Section 2

Planning and Preparation of a Baseline Data Survey

2.1. IDENTIFICATION OF A POTENTIAL PROJECT AREA

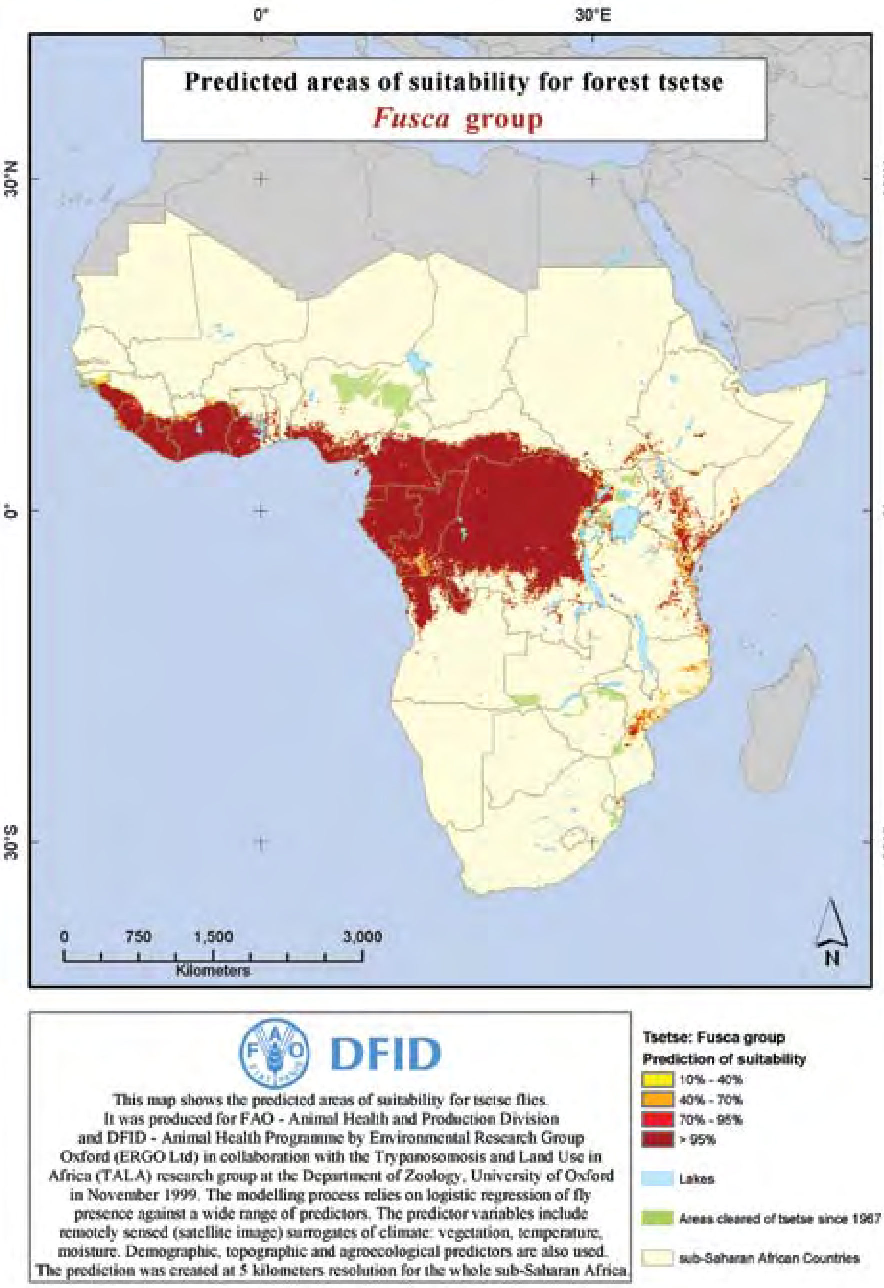
The first step to be taken is to identify areas that will be suitable to apply the control tactics on an area-wide basis, irrespective whether an eradication or suppression strategy is selected. Site selection will be based on the identification of an isolated tsetse population in a region or a country, for which an area-wide approach would be suitable. Most tsetse-infested areas will extend from one country to another and will therefore require a regional approach, although there may be one or more smaller areas within a single country. Where there is more than one potential site identified, a process of prioritization for area-wide control will be necessary. Prioritization will be carried out using various criteria such as shown in **Tables 2.1** and **2.2**.

A necessary concept to understand regarding AW-IPM is that it is an entire tsetse population that is being targeted, not simply a geographical area from which tsetse are being removed; therefore the area (in terms of numbers of square kilometres) can be very variable. Thus it might vary from an area around 1000 km^2, e.g. the Niayes area of Senegal (estimated to be approximately 10 km wide by 100 km long), up to a maximum limited by what is feasible from a practical, logistical standpoint (likely to be around 20 000–40 000 km^2, as in the Ethiopian Southern Rift Valley (STEP) project). In such a large project area, however, the approach to eradication activities will be phased, starting at one side/edge and working in phases across the area until it is complete. It is unlikely that an attempt would be made to undertake activities over the whole area simultaneously. This principle of the "rolling carpet" is fully described and developed in Hendrichs et al. (2005).

