2012). Collecting many signs such as scats is good as it increases sample size, but extreme care must be taken when there is the slightest doubt about positive identification of animal sign and records, which is where DNA analysis provides irrefutable proof.

If you are able otherwise to identify with precision your animal records (for example, if you are able to either photograph or to record unmistakeable tracks of your species of interest), then DNA analysis could be regarded optional (but it would still be useful for cross-checking and adding another layer of information). The use of trained dogs to find hidden scats, as mentioned earlier, is another method that can be used when scats are difficult to find and identify, but this requires facilities that are unlikely to be available during short-term expeditions.

There are two types of DNA analysis: species level and individual animal level. There is a large difference in the cost (with the individual level much more expensive) and you should choose which one is best to answer your ecological questions. If you are happy with distributional information and occupancy, species level identification is enough. If you want to know how individuals range over a given area or calculate densities, then resolution at the level of individual animals is probably what you need. Of course range data for an individual can also be obtained by telemetry, preferably with a GPS collar that yields a continuous data stream once fitted. Remember that in order to have a statistically useable count to estimate densities, you need at least two sampling occasions (capture and recapture) (see Boulanger et al. 2008 for an application).

It may also be that not all scats of herbivores are readily identifiable. Define which ones are and which are not before your expedition, unless your expedition is the first, pilot study. Have the scats of herbivores photographed with a scale and incorporate that photograph into the field guides for your volunteer team (figure 2). If possible make sure that photographs in your field guide are life size, i.e. 1 cm on the photo corresponds to 1 cm in nature. It is also a good idea to have a scat reference collection in labelled jars at base so that your volunteer team has a life size 3D study aid.



**Figure 2.** Example of how to have identifiable scats photographed to assist during field study. Scats from ibex (left), hyrax (top) and gazelle (bottom right). Photo G. Kelly. From the Biosphere Expeditions Oman 2008 expedition report (see [www.biosphere-expeditions.org/reports](http://www.biosphere-expeditions.org/reports)).

#### 1.4.8. Track identification

As with scats, track identification is very useful, but again accurate track identification may be very difficult if you do not establish first which species can and which cannot be identified easily and reliably by their tracks by volunteers. For instance, there are several species of brocket deer and small cats in Brazil that cannot be distinguished from one another. Tracks of wolf and German shepherd dog, for example, are also very hard to distinguish, even by experts. Again, there are very few people left in the world who can identify animal tracks with the precision required for scientific studies, especially if the substrate is not favourable for clear imprints. If your target species (those of fundamental importance for your research) can be confused with other species using track identification (or any other method by that matter), search for other sampling techniques that give more precise results. Also always be aware of human nature and the pressures of an expedition environment. Many people will claim to be able to identify tracks accurately, but very few will actually have that skill. Communicate clearly to your volunteers and staff the fact that species identification by tracks is a difficult skill, mastered only by very few after a lifetime of learning. If you discount track and scat identification of certain species from the start and give the reasons why (inaccuracy, high mistake rates even amongst experts, etc.), then you will remove a lot of pressure from the group and increase your data collection accuracy. Be sure to mention this in your report too.

If you do decide to allow for track data collection, then, as with scats, have the tracks of target species photographed side by side with a scale and incorporate that photograph into the field guide for your volunteer field team, preferably at life size 1:1 scale. Plaster casts of tracks or other study aids, where available (such as models of hooves), are also useful.

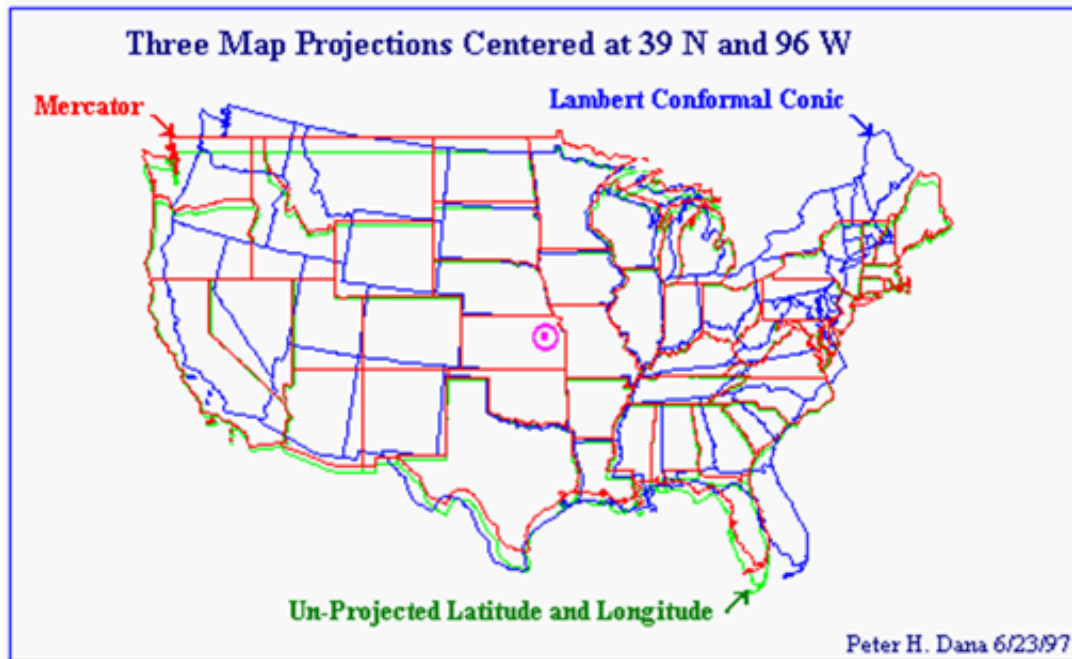
#### 1.4.9. Geographical information system (GIS) & GPS settings

