aged, then soil temperature may be a necessary parameter to measure for more accurate determination of the duration of pupariation.

Observations should be made each day of the year by a competent observer, preferably at the same time each day and instruments should be of a standard design, and should be set up on generally level ground away from obstructions like fences, plants, trees and buildings. The site should be representative of its general location and be sufficiently durable to last for the duration of the project.

2.4. PREPARATORY PHASE

AW–IPM for tsetse flies cannot be successfully planned and implemented without a survey to collect essential baseline data. The importance of the initial planning phase to the successful implementation of such a tsetse suppression/eradication eradication project cannot be overemphasized. Whilst seemingly obvious, this very often does not happen, partly because project funding is frequently of a limited duration, typically a maximum of five years and as soon as project staff is recruited/assembled, there is pressure on them to start implementation of the suppression phase as soon as possible. Furthermore, there are few purely tsetse suppression/eradication projects and most projects will most likely be associated with rural development or human African trypanosomosis (HAT) outbreaks, and therefore, there will be additional activities to prepare and implement at the same time as a tsetse survey. It is therefore appropriate to give attention to the following steps that are necessary in the planning of a tsetse survey.

2.4.1. Area Identification

The first step is the selection of a tsetse-infested area in which an area-wide suppression/eradication programme is proposed, requiring the survey to take place. This area will normally have been determined by a regional coordination meeting comprising representatives of national governments of the countries involved, or, in the case of areas of infestation that do not cross international borders, representatives of the national and local government. The area will have been selected using criteria such as high potential for agriculture and livestock production (**Table 2.1**) (high rainfall area); relative isolation of the tsetse infestation with a limited number of tsetse species; or it may have been selected in response to an epidemic of trypanosomosis (animal or human) or the need to resettle human populations. Predictive and known distribution maps will be very important in selecting, and determining the limits of locations suitable for AW–IPM.

Assuming that technical specialists have assessed that the area is suitable for the proposed suppression/eradication interventions, the next step is to define the limits of the area.

2.4.1.1. GIS as a Planning Tool

A geographic information system (GIS) offers a powerful collection of software tools, instruments (global positioning systems - GPS) and techniques to manage and display data when at least part of the data contains a location component. Using GIS we can merge together and present data on maps in a clear and graphically powerful manner. GIS software such as Arcview® and ArcGIS® can read data or convert files from a wide variety of sources.

2.4.1.2. Preparation of Maps of the Area

To initialize the GIS capabilities for use in a tsetse control programme, a collection of base layers or maps must be obtained. These base maps are computer files in a format which GIS software uses, such as the popular shape file. Some layers are available freely from various sources, e.g. ESRI world maps, Africa data dissemination service, and digital charts of the world (basic maps that are freely available on the internet, but the borders of these maps are not always precise).

Accurate maps are often available from various sources within a country such as the government survey office. These may include land use/vegetation cover, detailed information on human habitation and road or communications networks, rivers and administrative boundaries. If digital formatted maps are lacking then printed topographic maps at scales of 1:50 000 can be scanned, and "registered" to appear in their proper location in a GIS programme. Obtaining hard copies of topographic maps at the 1:200 000 or 1:50 000 scales can sometimes be difficult, especially in countries involved in conflicts, requiring bureaucratic procedures to be followed.

In contrast, satellite images can be obtained commercially over the internet and can be invaluable for identifying potential habitats, vegetation and land use mapping. Some of the satellite imagery is available at low cost, or for free at one kilometre or 30-metre resolution. Higher resolution images, with a 10-metre or finer resolution are more expensive and are required for projects of small scope.

Other maps should also be obtained, if available, for land use/vegetation, habitation, previously determined tsetse distribution and human and livestock distribution and abundance. If possible such maps should be obtained as data files in a GIS format. Otherwise, digital files should be prepared by scanned and registering hard copy maps. The International Atomic Energy Agency (IAEA) commissioned a project for creating a data set of predicted tsetse distribution from the Environmental Research Group Oxford (ERGO). In May of 2003 dataset of predictive distribution layers was completed, and the GIS files are supplied by IAEA on CD for all African countries covered by the project and for all species of tsetse. While the maps can be viewed on the web (http://ergodd.zoo.ox.ac.uk/tseweb/distributions.htm) the GIS data files themselves are supplied on request from IAEA. Finally, other layers can be added by utilizing a GPS instrument to locate and trace out features in the field that are not available from other sources (see 2.4.2).

TABLE 2.5
Map scale and satellite imagery in relation to project size.

Size of project	Preferred map scale	Source of satellite imagery
Up to 1000 km^2	1:50 000 minimum	LandSat, Quickbird, SPOT
1000 km^2–4000 km^2	1:250 000	SPOT, LandSat
Above 4000 km^2	1:100 000 or smaller	LandSat

2.4.1.3. Role of GIS and Remote Sensing

At present GIS and remote sensing are still underused, partly because of a lack of sufficient expertise, but there is no doubt that they will become indispensable for any systematic survey in the years to come (Cox and Vreysen 2005, Cox 2007).

The benefits of the new technologies include: (1) digital maps – to which new layers can be added – for planning surveys and monitoring progress, (2) satellite images – that can be used to identify and map land use characteristics such as vegetation types that can be linked to tsetse habitat – for planning surveys and interpretation, (3) analytical tools – (software) that will allow complicated analyses to be made – correlation with parameters in other layers, e.g. vegetation types, climatic data, distributions of livestock and many more, and the possibility of making predictions of distribution and abundance (predictive maps) based on those data, and (4) clear understandable results – mapping out the results of a survey gives everyone a clear graphic view of the area treated, abundance of tsetse, and allows cross referencing and intersecting of data that is not comprehensible in any other way.

The following provides some examples on the potential that GIS has to offer with respect to entomological surveys.

In **Figure 2.3**, Arcview® GIS software was used to display each trap position as a blue symbol on the background of vegetation layers, and roads and rivers. In this example, cattle being monitored for trypanosomosis are also shown. **Figure 2.4** shows the apparent densities (flies per trap per day) of tsetse caught at each trap position over the period of the survey using a colour ramp (known as a "coropleth"). Values are grouped into classes of high, medium, low and zero density. These same values of flies per trap per day are shown

FIGURE 2.3
Display in Arview® GIS showing a map indicating tsetse trap locations in western Gambia

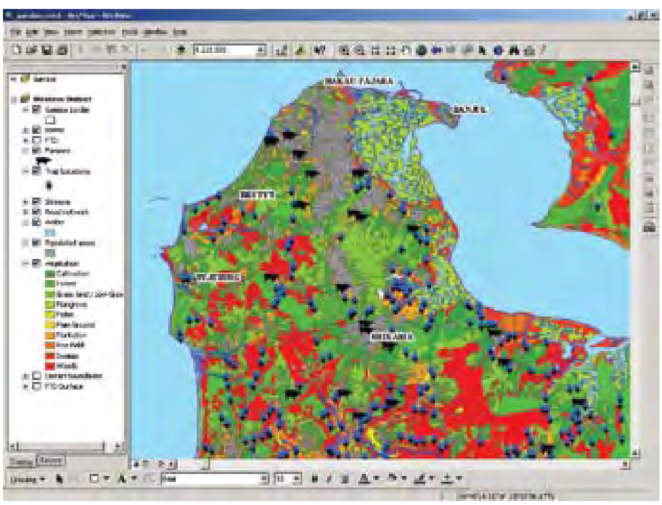


FIGURE 2.4
ArcView® GIS image of a map in western Gambia, displaying tsetse fly apparent densities (no. flies per trap per day) by a colour map

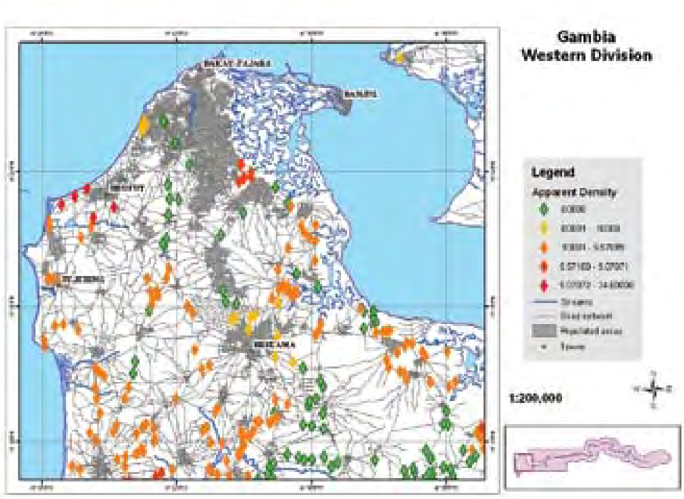


FIGURE 2.5
ArcView® GIS image of a map in western Gambia, displaying tsetse fly apparent densities (no. flies per trap per day) by graduated symbols

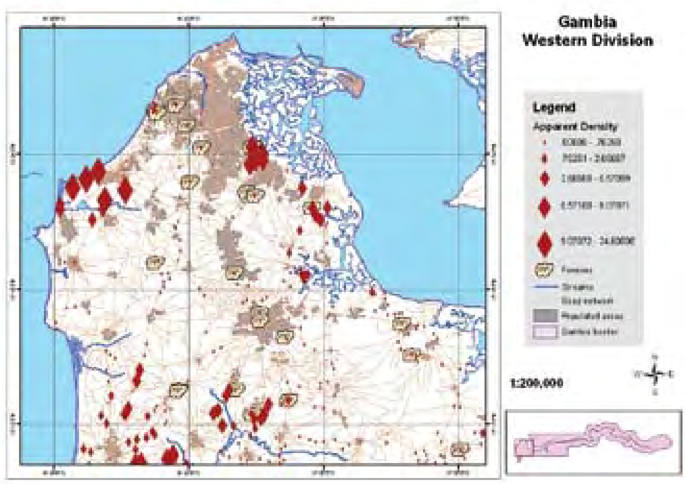
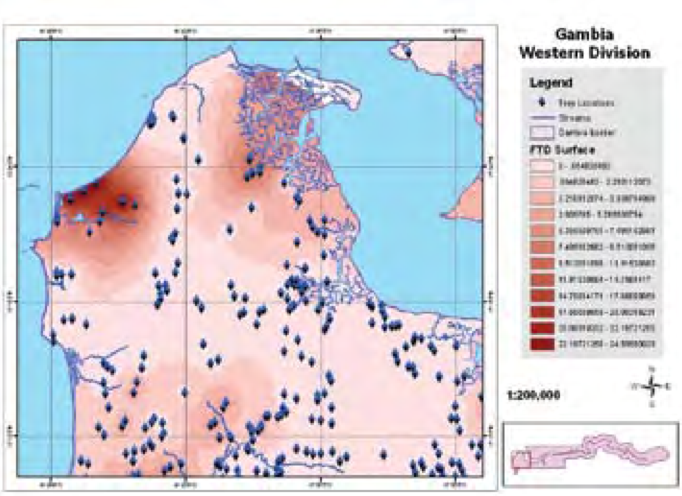


FIGURE 2.6
ArcView® GIS image of a map in western Gambia, displaying trap locations and tsetse fly catch data (no. flies per trap per day) interpolated to a surface



in **Figure 2.5** by using graduated sizes of symbols. This facilitates the identification of areas of high and low tsetse density, which is usually linked closely to trypanosomosis risk and by including the data layer for vegetation types (not shown here for clarity), associations can be made between those vegetation types and favourable tsetse habitat; such data can be important in planning the suppression or eradication of a tsetse population. GIS software also incorporates tools for interpolating observed data to neighbouring areas (e.g. grid squares from which no data were obtained). Using this method, observations at a collection of points can be averaged over the whole region to obtain a "surface" representation of tsetse infestation. From this surface, contour lines of level of infestation can be calculated. **Figure 2.6** shows average tsetse infestation over the whole region as a surface coloured darker shades of red for higher levels of tsetse population.

2.4.1.4. Satellite Imagery

Standard 1:50 000 scale maps normally have very basic information, if any, regarding land use and vegetation. As it is of great importance for surveys of almost any insect to know the locations of its preferred habitats, detailed spatial information on vegetation is required.

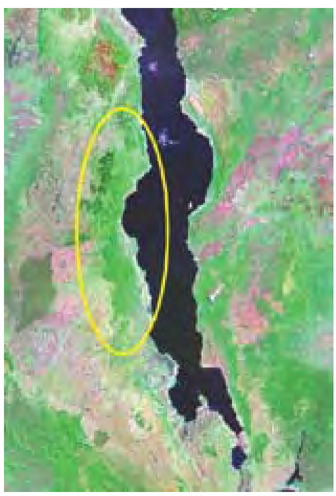
Ecological requirements and habitat types for tsetse species have been widely studied, providing information that can be used in conjunction with satellite images to determine appropriate trap deployment sites (Leak 1998). Sometimes vegetation maps are available for an area, but very often they are not, or they are out of date. Previously, aerial photographs have been used to identify areas of tsetse habitat and for planning of suppression or eradication. However, aerial photography is expensive and can be difficult to handle and

satellite images are now available to provide an economic alternative for photographs, with the advantage of being easy to manipulate using computers.

Satellite images of an adequate resolution can be used to reliably identify suitable tsetse habitats provided there is some basic knowledge available for their interpretation. Remote sensing image analysis is beyond the scope of this manual, but with some GIS expertise it is also possible to prepare land use/vegetation maps from these satellite images. Satellite images are now more readily available and cheaper than previously and some may be obtained free of charge (e.g. 1-km resolution LandSat 5 or LandSat 7 images, and under certain circumstances, European Système Pour l'Observation de la Terre (SPOT) 4 vegetation images). The older, 1-km resolution, LandSat 5 and LandSat 7 satellite images, currently dating from 1999–2000, are likely to be adequate for many tsetse survey purposes unless it is known that significant land use changes have taken place. Higher-resolution (< 30 metres) satellite images will give a much more precise indication of tsetse habitat. Sources of satellite images, and links to suppliers are given in annex 1.

Satellite images and savannah tsetse species — The satellite image of a savannah area in **Figure 2.7** shows a less clearly defined habitat (*G. morsitans*) in which it would be more difficult to define the sampling area. However, within that image, using predictive (probability of presence) maps (ERGO) an isolated area of tsetse infestation can be identified (circled). This area is surrounded by a natural barrier (Lake Malawi) on the eastern side and unsuitable habitat (a high altitude escarpment) on the western border. Savannah

FIGURE 2.7
Satellite image of savannah woodland in Malawi indicating an isolated tsetse area (circled) bordering Lake Malawi in the east and a high altitude escarpment in the west



NASA

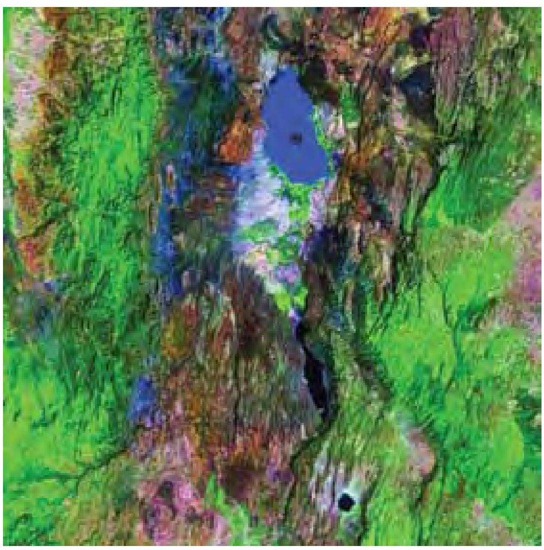
FIGURE 2.8

Satellite image displaying a typical Guinean forest zone in West Africa

NASA

FIGURE 2.9

Satellite image of the Lake Baringo (blue lake, upper part of the image) and Lake Bogoria (black lake, lower part of the image) area in Kenya selected as a possible site for eradication of *Glossina pallidipes*



NASA

areas of East and southern Africa, such as the miombo and mopane woodland, dominated by *Brachystegia* spp. and *Colophospermum mopane*, respectively, tend to be quite extensive, as can the central Africa rain forest, resulting in situations requiring a rolling carpet approach and the establishment of temporary barriers (except where lakes and regions of high altitude are natural barriers to the tsetse distribution).

Satellite images and forest tsetse species — The satellite image shown in **Figure 2.8** shows a much more uniform forest habitat typical of West or Central Africa, with few characteristic features other than a river, some villages and areas of cultivation. Inhabited by a variety of tsetse species (forest and riverine), such an area can only be tackled using a rolling carpet approach (Hendrichs et al. 2005) because it is unlikely that there would be a clearly delineated area of infestation by a single tsetse species, of a size that could be contemplated for such an activity.

2.4.1.5. Interpreting Satellite Images

Satellites provide information on land cover and condition because features of the landscape such as bush, crop, salt-affected land and water reflect light differently in different wavelengths. Satellites carry instruments that detect and record the reflected energy. The detectors are sensitive to particular ranges of wavelengths ("bands") and satellites are therefore characterized according to the related parameters (see box 2.3 for details).