2.1.1. Selecting an Area

Predictive maps (**Figure 2.1**) of tsetse presence or absence have been developed covering the whole of Africa for each tsetse species (http://ergodd.zoo.ox.ac.uk). The first predictive tsetse distribution maps were developed using discriminant analysis and maximum likelihood statistical techniques. These methods have since been replaced by simpler logistic regression modelling based on the same predictor variables. The predictor variables upon which the modelling is based include data from earlier tsetse distribution maps (Ford and Katondo 1977) supplemented and updated with more recent knowledge including, satellite-derived climatological data (rainfall and temperature and elevation data) and vegetation cover data. The methodology is described in detail in Wint (2001).

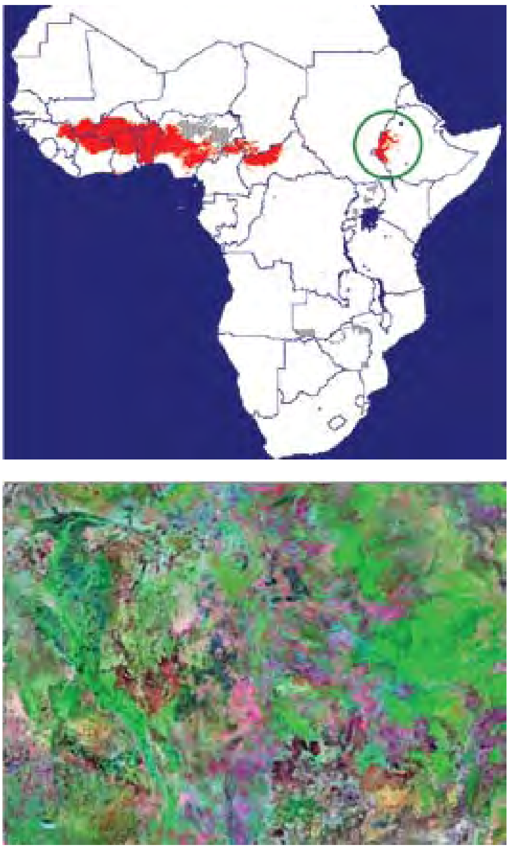
FIGURE 2.1
Map indicating the probability of presence of the *fusca* group of tsetse species in Africa



MAP PRODUCED BY ERGO, FOR FAO AND DFID

Using predictive maps (Wint 2002, 2003), likely isolated areas of tsetse infestation can be identified. An example is shown in **Figure 2.2, upper**, of a continental scale predictive map for the presence or absence of *Glossina tachinoides*. This map shows a belt stretching across much of the subhumid Guinea zone of West Africa and an additional isolated area of infestation in Ethiopia. The latter could be selected for area-wide eradication, however, the map of this infestation illustrates the limitations of large-scale predictive maps. As they are just predictions and do not provide precise limits of infestation they can only be used as a guide, they are based on the available data and whilst they have been shown to predict presence with a high degree of accuracy, there is still a need for verification in the field. It is improbable that the western edge of the infestation in Ethiopia stops neatly along the border with Sudan, rather, it is likely that imprecise climatological data or vegetation data were available for this border area or that no previous records of presence of *G. tachinoides* were available for Sudan. The predictive map shown in **Figure 2.2, upper** has been super-

FIGURE 2.2
(upper) Predicted probability of presence of *Glossina tachinoides* in Africa, and (lower) satellite image of the isolated area of *G. tachinoides* in south-western Ethiopia



MAP PRODUCED BY ERGO, FOR FAO AND DFID; IMAGE: NASA seded by subsequent predictive maps at a 1-kilometre resolution that are obviously more accurate but are not available for all of tsetse-infested Africa. A satellite image showing the vegetation in the circled area of **Figure 2.2, upper** is shown in **Figure 2.2, lower** and could be used as an aid to determining whether it is likely that the *G. tachinoides* distribution actually extends into the eastern part of Sudan and potential areas that should be surveyed based on that assessment

Having identified the isolated tsetse population, available maps for land use, distribution of livestock, human population, communications infrastructure, etc., will be collated

BOX 2.1

Baseline Survey Data and the Sterile Insect Technique (SIT)

The area-wide pest management programmes for tsetse flies will, in many cases, include the release of mass-reared male sterile flies as a technique for eradication. Population eradication by the release of sterile insects is generally regarded as having three components:

1. the production of sterile insects in sufficient numbers and of adequate biological quality to induce sufficient sterility into the pest population to reduce or eliminate the pest from the treated area,
2. effective distribution of the sterile insects so that the sterile and pest insects interact and inter-mate,
3. the sterile insects are behaviourally and genetically compatible with the pest population so as to be able to achieve matings that induce sterility into the pest population.