In simple words a GIS (geographical information system) is a means to connect a database to features (polygons, lines and points) on a map. The GIS will store any information you want to include regarding any feature on a map. These features can then pop up with a mouse click as required and be cross-referenced on your screen. Features are stored in layers. For example one layer with vegetation, another with water bodies, one layer for carnivore data, another for herbivore data, etc. The GIS can also process information and produce maps on agglomeration of species and other phenomena that you might be interested in analysing, or categorise features from satellite images, such as land use.

While we consider it worthwhile to learn how to use GIS, we do not encourage its use for those that are being introduced to spatial ecology, nor is it needed for the purposes of this manual. The GIS substitution method that we employ here is not displayed in layers and cannot analyse data. Although fairly simple, the method is enough to yield satisfactory outputs for sound ecological inferences and as such is appropriate for publication in international scientific journals and of course for expedition reports.

Before using GIS or any other software that has a coordinate system, you must understand the basics of map projections. Projections are how the world or any part of the world is seen in two dimensions, or in other words, a method of representing the surface of a naturally curved geographic region on a flat surface. Why is this important? Depending on what projection you are using, your map (and other features such as data points) may fall in different places (figure 3).

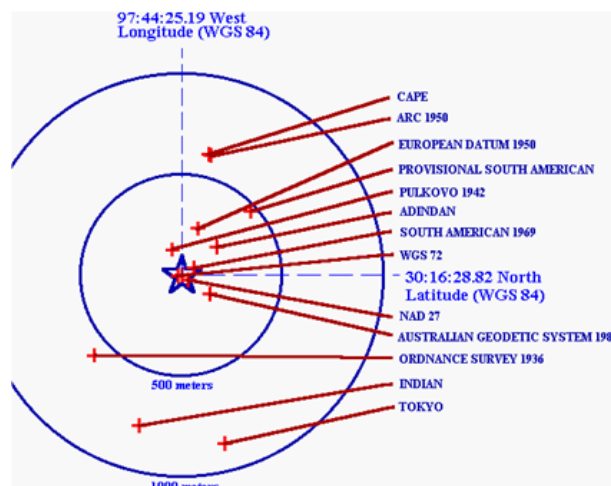




**Figure 3.** Three different map projections of the United States, highlighting the different positions of each.

Datum is another configuration that should be exact. Datum is the way the earth is represented as an ellipse. There are different ellipses and thus different types of datum.

Both datum and projections must be configured in your GPS and also in the coordinate system of your software. Make sure that all GPS units used by your research team use the same coordinate and location systems! The most commonly coordinate systems are the Universal Transverse Mercator projection, which is a metrical grid, and the WGS 84 Datum (Figure 4). In high latitudes, the Universal Polar Stereographic projection is used instead. Most GPS and pieces of software come with the two options together (UTM/UPS). The UTM projection is divided into zones. The zone number followed by a letter appears in your GPS when you select UTM as the method of recording your data points. It is important to record the zone in your datasheet when using UTM/UPS systems, particularly if your study area is located across two zones. If you are not working in zones, make sure all GPS units are set to display and work in the same units (for example degrees, minutes and seconds). Finally using the track log function can also be a great help as tracks can easily be exported into Google Earth and other applications.