Sensors in satellites detect the amount of electromagnetic energy reflected by (or emitted from) objects on the earth's surface. For vegetation, the percent reflectance in the green region is not as high as in the near infrared. This is why false colour or infrared images are

BOX 2.2

Satellite Images

Satellite imagery has been available since the start of the LandSat programme in 1972. The LandSat project is a joint initiative of the United States Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) to gather earth resource data using a series of satellites. LandSat's Global Survey Mission aims to establish and execute a data acquisition strategy that ensures repetitive acquisition of observations over the earth's land mass, coastal boundaries, and coral reefs; and to ensure the data acquired are of maximum utility in supporting the scientific objectives of monitoring changes in the earth's land surface and associated environment. At the time of printing of these guidelines, LandSat 7 images cost USD 250 per scene.

The Enhanced Thematic Mapper Plus (ETM+) is a multispectral scanning radiometer that is carried on board the LandSat 7 satellite. The sensor has provided nearly continuous acquisitions since July 1999, with a 16-day repeat cycle.

The SPOT 4 satellite, managed by the European Union specifically provides vegetation data that is becoming much more readily available (e.g. http://www.vgt.vito.be).

BOX 2.3

Remote Sensing and Satellite Images: Wavelength ("bands") at which Reflected Energy is Measured

The LandSat TM satellite has bands at the blue, green and red wavelengths in the visible part of the spectrum, three bands in the near and mid infrared part of the spectrum and one band in the thermal infrared part. The satellite detectors measure the intensity of the reflected energy and record it as a number between 0 and 255.

The size of the footprint (pixel) for which satellites measure reflected energy

The "footprint" or pixel size is the smallest area on the ground for which the detector can record the reflected energy. For every 30 m by 30 m plot of land, the LandSat TM scanner records a number for each of the seven bands, which is the average intensity of the reflected energy for the features in that plot of land.

The frequency with which satellites revisit a particular location

A third feature that characterizes a satellite system is the frequency with which it revisits a particular location. The LandSat TM satellite revisits each location every 16 days. Each image is routinely archived. Theoretically, a site could be viewed every 16 days to detect changes in land use or condition. In practice, some of these images are unusable because the satellite sensors cannot see through clouds.

The goal of image processing is to detect features and changes in those features over time, and to be sure that what is seen is related to the ground cover rather than to interference caused by the atmosphere. To do this, sequences of images are aligned to each other and to standard map grids (registration and rectification) and are calibrated to remove the effects of atmospheric differences.

Satellite images consist of numbers; the measurements of the amount of energy that has been reflected from the earth's surface in different wavelength bands. Some of these bands, such as the infrared bands that contain much information about vegetation growth and condition, can't be seen with the human eye. To convert data into pictures that show changes in reflected energy, the data are represented on a computer screen, or on a hardcopy print, using visible colours. The numbers recorded for the different satellite bands are displayed in red, green and blue "colour guns" on a computer screen.

Although the satellite can record intensities between 0 and 255, typically the actual intensities associated with the ground covers present in agricultural images occupy a much smaller range of values. "Image enhancement" is the term for the process of assigning the range of digital numbers in an image to the computer colour levels.

Different image enhancements can be used to highlight different detail in an image. For example, the minimum image intensity could be set to colour level 0 and the maximum set to colour level 255. This would maximize the number of colours on the computer screen and show some information over the whole image. atively, the range of image intensities corresponding to just remnant vegetation could be assigned to the 256 colour levels, highlighting the detail in the image about remnant vegetation at the expense of other cover types in the image.

used instead of true colour images when sensing vegetation. The uniqueness of satellite remote sensing lies in its ability to show large land areas and to detect features at electromagnetic wavelengths that are not visible to the human eye. Data from satellite images can show larger areas than aerial survey data and, as a satellite regularly passes over the same plot of land capturing new data each time, changes in the land use and land cover can be routinely monitored.

To compose a satellite image the data on wavelengths are converted to colours (red, green, and blue), used to make combinations (see box 2.3) that can be seen on an image. When the red, green and blue bands of an image are assigned to the same colours on the computer screen, a true-colour image is formed. These images look like aerial photographs, since they indicate the true colours of objects – green trees and grass and brown soil. When mixtures of the visible and infrared bands are assigned to the red, green and blue colours on the computer, false-colour images are formed. In these images, the different colours on the screen represent different intensities in the wavelength bands that are assigned to each screen colour. The human eye distinguishes changes in red better than in blue or green, so the band mostly strongly related to the feature of interest is usually assigned to the red colour on the screen.

Grass looks green because it reflects green light and absorbs other visible wavelengths. This can be seen as a peak in the green band in the reflectance spectrum for green grass. Grass reflects even more strongly in the infrared part of the spectrum as can be shown by infrared sensors on the satellite that detect this part of the spectrum.

2.4.2. Georeferencing

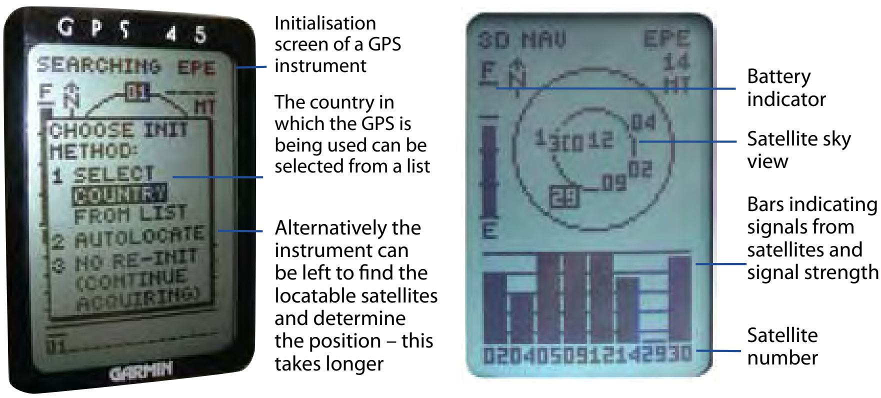
2.4.2.1. Global Positioning System (GPS) Instruments

In order to be able to accurately map the results of a survey and to be able to see precisely which areas have been surveyed and which have not, it is essential to know the positions of traps or other sampling devices. By identifying topographical features and in conjunction with maps and sometimes using compasses, it is has been possible, with some difficulty to identify more or less where sampling devices have been situated. Since the 1980s, a much more precise means of identifying locations on the earth's surface (of traps, for example) has been possible by using small instruments known as global positioning system (GPS) instruments. The Global Positioning System (GPS) (boxes 2.4 and 2.5) is a satellite-based radio navigation and timing system developed and operated by the United States Department of Defence. The system permits land, sea, and airborne users to instantaneously determine their three-dimensional position (latitude, longitude and altitude) within less than one metre, velocity (within a fraction of a kilometre per hour), and time (calculated within a millionth of a second) 24 hours a day, anywhere in the world.

2.4.2.2. Initialization, Data Collection and Waypoints

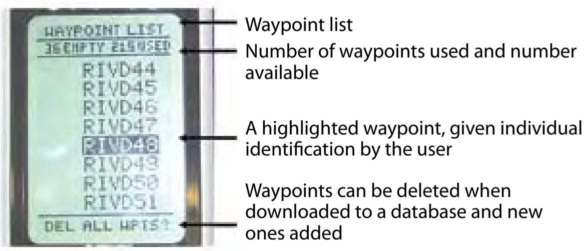
When the GPS instrument is switched on for the first time it has to be initialized: that means it has to be given some information of approximately where in the world it is. This can be done by selecting the country from a list (**Figure 2.10, left**) or by putting in approximate latitude and longitude value. This will speed up the processing and finding

FIGURE 2.10
(left) Example of a GPS initialization screen, and (right) satellite status page, indicating the signals received from the satellites



When sufficient signals have been received the screen will change to one giving the position coordinates

FIGURE 2.11
Screen of a GPS instrument showing a waypoint list



the precise coordinates. The GPS could still find the location without that information input but it would take longer. The instrument will then automatically start searching for satellites, and, depending on the model, will show what satellites it has located on the screen (**Figure 2.10, right**). When it has acquired sufficient satellites and determined the position, the screen will automatically change to one showing the coordinates, speed (velocity) if the GPS is moving, direction that it is moving in, the time and the date.

The units in which the coordinates are shown will depend upon the units that have been set on the machine — either the default units from the manufacturer or the units selected by the operator. GPS instruments have evolved rapidly as has the accompanying software for downloading the stored data to available GIS software and now, rather than writing down each individual GPS position at the time, which could be a potential source of error, the coordinates can be stored by the instrument as what are called waypoints (**Figure 2.11**). GIS software such as ArcView® / ArcGIS® and IDRISI has the ability to use a

list of waypoints as input and to create a GIS layer of points from them. So the waypoints can either be downloaded onto a computer using the appropriate cable and software available from the manufacturers, or hand typed into a table for import into a GIS. Software can also be obtained from the internet for downloading data from GPS instruments. There is a limit to the number of waypoints that can be stored on a GPS instrument, depending upon the model. When the limit is reached the waypoints have to be downloaded and deleted from the instrument. The GPS instrument's users manual will show how to download waypoints using a simple, on-screen menu. Each waypoint can be given a short identification code number (for example, the trap number or ID).

When entering, or loading a table of GPS positions manually the following points should be noted: X = longitude; Y = latitude; enter X and then Y. Coordinates should be written as decimal degrees (the instrument must be configured to display as decimal degrees) or UTM, but not as degrees, minutes, seconds (**Figure 2.12**). West of Greenwich, England, longitude values are negative, and a minus sign must be entered before each value. South of the equator latitude values are negative, and again a minus must be recorded.

Note: Collecting X,Y locations manually and entering them into a table for import into GIS should only be used when automatic downloading of files from the GPS to the computer fails. Handwritten lists always introduce errors, which are very difficult to locate afterwards.

2.4.2.3. Coordinates Systems for Georeferencing Data

Background — A coordinate system gives us a way to precisely describe a feature's geographic location, in other words, a frame of reference. Each coordinate system is composed of a datum that must be based on a certain ellipsoid, and a projection. The ellipsoid gives us the shape of the earth. The datum determines where the centre of that shape is, and local variations around the earth. And finally the projection converts from lat/log degrees around the ellipsoid to a flat plane for printing paper maps. There are several hundred coordinate systems in use around the world. Each country chooses a coordinate system that is best suited to the local conditions. We usually speak of two groups of coordinate systems: geographic and projected.

FIGURE 2.12
Screen of a GPS instrument showing geographical coordinates (UTM)

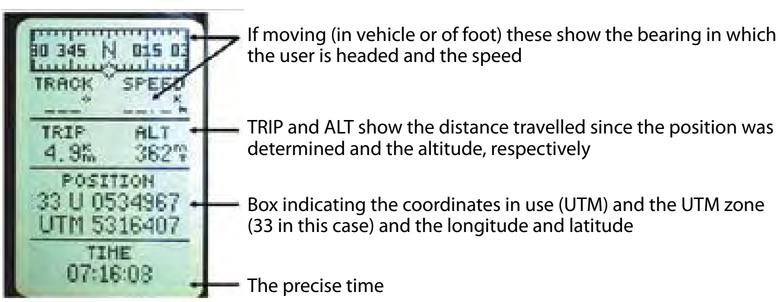
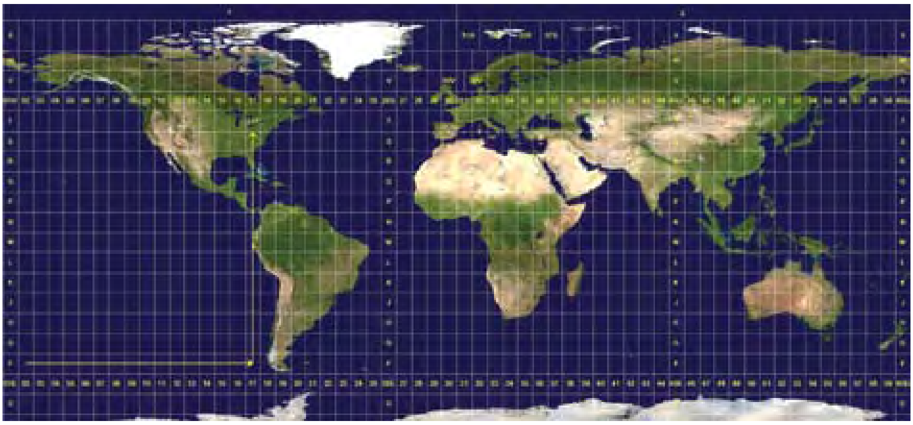


FIGURE 2.13
Satellite image of the world showing the UTM zones



NASA

The geographic coordinate systems have no projection. They are represented by a datum and ellipsoid only. Coordinates are in degrees latitude and longitude. GPS instruments always use a default geographic coordinate system known as WGS84.

Projected coordinate systems employ one of several dozen projection methods. Every projection causes distortion to some measure. Some projections maintain an accurate size of areas, but the features loose their shape. Others keep correct directions between features, but the measurement of areas gets distorted.

Country coordinate systems — Government survey offices will choose a coordinate system that gives the most accurate representation of reality on flat paper maps for that country. The choices depend on the shape of the country and local variations to the ellipsoid representation of the earth's surface. For example, countries with a longer N-S extent, that are less that 500 kilometres wide often choose a variation of the Transverse Mercator projection, which maintains accuracy in a north-south direction, but begins to loose accuracy when moving too far east or west.

UTM — UTM is a well-known set of coordinate systems, which uses the WGS84 datum and the Transverse Mercator projection (**Figure 2.13**). UTM is comprised of 120 different coordinate systems. The earth is divided into 60 longitudinal zones, each zone being 6 degrees wide. Each of those 60 "strips" is split at the equator creating a north zone and a south zone, thus 120 separate coordinate systems. Each zone has a central meridian, the line that goes down the centre of the strip. UTM units are meters. For northern UTM zones the origin (0,0 coordinate) is at the equator, and 500 kilometres west of the central meridian. For southern zones, the origin is 10 000 kilometres south of the equator, and also 500 kilometres west.

BOX 2.4

How GPS work

GPS instruments calculate their position on the earth by measuring their distance from a group of satellites in space that act as precise reference points. This depends on a process of triangulation in which a GPS receiver measures distance using the travel time of radio signals. The distance from satellites is calculated using the formula:

Velocity × Time = Distance

Knowing our exact distance from a satellite in space, we know we are somewhere on the surface of an imaginary sphere with radius equal to the distance to the satellite radius. If we know our exact distance from two satellites, we know that we are located somewhere on the line where the two spheres intersect. A third measurement will give the only two possible points, one of which is usually impossible and is eliminated by the GPS receiver.

GPS instruments measure a radio signal so the velocity is equal to the speed of light (299 792 458 metres per second). The measurement of travel time obviously requires very precise timing made available from atomic clocks on board the satellites. The precise location of the satellites in space is also required and this is achieved by placing them in carefully monitored high orbits. Mathematical procedures are used to correct for delays in the time taken for the signals to pass through the atmosphere in order to increase precision.

Each GPS satellite transmits an accurate position and time signal. The type of signal transmitted is a pseudo random code (PRC). The PRC is a digital code, consisting of a sequence of "on" and "off" pulses. The complicated nature of the signal is similar to that of random electrical noise, hence the name pseudo random. Each satellite has its own unique, complex PRC and signals from other satellites are unlikely to have exactly the same shape and thus interfere with the receivers operation. Consequently, all satellites can use the same frequency. The GPS instrument measures the time delay for the signal to reach the receiver, which is a direct measure of the apparent range (distance) to the satellite. Measurements collected simultaneously from four satellites are processed to determine the three dimensions of position, velocity and time. Mathematically four satellite ranges are needed to determine the user's exact position, but three are sufficient as some positions (not on earth) are not possible. GPS receivers differ in the number of satellites they can receive from simultaneously, their precision, the nature of the display, and computer-downloading capabilities. All major manufacturers of GPS equipment maintain websites that include basic information about how the GPS works. Some GPS units display additional data, such as distance and bearing to selected waypoints or digital charts.

GPS provides two levels of service — a standard positioning service (SPS) for general public use and an encoded precise positioning service (PPS) primarily intended for use by the United States Department of Defence. There are some potential sources of error preventing absolute accuracy with standard GPS, however, these errors can largely be

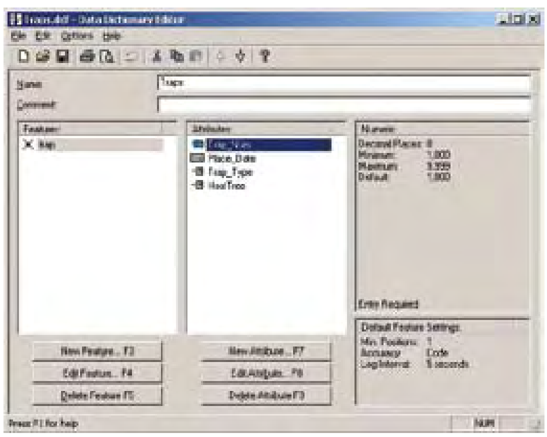
corrected for using differential GPS providing accuracy within less than one metre. These are more expensive to use and only necessary if a high degree of accuracy is required. SPS signal accuracy was intentionally degraded to protect United States national security interests. This process, called selective availability, controlled the availability of the system's full capabilities but was turned off in May 2000 resulting in GPS becoming more accurate for civilian users.