The successful execution of these components is dependant to a large degree on features within the area where the programme is to be applied as well as distances from the sterile insect production site to the programme site. Costs and loss of sterile insect quality during transport has, in many programmes, such as fruit flies and screwworms, been a major factor determining rates of eradication. In many of these programmes, flies have been shipped as irradiated pupae from the mass-rearing facility to dispersal centres (where flies emerge from the pupae and are collected for dispersal) close to the target area. If the sterile release is near to the site of the sterile insect production facility, distance factors may not be important and this will be a positive consideration in site prioritization. If the release site is more distant so that considerable transport times by air or ground transportation are required, ferry costs or costs of procuring, fuelling and maintaining trucks should be considered. If sterile insects are to be transported by ground vehicles to sites for aerial release, airports or air-strips must be available and areas for transferring sterile insects to the aircraft must be available.

Other factors such as monitoring the distribution of the sterile insects and evaluating their quality will be carried out during the monitoring and suppression period of the programme.

and consulted in order to facilitate the survey planning. Communications infrastructure (roads and other means of access) will be particularly important. It is impractical to plan trap deployment in areas that are too inaccessible by road unless the area is very small because too much time would be spent deploying and revisiting traps. A compromise has to be reached between deploying traps in areas very close to roads and human habitation

TABLE 2.1
Criteria/guidelines for prioritizing areas for joint international action against tsetse and trypanosomosis in the context of sustainable agricultural and rural development (SARD) (adapted from PAAT 2002).

Prioritization Criteria
1. Severity of the impact of the T&T problem
2. Desire/need for intervention by local communities and national governments
3. Opportunity to support poverty reduction, increase food security and maximize socio-economic returns through enhanced sustainable agricultural and rural development (SARD), such as: a) Expansion and intensification of mixed farming b) Improved subsistence farming and/or production of cash crops c) Land use and tenure as components of sustainability d) Sustainable and environmentally appropriate utilization of natural resources
4. Factors contributing to increased feasibility and early success of project activities and sustainable outcomes, such as: a) Activities phased and initial objectives achievable within 5 – 7 years of a programme/project cycle b) Natural barriers

TABLE 2.2
Criteria for the selection of areas suitable for area-wide integrated pest management (AW–IPM) programmes and means of verification.

	Criteria for selection	**Means of verification**
Selection of sites based on feasibility for AW-IPM and subsequent prioritization of those sites	Isolated tsetse infestation	Predictive maps Existing tsetse distribution maps based on previously conducted surveys Identification of clear, natural boundaries, e.g. Lakes, oceans, mountain ranges
Justification for AW–IPM	**Size of the area**	**Geometrical estimation**
	Potential for agricultural/ rural development	Land use maps Livestock distribution maps Human population distribution maps
	Endemicity of human sleeping sickness	Ministry of health records of reported sleeping sickness cases/prevalence of infection
	Other economic impact e.g tourism	Statistics on tourist numbers and destinations Reports of concerns by tourists – tour operators

that might be poor habitat for tsetse and selecting deployment sites that might be ideal tsetse habitat but cannot be easily reached. The aim should be to be able to deploy and service about 20 traps per day per team within a normal working day. Having selected an area through prioritization criteria, feasibility of carrying out area-wide eradication will be assessed based on additional criteria (**Table 2.1** and **2.2**), on the size of the area, the potential means of tsetse population reduction and their suitability (e.g. is the terrain and distribution of tsetse suitable for aerial spraying with insecticides (sequential aerosol technique (SAT))? Is the suitability of the habitat such that tsetse may be present but at a low density (due to low suitability of the habitat) to make SIT a more suitable option?)

2.2. OBJECTIVES OF THE SURVEY

The primary objectives of a survey should be carefully considered before the planning phase as they will influence the type of survey and the way it is implemented. The primary objectives of a survey are: (1) to determine the precise distribution and limits of a tsetse population in a given area, (2) to determine all the tsetse species present in the area, (3) to determine the relative abundance (apparent density) of each species present in time and space, and (4) to identify the main ecological niches (habitats) for each tsetse species.

There may be some specific secondary objectives of a survey; for example, it might be useful to monitor other biting flies (Tabanidae, *Stomoxys* spp., etc.). It is known that biting flies are able to mechanically transmit some species of trypanosomes pathogenic to cattle (Leak 1998, Desquesnes and Dia 2004, Hall and Wall 2004). Although traps designed for catching tsetse are not generally efficient for sampling biting flies (exceptions are the Vavoua and NZI traps), they do catch them, and data on catches of biting flies can therefore be recorded. Such catches can be used to assess the potential for mechanical transmission of trypanosomosis, or to assess the impact of suppression techniques such as the use of insecticide-treated cattle on nuisance flies such as *Stomoxys* species that can cause economic losses to livestock production. It is probable that the survey procedures, whatever the objectives, will be refined as a response to data analysis reports, thus, it may be necessary to expand or contract the area surveyed or to concentrate more in certain areas or adopt a different methodology, for example utilization of alternative sampling devices.

The tsetse survey may well be conducted simultaneously with different teams also conducting trypanosomosis surveys of humans or livestock that can provide complementary information on potential vector distribution and disease risk. In addition, socio-economic and environmental surveys need to be undertaken to provide the necessary information for impact assessment studies of any intervention eventually undertaken. Whilst requiring different skills and methodologies, it is desirable that there are links, both in the planning and implementation of these respective surveys as far as possible.

