Chapter 13

Monitoring of Areas and Species/ Populations to Assess Effectiveness of Conservation/Management Actions

Introduction: Surveillance and monitoring

> *The primary purpose of monitoring, if not launched purely for scientific interest, is to collect information that can be used for development of conservation policy, to examine the outcomes of management actions and to guide management decisions* (Kull et al, 2008).

Monitoring is a core activity of biodiversity conservation and of conservation biology (Marsh and Trenham, 2008) and has been described as a centrepiece of nature conservation across the globe (Schmeller, 2008). And yet, as often noted, many monitoring programmes do not have a sound ecological basis, are poorly designed, do not lead to management interventions or responses and are disconnected from decision-making. Monitoring is often given low priority because it can be difficult and expensive to implement (Danielsen et al, 2009) and monitoring programmes are often inadequately funded and inadequately implemented.

Essentially, monitoring consists of making reliable observations from nature to detect, measure, assess and draw conclusions as to how species and ecosystems are changing through time and space, either naturally or as a consequence of deliberate or inadvertent human intervention. It is applied in many different ways – to track the status of endangered species, the spread of invasive species, the health of ecosystems, the effectiveness of protected areas and other conservation actions, and more generally to assess the state and main trends of biodiversity through indicators and monitoring at national, regional and global levels. A useful review of the conceptual issues involved in ecological monitoring is given by Noon (2003).

Monitoring is undertaken at various scales: it can be applied from the population and individual level to the whole biosphere. Monitoring is undertaken at a global level by the Convention on Biological Diversity (CBD), United Nations agencies (e.g. the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Environment Programme (UNEP)), by international non-governmental organizations (INGOs) (e.g. the Consultative Group on International Agricultural Research (CGIAR) and the Organisation for Economic Co-operation and Development (OECD)) and by non-governmental organizations (NGOs) (e.g. the International Union for Conservation of Nature (IUCN), the World Wide Fund for Nature (WWF) and the World Resources Institute (WRI)). It is also undertaken at the regional level (e.g. by the European Community) and at national and local levels.

The CBD proposes the following actions under Article 7: Identification and Monitoring:

- identify ecosystems, species and genomes important for conservation and sustainable use;
- monitor the components identified to determine priorities;
- identify and monitor activities that may be harmful to biodiversity;
- maintain and organize data obtained from the above.

The International Treaty on Plant Genetic Resources (ITPGRFA), on the other hand, does not mention the monitoring of biodiversity or agricultural biodiversity, even though it is clearly an important component of actions needed to maintain such biodiversity and use it sustainably (see Box 13.1). A summary of agrobiodiversity monitoring information at a European level is given by Schröder et al (2007) who note that one important precondition of agrobiodiversity indicators is the documentation of genetic resources in national and international inventories.

Biodiversity monitoring is a highly technical and complex area and it is beyond the scope of this manual to go into additional details on this topic. Several major texts and handbooks have been published to which the reader is referred

Box 13.1 Agricultural biodiversity monitoring

The monitoring of agrobiodiversity has two main tasks: to document loss of agrobiodiversity as early as possible and to work as a management tool concerning the objectives, the programmes and the necessary measures for the conservation and sustainable use of agrobiodiversity. In addition, it visualizes the outcomes of a policy that is dedicated to sustainability. Therefore the instruments of monitoring, like regular surveys, indicators and inventories, need to be further developed.

Source: Information System Genetic Resources (GENRES)
http://www.genres.de/genres_eng/agrobiodiv/agrobiodiv_mon.htm, accessed 1 October 2009

(see the section on further information at the end of the chapter). A critical review of biological monitoring and of recent developments is given by Yoccoz et al (2001).

Monitoring is defined by Elzinga et al (1998) as 'the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective'. The term 'surveillance' which originates from the French word meaning to 'watch over' is often used interchangeably with 'monitoring'. Both imply repeated recording of information over time. 'Sampling', 'recording' and 'observation' may be one-off events, or form part of a surveillance or monitoring scheme. A more rigorous definition is given by Hellawell (1991): 'intermittent (regular or irregular) surveillance undertaken to determine the extent of compliance with a predetermined standard or the degree of deviation from an expected norm'. The standard, in this context, according to Tucker et al (2005), can be a baseline position such as the maintenance of a particular area or population or a position set as an objective such as 200ha of a particular habitat or 200 individuals of a population.

Briefly, monitoring can (Tucker et al, 2005):

- establish whether standards are being met;
- detect changes and trigger responses if any of the changes are undesirable;
- contribute to the diagnosis of the causes of change;
- assess the success of actions taken to maintain standards or to reverse undesirable changes and, where necessary, contribute to their improvement.