2.4.2.4. Types of GPS Instruments

The wide variety of GPS instruments is sometimes grouped into two categories: navigation or recreational units, and data logger units. The navigation units will have a screen, often showing a simple map background. The user can set his destination, and the GPS will guide him/her to that spot. In addition the GPS can record waypoints as spot locations along the way. These instruments are relatively inexpensive, and often limited in memory and battery power. They are designed, as the name suggests for navigating, and not for data collection.

At the other end of the spectrum are data logger GPS units. These are typically much more expensive, and they are actually a mini computer sometimes running the Windows CE (Personal Digital Assistance) operating system. They are primarily designed for collecting data along with the GPS location. The internal battery will last all day, and is rechargeable. An auxiliary battery can be attached if necessary. They come equipped with very large memory allowing for collection of thousands of features as well as their accompanying attributes. Usually the GPS case will be sealed insuring that dust and moisture will not

FIGURE 2.14
Example of a data dictionary screen



BOX 2.5

GPS Elements

GPS has three parts, termed segments, i.e. the space segment, the user segment, and the control segment (**Figure 2.15**). The functions of these are as follows:

Space segment

The space segment, consists of a series of 24 or more satellites (variable because new satellites are launched and older ones taken out of the system periodically, 21 active at any time) in six circular orbits 20 200 km above the earth at an inclination angle of 55 degrees with a 12 hour period. The GPS satellites (**Figure 2.16**), each taking 12 hours to orbit the earth, are equipped with accurate atomic clocks that keep time to within three nanoseconds, i.e. 0.000000003 seconds, or three billionths of a second and continuously transmit data signals including position and a precise time message on two different frequencies. This precision timing is important because the receiver must determine exactly how long it takes for signals to travel from each GPS satellite. The satellites, deployed and maintained by the United States Department of Defence, are spaced in orbit so that at any time signals can be received from a minimum of six of them anywhere in the world, i.e. the minimum signals required to get the best position information. The receiver uses this information to calculate its position.

Control segment

The control segment consists of a master control station (at Schriever Air Force Base, Colorado, USA), with five unmanned monitor stations and three ground antennas located throughout the world, and four large ground antenna stations that broadcast signals to the satellites. The monitor stations track all GPS satellites in view and collect ranging information from the satellite broadcasts. The monitor stations send the information they collect from each of the satellites back to the master control station, which computes extremely precise satellite orbits. The information is then formatted into updated navigation messages for each satellite. The updated information is

FIGURE 2.15
Diagram displaying the three major segments of a GPS, i.e. the space segment, the user segment, and the control segment

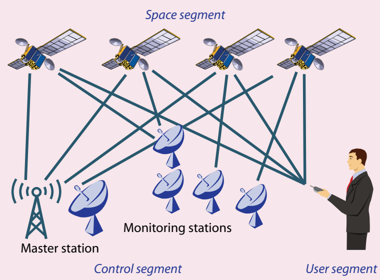


FIGURE 2.16
Photo of a GPS satellite

transmitted to each satellite through the ground antennas, using an S-band signal. The ground antennas also transmit and receive satellite control and monitoring signals.

User segment

The user segment consists of the hand-held, or vehicle-mounted signal receiver units, that allow land, sea, or airborne operators to receive, decode and process the GPS satellite broadcasts to compute their precise latitude, longitude, altitude, velocity and time. A wide range of receiver models are now available, some, pre-loaded with road or other maps and additional features. The typical hand-held receiver is about the size of a cellular telephone, and the newer models are even smaller. Price has also significantly decreased since the first GPS instruments were commercially available.

interfere with operation. And the most important feature available with these instruments is their smooth interface with GIS.

Using a data dictionary — The data logger GPS allows one to define in advance which attributes we want to collect together with the location data. A data dictionary file is created in the computer that defines each attribute (or column). The data type, default values, menu items, etc., is determined (**Figure 2.14**) and the data dictionary file is uploaded to the GPS data logger. When collecting features in the field, attribute data is entered as the GPS is collecting the location data. Later, the GPS data file can be downloaded to the computer, the conversion programme can be run, and within the GIS our locations together with the attribute data entered in the field are immediately available. This method saves a tremendous amount of time, and avoids errors in data entry.

GPS data imported to GIS software — Any reasonable GPS instrument comes supplied with a software application to download GPS data to a personal computer. In addition, most sophisticated instruments include software modules to convert the downloaded GPS files to GIS format, and at the same time to re-project the data to the local coordinate system. The Trimble® line of GPS instruments use the Pathfinder Office software package for just that purpose. The user must know which coordinate system is used in his country in order to setup the conversion programme correctly. Once configured, the programme will automatically convert GPS captured locations to GIS layers that will correctly overlay other data obtained from outside sources. Pathfinder Office can convert the GPS data to shapefiles for use in any GIS application.

Note that the shapefile format contains the attribute data in a *.dbf file (part of the shapefile standard). This table of data can also be imported into the Tsetse Intervention Reporting and Recording System (TIRRS) (see 2.4.4) database application or other applications that recognize the *.dbf format.

Furthermore, a data logger GPS allows us to collect GIS features: lines, areas, as well as points. This concept is important to understand. The data logger GPS is not simply for

collecting waypoints. We can map out fields, roads, vegetation or land use areas. And in each case we enter attributes for each feature as the GPS collects the locations. Once the GPS data is transferred to the computer we will have all entered data immediately available in our GIS programme.

Mapping out roads and tracks is a simple and very useful GPS activity. A data logger GPS will automatically record locations all along the road as we travel, and when the GPS file is exported to GIS in the computer, all the locations are joined together resulting in a GIS line layer. Before starting to capture the road we can configure the interval of time (or distance) the GPS uses to log locations. Thus, if we are travelling at a high speed along a well-paved road, we would choose a small interval – about three seconds – for the logging interval. If, on the other hand, we wish to capture a track through rough terrain, where our speed changes all the time, we can choose to log by distance rather than by time. Logging a location every 50 meters insures that we will capture all turns and twists in the track. If we come to an obstacle while recording the track, and we must detour, the GPS allows us to pause collection of locations. After circling around the obstacle, and getting back onto the track, we can resume logging, and the final GIS layer will still be one connected line. In addition, we can define in the data dictionary the road condition as an attribute. As we advance along the road, we can section the road off, and choose the current condition to be recorded in the GPS. Again, the resulting GIS layer will contain the road condition as an attribute for each road section.

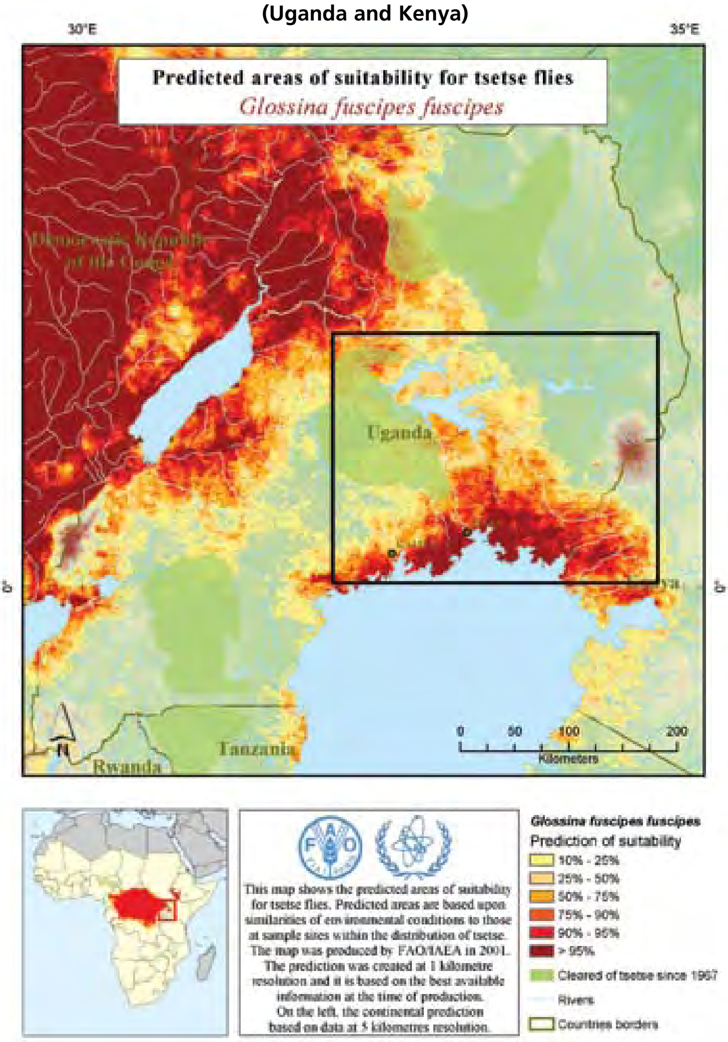
2.4.3. Defining the Limits of the Survey Area

The preparatory phase for any project involving large- or small-scale tsetse surveys in the context of AW-IPM will include the collation of available data on tsetse distribution from previous surveys, reports of trypanosomosis infections of livestock (or humans), etc., including any available distribution maps. The most widely available continental tsetse distribution maps have been, until recently, those published by Ford and Katondo (1977) but these were of limited precision as well as being rather outdated. In some areas significant changes in distribution have taken place due to re-occupation of formerly inhabited areas by tsetse recovering from the 1890s rinderpest epidemic or for other reasons. Recently, those maps have been updated and published (Maudlin et al. 2004). Much valuable information may be obtained from published scientific or other literature such as reports and various archived documents.

Determining the limits of distribution is one of the most important objectives of a survey, and more difficult than showing the presence of tsetse within an area. Tsetse density will be low, and presence may be seasonal and, as often stated, catching a tsetse shows their presence but not catching them does not prove their absence. The limits of the survey area will therefore normally extend beyond the expected limits of distribution. It may sometimes be necessary to adjust the limits of the survey area if initial survey results suggest that they were not well defined. Based on the available information on tsetse distribution, plus predictive maps, preliminary survey data and satellite imagery, a better estimation of the limits of the area to be surveyed can be made. The limits of the area may be determined partly by the presence of natural boundaries to tsetse infestation such as lakes, or areas of high altitude, that are unsuitable tsetse habitat. Other limits may be less clear and might

have to be determined using data obtained from preliminary surveys that will have to be (or will have already been) conducted in the area. If an area is selected because of endemic trypanosomosis, it is probable that previous disease prevalence data are available. The available predictive maps of tsetse species distribution in Africa, based on climatic and other data have already been referred to. These maps, freely available over the internet or on CD-ROM can be used, in conjunction with satellite images, as a basis for determining the limits of an area, bearing in mind the necessity to survey some adjacent areas in which tsetse are

FIGURE 2.17
Predicted distribution of *Glossina fuscipes fuscipes* in northern Lake Victoria (Uganda and Kenya)



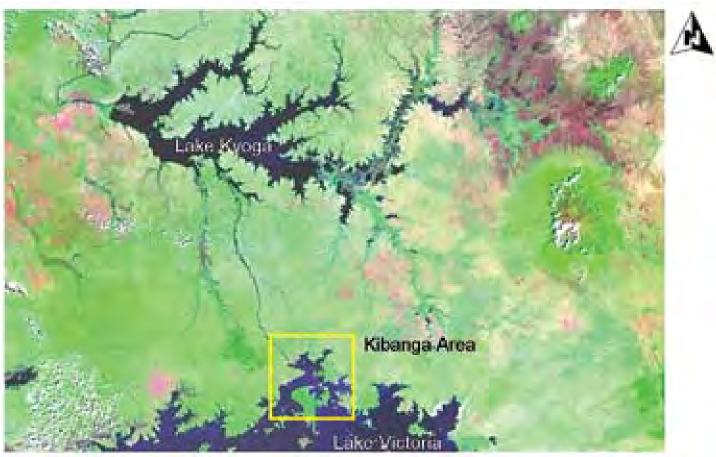
The rectangle is the area covered by the satellite image in Figure 2.18

MAP PRODUCED BY ERGO, FOR FAO AND DFID

potentially absent in order to verify this. The maps can be viewed and other information is available from the following link: http://ergodd.zoo.ox.ac.uk.

Figures 2.17 to **2.24** illustrate the hypothetical sequence of survey planning from the early stage of identifying a circumscribed tsetse population, potentially suitable for AW-IPM, from a predictive map showing the probability of presence, through to a survey map showing distribution. **Figure 2.17** shows the predicted distribution of *G. fuscipes fuscipes* around the northern shores of Lake Victoria in East Africa. Having identified an area of interest such as this, a satellite image is acquired of the part of that area (**Figure 2.18**) in which AW-IPM is contemplated, and a survey is to be planned. That satellite image can be used to prepare a vegetation map, or, if such maps already exist (**Figure 2.19**), can be used in conjunction with them, to identify the vegetation types that are associated with the predicted presence of tsetse. That process is likely to require some ground truthing (physically visiting an area identified on the satellite image and predictive map) to be able to characterize the type of vegetation (e.g. savannah woodland, thicket or lacustrine forest) associated with the presence of tsetse. The process of identifying the types of habitat in which tsetse are likely to be present will also make use of the entomologists knowledge of the ecology of the tsetse species and its known habitats and of areas that are likely to be unsuitable for the flies. At the end of this process the entomologist will be in a position to use standard 1:50 000 scale topographical survey type maps to outline the limits of the survey area (**Figure 2.20**) and to start to construct a grid overlay based on the grids found on the standard hard copy maps, or, if they don't exist, to construct an electronic grid that can be overlaid on satellite images of digital maps or printed out on transparent paper for use with hardcopy maps. **Figure 2.21** shows a satellite image corresponding to the same smaller area of Kibanga that is shown on the previous maps to illustrate the way in which it is possible to zoom in on the higher resolution satellite images in order to obtain a

FIGURE 2.18
LandSat 7 satellite image of Busoga, south-eastern Uganda



Yellow square shows area of Kibanga covered by the topographical map in Figure 2.20