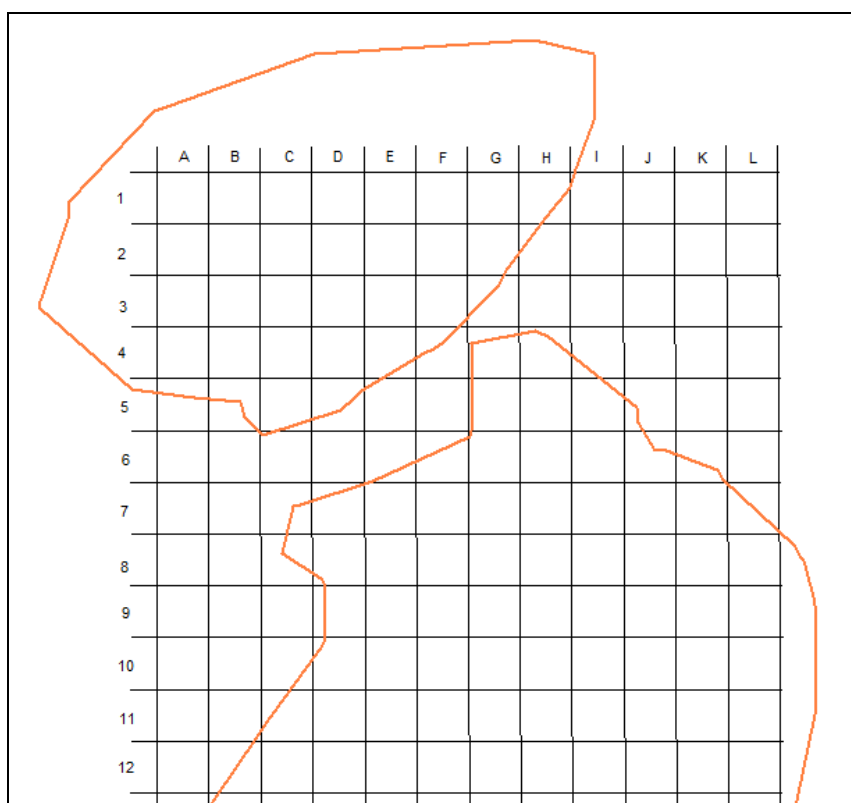
**Figure 4.** Differences in distance of the same data point taken using different types of datum. The inner circle is 500 metres in diameter, the outer circle is 1000 metres.

## PART 2: Practical application

### 2.1. Equipment and software

You need a GPS that you can upload maps to, so that you can upload a grid, with cells that will be the units of your analysis. The Garmin models HCX and GPS60 have worked fine on expedition. Avoid the ones in which the screen is pixelated, such as the Garmin H model – you will not be able to read the cell codes that are uploaded with the grid. If you already have a set of GPS units that are outside these specifications, you need to record every feature you see in the field as coordinates. It will take more of your precious field time (and it may result in smaller areas surveyed), by eventually and unknowingly having to repeat recordings of the same species in the same cell, on the same day - not necessary if you consider the cell as your smallest sampling unit.

We will be using the software TrackMaker (Geo Studio Tech, MG), a Brazilian software with an option to be used in English (available as freeware at [www.trackmaker.com](http://www.trackmaker.com)). It is capable of uploading from and downloading to GPS units and it also imports from and exports to Google Earth. An example of this functionality is the definition of the study area in Slovakia. The study area was located in Google Earth and a square was drawn around it. The square was then exported from Google Earth as a .KML file and imported into TrackMaker, with the coordinate system intact, to have the grid designed over that area (see details on the use of grids below). For illustrative purposes the (rough) boundaries of the two national parks containing the sample areas were also drawn (figure 5). Remember that the software will work only after you install the GPS recognition software (drivers) on your computer.



**Figure 5.** The grid system over part of the study area in Slovakia.

Contours of the national parks Malá Fatra and the northern area of Veľká Fatra are rough sketches for illustrative purposes. The grid is available [here](#) and can be used as a template for different projects.

## 2.2. Using the grid system

Using cells as units of analysis is usually better than using individual GPS points. Using cells allows the examination of data at a wider scale, that is, you must seek information from different cells that are spread from each other to have a significant result, avoiding data autocorrelation. Grid cells that are 2 by 2 km in size have been employed successfully so far. But using a cell system does not mean that you should avoid taking individual GPS points of findings of interest. Those individual GPS points are still useful; for example to guide you back either to install camera traps or to double check information that has been recorded at such points.

The grid will be used only to be uploaded to the GPS units. The data on species presence inside each cell will be read in the field and transferred to datasheets designed to be used with the system.

In practice, research teams will walk with their GPS units with the map page containing the grid and the cell codes. When teams find occupancy evidence, they will record on their datasheet the presence of a species inside the cell code shown on their GPS. In the end this will result in a GIS in which species are recorded as being present in particular cells (table 3).