The primary and secondary outputs of the survey(s) can then be used to develop longer-term objectives, for example to: (1) assess the risk of trypanosomosis to livestock and humans, (2) plan area-wide tsetse suppression/eradication, (3) determine which method of population reduction would be most appropriate, (4) plan monitoring of pre-release tsetse population reduction, (5) plan the monitoring of progress of release of sterile male tsetse, and (6) plan (before tsetse population reduction) the potential land use pattern following tsetse population reduction.

2.2.1. Subsequent Phases

The nature of activities following the initial survey will depend upon the original objectives of the survey; if the objective was to obtain data for a suppression/eradication programme then the survey results will be used to plan the most appropriate approach for population reduction. The most likely scenario following a tsetse survey, planned with an AW-IPM programme in mind, is that it will lead into a monitoring programme involving trapping in a more limited number of reference monitoring sites (RMS) or fixed monitoring sites (FMS) (Vreysen 2000, 2005).

2.2.2. Types of Survey

The broad survey objectives have been outlined above. The more detailed objectives of a survey must also be clearly defined before the sampling technique is decided upon. There is a significant difference between a survey, which is usually an activity carried out once over a period of time in an area, and monitoring, which implies a long-term activity where the population is sampled frequently. Surveys can be divided into the following categories:

Minimal survey — A minimal survey is one that will be carried out once to determine the distribution of a species. There will be no dissection of tsetse to determine trypanosome infection rates or physiological age structure, simply the determination of presence and absence and distribution limits. The objective here is primarily to establish the presence or absence of flies, usually to determine distribution limits rather than the level of abundance. If it involves more than one species, several sampling methods that can be readily and practically implemented may be employed.

Seasonal survey — A seasonal survey will have similar objectives to the minimal survey, but in addition will determine seasonal variations in distribution and abundance by being repeated at different seasons. As a more intensive form of survey, it should include dissection (e.g. ovarian ageing, determination of trypanosome infection rates or possibly mark-release-recapture experiments), all contributing to the planning of subsequent suppression/eradication of the tsetse population. The intensity and location of surveys will depend on the type of suppression/eradication being implemented. For example, if aerial spraying of insecticide is to be carried out, then surveying the interior of the target area will be of little importance; the requirement will be for more intensive survey of the limits of distribution to determine the spray area. If traps are to be used for population suppression then identifying important tsetse habitats within the target area is important.

A survey to be followed by suppression/eradication of a population will lead into a monitoring programme as this is essential pre-, during, and post-suppression/eradication. The implementation of suppression will be influenced by the monitoring results and evaluation of the success of the suppression or eradication will depend on monitoring (Vreysen 2005). Criteria for determining probability of eradication have been identified that indicate the intensity and duration of monitoring required (Barclay et al. 2005, Barclay et al. in preparation). Unfortunately, adequate long-term monitoring is frequently not carried out because where large areas are involved cost often becomes a major constraining factor. A monitoring system is therefore required that minimizes the cost relative to the actual control measures, yet gives sufficient data to assess whether the control is effective or not (Vreysen 2005). Where traps are used both for control and monitoring, they can indicate areas of re-invasion pressure and those with insufficient trapping densities to achieve the desired result. RMS will be selected largely based on the results of the baseline survey.

2.2.3. Population Dynamics and Behavioural Studies

Studies on population dynamics or behaviour of tsetse undertaken by a separate team or by university or technical college students (providing them with opportunities for useful field research) can be very valuable; providing essential information to increase the efficiency of suppression or sampling methods or to "fine tune" control programmes. A variety of sampling methods may be used to maximize the information obtained; as such studies are usually carried out over a relatively small area with a relatively small input compared to the overall survey. The sampling method used for population dynamics studies should only remove a very small percentage of the individuals if it is not to affect the overall population structure.

2.3. DESIGNING A SAMPLING STRATEGY

2.3.1. Design of a Survey Programme

Whether a survey area is large or small, there will be limitations to the density of trapping that can be carried out within a given time frame, and this requires some selection of where the traps will be deployed. The area can be divided up into grid squares of any given size; commonly these will be 10 × 10 km Universal Transverse Mercator (UTM) grid squares for large areas or one km^2 squares for small areas (see 2.4.3.1. for more details). Within the grid squares a choice has to be made concerning where precisely to site the traps. In a perfectly uniform situation, such as might theoretically occur in some savannah areas, the selection could be completely random, i.e. based on random selection of geographical coordinates for each of the required number of trap positions. In reality, it is rare to find a large and completely uniform habitat. There will always be areas of woodland, grassland, thickets, cultivation, etc., and there will be differences in distance from water sources (important for *palpalis* group tsetse). It is therefore necessary to adopt some strategy for selecting deployment sites. This strategy will depend to some extent on the objectives of the survey.

It is important at this stage to distinguish between collecting tsetse for laboratory work or estimation of trypanosome infection rate, and sampling to assess the distribution and/or abundance of tsetse in an area. In the former case, the traps are deployed where they catch the most flies. In the latter case a methodical sampling programme must be designed.