NASA

FIGURE 2.19
Land cover map of Jinja, south-eastern Uganda

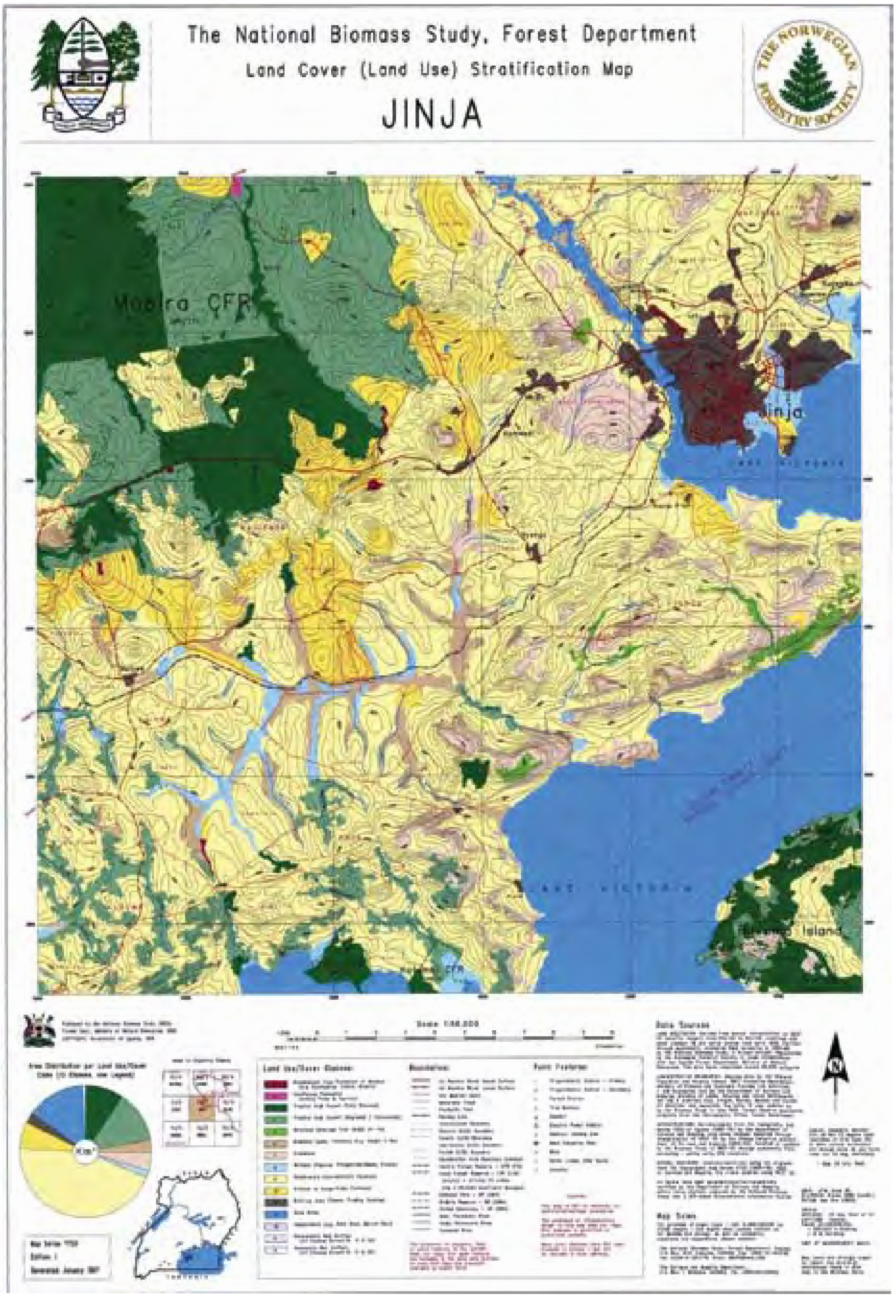
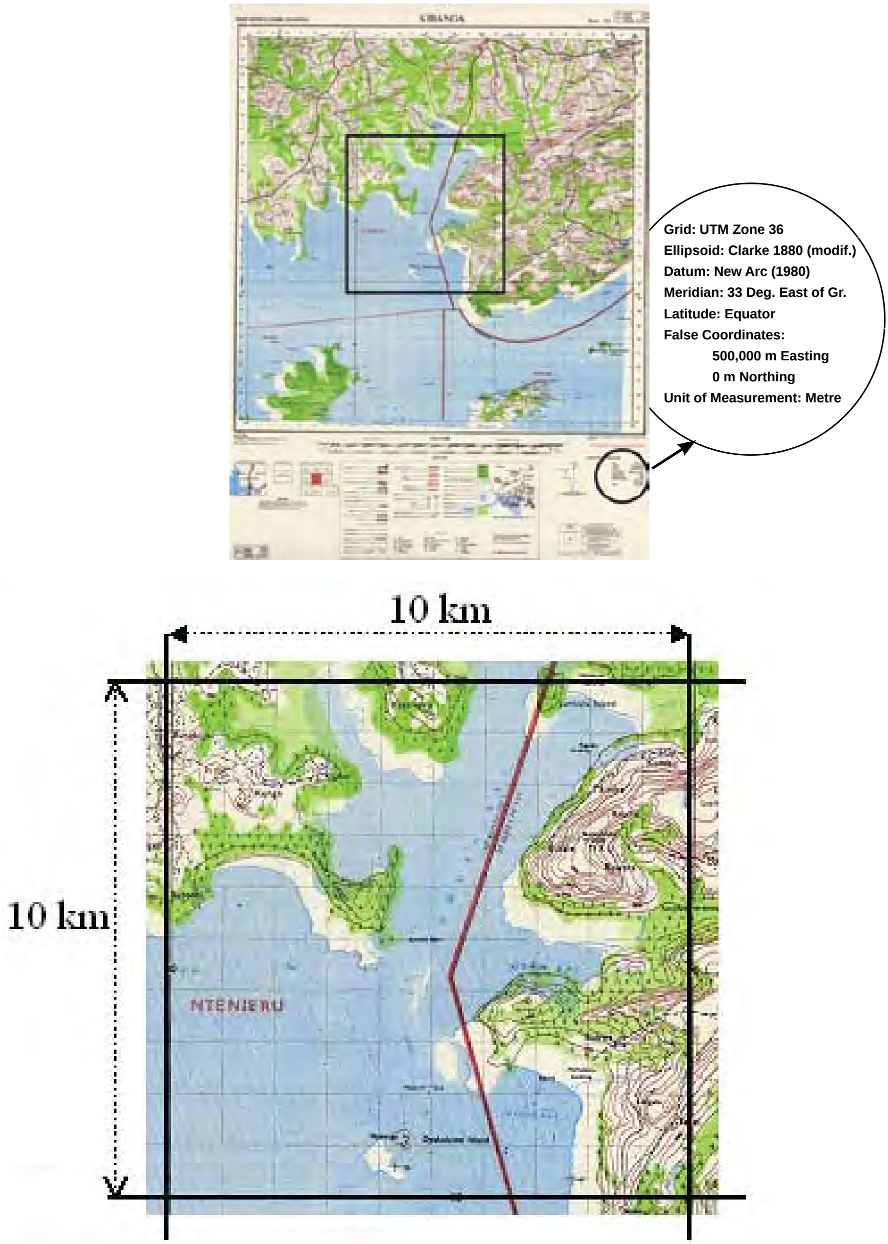


FIGURE 2.20

(upper) National survey map of Kibanga, Uganda, showing (circle) details of map projection, and (lower) a 10 × 10 km UTM grid square enlarged (area shown in Figure 2.21 as a satellite image)



DEPARTMENT OF LAND AND SURVEYS, GOVERNMENT OF UGANDA

FIGURE 2.21
LandSat 7 satellite image of Kibanga, Uganda

NASA

greater detail. The very high, submetre resolution images of the type available from Quickbird (www.digitalglobe.com/about/quickbird.html) or Ikonos (http://www.landinfo.com) will even show roads and tracks that can be used for planning access routes, however, at present their cost is likely to be too great and the 30-metre resolution LandSat 7 images are adequate for survey purposes.

The details of the type of grid structure to be used, and the organization of the survey and its teams based on the grid structure are given in 2.4.3.1. It is becoming increasingly common to find that accurate and recent digital or hardcopy vegetation or land use maps are already available for an area such as that shown in **Figure 2.22** which shows land use

FIGURE 2.22
Vegetation map of part of The Gambia

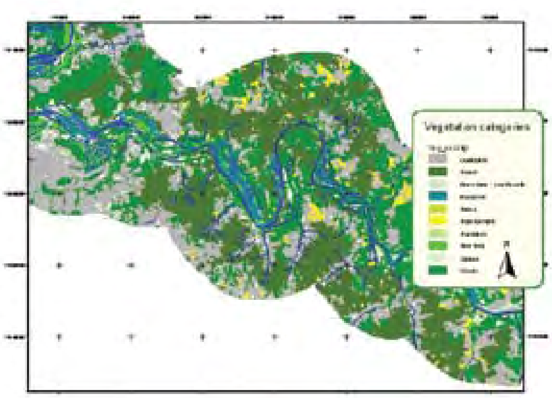


FIGURE 2.23
Map indicating the results of a survey of *Glossina morsitans submorsitans* in the Gambia

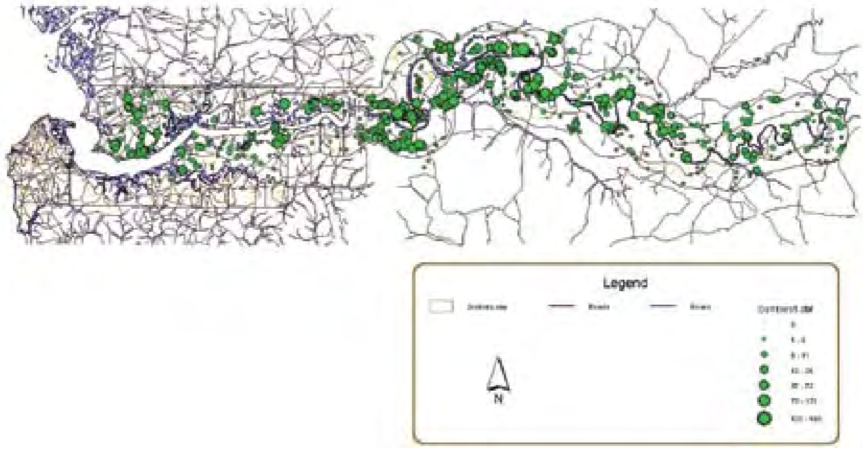
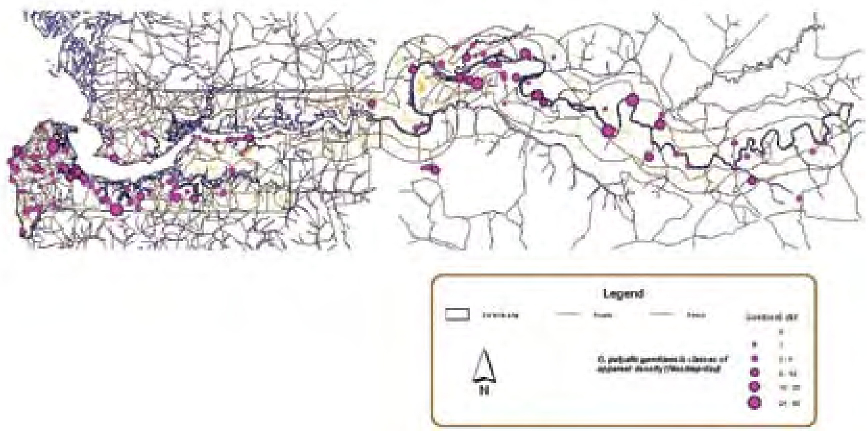


FIGURE 2.24
Map indicating the results of a survey of *Glossina palpalis gambiensis* in the Gambia



in a section of The Gambia from satellite interpretation and mapping carried out by the Japan International Cooperation Agency (JICA) and the Gambian Department of Surveys in 2002. Similar land cover maps are available for many parts of Africa, sometimes freely over the internet (i.e. FAO AfriCover — http://www.africover.org) and may be readily customized to map tsetse habitat (Cecchi et al. in press). The International Livestock Research Institute website (http://www.ilri.cgiar.org/gis/) provides GIS databases for Ethiopia, Kenya, Uganda and such sites are continually being added to.

In the vegetation map of part of The Gambia (**Figure 2.22**), produced in GIS using a recently produced land use coverage data layer, the main potential classifications of habitat suitable for tsetse are: forest, woods and palms. Cultivated land, rice fields, swamp and plain ground are less suitable habitats. Note the location of rice fields in proximity to the River Gambia and the relationship between cultivated land and alluvial soils along tributaries, particularly on the south bank of the river.

The final result of the survey can be depicted on maps using GIS software in a variety of ways, one of which, using size graduated circles to represent different apparent density classes is shown in **Figure 2.23** and **Figure 2.24** for the two species of tsetse present in The Gambia, *Glossina morsitans submorsitans* and *Glossina palpalis gambiensis*, respectively (data from Rawlings et al. 1993, converted to a GIS format and redrawn by Leak et al. 2004).

Standard ordnance survey type maps, especially the older ones, are often based on aerial photographs. They generally show contours, which are useful in some regions for defining limits, but show a limited amount of detail on land use/vegetation types, and that information may be out of date. That is why they are used in conjunction with satellite images that can provide contemporary information on vegetation and land use. The type of map shown in **Figure 2.22** is produced from recent interpretation of satellite images carried out together with "ground truthing" (verifying on the ground that the interpretation made from an image is correct).

2.4.3.1. Setting Up a Grid

A grid system is used for planning and organizing a survey because it permits a logical sequence of activities to be followed, efficient organization of teams and a means of checking on progress. Although grid structures have been used to provide a framework for visualizing survey results, especially before the wide use of GIS software, this is not the best means of displaying such data. Rather than averaging data and forcing it into a grid structure for visualization, GIS tools for interpolating data from traps can be used to give a better visualization of results over a large area. In order to create a grid structure for survey management, a grid of the required size is superimposed over a map of the area. This will either make use of existing grids found on standard ordnance survey type maps, simply constructing one with a ruler, or alternatively using a computer to make a grid on an electronic copy of a map. The grid square size will be decided upon according to the size of the survey area, as described below, and the grid squares covering the survey area will be divided up into blocks subsequently assigned to each survey team. The survey teams will then work through each of their assigned grid squares in their block sequentially and methodically.

In the past, surveys were often carried out using administrative boundaries (provinces, districts, divisions, etc.) as units defining survey limits. That procedure may have been adequate at the time and for the purposes for which it was intended, but is inappropriate for surveys in the context of AW-IPM, in which the entire population has to be surveyed, as that population will not be confined to administrative (even national) boundaries. In the past it was easy to organize surveys based on administrative boundaries. In contrast, mobilizing staff allocated to local administrations or alternatively using a national survey

team carrying out surveys crossing administrative boundaries may now meet some difficulties, especially related to decentralization of local governments and budgets, requiring all the administrative units involved (including governments in the case of regional projects) to agree to coordinated activities, it is, nevertheless, the required approach.

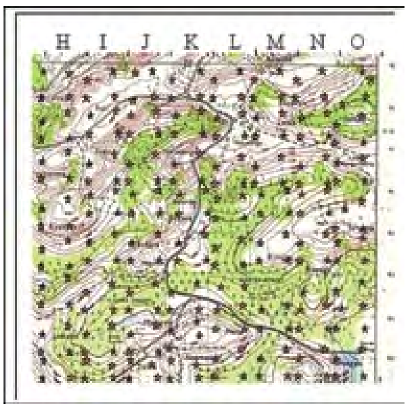
The grid structure provides a framework that can be used for planning the distribution of trap deployment. The type of grid used will depend upon the size of the area to be surveyed. In relatively small areas it might be appropriate to use 1-km^2 grids and to conduct quite an intensive survey that will give a better "resolution" of the survey results. However, where area-wide tsetse control/eradication is being considered the area to be surveyed is quite likely to be large and small grids of 1 km^2 would be impractical because it would not be feasible to deploy traps in every square, given likely difficulties of access to some areas. In such situations a 10 × 10 km grid square (i.e. 100 km^2) would be more appropriate, as described below in the example from Ethiopia of the baseline survey of the Southern Rift Valley Tsetse Eradication Project (see 3.5.2.). Similarly, in Togo, a country-wide survey (not for the purpose of AW–IPM) made use of a grid base of 311 identical cells, with each cell side measuring 0.125^o latitude/longitude (see 3.5.1.). In larger-scale grids, more care has to be taken in selecting sites for deployment of traps that are representative of the vegetation types in the grid square as it will not be possible to deploy traps in all of them. Obviously, this provides a lower level of resolution and the interpolation of data to unsampled areas may have limited accuracy. The methodology used for organizing surveys on a grid structure is the same whichever size of grid is used. Having an appropriate size of grid will ease the logistical management of the survey.

2.4.3.1.1. Procedure for Preparing a Grid and Allocating Blocks to Survey Teams

Having defined the area for the survey using predictive (probability of presence) maps, satellite images and probably national survey maps, 1:50 000 scale and 1:200 000 scale maps covering the entire area, normally with a bit of overlap into surrounding areas should be obtained. A minimum of one set of maps per team will be required plus an additional set (or two) for the survey management office. It is advisable to trim or fold and fasten together at least one set of these maps so that the whole area can be displayed. The boundary of the survey area is outlined with a felt-tip pen, as well as the grid squares (either UTM grid squares or 1 × 1 km squares, whichever is chosen). An identification system for each grid square is created using for example letters for the grid squares going from left to right and numbers for the grid squares from top to bottom. Those grid references will remain fixed and will be recorded on the top of each survey data-recording sheet so that the data can be correctly assigned to the appropriate grid square. Grid squares are assigned to each survey team, taking into account the location of the survey teams base (not always the same as the project management office or for each team, depending on the size of the survey). The terrain and difficulty of access should also be taken into account when assigning grid squares to teams; it may not always be the case that each team will have exactly the same number of grid squares to cover (e.g. **Figure 3.20**). A sketch (or printed) maps is then provided showing the grids assigned to each survey team, together with the 1:50 000-scale set of maps.

FIGURE 2.25
Topographical map with a hypothetical grid covering an area of south-eastern Uganda

FIGURE 2.26
A 1 × 1 km grid square with trap positions (stars)



Small-scale surveys based on 1 km × 1 km grid squares — Following selection of the area, and identification of the limits of the survey area, based on approximately known boundaries of the infestation and natural boundaries such as highland or lakes, a grid is constructed over the base map. Standard 1:50 000 ordnance survey type maps already have a 1-km^2 grid overlay in addition to the 10 × 10 km grid. This 1-km^2 grid can be highlighted on the map and each grid square given a unique identifier using an alphanumeric system as shown in **Figure 2.25.**

Figure 2.25 shows a hypothetical simplified (and therefore not completely realistic) example of how to set up a small-scale grid. The basic map is a 1:50 000-scale ordnance survey type topographical map of a kind that is almost universally available. The map has the 10 × 10 km UTM grid squares in bold outline, and 1 km × 1 km grid squares in fainter

outlining. Let us assume that the area within the brown line is an isolated infestation of a tsetse species bounded by the natural barrier of the lake, highlands to the north and east and intensive agriculture on the west. A 1 km by 1 km grid is constructed simply by highlighting the existing grid structure that overlays the area to be surveyed. Rows of letters along the top and numbers along the side can be used to give a unique identifier to each square. So that the square indicated by the arrow can be identified uniquely as F12.

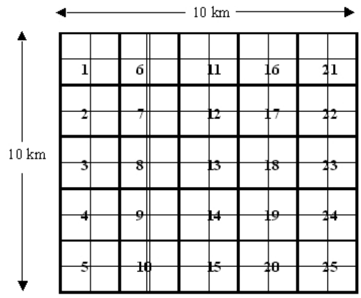
Having developed a grid, the survey can be planned systematically. The area covered by the grid in this example is just 315 km^2, although some of those grid squares are entirely water so they would not be surveyed. That area could be covered by three survey teams each responsible for 105 grid squares and in this example the area could be easily divided up, with the first team taking columns A–O and rows 1–7; the second team takes columns A–O and rows 8-14; and the third team taking columns A–O and rows 15–21.

With three teams covering a relatively small area it would be quite feasible to deploy four traps in each grid square, selecting sites considered to be most suitable for catching tsetse, for three days of trapping with each trap being serviced (cages checked, emptied and replaced) daily. Deploying 20 traps a day, each team would finish surveying its area in 23 days. The approximate areas for deployment of traps could be pre-selected based on access, vegetation type and proximity to rivers and streams, as indicated by the stars in each 1 × 1 km grid square of **Figure 2.26** and the precise positions would be recorded with GPS instruments after deployment.