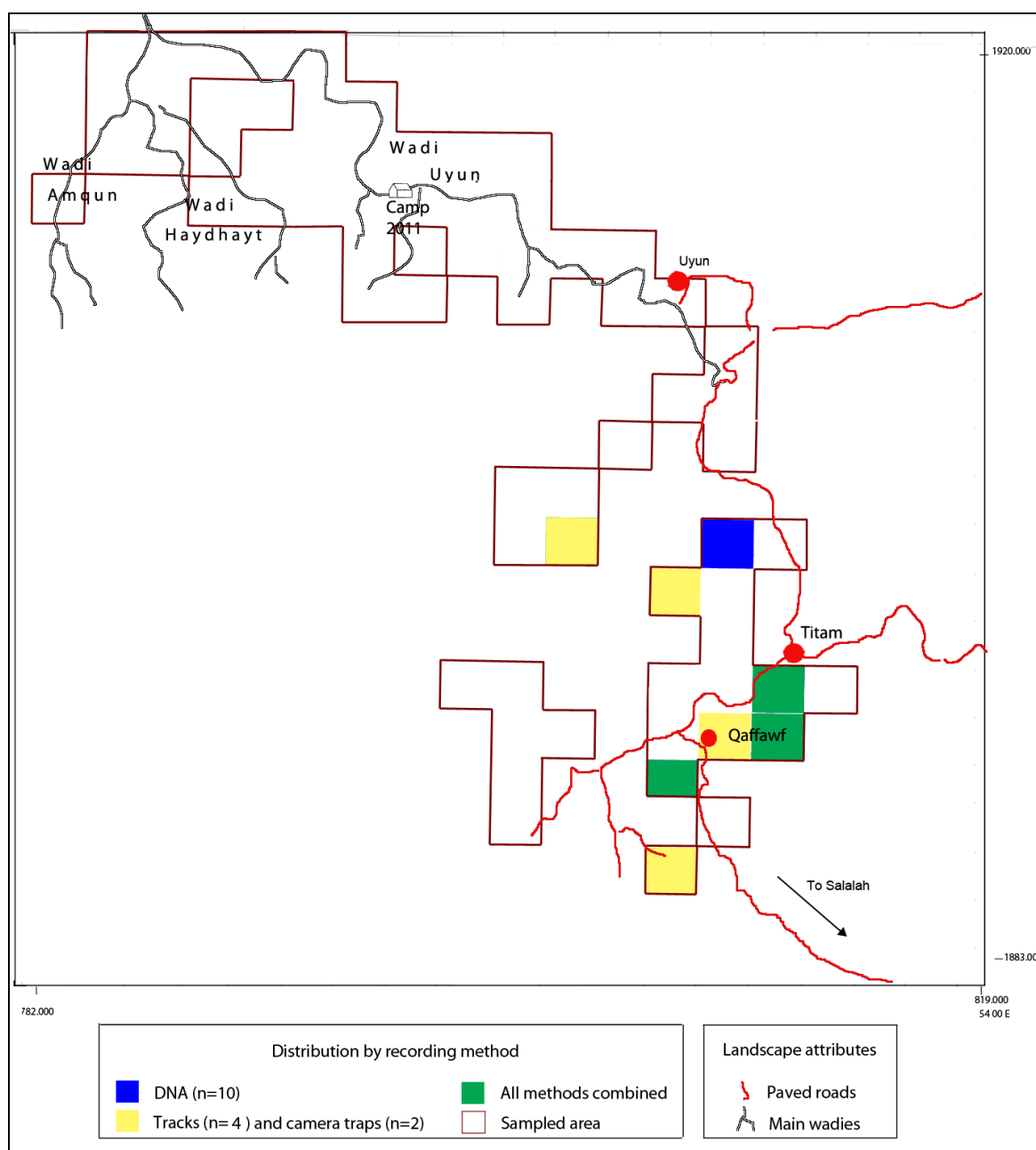
**Table 3.** Example of data collected with the grid system. DNA analysis not included here. From the Biosphere Expedition Oman 2012 report (see [www.biosphere-expeditions.org/reports](http://www.biosphere-expeditions.org/reports)).

Species	Cells	Type of record
Caracal	10B/18E	Track, camera trap
Hyrax	21F/18F/15D/15C/20F/19E/ 14B/15-16F/11B/11A/10B/ 20I/22G/22H /17D/17E//17N/18C/18E/18J/18K/18Q/19J/19K/21L/22L/22N/24N/14C	Track, scat, camera trap, carcass
etc		

The grid cell system also has the added advantage of being a real motivator for participants. Make sure you have a large map or sheet prominently displayed at your volunteer base. At the end of each day, gather together your research team and add which species were found in which cells by whom. Doing this is a great way to motivate the team. They can see progress, their contribution and they gain an understanding of how hours spent walking around the study site looking for things slowly add up to a bigger, useful picture. It is also likely to motivate people to work harder. Under your guidance people may compete for number of cells covered each day, signs found, etc. Make sure, however, that this enthusiasm and competition does not result in sloppy, fast surveying to cover more cells, or data points being invented to “beat” the others. Your role as lead scientist in channelling enthusiasm in the right direction is vital. We also recommend that you are the only person adding data to the big, public sheets as otherwise things may get written down several times by different people who do not communicate what they have done.

When you have gathered all your data, you should fill the cells with the presence for each species. GIS software has graphical means to do that, but in our example with TrackMaker, we will use a piece of paint software to do that. Any paint program will do, from Adobe Photoshop to Windows Paint. The trick is to capture the grid system (as in figure 5) and paint the cells individually.