2.3.2. General Principles

Because not all the tsetse flies in a population can be counted, aged, sexed, etc., reliance has to be placed on the collection of representative samples (i.e. a selection of sampling sites that are representative for a larger area). Ideally the absolute population density, the number of tsetse per unit area, could then be estimated. In practice this is often not possible, so instead the relative population density is determined, i.e. the number of flies sampled per section of fly round or the number of flies caught per trap per day. Such measures are then used to compare apparent densities in different localities or at different times of the year in the same locality, to determine seasonal population fluctuations.

Ideally the sampling method would take a fixed proportion of the population, regardless of the vegetation type or the time of year, i.e. the catch would give a consistent indication of the actual number of flies present. However, when the method depends on tsetse being attracted to a man or to a trap, the numbers depend not only on the density of flies but also on their degree of activity and on the attractiveness of the sampling system. The activity of flies depends on environmental factors, on age, and physiological state, so the proportion of the population sampled may not be constant.

The sample may also not be representative of the population composition for the same reason. Certain categories of the population, age groups, hunger stages, pregnancy stages, are more active than others, and respond differently to the sampling methods. Hence samples tend to be biased in favour of certain segments of the population.

2.3.3. Pattern of Spatial Sampling

Many species of tsetse change in their seasonal distribution. Generally, they concentrate in dense vegetation in the dry season and extend into more open areas during the rains. Such seasonal changes in distribution take place not only with savannah species, such as *Glossina pallidipes*, but also with riverine species, for example, *Glossina fuscipes fuscipes* and *G. tachinoides*. In such a situation, sampling must be carried out over the full range of vegetation types that the flies occupy at different times of year. If sampling is only carried out in dense vegetation, there may be a marked decline in apparent density in the rains mainly because the population becomes spread over a larger area.

In order to identify the seasonal changes in distribution, surveys using traps could be carried out either by the method of stratified sampling (see 2.3.5.), repeated for each season, or by systematic sampling in which transects are cut to pass through all vegetation types and traps positioned at regular intervals. For the types of survey described here, in which trapping is carried out at each deployment site for only a few days, the latter method is less appropriate and is more suited to long-term monitoring.

2.3.4. Pattern of Sampling in Time

The next questions to be addressed are how often should sampling be conducted, and for how many days at a time. If the purpose is to determine the presence or absence of flies over a large area, sampling should be carried out at least once during the dry season and again during or immediately after the rains. Sampling should ideally continue for up to one month (but this will depend on the efficiency of the trapping device) at the limits of distribution to be certain of those limits, although a shorter period may be a necessary compromise between theory and practicality; the longer the sampling is continued, the greater the chance of detecting tsetse at low densities. In extreme situations, continuous surveying for over one year has been required to detect low-density populations. A model developed by John Hargrove, that will indicate the number of trapping days needed with a given number of traps, and a given efficiency of the trap used, to catch one fly in a given area (1 km^2) with a certain statistical probability, can provide good guidance in this respect (Barclay et al. in preparation). In such situations the sampling of livestock for the presence of trypanosomes (indirect monitoring (Vreysen 2005)) should also be considered as an indication of whether or not the presence of tsetse is likely.

Tsetse have a relatively slow rate of reproduction, so very rapid changes in the population size of flies are unlikely, unless some unusual intervention occurs such as a bush fire, the introduction of insecticide or sudden invasions of flies. However, catches may vary considerably from day to day or from month to month, depending on fly activity in relation to climatic factors, their physiological state or the availability of hosts. Some factors causing changes in trap catch size (unrelated to population size) remain obscure.

The savannah species, such as *Glossina morsitans* and *G. pallidipes*, are active mostly for the first two hours and the last two hours of the day (Hargrove and Brady 1992). Many of the riverine species such as *G. f. fuscipes* are active in the middle of the day (Crump and Brady 1979). There are exceptions to these generalities: the savannah species *Glossina longipennis* is most active just after sunset (Kyorku and Brady 1994), and *Glossina austeni*, another savannah species, is active in the middle of the day during the cold season and in the early morning and late afternoon during the hot season (M. Vreysen, unpublished). These factors have to be taken into account when planning the time at which traps will be deployed and subsequently checked for caught flies or if alternative survey methods are being used such as fly rounds or traverses with vehicle-mounted traps.

Recent work suggests that sampling once a month for a minimum of three days and ideally for a 7–10 day period enables major changes in density to be detected, and this should be regarded as the minimal level of sampling intensity. The appropriate duration of trapping is described further in 2.4.3.1.2.

2.3.5. Stratification and Stratified Sampling

For a large area, it is unlikely that there will be sufficient human or material resources to survey the whole area in detail. It is therefore necessary to select areas in which surveys should take place. This will require that representative areas to be chosen. If the area was completely uniform in all respects (vegetation, climate, altitude, land use, distribution of human habitation, etc.) then an appropriate number of sampling sites could be selected at random (superimposing a grid of numbered squares over the area and selecting the appropriate number of squares with a random number generator for example). Stratified sampling techniques are generally used when an area is heterogeneous, or dissimilar, but in which, certain homogeneous, or similar, subareas (strata) can be isolated. In these areas, the measurement of interest (tsetse apparent density) is likely to vary among the different subgroups. For example, tsetse habitat is unlikely to be uniform within a large area; there may be areas of forest, cultivated land, riparian forest, grassland and savannah woodland for example. This has to be accounted for when we select a sample from the area in order that we obtain a sample that is representative. This is achieved by stratified sampling. In stratified sampling, a random sample is normally drawn from each of the strata, however, for tsetse surveys the selection of strata for trap deployment may be less random as there has to be a compromise to achieve a feasible approach. Therefore factors such as accessibility have to be taken into consideration.