In 3.5.4., an example is provided of a small-scale intensive survey conducted in the Ghibe (Omo) River Valley in Ethiopia, in which the total area to be surveyed (in two sites, i.e. Ghibe and Tolley/Gullele) was only about 450 km^2. In such a situation a quite detailed tsetse distribution map can be produced allowing correlations to be made with specific ecological and environmental parameters.

Large-scale surveys based on a 10 × 10 km grid square — The methodology for setting up a large-scale survey grid based on 10 × 10 km squares is exactly the same as described for the small-scale survey except that it uses the larger squares, covering a greater area of 100 km^2 per grid square. For a large area it becomes logistically not feasible to use the same density of traps as for a small area. The resolution of the data on tsetse distribution and abundance will therefore necessarily not be as good as is possible for a smaller area. For that reason, care has to be taken to select representative areas within the 10 × 10 grid and deploy traps in those representative areas in numbers proportional to the size and importance of them. Consequently, the deployment of traps will not be uniform as suggested by the hypothetical illustration in **Figure 2.27**. That figure shows diagrammatically, a single 10 × 10 km grid square within which there are 100 1-km^2 grid squares that can be grouped in fours. Even if the type of habitat within the 10 × 10 km grid were uniform, the deployment of traps also depends very much on accessibility and they will therefore be more clustered. Where there are grid squares that are unsuitable for tsetse or of very low suitability (water, high altitude, no suitable vegetation) those cells will be left empty. In a large area, the deployment of 20 or 25 traps per 10 × 10 km grid-square is the minimum to be aimed for (allowing an average of one trap for every 4 or 5 km^2, although not actually so uniformly distributed). There is no upper limit to the number of traps than can be deployed

FIGURE 2.27
A 10 × 10 km grid showing a hypothetical distribution of 25 traps

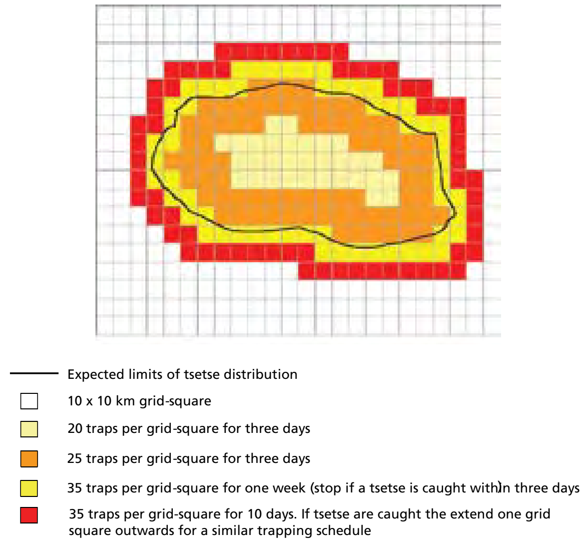


other than that which is practically feasible. The type of trap deployment described will give a lower resolution for tsetse distribution than is possible with the small-scale survey described above, and each trap has therefore to be carefully sited. Because of the lower resolution, and especially if, for example, aerial spraying is foreseen as the purpose of the survey, there will have to be a concentration of effort on the outer limits of the tsetse distribution rather than on the interior, as described in the following section.

2.4.3.1.2. Intensity and Duration of Sampling in Relation to Grid Structure

The intensity and duration of sampling in different areas of the survey area will depend partly upon the objectives of the survey (if aerial spraying of the population is to be undertaken surveying the interior of the block will be of little importance but defining the limits will) as well as on logistical feasibility. In theory, the duration of trapping, and number of traps could be determined by estimating those parameters in order to give a 95% probability of detecting any tsetse in the area, however, in addition to logistical difficulties there are many unknown parameters especially in relation to efficiency of traps for different tsetse species, in different locations and in different seasons. It has been shown that a minimum period of three days trapping is required to reduce variability of trap catches to acceptable levels and this is therefore taken as the minimum period for sampling (Williams et al. 1990). The most important part of a tsetse survey is to determine the limits of distribution and therefore sampling along the edges will be most intensive. The expected distribution limits may be known or roughly defined, enabling the outside boundary of the survey area to be approximated. Trapping in grid squares along this boundary will ideally be carried out using 35 traps in a 10 × 10 km grid square for a period of one week. If tsetse are caught within three days then trapping can stop, however, and proceed to the next grid square out. In that square the same number (35) of traps will be used for a period of 10 days to confirm, within practical limits, the absence of tsetse in that area. Similarly, if tsetse flies are caught then the next grid square is included until a grid square in which no tsetse flies are caught is reached. This approach to intensity and duration of sampling is illustrated in **Figure 2.28**.

FIGURE 2.28
Diagram indicating the survey sampling frequency and intensity in relation to the limits of the tsetse distribution



Off course, if the boundary of the distribution limits is well defined and unambiguous (a lake, ocean or high mountain range), then this procedure will be unnecessary.

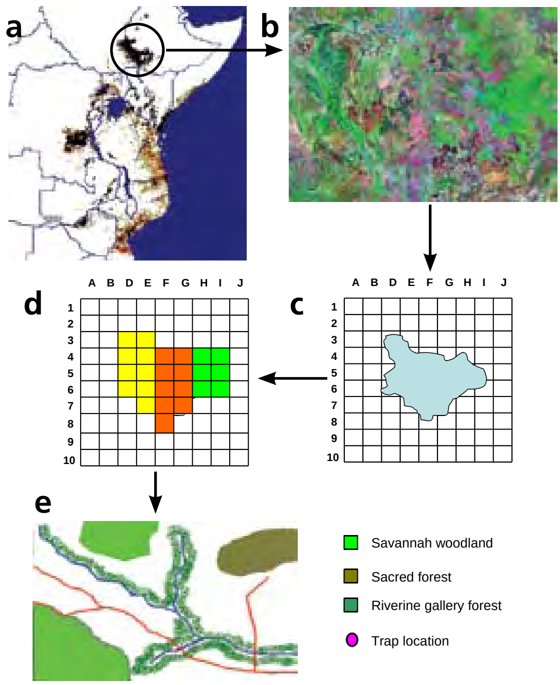
Figure 2.29 provides a summary of the sequence of planning for an entomological baseline data survey.

2.4.3.1.3. Grid Systems for Riverine Tsetse Species in Humid Savannah

A grid system can be equally effective for planning a survey of *palpalis* group tsetse, although the differing habitat structure for these flies, compared to *fusca* or *morsitans* group tsetse needs to be considered. *Palpalis* group tsetse flies predominantly occupy a more linear habitat in humid savannah (**Figure 2.30**), with areas between gallery forests that may not be occupied by them as they are almost always found in close proximity to water. However, in forest areas, these gallery forests are often connected by forest and here, the flies may extend over a wider area. Furthermore, although *palpalis* group tsetse flies are known to be largely confined to the gallery forest habitat, especially in the dry season towards the northern limit of their distribution, they can disperse outwards into the bordering savannah, especially during the rains and this has to be taken into account when defining the area to be surveyed. Unfortunately, not enough is known about the extent of the seasonal dispersal away from the riverine habitat for different areas.

In the example given in **Figure 2.31**, although it might be strictly unnecessary to survey in the shaded ¼ grid squares, from a practical point of view it might be easier to simply survey the whole grid square. This would also give a better indication of the risk of re-invasion from neighbouring river systems. As Hendrickx et al. (2004) reported, a well known and typical feature of the climate and consequently of the vegetation type in West

FIGURE 2.29
Diagram that summarizes the sequence of planning for an entomological baseline data survey

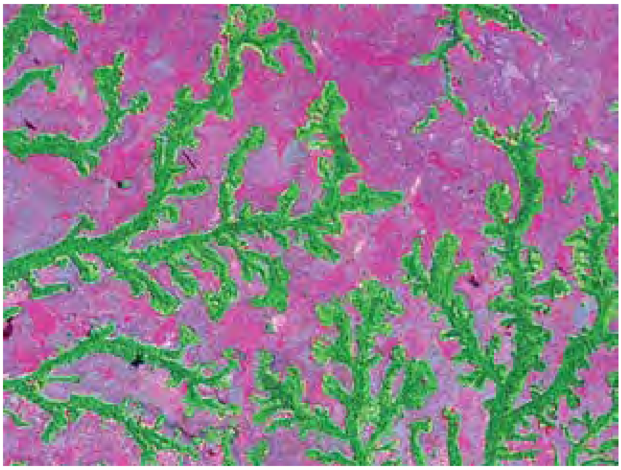


(a) predictive tsetse distribution map, (b) satellite image of selected area, (c) defined limits of survey area with grid, (d) survey area divided into three blocks of grid squares: one each for three teams, and (e) satellite-derived-vegetation sketch map of a single grid square showing preliminary selection of trap deployment sites (representative habitat and access).
The illustrations are used to represent the procedure and are simplified, and are thus not intended to be accurate scale maps interpreting a real situation.

Africa is its band-like pattern. This can be shown using data on rainfall, vegetation index and the length of growing period. From north to south the climate changes from arid to moist. This strongly affects tsetse ecology and distribution, thus in the northern area of West Africa, close to the northern limits of their range, climatic conditions become less suitable for tsetse. It is particularly important to assess the seasonal changes in distribution and to survey so-called "forest islands" that might harbour tsetse, because of the suitable microclimate provided, in areas that are otherwise too hot and dry. *G. tachinoides* is particularly known to be able to survive further north in this region than other tsetse species by making use of the small, fragmented areas of habitat. In more southerly areas, where conditions are more favourable and tsetse flies are widespread, seasonal dispersal, rather than identification of isolated habitats, needs to be determined. This can be achieved by placing transects of traps outwards into adjacent grid squares from gallery forests into the bordering savannah grasslands or forests.

FIGURE 2.30

Band and enhancement combinations that highlight the gallery forests that are typical for parts of Central and West Africa

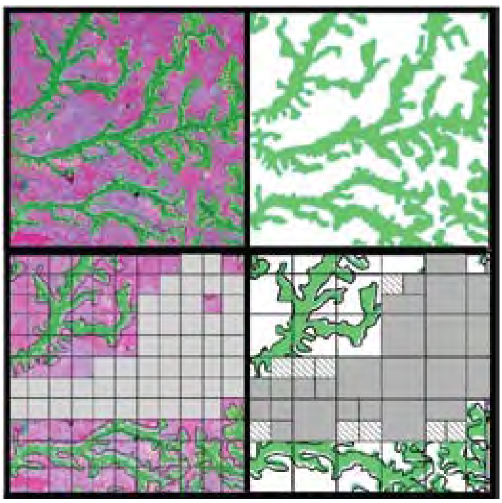


The image is used to illustrate the process of setting up a hypothetical survey grid for *palpalis* group tsetse flies

NASA

FIGURE 2.31

Grid system for riverine tsetse in humid savannah



(upper, left) LandSat 7 satellite image showing Central African gallery forests that would be inhabited by riverine tsetse species of the *palpalis* subgenus, (upper, right) a simplified vegetation map showing only the gallery forests derived from that satellite image, (lower, left) a 10 × 10 km grid superimposed over the image/map, and (lower, right) the grid squares included (grey) and excluded (shaded) in the survey

2.4.3.2. Correcting Data for Seasonality of Survey Catches

Ideally, a survey should be repeated at different seasons of the year (as with the Ethiopian Southern Rift Valley Tsetse Eradication Project survey: see 3.5.2), in order to be able to assess seasonal changes in distribution and abundance and obtain more accurate data on tsetse distribution. However, for economic reasons, surveys may be carried out over an area with trapping once only in whatever season a particular area happens to come into the work plan. That will result in difficulties in comparing densities between one area and another if they have been surveyed at different seasons. Provided that some representative sites are identified for continual monthly trapping to provide the necessary data, there are appropriate methodologies that can later be used to correct the survey data for season. Note that the following correction methodology does not help to provide information on seasonal variations in distribution (presence or absence), only on seasonal abundance.

In order to correct for differences in time of year of the survey the catch data is standardized for month of collection by calculating the annual catch T, by adding the individual monthly catches (t1, t2, t3,….. t12) from the sites have been monitored monthly at all seasons (routine monitoring sites). The standardized survey catch is then calculated by dividing the actual catch (N) by the relevant proportion constituted by the monthly catch of the annual total catch N/(tn/T), giving an annual expected catch at each site. This is then reduced to a monthly value by dividing by 12. This assumes that each 24-hour collection during the survey was representative of a whole month. That is of course, often likely to be an inaccurate assumption, especially in the rainy season, at which time there would be a good chance of a catch being disrupted and unrepresentative.

2.4.3.3. Examples of Grid-Based Planning for Large-Scale Tsetse Surveys

Some examples of tsetse fly surveys that have made use of grid-based systems for planning are given in 3.5. Although these examples used the grid structure to display the survey data, a better approach is to use GIS tools for interpolation of the data as described in a subsequent section. Only the Ethiopian example was a survey conducted specifically for the planning and execution of an AW-IPM programme, and covering what was believed to be the entire population of an isolated *G. pallidipes* infestation (Vreysen et al. 1999). Although the other examples were not in the context of AW–IPM control efforts, they do illustrate the methodology used for both large- and small-scale surveys conducted for different purposes. The surveys in The Gambia (Rawlings et al. 1993) and in Togo (Hendrickx et al. 1999) were similar in that they were country-wide surveys (both covering small, long and narrow Africa countries), and were conducted for epidemiological reasons rather than with immediate control/eradication projects in mind. In contrast, the survey in the Ghibe valley of Ethiopia was small-scale, and conducted primarily for research purposes in order to understand the success or failure of pour-on treatments of cattle for tsetse control and of the trypanosomosis epidemiology in the area (Leak et al. 1995).

2.4.4. Setting Up a Database

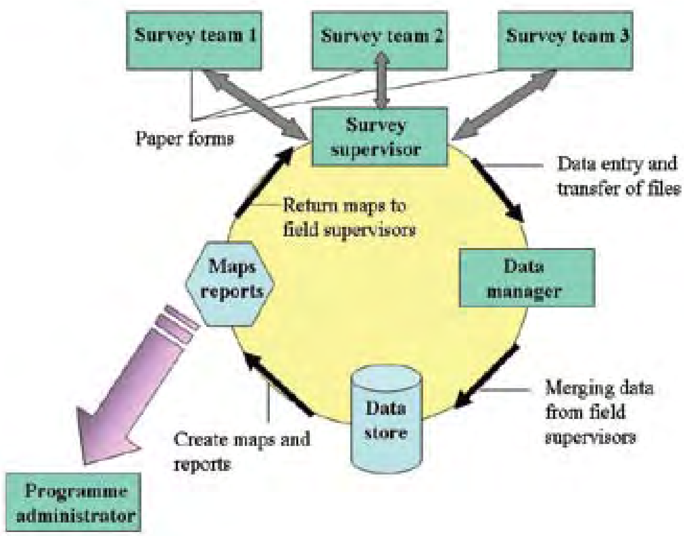
2.4.4.1. Introduction

It is important to ensure from the initial planning stages that the method of data collection and recording and the way in which it is analysed is standardized. This can be achieved by having uniform, pre-printed data-recording sheets for field use and by making use of a standard database management system that has pre-prepared data-entry forms that are fully compatible with the paper recording sheets to be used by field teams. To standardize analyses, queries and report forms can also be prepared. The database and programmes for analysis and reporting should be designed and tested before the start of data collection to ensure that they provide the sort of data analysis that will be required. FAO/IAEA commissioned the development of a database package entitled "Tsetse Intervention Recording and Reporting System" (TIRRS) that can readily be linked to GIS software. Microsoft Access® provides users with one of the simplest and most flexible database management system solutions and TIRRS is a Microsoft Access®-based package that is customized to handle data from monitoring and baseline data tsetse surveys in the context of AW–IPM programmes.

To ensure standardization of data processing it will also be necessary to carry out a practical training course with the survey team members, with a dry run of data collection, entry and analysis to ensure that the system works. It is far preferable to put some effort into making sure that the required data is being collected, stored and analysed correctly at the beginning of a project rather than attempt to revise databases and data collection during the implementation phase.

FIGURE 2.32

Diagram showing the data flow in a tsetse baseline data survey



2.4.4.2. Data Flow

In a survey over a big area, a large quantity of data will be generated. In order for these data to be fully used in an interactive way that will allow the survey procedure to be "fine-tuned" as it progresses, those data will have to be rapidly entered into a database, analysed and results reported. This will require an efficient, two-way channel of communication between survey technicians, data entry persons, data managers, and the survey management team as outlined in **Figure 2.32**.

In a large survey area, or where there are some physical barriers to communications (lakes or rivers), it might be appropriate to have field teams based in different locations within their area of activities. In such circumstances, each team should be equipped with a computer for data entry. Data will then be transmitted from each field team on a weekly basis to the survey supervisor. The survey supervisor will pass data to the data manager, who will pass it to the data entry personnel for collation in an overall database from which weekly reports will be generated. Any problems with data noticed during data entry (incorrect or missing data) will be passed back through the data manager and survey supervisor to the field teams for correction/verification the following week. Similarly, the weekly-generated report will be passed back to the survey supervisor for evaluation so that, if necessary, alterations can be made to the survey procedure or work plan, in response to observations arising from the report (e.g. areas that might need repeated or more intensive survey).