This can be done with different colours or shadings for different species or different graphics for each species. The free version of TrackMaker does not export in image format (JPG, TIF, etc), so you need to take one or more screen shots and combine them in your paint program. Do not forget to add reference points such as base camp location and trails sampled. In the Oman example below (figure 6), trails sampled were the 'wadis' (valleys). These features were obtained from a local map inserted in TrackMaker as a background for the GPS points, and the trail lines were drawn on top of it. You can also draw features such as roads, forest tracks, etc. in Google Earth instead of using background maps, and insert them into TrackMaker. The final result is the contour of the study area (all the cells that have been sampled), where cells painted are those where species have been recorded. In the example below (figure 6), the distribution shown is that of wolf during the 2011 Biosphere Expeditions study in Oman. Note the wolf's geographical restriction to the south of the sampled area (a worthwhile ecological finding). Note also the different colours representing different sampling techniques.



**Figure 6.** Grid contour of the study area with presence of wolf highlighted in painted cells. Different colours represent different recording techniques or combination of techniques.



## 2.3. Resampling information

As mentioned earlier, it is advisable to keep a resampling record, which can be of species or cells. Both examples are given below with data from the Biosphere Expeditions Peru expedition (Mazzolli 2011) and Projeto Puma expedition to Brazil (Mazzolli 2010b) (table 4) and a hypothetical resampling of cells (table 5).

**Table 4.** Two examples of tabulating species resampling data.

Using track-trap data. J = jaguar, X = absence of tracks, — = not sampled during the period.

Nº	Cell code	Track trap code	Occasions - Days in June 2011									
			10	11	13	14	15	16	20	24	27	28
1	I8	TC 550	—	X	X	X	—	—	—	X	J	—
2	I8	TC 850	—	X	J	X	—	—	—	X	X	—
3	I8	TC 1000	—	J	X	J	—	—	—	X	X	—
4	I8	TC 1100	—	J	X	X	—	—	—	X	X	—
etc	I8	TC 1500	—	X	X	J	—	—	—	X	X	—

Methods combined.

Espécies / Species	Data / Date (2010)			
	2 August	5 August	6 August	8 August
Anta / Tapir		X	X	X
Bugio / Howler monkey				
Gambá / Opossum				
Etc				

**Table 5.** Example of resampling of cells with hypothetical data.

Quadrat (cell)	Number of times resampled					
	1	2	3	4	5	6
9i	x	x	x			
9j	x	x				
10h	x	x	x			
Etc						

## 2.4. Organising your data while in the field

As mentioned above, it is recommended that you have datasheets of species and/or a map of the study site with cells hanging on the wall of your main expedition communal area. Add your data to this every night, so that the progress you make can be seen by everyone. It is also much easier to produce the report if you keep on top of data organisation every day. You can also use the information you have already gathered to inform your strategy for further data collection. Again, the more you involve your volunteers into your thinking and decision-making, the more motivated they will be, and the easier it will be to channel their enthusiasm. Better understanding by motivated volunteers also results in more accurate data collection.

Also make sure to download data from all GPS units every night, saving the day-by-day files. From those, build a new map every night, with trails and features that you want everyone to have in their GPS units for the next day. Upload the updated file to all GPS units. GPSs are usually bloated with useless information such as back and forth tracks of the same trails. Clean those up by drawing a single line over them in TrackMaker and erase the rest. But remember to always keep the original files as a backup.

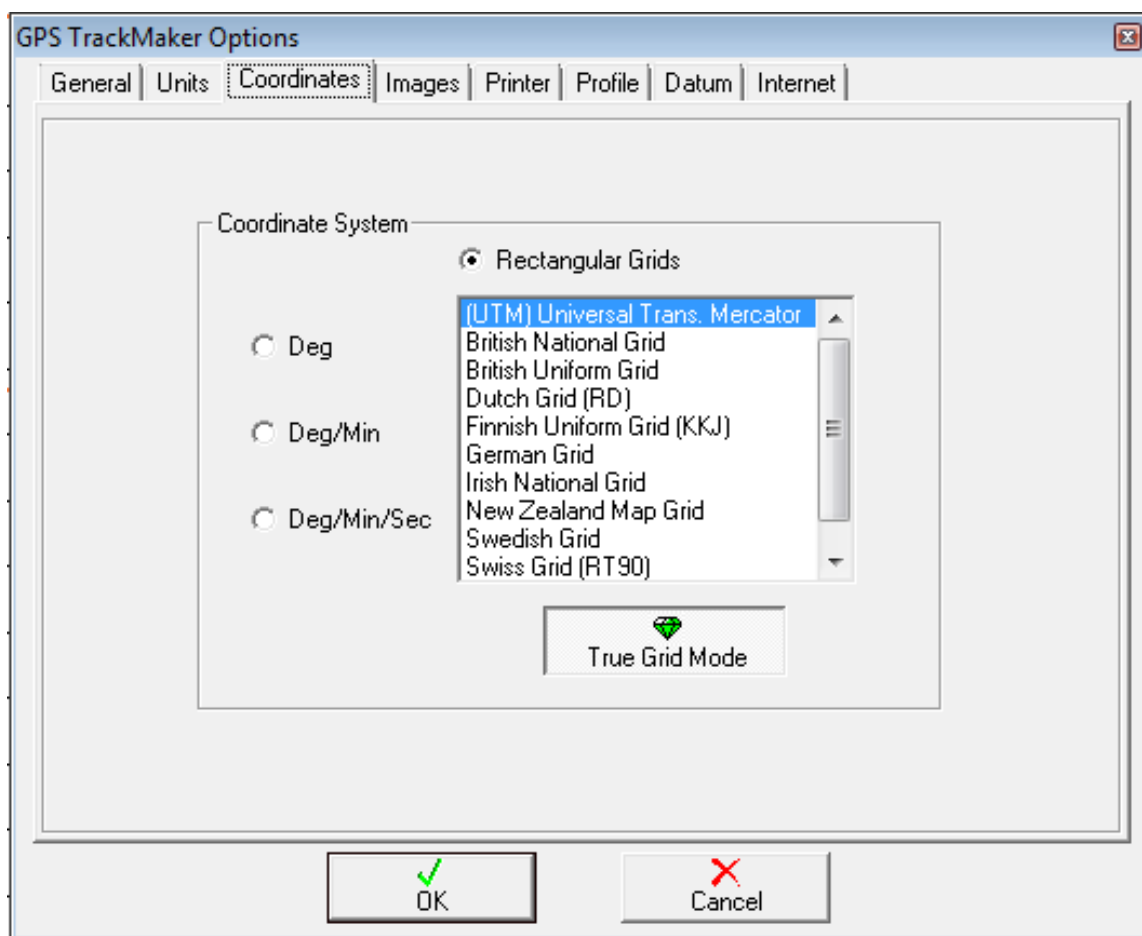
## Part 3:

# Using software: TrackMaker and generic paint software

### 3.1. TrackMaker

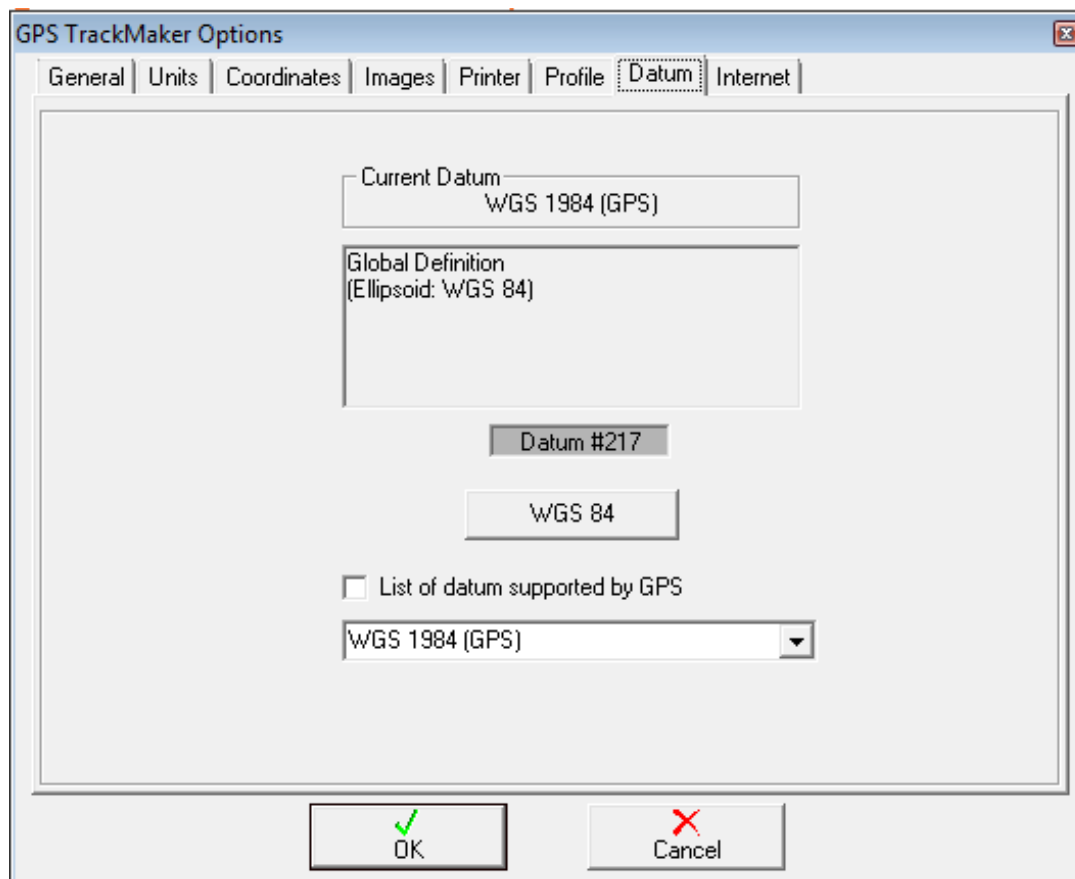
The manual that comes within the program is very self-explanatory and the grid template should help with the implementation of the cell system. Below we explain some features that we deem relevant.