When sampling an area with several strata, the proportion of each stratum in the sample is normally the same as in that area. Some reasons for using stratified sampling over simple random sampling are: (1) the cost per observation in the survey may be reduced, (2) estimates of the area parameters may be wanted for each subpopulation, and (3) increased accuracy at given cost.

As it is unlikely that a homogeneous, uniform area will be found, (there will be areas of riverine vegetation, areas of savannah, areas of cultivated land, and an altitude gradient, etc.), it is necessary to choose strata that will have an impact on tsetse distribution and abundance. Two approaches could be taken in this more realistic situation. Firstly, the area could be divided into blocks of sufficient size to have a good chance of containing several of these strata, then within the blocks trapping sites could be chosen for each stratum within the block. Secondly, having identified the relevant strata, the appropriate number of sampling sites could be randomly selected for each stratum. The number of trapping sites for each stratum is then weighted according to various criteria such as suitability of the habitat for tsetse. That would be unlikely to be the main criteria however; more weight might be attached to potential sources of reinvasion such as an area of lower altitude separating two supposedly isolated tsetse infestations, or to the edges of the area where the seasonal limits of tsetse distribution might need to be more precisely determined. There are various statistical methods available for preparing a statistically valid, representative sampling design (Thrusfield 1996) and these must be considered carefully in the planning stage.

2.3.5.1. Vegetation Types

In order to select the appropriate strata, the vegetation types that constitute the important habitats of tsetse have to be considered. Vegetation classification is a difficult area as botanists may classify many different types, and their definitions may vary according to the authority. For this reason, the Food and Agriculture Organization of the United Nations (FAO) is developing a vegetation classification that, it is hoped, will be internationally accepted. This will still have many categories that will be impractical for use by entomologists carrying out tsetse surveys and therefore a smaller number of broad categories have to be used unless detailed studies are planned. An understanding of the main, broad vegetation types will facilitate the correct identification of likely habitats for each of the 31 tsetse species and subspecies. The main tsetse habitats are the savannah woodlands (*morsitans* group), thickets (especially *G. pallidipes*), riverine/riparian (gallery) forests (*palpalis* group), and forests (*fusca* group). There are, however, many variations on these ranging from mangrove swamps (e.g. for *Glossina frezili*), to *Euphorbia* and *Lantana camara* hedges or scrubland on unused farmland, pine tree plantations and citrus or mango orchards. Detailed coverage of vegetation types and their species composition is beyond the scope of this document. The reader is referred to FAO training manual for tsetse personnel, volume 1 (FAO 1982a), and Leak (1998) for more information on tsetse habitats, whilst some general information follows. Vale (1998) gave a comprehensive review of the responses of tsetse to vegetation in Zimbabwe in relation to trapping, the principles of which are likely to be applicable in other regions of Africa. A further difficulty is that some definitions may vary, for example, a definition of "forest" in East Africa may be quite different from that used in West Africa.

Savannah vegetation is widespread and can take the form of any tropical or subtropical grassland characterized by scattered trees or shrubs, a pronounced dry season, and periodic bushfires. The savannah biome is transitional between those dominated by forests

TABLE 2.3
Suitability of vegetation types for the different groups of tsetse flies.

Category	Vegetation Type	***Morsitans***		***Palpalis***		***Fusca***	
		Yes	**No**	**Yes**	**No**	**Yes**	**No**
Peridomestic	Various			•			
Cultivated	Citrus or mango orchards			•			
	Cotton		•		•		•
	Cereals		•		•		•
	Coffee/cocoa plantations			•			
	Vegetation associated with overgrown cultivated areas (e.g. *Lantana camara or Euphorbia)*	•		•			
Grassland	Natural or improved pastures		•		•		•
Plantations	Pine/casuarina	•					
	Sisal		•		•		•
	Pineapple		•		•		•
	Palm plantations (natural and man-made)	•		•			
Savanna woodland	Subhumid; mopani, miombo, doka: *Isoberlinia, Parkia*	•		•			
	Semi-arid: *Acacia, Combretum*	•		• *G. tachinoides*		• *G. longipennis*	
	Arid: Acacia (thorn savanna)						
Thicket	Semi-evergreen and deciduous trees, *Euphorbia*	• *G. pallidipes*				• *G. brevipalpis*	
Mangroves				•		• *G. frezili*	
Forest	Rain forest			•		•	
	Gallery forest: evergreen tree species and deciduous			•		•	

and those dominated by grasses and is associated with climates having seasonal precipitation accompanied with a seasonal drought. The tropical savannahs are generally found in regions dominated by the wet-dry tropical climate. An extensive cover of tall grasses, sometimes reaching a height of three metres, is found in the tropical savannah. Most savannah grass is coarse and grows in tufts with intervening patches of bare ground. Scattered, individual trees or small groves of trees are common. The umbrella shaped *Acacia* spp. tree is a notable species of the savannah biome. In eastern Africa where precipitation is higher, savannah vegetation is maintained by periodic fires that burn back the forest and stimulate the growth of grasses.