2.4.4.3. Database Management Systems

A database is an organized collection of data. Database management systems such as Microsoft Access®, Oracle, SQL Server or MYSQL provide us with the software tools we need to organize data in a flexible manner. It includes facilities to add, modify or delete data from the database, ask questions (or queries) about the data stored in the database and produce reports summarizing selected contents.

Microsoft Access® provides users with one of the simplest and flexible database management system solutions. TIRRS is a Microsoft Access®-based database management system that is customized to handle data from baseline tsetse surveys in the context of AW–IPM programmes. The four major components of any Access®-based database management system that most database users will encounter are tables, queries, forms and reports.

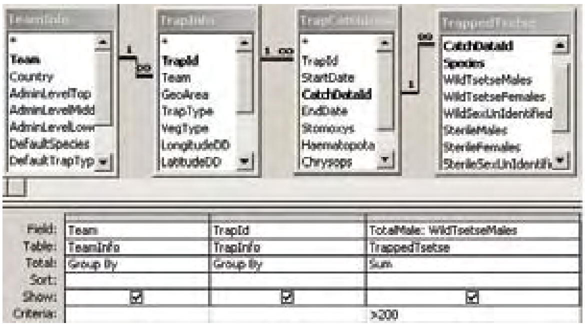
Tables comprise the fundamental building blocks of any database. If you're familiar with spreadsheets, you'll find database tables extremely similar, e.g. the example of a table

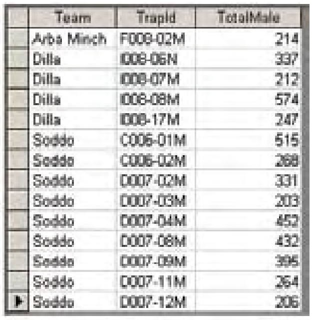
FIGURE 2.33
An example of a data sheet view of a table in the Tsetse Intervention Recording and Reporting System (TIRRS) database

Field Name	Data Type
TrapId	Text
Team	Text
GeoArea	Text
TrapType	Text
VegType	Text
LongitudeDD	Number
LatitudeDD	Number
LongitudeUTM	Number
LatitudeUTM	Number
UTMzone	Number
Altitude	Number
Remark	Memo

TrapId	Team	GeoArea	TrapType	VegType	LongitudeDD	LatitudeDD
D012-03M	Arba Minch	Nechisar	Ngu2F	WGL	37.5698	5.98921
D012-05M	Arba Minch	Nechisar	Ngu2F	Bul/WGL	37.56935	5.98597
D012-04M	Arba Minch	Nechisar	Ngu2F	WGL	37.56928	5.98744
D011-03M	Arba Minch		Ngu2F	RFF/FFF	37.559722	6.116194
F006-09M	Soddo		Ngu2F	FFF	37.815667	6.522083
I008-09M	Dilla		Ngu2F	WGL	38.009444	6.379444
F006-07M	Soddo		Ngu2F	RFF/FFF	37.811139	6.529222
I008-08M	Dilla		Ngu2F	FFF	38.01	6.375556
F007-01M	Arba Minch		Ngu2F	Bul/WGL	37.77597	6.50186

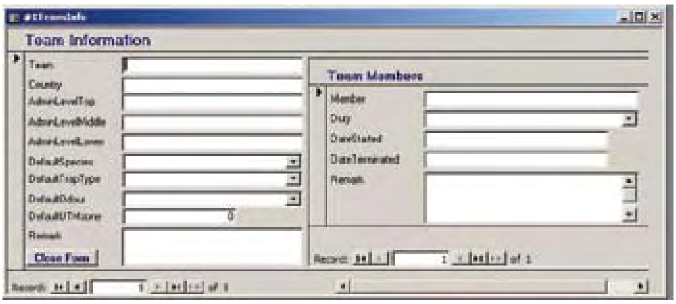
FIGURE 2.34
An example of a query and its result in the Tsetse Intervention Recording and Reporting System (TIRRS) database





Team	TrapId	TotalMale
Arba Minch	F008-02M	214
Dilla	I008-06N	337
Dilla	I008-07M	212
Dilla	I008-08M	574
Dilla	I008-17M	247
Soddo	C006-01M	515
Soddo	C006-02M	268
Soddo	D007-02M	331
Soddo	D007-03M	203
Soddo	D007-04M	452
Soddo	D007-08M	432
Soddo	D007-09M	396
Soddo	D007-11M	264
Soddo	D007-12M	206

FIGURE 2.35
An example of a form for data entry in the Tsetse Intervention Recording and Reporting System (TIRRS) database



design and its datasheet from the TIRRS system (**Figure 2.33**). The table in **Figure 2.33** contains the trap identification information like longitude, latitude, trap type and vegetation type. Each column of the table corresponds to a specific trap identification (trap ID) characteristic (or attribute in database terms). Each row corresponds to one particular trap ID and contains its information.

Queries provide the capability to combine data from multiple tables and place specific conditions on the data retrieved. Looking again at the TIRRS database, suppose that we need to create a list of those trap sites whose altitude range is between 1300 and 1700 m. A simple query allows us to request that information and the system returns those records that meet the above condition. Additionally, you can instruct the database to only list specific attributes such as the grid no, trap ID, and altitude. A sample query and its corresponding output are shown in **Figure 2.34**.

Forms provide a user-friendly interface that allows users to enter data in a graphical form and have that data transferred to the database. **Figure 2.35** provides an example of a form for data entry.

FIGURE 2.36
An example of a report taken from the Tsetse Intervention Recording and Reporting System (TIRRS) database

Periodic Monitoring Report by Grid, VegType and Species — **Ethiopia/Dilla**

Period (Cycle): 11/2005 **Grid: H010**

Species	TrapId	Altitude	W. Male	AD W. Male	W. Female	AD W. Female	W. Unidentified	Total	AD Total
Grassland									
G. pallidipes	H010-01	1256	1	0,333	2	0,667	0	3	1,000
	H010-01	1256	2	0,667	1	0,333	0	3	1,000
	Total/Avg	1256	3	0,500	3	0,500	0	6	1,000
G. fuscipes fuscipes	H010-01	1256	0	0,000	0	0,000	0	0	0,000
	H010-01	1256	0	0,000	0	0,000	0	0	0,000
	Total/Avg	1256	0	0,000	0	0,000	0	0	0,000
Woody grassland									
G. pallidipes	H010-01	1227	3	1,000	5	1,667	0	8	2,667
	H010-01	1227	2	0,667	4	1,333	0	6	2,000
	H010-03	1239	1	0,333	0	0,000	0	1	0,333
	H010-03	1239	0	0,000	0	0,000	0	0	0,000
	H010-06	1320	3	1,000	4	1,333	0	7	2,333
	H010-06	1320	0	0,000	0	0,000	0	0	0,000
	H010-07	1350	0	0,000	0	0,000	0	0	0,000
	H010-07	1350	1	0,333	5	1,667	0	6	2,000
	Total/Avg	1284	10	0,417	18	0,750	0	28	1,167

Reports provide the capability to quickly produce formatted summaries of the data contained in one or more tables and/or queries. Reports allow us the inclusion of graphics, attractive formatting and pagination. Look at the example report in **Figure 2.36** taken from the TIRRS database.

Relationships between data in different tables allow us to correlate data in many ways and to ensure the consistency (referential integrity) of these data from table to table, as illustrated in the example of **Figure 2.37** of part of the TIRRS database relationships.

Notice, for example, that each trap ID is associated with a specific grid; each trapping period is associated with specific trap ID data, etc. The lines running from one table to another indicate a one-to-many or one-to-one relationship between the tables. Once the

FIGURE 2.37
Diagram showing a portion of the relationships between tables in the Tsetse Intervention Recording and Reporting System (TIRRS) database

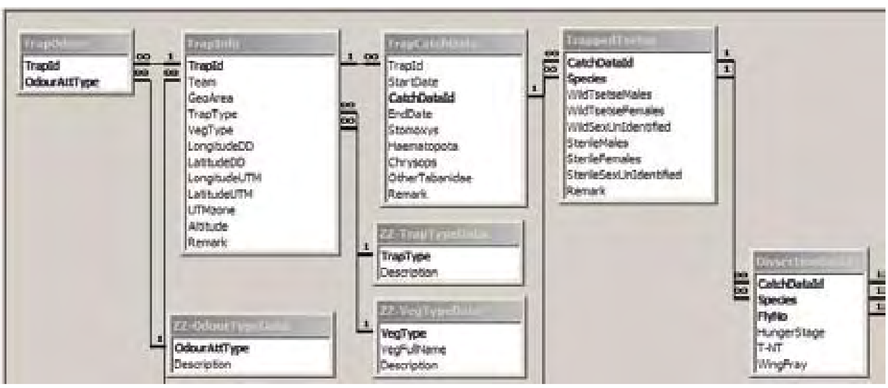


TABLE 2.6.
An example of a recording sheet to enter tsetse trap data during a baseline data survey.

Tsetse Survey Data Sheet

Grid ID		Team Leader		Month	
Admin level 1		Data Officer		Year	
Admin level 2		Date of entry		Map datum	
Admin level 3		Accuracy		UTM Zone	
Country				Page	of

Trap no.	Longitude (x coordinate)	Latitude (y coordinate)	Altitude	Vegetation type	Start Date	Start Time	End Date	End Time	Tsetse Flies			Biting flies		Other	Remarks
									Species	Males	Females	Family	No		

relationship is established, the database will ensure that only values corresponding to valid data in one table can be inserted in the other table. Additionally, we have the option of instructing the database to remove a record from a table on one side of the relation and then remove or update all associated records on the other sides throughout the hierarchy.

2.4.4.4. Data Recording Sheets

Examples of survey recording sheets, indicating the essential data that should be recorded are shown in **Tables 2.6** and **2.7**. Most importantly, recording sheets should show the locations of the traps from which the data were obtained. This consists of the identification of the trap ID of the given trap; the identification of the grid square in which the trap is located and next the exact position of the trap given as geographical coordinates. The most useful coordinates to be used are latitude and longitude expressed as decimal degrees or UTM coordinates. If UTM geographical coordinates are being used then the UTM zone, which covers a large area, should also be recorded. As this information is fixed for a large area, it therefore only needs to be recorded once, and not on each trapping occasion. Each trap will thus have a unique identifying number or combination of letters and numbers and corresponding coordinates (latitude and longitude expressed either as decimal degrees or UTM Eastings and Northings). It is advisable to use different recording sheets for different grid numbers. The dates of capture must be recorded. Next come the details of the tsetse and biting flies that have been captured. The type of details recorded for tsetse flies may differ from project to project, and can either consist of summarized catch data, i.e. total number of males and total number of females per trap per day **(Table 2.6)**, or can be detailed for each fly, noting its sex and the results of dissection for trypanosome infection or ovarian age on the same sheet (**Table 2.7**). Most importantly, duplication of work by unnecessarily entering the same data more than once, increasing the chance of data-entry errors, should be avoided.

Data for dissection results have to be entered for each individual fly and infection types and rates will be calculated using queries.

2.4.4.5. Using the TIRRS

The TIRRS is designed to be used by three groups of people with different levels of expertise in database use and different responsibilities in the pest management programme. These groups are data entry personnel or trap site survey workers, data managers and database experts.

Data entry personnel or trap site survey workers use the graphic interfaces and menu items customized to fit in to their interests and their needs. Users in this category are allowed to interact only with the interfacing items so that they do activities that are limited to those that are given in the TIRRS menu. They should be allowed to have access only to the MDE[1] file version of the TIRRS.

1 MDE: Microsoft Access Database: Microsoft Access database file with all modules compiled and all editable source code removed. In MDE file all Visual BASIC for Applications (VBA) procedures are compiled — converted from human-readable code to a format that only the computer understands. This change prevents a database user from reading or changing your VBA code. No one can create forms or reports or modify the existing ones but can create queries.

TABLE 2.7.
An example of a recording sheet to enter data of tsetse dissections.

Tsetse Dissection Sheet

Dissector ______________________ Mag. WVL ______________________

Mag. Ovariole ______________________ Date of entry ______________________

No.	Date	Trap site	System	Species	Sex	T/NT*	F.N.O.S.**	No. of ovulations	Ovariole sizes			
									largest		second	
									length	width	length	width
1												
2												
3												
4												
5												
6												
7												
8												
9												

* T – Teneral, NT – Non Teneral
** Follicle Next in Ovulation Sequence

Data officer ______________________

Uterus content	Spermathecae index		Hunger stage	Trypanosome Infection				Wing measurements			Width apical body
				Proboscis				Vein length	Wing fray	Sample	
	left	right		lab	hyp	midgut	sal. glands				

Data managers are persons with a good background and knowledge of using database management systems in general and Microsoft Access® in particular. They are advised to work only on MDE versions of TIRRS. They will be responsible to extend the use of TIRRS by:

- creating new queries according to new requirements,
- importing and merging data collected from different areas,
- making backup and restoring data from backups,
- making sure that data collection sheets are used in a proper manner,
- supervising the data-entry process and device mechanisms of minimizing errors,
- training the data-entry personnel on how to use TIRRS,
- assisting the data-entry process and solving related day-to-day problems, and
- dealing with all other TIRRS related activities and problems.

Database experts are persons with a solid background and knowledge of database design and programming. Such persons must be able to read and understand others work (programme and design) so that they can suggest necessary changes. All database related problems and new requirements that are beyond the capacity of the data manager are to be dealt with by such experts. They can work both on MDE and MDB[2] versions of TIRRS but any change on the structure of the system must be well documented and reported to the central office before its redistribution to the users. Care should be taken when changing components of MDB file. Organizing a new testing scheme may be necessary after the new change on MDB components so as to make sure that the changes are done according to need. Major duties will be:

- designing new or redesigning existing components of the system so that they fit to new requirements,
- caution: if the changes involve the MDB version of TIRRS, compilation into MDE and transfer (importing) of all data tables in previous MDE to the new MDE is necessary before distributing the system to the end users,
- assisting the database manager in solving prevailing problems,
- dealing with all other TIRRS problems encountered by the users and the data manager, and
- documenting any changes made to the structure of TIRRS.

2.4.4.6. TIRRS Menu System

The TIRRS menu system is organized into hierarchies of menu items organized into groups and subgroups. In this section, we will look at the components and the purposes of each of the menus and the menu items.

TIRRS start-up screen — This is the main screen that appears when we start TIRRS. It has four buttons to choose from, i.e. (1) a button to continue working in TIRRS system, (2) a button to create a table of the apparent density of tsetse flies for each trap (expressed as the average number of tsetse of each species caught per trap per day) for further GIS

2 MDB: Microsoft Access Database File

FIGURE 2.38
Main start-up screen of the Tsetse Intervention Recording and Reporting System (TIRRS) database

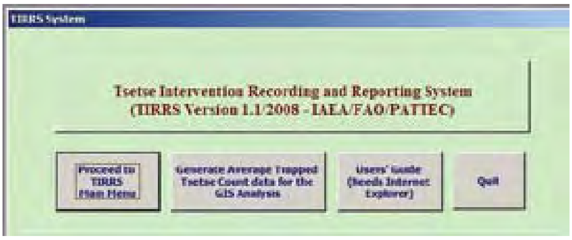


FIGURE 2.39
Pop-up box for setting condition to generate data for GIS in the Tsetse Intervention Recording and Reporting System (TIRRS) database

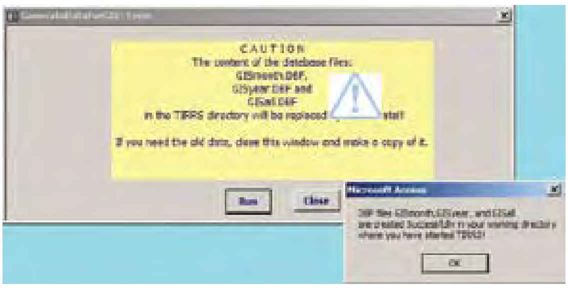


FIGURE 2.40
A sample of the table output in the Tsetse Intervention Recording and Reporting System (TIRRS) database used as an input for GIS analysis

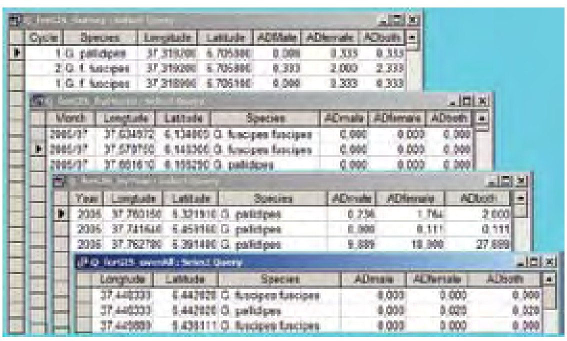


FIGURE 2.41
Main switchboard menu in the Tsetse Intervention Recording and Reporting System (TIRRS) database

analysis, (3) a button to read this user guide, and (4) a button to exit from the system (**Figure 2.38**).

The "Proceed to TIRRS Main Menu" button in the figure is the one that takes us to all hierarchies of available options in TIRRS. The "Generate Average Trapped Tsetse Count Data for the GIS Analysis" button takes us to another small popup window in which we select the period of trapping and tsetse species for which we want to generate a resource table for GIS analysis. Look at the figure of this popup in **Figure 2.39**.