First of all you should check if your configurations are correct. Access the menu Tools/Options and the tab Coordinates to see the coordinate configuration (figure 7). It is recommended to work with the UTM system, unless you want to use features from a background map of the study area that uses a different system. You can always change from one system to the other, either in your GPS or in TrackMaker.



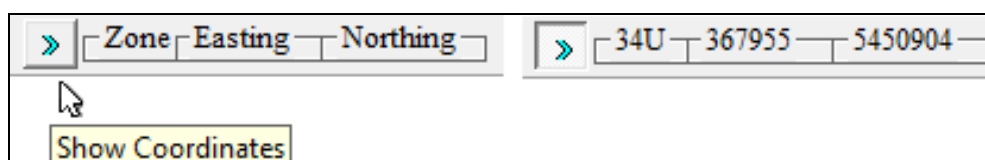
**Figure 7.** Configure your coordinate system to UTM or any other system projection you want to use.

In the same menu window, choose the tab Datum to select the appropriate Datum (figure 8).



**Figure 8.** Choose the appropriate Datum. Google Earth uses datum WGS 1984.

Now you are ready to insert or build your cell grid. Activate the grid in the View menu to see a grid background on your drawings. Zoom in until the grid is seen at one by one km squares. Draw a line at every two lines of the grid to have a 2x2 km grid. After you have done that, make sure it is in the correct location. One way to do this is to check if it is in the correct UTM zone in case you are using UTM projection (figure 9).



**Figure 9.** The menu at the top shows the UTM zone and coordinates when you browse with your mouse pointer through the grid system. Click the blue arrows to 'show coordinates'.

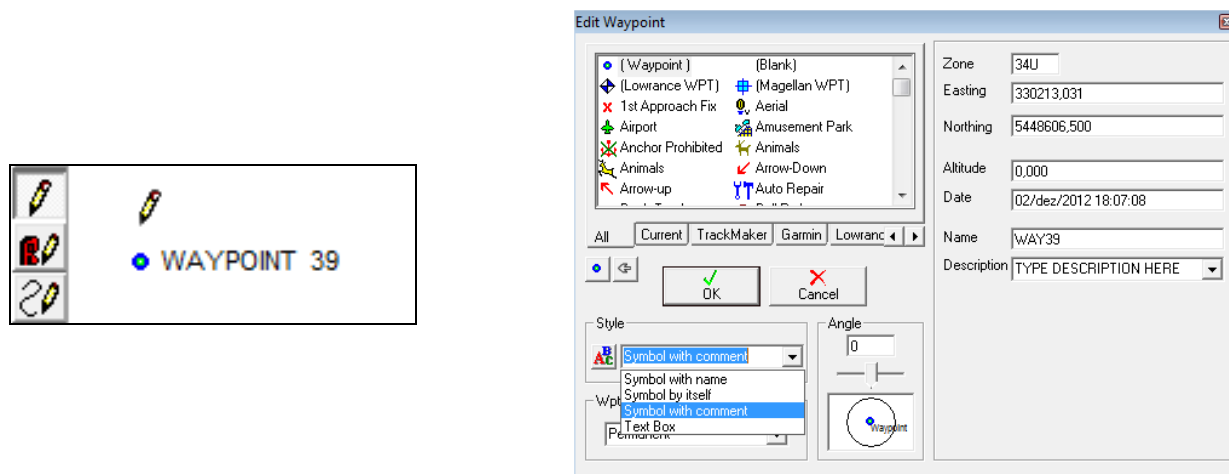
Another handy tool is the Google Earth direct link. Click its button and your features will be transferred to Google Earth (if you have it installed on your computer) (figure 10).