Table 2.3 attempts to summarize the main vegetation types that are likely to be inhabited by tsetse, bearing in mind that other factors play important roles in determining whether or not tsetse will be present or absent, and that local variations can create atypical habitats. During periods of civil unrest or economic disturbances important changes can occur, such as the overgrowth of fields cultivated for cotton or coffee, creating conditions suitable for tsetse, whereas when well maintained, those environments would not be so suitable for tsetse flies.

Note: Although a particular vegetation/land use type may be classed as unsuitable for tsetse, this should not be interpreted as meaning that tsetse will never be found in that category, simply that it is not considered as a habitat in which tsetse permanently live and breed. Clearly, at the ecotone between, for example, grassland and savannah or forest, there will be an interface in which tsetse are found, especially when they venture out of their habitat to feed on hosts in the grassland. In the sense that the areas in which the tsetse disperse to feed also form part of the habitat, a wide variety of land use categories would have to be included, but in the context of this table, habitat can be interpreted as breeding areas. Tsetse fly populations are not linked strongly to species of vegetation but rather to the types of environmental condition that those species create. Thus, the link between *palpalis* group tsetse and citrus orchards comes because citrus orchards grown in suitable climatic regions, when irrigated, or within a humid climatic zone, provide the required conditions of shade and humidity. There will also be a requirement for them to be close to an adequate number of suitable hosts. Savannah woodlands also provide shade and humidity, and above all, suitable hosts, although in some areas, in the dry season, conditions become less favourable and tsetse either become restricted to locations closer to water or adopt behavioural patterns to avoid heat and conserve moisture.

2.3.5.2. River Systems

Surveying a river system for tsetse of the *palpalis* subgenus may require a different methodology from that appropriate for savannah or forest species; basing trap selection on a grid system may be somewhat different due to the linear nature of the riverine habitat. If the area is large and 10 km × 10 km grids are used, there may be more than one river system/watershed in the same square, it will be important to determine if there is any flow of tsetse populations between these river systems. It would then be necessary to deploy survey traps in each river system in the square, not just along one of them. When surveying a river system for *palpalis* group tsetse, there is a high probability that if tsetse flies are found along a gallery forest, they will be present, at least seasonally, along the whole length of that river/stream, unless there is a marked discontinuity in the vegetation. It will therefore probably not be worthwhile expending too much effort trapping intensively along that stream, especially in those situations where the vegetation encountered is becoming denser and more favourable for riverine tsetse flies. It may be tempting for a survey team to walk along a gallery forest putting out traps at the recommended interval in order to complete the daily deployment quota. However, for the reason given above, it will be more productive to move to another gallery forest/river. This may entail a lot of travelling for deployment of a few traps but would provide more valuable data, i.e. a more efficient implementation of the survey. Within a grid structure, therefore, sampling will be more limited than in an equivalent grid square for savannah species and would concentrate on the gallery forest and peridomestic habitats. Particularly for *palpalis* group tsetse, the most important objective of a survey will be to define the limits of the infested area, and to do this the most efficient approach will be to start at the suspected limits of distribution and progress inwards. Another important consideration when surveying *palpalis* group tsetse in West Africa with a view to suppression/eradication is the degree of isolation of one river system/watershed from another. River systems may have their origins in highlands that separate them by a small distance, for example, the Didessa valley river system in south-western Ethiopia, flowing into the Blue Nile (eventually flowing north, into the Mediterranean) is separated by only a few kilometres from the Ghibe/Omo river system that flows southwards into Lake Turkana in Kenya; similarly in West Africa, the Niger River and the Gambia River originate in the highlands of north-eastern Guinea.

2.3.5.3. Accessibility

Sites close to roads and tracks may not be the best sites for catching tsetse at low densities because such sites are likely to be more disturbed by people, and have fewer wild hosts in the vicinity. However, as with many aspects of a tsetse survey, a compromise has to be made between selecting ideal sites for tsetse, possibly several kilometres from the nearest access route for a vehicle and the time taken to deploy a reasonable number of traps in appropriate locations with the available resources. Many areas are of unsuitable terrain for vehicles, e.g. hilly escarpments, valley sides, or difficult to access in the wet season. In such difficult situations the number of traps that can be deployed in a day may then be limited to 10 per day per team (a team consists of around four people — the number required to physically carry the number of traps that can be deployed in the day and should include one person with good training and experience in trap deployment).

In other areas, e.g. the Nguruman area in Kenya, the terrain may be flat (the escarpment at Nguruman is an exception but was not included in routine monitoring and other tsetse work carried out by the International Centre for Insect Physiology and Ecology (ICIPE) in the 1980s). The Nguruman area is also dry for nearly all the year and there are many tracks, as a result of which, vehicles could easily be used for assisting with the deployment of traps and a larger number could be deployed and checked in a day. It takes a lot longer to deploy traps, selecting a suitable site, clearing surrounding vegetation, erecting the trap, than it does "to harvest" the flies or to dismantle the trap at the end of a trapping session. However, since repeated seasonal surveys (or monitoring) are carried out at the same fixed sites, it is the initial deployment that takes longest.