The type and content of the table that we get as an output from this process and that will be used as an input by the GIS is given in **Figure 2.40**

Main switchboard menu — The first menu that we get after clicking the TIRRS option is the "Main Switchboard" menu. It consists of submenu items indicated in **Figure 2.41**.

Under the main switchboard menu select:

1. The submenu for basic/setup data forms. Data in this category is entered at the setup level before the working data is to be entered. It can be extended any time. Examples are; list of species available, type of vegetation, type of trap used, team related data, etc.;
2. The submenu for working data entry forms;
3. The submenu for displaying/printing ready-made reports (reporting options);
4. The submenu to generate aggregated data for GIS analysis;
5. The submenu to exit to Microsoft Access® environment where data managers or database experts can make changes to some of the components of the TIRRS or perform other activities like querying the database, etc., and
6. The submenu to exit TIRRS.

Data entry forms menu — This menu consists of submenus for basic data entry (**Figure 2.42**) and working data entry (**Figure 2.43**). The forms are also linked to each other and therefore we can, for example, access the "trap ID" form from within the "grid" form; similarly "trapping occasion" "site instance" from "trap site", etc. This method of access-

FIGURE 2.42
Menu in the Tsetse Intervention Recording and Reporting System (TIRRS) database to select setup data entry forms

FIGURE 2.43
Menu in the Tsetse Intervention Recording and Reporting System (TIRRS) database to select working data entry forms

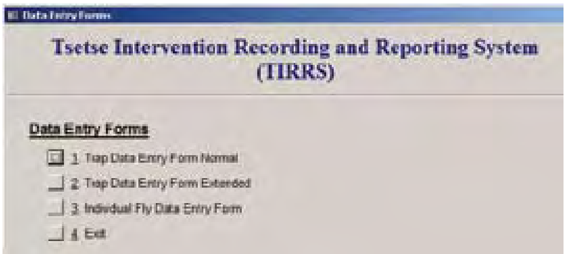


FIGURE 2.44
Menu in the Tsetse Intervention Recording and Reporting System (TIRRS) database to select reporting options

ing lower level forms is good when we want to limit the number of items displayed to only those related to the current record.

Reporting options menu — This menu consists of submenu items indicated in **Figure 2.44**. Each menu item takes us to another submenu with group of options that can be selected in a similar manner.

2.4.4.7. Forms in the TIRRS

Data entry forms in the TIRRS are designed to be user friendly and are linked to each other so as to comply with the database design structure. The database is designed to support relational database principles. Data do not have to be recorded in the same table as this could become cumbersome and might entail duplication of data entry – for example, entering the same trap details and coordinates for each dissected fly from a trap. Instead, repetitive data such as trap coordinates are entered once in a table for that data, which is then linked by the software to other data such as individual fly data. This will also minimize data errors, as the more information generated by the computer, the less opportunity for mistakes. Microsoft Access® links tables together, using common, primary and foreign key fields so that data can be matched between tables. **Figure 2.45** illustrates an example of the relationships between tables in the TIRRS. The lines between tables indicate the common fields that enable the rest of the data within them to be linked.

Forms for data entry are also organized to support this link. We have main forms corresponding to the main tables in the structure. These forms can be accessed using the hierarchies of menus in the "TIRRS Menu System" section and are designed to support up-to-date user-friendly data-entry features. **Figure 2.46** shows some of the features included in our data entry forms to simplify the data entry process and for error minimization. Among the features are:

FIGURE 2.45
Diagram that shows relationships between tables in the Tsetse Intervention Recording and Reporting System (TIRRS) database

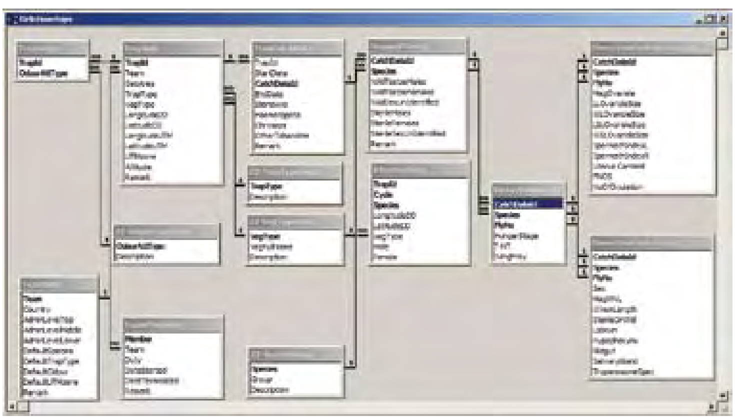


FIGURE 2.46
Sample form to enter tsetse fly dissection data in the Tsetse Intervention Recording and Reporting System (TIRRS) with different user-friendly features

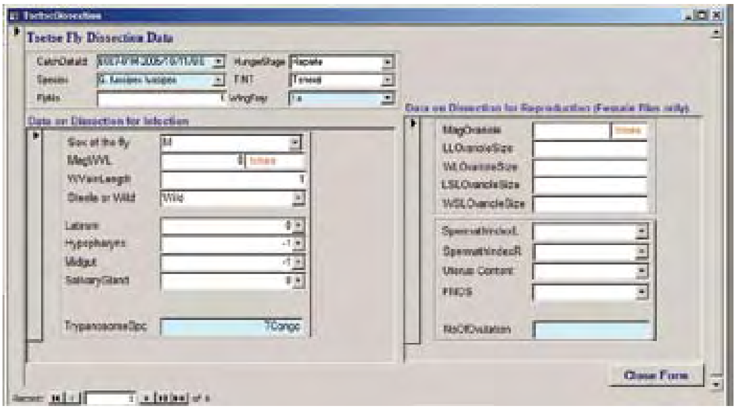
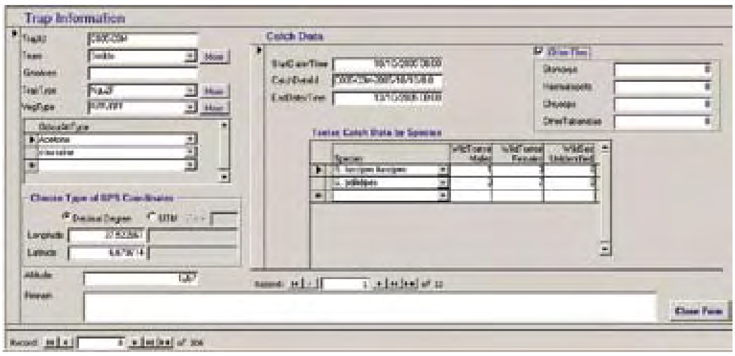


FIGURE 2.47
A form in the Tsetse Intervention Recording and Reporting System (TIRRS) with option buttons and check boxes



- The use of auto retrieval of linked data values: this is important to keep data integrity by working on data whose complete history is already recorded in the database. While working on the trapped tsetse recording form, for example the system makes sure that all relevant data like trap and grid already exists in the corresponding table.
- The use of drop-down boxes: this method avoids data entry errors that come from typing long entries like tsetse species name.
- The use of filtering features so as to view and work on selected records: this feature automatically limits our access range in the data table to only sets of records that are

related to our current recording. While, for example, working on fly dissection data entry of flies from specific trap site, the system limits us to work only in that particular grid and trap site.

- The use of auto entry of values by calculating from already existing data: some data such as the number of trapped flies, should be normalized to the per-day rate as trapping, for different reasons, may extend to more than one day. In this case, the system uses starting and ending date information to calculate the number of days. And then normalize the number of flies captured to the per-day count, and
- The use of option buttons and check boxes: option buttons and check boxes are used to avoid confusion on a complex entry form. In the TIRRS the trap info data entry form, for example, is equipped with such features (**Figure 2.47**).

2.4.4.8. Reports in the TIRRS

The TIRRS has many ready-made reports to show trends, summarize data, and tabulate values. All the reports that were envisaged during the design of the system are categorized and listed under the reports submenu of the TIRRS switchboard menu. Once the data is in the TIRRS, anyone with some knowledge of database management (in our case the data manager) can create any report of interest. Categories of the currently added reports include: trap density, dissection, population structure, reproductive structure, and other customized reports that summarize and tabulate different data by parameters like vegetation type, altitude range, trap type, type of odour attractant, etc.

The report shown in **Figure 2.48**, for example shows the average daily fly catch for a given trap for six tsetse species recorded (hypothetical data). All other necessary information is added to the report to make it more readable and understandable.

This type of report can be printed by entering specific conditions in the report setting a popup window (**Figure 2.49**) that is displayed when selecting any report item. We have several such types of ready-made reports that can be accessed from the report menu.

2.4.4.9. Backing Up the Database

Most people using computers know that they should back up their work in case something happens to their computer, or to the data file, yet many people still do not do this. For some types of work it may not have important consequences if it is lost, but for a large database, taking a lot of time to enter, it is essential that backups are made regularly so that the data is not lost, as this could create a serious set-back to planning and implementation. It is recommended that weekly backups of the database constructed using TIRRS are made on CDs, on external hard drives, or, where available on a server. Most PC's now come with an in-built CD/DVD writer and using rewriteable CDs and making CD backups is neither difficult nor costly. A copy of the database should also be stored in a separate, headquarters office as well as at the project site office. To take a backup of data in the TIRRS, we use the backup option of the Microsoft Access® itself.

Steps for making a backup

1. Save and close all objects in the database.
2. On the File menu, click Backup Database.

FIGURE 2.48

Sample report of period monitoring by grid and species in the Tsetse Intervention Recording and Reporting System (TIRRS)

Periodic Monitoring Report by Grid and Species — **Ethiopia/Soddo**

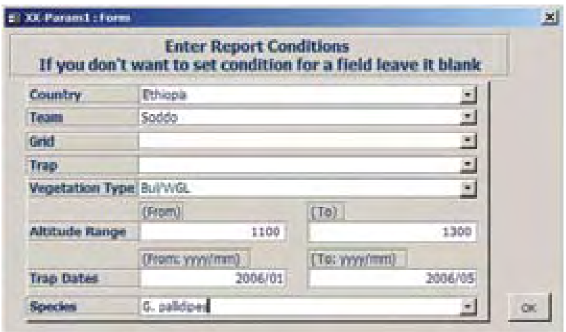
Period (Cycle): 9/2006 — **Grid: C006**

	TrapId	Veg Typ	Altitude	W. Male	AD W. Male	W. Female	AD W. Female	W. Unidentified	Total	AD Total
G. pallidipes	C005-01M	RFF/FFF	1375	1	0,333	2	0,667	0	3	1,000
	C005-02M	RFF/FFF	1356	1	0,333	1	0,333	0	2	0,667
	C005-03M	RFF/FFF	1267	2	0,667	4	1,333	0	6	2,000
	C005-04M	Bul/WGL	1392	0	0,000	2	0,667	0	2	0,667
	C005-05M	Bul/WGL	1346	0	0,000	1	0,333	0	1	0,333
	C005-06M	Bul/WGL	1345	0	0,000	0	0,000	0	0	0,000
	C005-07M	Bul/WGL	1359	0	0,000	0	0,000	0	0	0,000
	C005-08M	Bul/WGL	1265	15	5,000	38	12,667	0	53	17,667
	C005-09M	Bul/WGL	1264	43	14,333	36	12,000	0	79	26,333
	C005-10M	Bul/WGL	1346	44	14,667	48	16,000	0	92	30,667
Total catches & Average ADs			1332	106	3,533	132	4,400	0	238	7,933
G. fuscipes fuscipes	C005-01M	RFF/FFF	1375	2	0,667	5	1,667	0	7	2,333
	C005-02M	RFF/FFF	1356	0	0,000	1	0,333	0	1	0,333
	C005-03M	RFF/FFF	1267	1	0,333	1	0,333	0	2	0,667
	C005-04M	Bul/WGL	1392	0	0,000	0	0,000	0	0	0,000
	C005-05M	Bul/WGL	1346	0	0,000	0	0,000	0	0	0,000
	C005-06M	Bul/WGL	1345	0	0,000	0	0,000	0	0	0,000
	C005-07M	Bul/WGL	1359	0	0,000	0	0,000	0	0	0,000
	C005-08M	Bul/WGL	1265	0	0,000	0	0,000	0	0	0,000
	C005-09M	Bul/WGL	1264	0	0,000	0	0,000	0	0	0,000
	C005-10M	Bul/WGL	1346	0	0,000	0	0,000	0	0	0,000
Total catches & Average ADs			1332	3	0,100	7	0,233	0	10	0,333

Filter Conditions Used (* means all): Country=Ethiopia, Team=Soddo, Grid=*, Trap=*, VegType=*, Altitude(from)=*, Altitude(to)=*, StartDate(from)=*, StartDate(to)=*, Species=*

FIGURE 2.49

Pop-up window to set conditions for all reports in the Tsetse Intervention Recording and Reporting System (TIRRS)



3. In the Save Backup As dialog box, specify the name and location of the backup copy.

Restoring the backed-up data — Use the explorer to copy the backup database to your database folder. If the existing database in the database folder and the backup copy has the

same name, restoring the backup copy may replace the existing file. If you want to save the existing file, rename it before you copy the backup database. The TIRRS database contains objects such as tables, queries, forms, reports, macros, and modules. Sometimes, it is possible to import only selected objects we want from the backup to our working copy.

2.4.4.10. Entomological Considerations Regarding the Database

This section provides some explanation for the construction of aspects of the database and the way it should be used. The database is constructed to accommodate the recording, storing and manipulation of all the theoretically desirable entomological data for conducting an AW-IPM programme. It is recognized, however, that not all projects will have the capacity and resources to collect all such data, or maybe perhaps only for limited periods of time. Similarly, for some projects certain aspects may be considered unnecessary. For this reason certain forms will have sections that can be selected or deselected such as the forms for recording reproductive details of female flies including ovarian age. This is a dissection requiring considerable skill and experience that may not always be available and may be required for specific phases of a project.

Identification of project staff — In relation to dissection, as well as other activities in the catching, managing and recording of fly details it is sometimes useful to record the names of the persons carrying out specific tasks so that queries can be made to the appropriate person if necessary at a later date. It would be inconvenient, however, to record the dissector of each individual fly: in some cases this could remain constant for a long period, or in others there may be several persons who could perform the task over a short period of time. The database is therefore designed to provide the names of members of a field team and it is expected that team leaders or supervisors will be able to use this information to assess the data or request verification as and when required.

Defining a trap identification — Tsetse trap data refers to a specific set of trapping conditions (trap type, type of odour attractants and dispensers); this allows comparisons to be made between catches at different time intervals. If some of those conditions change, a reliable comparison may not be possible. For example, one cannot compare catches with a biconical trap with attractants with catches from one without attractants unless some correction is made for the effectiveness of an attractant. Similarly, a comparison between catches from a biconical trap and an F3 trap cannot be made directly because the traps have different efficiencies. For these reasons, if there is some significant change in the trap data over time, it is preferable to give the changed trap a new unique trap ID rather than to record it as the same trap with some modifications – even if its geographical location has not changed.

The database contains a drop-down list of trap types; if additional trap types are to be used, they must first be added to the trap type list (Table zz-Traptypedataform) before they will be accepted in the database when entered in the trap ID form.

Also included as a dropdown list is a selection of vegetation types with a description of how they are defined. Additional vegetation types may be added together with their descriptions if required. The FAO AfriCover project lists a large number of vegetation types

but such an exhaustive list would be unsuitable for use on a tsetse survey in which a rapid determination has to be made, by entomologists with a minimum necessary amount of training in this area. Ideally, there should be a fixed number of standardized vegetation types and recently, FAO has customized the various vegetation types of the AfriCover project for use in tsetse projects (Cechi and Mattioli 2007, Cechi et al. 2008). Vegetation types may change over time if areas of forest in which traps have been deployed are cleared. This must be taken into account when analysing and comparing results over time. If necessary, a trap needs to be re-identified (given a new identification) if the vegetation has changed significantly.

Defining a trapping period — It is common practice to carry out a period of trapping, say for three days, and to calculate the apparent density, expressed as the number of tsetse of a particular species caught per trap per day, by simply totalling the number of tsetse of that species that have been caught and dividing the total by the product of the number of trapping days and the number of traps used to catch them. The number of traps could be one if a figure of apparent density for an individual trap is required, but more commonly is for a group of traps in a given location such as a village or a grid square, etc. It would be more precise to take into account the number of hours that a trap has been in position. It is logistically unlikely to be possible to put out a series of traps all at the same time and to collect the catch from each trap all at the same time.

Commonly, a team will deploy a number of traps, starting with the first early in the morning and finishing with the last after a considerable time has elapsed, perhaps even late in the afternoon. This has implications for the interpretation of catch results not only because of the difference in length of time that a trap might be deployed but also in relation to the activity cycles of tsetse. This is complicated by the fact that activity cycles can vary seasonally throughout the year with temperature, etc. There is commonly an activity cycle in the late afternoon/early evening. Thus, a trap that has been deployed for three days and is "harvested" early in the morning on the third day, might miss the final day's activity cycle compared to the last trap to be harvested that may not be visited until late in the afternoon and that will have caught flies in the afternoon activity cycle. Whilst this might not be significant for a one-off survey determining where tsetse is found, it could be significant during the monitoring of the suppression or eradication phase of a project. The TIRRS database has been designed to incorporate the start- and end-times of a trapping period and to calculate the apparent density corrected for the number of hours of trapping but it cannot interpret the results in relation to activity cycles – that has to be done by the project entomologist. The TIRRS programme will allow the user to leave the times blank if those data are not recorded but will automatically enter a default "start time" of 08.00 a.m. for the start of trapping for the purposes of calculating the apparent density. Aspects of activity cycles and trapping duration are discussed elsewhere in the survey manual.