**Figure 10.** Click the Google Earth button to transfer your features to Google Earth.

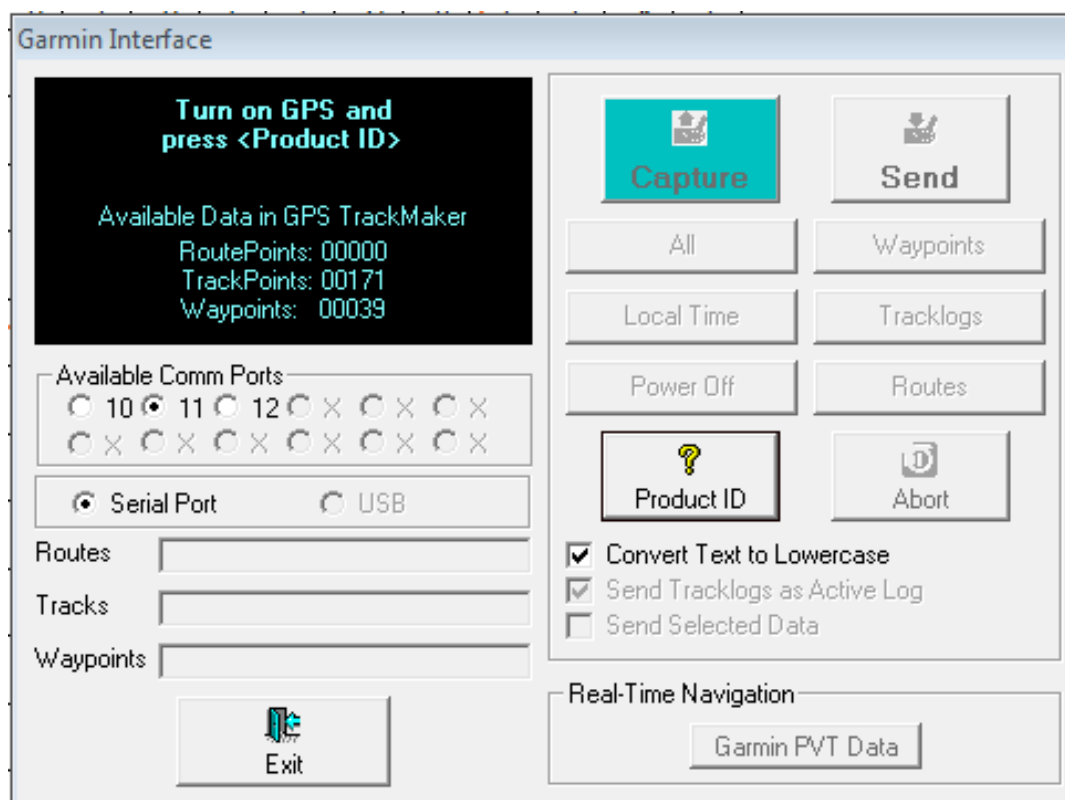


You can use the pencil tool to insert waypoints (data points) directly into TrackMaker (figure 11 left). This is also the only way to type text into the program. The numbers and letters in the grid systems are in fact waypoints whose names have been changed. Options for changing description and symbol appear when you right-click the waypoint (figure 11 right).



**Figure 11.** The waypoint tool (pencil) and options to edit waypoints. Right-click on the waypoint to edit it.

Connect your GPS to upload the cell grid by accessing the menu GPS and then the brand of your GPS. Below is an example of the pop-up window of the Garmin interface, but with the device not connected (figure 12). Once it is connected and working, it will automatically detect the device's brand and model.

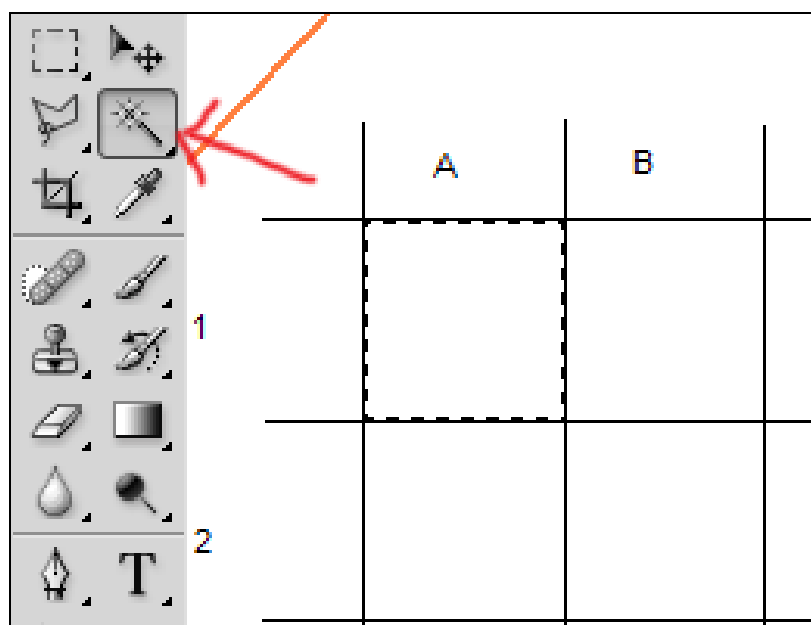


**Figure 12.** Window to upload and download features to the GPS. You can choose to upload/download just waypoints or also trails (tracks).


### 3.2. Generic paint program

Capture your final cell grid and paste it into your paint program. You may need to capture the cell grid in pieces and then join those in your paint program.

The main editing will be the legend and text, as well the colouring of cells. Do not forget to bring at least two coordinate points on your grid into the paint program, an upper left and a lower right point. To paint a cell, select the Magic Wand (figure 13) and select the inner part of the cell you want to colour. If needed, set the tolerance level to an appropriately low value. Low means that the wand will select pixels with colour close to where you touch the wand; higher tolerance selects a broader range of colour values.



**Figure 13.** The Magic Wand tool in Adobe Photoshop.  
Other paint programs will have a similar looking tool.

Use the Bucket  tool to add colour. You may need some time to get acquainted and find some of the tools. Select a colour and colour the cell as you need to.

Once you have finished your grid, save it as TIF or JPG file and import it into your report.

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