2.3.5.4. Altitude

Tsetse distribution is limited by altitude, due to the cooler temperatures found at higher altitudes. The altitudinal limit will vary with distance from the equator. In Ethiopia, the limit is variable according to season and tsetse species but is between 1600 and 2000 m for *G. pallidipes* (it has apparently increased in altitude over time, possibly due to global warming or vegetation/land use changes (Vreysen et al. 1999)). Altitude may be included in the list of strata for sampling if appropriate.

2.3.5.5. Density and Distribution of Human Population

In some circumstances the distribution and abundance of the human population may be of interest, for example, where surveys are being conducted in relation to the occurrence of human African trypanosomosis (HAT) or sleeping sickness. In such cases it may be necessary to identify areas of human/fly contact for targeted intervention. Such places would include bathing places, washing places, points used for boats, either for fishing or transportation of humans and cargo. In other situations large aggregations of people might render the habitat unsuitable for tsetse and fewer survey traps would be deployed (exceptions might be where the areas of human habitation are on or near the limits of infestation that need to be defined with some precision). Tsetse flies can also occur near or in large cities, e.g. Stanley Pool area of Kinshasa (Democratic Republic of the Congo), zoological gardens in Dakar (Senegal), and Brazzaville (Republic of Congo).

2.3.5.6. Density and Distribution of Cattle Population

Depending upon the purpose of the survey, it may be necessary or useful to take into account the distribution and abundance of cattle/livestock, e.g. if a survey is being carried out for the purpose of assessing disease risk (African animal trypanosomosis (AAT)) to livestock. Watering places of cattle and overnight guarding places (kraals, etc.) would be among the places where traps would be deployed, it might also be necessary/of interest to determine the main seasonal grazing areas of the livestock (Rawlings et al. 1993). A survey of trypanosomosis infections in cattle may be useful in some circumstances to suggest whether tsetse may or may not be present in an area.

2.3.5.7. Seasonality

As referred to in 2.3.3, with respect to the pattern of spatial sampling, there can be significant changes in distribution of tsetse populations between seasons. It is therefore necessary to determine the dry and wet season and/or hot and cold season distribution limits. For this reason a survey should ideally be repeated at each season (as was the case in the survey carried out in the Southern Rift Valley of Ethiopia (see 3.5.2.). If this is not possible for financial or logistical reasons, it may be possible to correct the data obtained for one season, using the method described in 2.4.3.2. However, this is only possible if some long-term data exists for the area that can be used for calculating the correction factor. This will not provide information on changes in distribution; if a survey can only be done at one season, it should therefore be planned for the season at which tsetse are likely to be most widely dispersed so that the maximum extent of their range can be estimated.

2.3.5.8. Population Genetics

The genetic characterization of tsetse populations can have great importance for tsetse suppression and eradication, for example, it is possible to determine if two adjacent populations are really isolated from each other or if there is gene flow between them. This will have major implications regarding the delimitation of the control area or the need to put barriers in place to prevent reinvasion. Techniques are now available to characterize genetics of tsetse populations and these are described in 3.3.

2.3.6. Meteorological Data: What Climatic Data Should Be Recorded?

Collection of basic meteorological data will allow better interpretation of survey results. For example, the relationship between apparent tsetse density and rainfall, relative humidity and temperature can be determined for understanding of seasonal effects, whilst daily rainfall information will contribute to understanding daily variability in trap catches that is not related to density or distribution, but to activity patterns (most tsetse tend to be inactive during periods of heavy rainfall).

The basic parameters that should be collected are: (1) daily rainfall, (2) maximum temperature, (3) minimum temperature, and (4) relative humidity.

Rainfall distribution can vary over quite small areas, but a single meteorological data collection station will be sufficient for most survey purposes unless there are specific requirements for more detailed observations. Data can be collected using standard meteorological data equipment (e.g. Stevenson screen and rain gauge) although more sophisticated automatic weather stations are now available. If a future aerial spraying programme is envis-

TABLE 2.4
Minimum requirements for a climatological station.

Element	Range	Resolution	Accuracy	Remarks
Maximum temperature	–30 °C to +40 °C	0.1 °C	0.5 °C	daily
Minimum temperature	–30 °C to +40 °C	0.1 °C	0.5 °C	daily
Rainfall	0 to 999 mm	0.2 mm	0.2 mm < 4 mm	
			5% > 4 mm	daily
Relative humidity	1% to 100%	0.1%	5% below 50%	
			2% above 50%	

Additional elements

Element	Range	Resolution	Accuracy	Remarks
Air temperature	–30 °C to +40 °C	0.1 °C	0.3 °C	1 minute mean
Soil temperature	–30 °C to +40 °C	0.1 °C	0.3 °C	
Wet–bulb temperature	–30 °C to +40 °C	0.1 °C	0.3 °C	
Wind direction	10 to 360°	10°	10°	hourly modal
Wind speed	0 to 150 kn	1 kn	1 kn or 5%	1–minute mean
Sunshine duration	0 to 24 hours	0.1 hour	0.3 hour	daily

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.