Geographical coordinates — Although a particular coordinate system can be recommended (e.g. decimal degrees), the TIRRS allows some flexibility to take into account project preferences for coordinate systems and it is possible to select between UTM or decimal degrees as the two major alternative systems that are expected to be used. With

ArcGIS® software, data from either system can easily be projected on the same map, with the projection conversion being made automatically by the GIS software.

Use of a grid system — The reasons for using a grid system for organizing a tsetse survey in the context of AW-IPM have been discussed and described in 2.4.3.1 of these guidelines. The grid structure is used to aid the planning and organization of logistic aspects of a project; data need not be analysed or displayed on a GIS map following a grid-based structure, although this is possible. As explained in this manual, although commonly based on the UTM 10 × 10 km grids found printed on paper maps, the identification of grid squares for a project is arbitrary, usually based on columns identified with letters starting with "A" and rows identified with numbers starting with "1". This structure allows the rough location of traps to be identified visually on a hardcopy map (within a grid square), which is less easily done with numerical geographical coordinates, although the latter allow the precise determination of their position. The grid structure is incorporated into the TIRRS database to allow a basis for dividing trapping results into spatial units for analysis. The same analyses can also be carried out for individual traps or for administrative units such as villages or similar artificial but identifiable geographical locations as well as by natural features such as vegetation or altitude.

FIGURE 2.50
A form in the Tsetse Intervention Recording and Reporting System (TIRRS) that shows GIS query choices

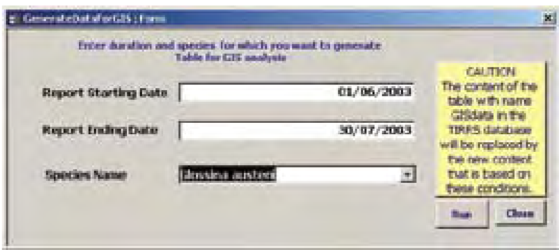


FIGURE 2.51
A form in the Tsetse Intervention Recording and Reporting System (TIRRS) that allows the creation of a new table of tsetse trap data for GIS

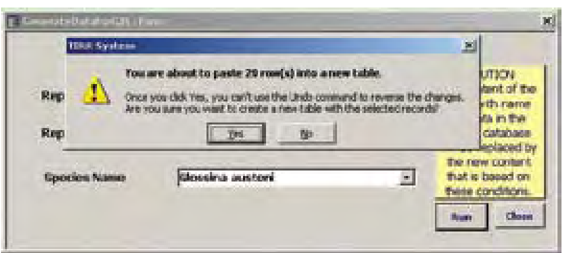


FIGURE 2.52
View of the "Add Data" button in ArcView® that can be used to choose a table from Access® database

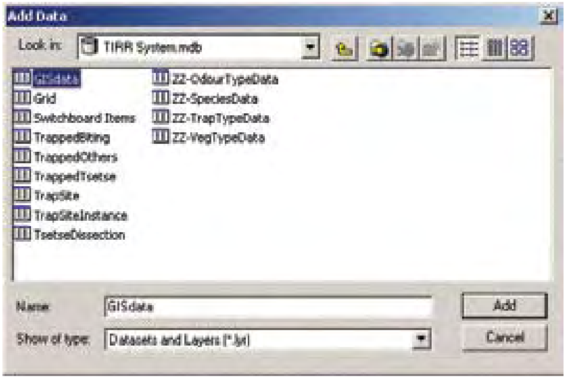
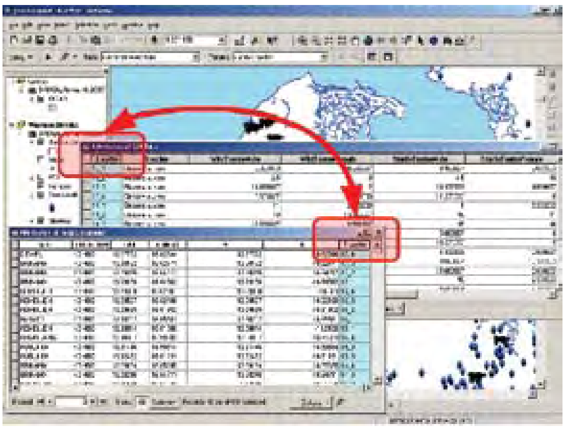


FIGURE 2.53
View in ArcView® GIS of the trap layer table of attributes joined to the Access® table of capture data by linking the "Trap No" field



2.4.4.11. Connecting the Database to GIS

The GIS program maintains a permanent layer of trap locations. Each trap has a unique ID number (or name). Within the database all capture data use the exact same unique trap ID number as an index for the capture data. Then when new data is brought into the GIS, a link is created between the trap's geographic location (GIS layer) and the updated capture data (tabular data table). This link is based on the matching trap ID numbers. It is crucial to keep these two sets of trap ID numbers synchronized. Normally synchronization will be maintained by first placing traps in the field and using a GPS instrument to georeference

the location. Then the GPS data file will be downloaded to the computer, and displayed in the GIS program. Finally, using the GIS layer of traps, a table of trap ID numbers will be extracted, or exported, to the database application. As the project progresses and new traps are added, they also will be georeferenced with a GPS instrument, and again an updated table of trap ID numbers will be exported to the database, thus keeping the two tables in sync.

Secondary information that will be obtained from the survey includes:

- The relationship between tsetse distribution/abundance and environmental characteristics (e.g. vegetation, altitude, temperature, relative humidity, rainfall). A requirement for analysing that information is an up-to-date vegetation/land use map, or satellite imagery from which it can be obtained and local, contemporary meteorological data.
- The mean apparent density per tsetse species per month (can also be split by sex) interpolated over the project region.
- Trypanosome infection rates in tsetse, and
- Age structure of the population.

The TIRRS main menu offers a button (**Figure 2.38**) for creating a GIS-specific table to be used to display tsetse capture data on a map as follows:

1. Be sure the trap ID number in the TIRRS table of traps is synchronized with the GIS layer of traps;
2. Run the above query, indicating the period of time (start date and end date) as well as the species of tsetse desired (**Figure 2.50** and **Figure 2.51**);
3. Within ArcView GIS, add the table "GISData" from the TIRRS database file (*.mdb) to the GIS project **(Figure 2.52**);
4. Create a join between the GIS trap layer, and the TIRRS table of average trapped flies (**Figure 2.53**);
5. use the GIS symbology tools to display the capture data (see 2.4.1.2).

2.4.5. Sensitizing the Local Population

It is important to sensitize and inform the rural population in the area of the survey in order to make them aware of what is going on and why. Unless this is done, the communities in the area will observe the activities being carried out, and the tools (traps) being used but will not be aware of the reasons or the significance. Lack of awareness can result in lack of cooperation and traps being stolen or damaged, thus disrupting the survey implementation. It is equally necessary to inform local government authorities of activities that are to be carried out in their area even if central government departments are aware of, and involved in the project.

This essential phase should be done in two phases:

1. The responsible person from the national authorities/local project management staff should contact all the relevant local government leaders at different levels to explain the objectives, type and locations of activities and the timing of events that will take place in the area,

2. During a second phase of sensitization, carried out at a local level during field operations, the field teams will inform the people living in the immediate vicinity of field operations of the activities, their importance and relevance to the community and the potential benefits. This information will be best disseminated in the local language and will seek the cooperation, and often, the active participation of the villagers for example in maintaining a trap in functioning condition.

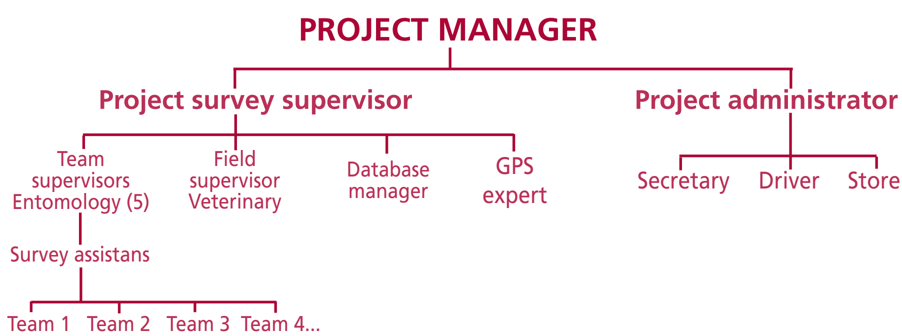
2.4.6. Management of Resources

During the preparatory phase, after determining where the project is to take place and prior to the detailed planning and start of operations it will be necessary to establish a project team both to manage and implement the activities. When established, that team will carry out the other preparatory phase activities such as preparing a detailed budget, procuring equipment (e.g. the number, type and source of tsetse traps, the most appropriate type of odour attractants required and their acquisition, compound and dissecting microscopes, drying ovens, desiccators, photocopier, printers, GPS instruments, maps, satellite images, etc.), needs in terms of human resources (field team size and composition) and preparing detailed work plans for implementation.

2.4.6.1. Human Resources: Establishing a Project Team

When planning the type of team required it is necessary to consider all of the tasks that will have to be undertaken and who will carry them out. For example, traps and cages will need regular supervision and repair – who will carry that out? The survey teams will probably be coming back late from the field and leaving early in the morning on a fixed schedule. If consideration isn't given to who will maintain the traps it may well be left inadequately done, and yet this seemingly minor component is crucial for the success of the survey. Who will maintain records of the available consumables and other items needed for keeping the work progressing on schedule? Will it be the project manager when he has some free time from providing technical supervision or will that lead to delays in replenishing essen-

FIGURE 2.54
Diagram showing the management structure of the survey component within a typical tsetse project



tial items? Who will be responsible if things are not available when required? Inevitably problems will arise if these things are not planned for and if each person's job description is not clear. Job descriptions should be clearly defined and provided to each team member, and where possible, check lists should be provided, and handed to supervisors monthly, to ensure that the necessary tasks have been fulfilled.

Project management unit — The size of the project management team will, of course depend upon the size of the project, which will be reflected in the budget available. For large projects there may be a large project management team, whereas, for a small project a smaller project management team will comprise staff having multiple functions. For example, the administrator might also be responsible for the store and the role of cashier. The overall manager would be a person with technical expertise, but also having good management capability (Dyck et al. 2005).

Project manager — Responsible for all aspects of the project, including the administrative management, procurement, recruiting staff, etc. Management staff should allow technical staff to make use of their technical expertise rather than to have too much involvement in administrative matters. The senior technical staff should make technical decisions on survey implementation.

Project survey supervisor — A qualified tsetse entomologist with experience in tsetse surveys will be responsible for the planning and implementation of the survey, providing technical backup and support to field teams. The project survey supervisor reports to the project manager.

Database manager — Expertise will be required in the initial stages for establishing a database and training project staff in its use, unless an off-the-shelf database is available that does not need adapting. In the latter case there will still be a training requirement to ensure that it is correctly used. Expertise will also be required for analysis of the data, although if a ready-made data management system with querying and reporting mechanisms is available those requirements will be minimal. The database manager will provide feedback to the project manager on progress of the survey and on any queries arising from the data. The technical project manager will in turn provide feedback to field survey teams.

Data-entry person(s) — Depending on the size of the project, one or more data-entry persons will be required to enter all the data received from the field into a single master database. They will also be responsible for maintaining backups of the data and verification of the accuracy of the data entry. They will report any errors or omissions of data to the database manager so that, through the technical project manager, feedback can be provided to the field teams.

GIS expert — It is recommended that there is a GIS expert on the management team. GIS expertise and experience with entomological/epidemiological survey work is an increas-

ingly valuable asset as more GIS applications become available and as their contribution to entomological and epidemiological work becomes more apparent (Cox and Vreysen 2005). At a minimum, a short-term GIS expert will be required at certain stages of the project. The GIS expert will provide not only maps, but interpretation of satellite images, analysis and interpretation of field data (correlations between tsetse catches and environmental factors – habitat, vegetation, altitude, etc.) – and will be able to contribute to predictions of areas of suitability for tsetse that might require additional surveying. It may also be desirable to commission specific detailed GIS analyses by specialists from external sources such as universities, national or international organizations or consulting companies.

Secretary — Required for normal secretarial duties**.**

Driver — Although the project managers and other staff may be able to drive themselves, it is likely that a driver will be required for the management unit. The driver will be responsible for ensuring that the vehicles are maintained and roadworthy.

Survey teams — Each survey team will require a driver or a member of the team responsible for driving the vehicle (however many teams there are). Ideally, the driver should also participate in the other survey activities — deploying the traps, etc. Trap assistants,

TABLE 2.8
Equipment and consumables with associated costs required for a large-scale (10 000 km^2) tsetse survey.

	Number	Unit price	Total (USD)
Transport			
Vehicles (coordinator and tsetse teams)	6	25 000	150 000
Fuel (200 km per day per survey vehicle; 15 km/litre + coordinator = 22 500 litres/year)	22 500	0.9	20 250
Oil (500 litres)			750
Fuel and oil filters (72 +72)			1100
Tsetse survey			
Traps (20 per team/day)	500	7	3500
Cages	1000	2	2000
Slides box of 150	5000		200
Cover slips (10 000)			100
Dissecting instruments	15	100	1500
Dissecting microscopes	5	6000	30 000
Compound microscopes	5	9000	45 000
GPS instruments	6	300	1800
Satellite imagery			700
Portable generators	5	400	2000

Stationery and office equipment			
Computer – GIS + software	1	1500	1500
Computer per team	5	1500	7500
Computer survey tsetse data	1	1500	1500
Computer for coordination / administration / communications	1	1500	1500
A3 Colour printer	1	500	500
A4 Laser printer	1	500	500
UPS	8	200	1600
Communications (telephone / email / internet, fax)			3000
Paper			150
Printer ink cartridges			1000
Computer software — Data management software such as Microsoft Access or "TIRRS"; GIS software			6000
Photocopier	1		1200
Personnel			
Coordinator / Office manager	1	5000	5000
Survey supervisor (entomologist)	1	5000	5000
Drivers	6	3086	18 516
Field entomologists	5	4937	24 686
Technicians	15	3086	46 286
Secretary	1	3000	3000
Data entry	2	3000	6000

technicians (whatever the terminology) will deploy traps, collect flies, dissect the flies, and record the data. The number will depend upon the size of the area to be surveyed, funding available, etc. For a large survey, this might range from 10 to 20, divided up into four or five teams up to as many as 40 persons in ten teams for an area of 10 000 km^2, which is probably about the maximum area that could practically be surveyed at one time.

Each team should include a tsetse entomologist supervisor who has sufficient experience in addition to a higher level of training, and who is capable of supervising the identification of good appropriate trap deployment sites, following the survey plan protocol that will be prepared by the technical project manager in consultation with other senior technical staff.

2.4.6.2. Budget Preparation and Procurement of Equipment

Having determined the team composition and prepared a list of materials/equipment and services that are going to be required it will be necessary to prepare a more precise budget

than what was prepared in the project formulation stage. The budget will depend on many factors, especially the size of the area to be surveyed and the time scale for the activities. **Table 2.8** shows an example of the sort of materials and quantities that might be required for a large-scale survey of 10 000 km^2 as a guide. Costs of the materials and equipment listed will vary with time and country and are therefore not to be taken as actual cost guidelines. Furthermore, it does not include some of the highly variable costs such as renting or constructing office buildings, electricity, water or other utility consumption costs.

Procurement of equipment from overseas can take much longer than expected if bureaucratic procedures have to be followed, involving international tenders and combinations of both national government and donor regulations. Although this point might seem unnecessarily obvious, it is important to start procedures as early as possible and to become familiar with, and follow established regulations and procedures closely if equipment is to be available at the time it is required. There are examples of delays in procurement in tsetse/rural development projects with a limited period of funding that have resulted in vehicles being delivered in the final months of the project. (Similarly, inadequate planning and preparation has resulted in instances of baseline survey reports only being available in the last month of a project).

2.4.6.3. Training

Training will be required for project personnel on tsetse biology, ecology, survey techniques, map reading, data management, and GIS. Although people will generally be recruited who already have some technical knowledge, short training workshops will be necessary to ensure that standardized methodologies are used – people coming from different former projects often have their own way of doing things that may differ. Furthermore, with ever-increasing knowledge of tsetse behaviour, trapping technologies, including further development of odour attractants, it is essential that opportunities are given for staff to be able to refresh their knowledge. Emphasis will be on practical aspects that are required for the efficient and effective conduct of the survey. The most basic and essential aspects for which training will be necessary will include:

- an understanding of tsetse ecology and biology, needed to aid the identification of appropriate habitats and locations for traps as well as the behaviour of tsetse in relation to traps and odours and patterns of activity,
- aspects of trap deployment – the need for standardization of procedures and trap design,
- map reading and use of GPS instruments,
- data recording and database management, and
- GIS.

For the team responsible for dissection of tsetse specialised technical training will be required on:

- identification and sexing of tsetse,
- wing fray ageing,
- ovarian dissection and ageing,
- dissection for detection of trypanosome infections, and