A distinction may be made between two types of monitoring: *status* and *strategy effectiveness* monitoring (Ervin et al, 2010). As they note, *status monitoring* asks the question, 'What is the status and trend of biodiversity independent of our actions?' while *strategy effectiveness monitoring* asks the question, 'Are our conservation actions achieving the desired results?' (see Ervin et al, 2010, Box 24). Both types are important in monitoring programmes for CWR.

Establishing a baseline

A critical issue in monitoring and the use of indicators is the need to establish a baseline from which to start and compare the data to be collected. This will involve compiling and reviewing existing information on the population, species, habitat or other element, process or action that is the target of monitoring. In practice, this is much more difficult than might appear at first sight. We have already seen how incomplete or inadequate is our knowledge of many aspects of biodiversity that affect the conservation of CWR, for example, the lack of inventory of protected areas, uncertainties about the detailed geographical distribution of species, the existence and pattern of genetic variation within populations, the extent of genetic erosion, the extent to which ecosystems are affected by invasive alien species, etc. Ecogeographic surveys, discussed in detail in Chapter 8, will provide such a baseline for many of the features that one might wish to monitor in a CWR conservation programme.

It is also important that agreed definitions of key terms are used so that measurements are comparable. Alternative values for definition of parameters can have significant impacts. For example, when FAO redefined the term 'forest' between the 1990 and 2000 Forest Resource Assessments, reducing minimum height from 7 to 5m, minimum area from 1.0 to 0.5ha and crown cover from 20 per cent in developed and 10 per cent in developing countries to a uniform 10 per cent, global forest increased by 300 million ha or approximately 10 per cent. Likewise, forests are defined in different ways by different countries – by principal land use (in Bolivia), by forest cover (in Chile) – and the threshold for the definition of forest cover differs from less than 10 per cent in Iran to 75 per cent in South Africa.

Faced with such a situation, the important thing in any monitoring programme is to ensure that terminology is used consistently by all participants, especially when many different actors are involved. As already discussed in Chapter 8, widely agreed standards should be followed, such as those of TDWG (Biodiversity Information Standards). Similarly, accurate taxonomic information is essential, as has been stressed already in Chapters 6 and 8 of this manual.

For guidance on sampling and measuring vegetation characteristics, such as stratification, cover, phytomass and leaf area index, see van der Maarel (2005) and Bonham (1989) and for structural-physiognomic features such as growth form, see the following texts: *Aims and Methods of Vegetation Ecology* by Mueller-Dombois and Ellenberg (1974); *Vegetation Description and Analysis: A Practical Approach* by Kent and Coker (1995) and Dierschke's (1994) classic, *Pflanzensoziologie – Grundlagen und Methoden*. For sampling of species characteristics see van der Maarel (2005). Much useful information on many aspects of sampling and census methods applicable to monitoring can be found in *Ecological Census Techniques – A Handbook* by Sutherland (2006) and information on monitoring can be obtained from Sutherland (2000), *The Conservation Handbook: Techniques in Research, Management and Policy*.

CWR and monitoring: Identification and selection of variables to be measured

For the effective conservation of CWR, a range of monitoring activities may need to be undertaken. These include monitoring the key characteristics of a species and its habitat to ensure that management interventions and actions are in fact meeting their objectives.

For example, one may wish to monitor:

- changes to population/species abundance, trends in population size and structure, so as to assess the health and viability of the population, both before and after any management intervention;

- changes in genetic diversity;
- predator numbers, to assess the effectiveness of control programmes;
- the spread or control of invasive species to assess their impact on the species populations and the habitat or area as a whole;
- changes in vegetation cover or soil condition, to assess the state of the CWR's habitat;
- the effects of management interventions undertaken as part of a species management or recovery plan.

Most schemes monitor both the distribution (range, area) and the species composition of the target habitats or ecosystems.

Species and population monitoring

What is it?

Species and population monitoring is the regular observation and recording of changes in status and trend of species or their populations in a certain territory. The primary purpose of such monitoring is to collect information that can be used to examine the outcomes of management actions and to guide management decisions. This is frequently carried out for species that have been assessed as threatened so as to determine when conservation actions are necessary or when existing ones need to be intensified.

In the case of CWR, it may be necessary to monitor population numbers, size, density, structure and demographic variables as part of the assessment of their conservation status, as well as the subsequent impacts on the CWR populations of any management interventions that are prescribed in the species management plan so as to judge their effectiveness.

Species and population monitoring programmes, like biological monitoring in general, are remarkably variable and diverse in scale, coverage and aims. Marsh and Trenham (2008) attempted to detect trends in plant and animal population monitoring, and the goals and strategies showed signs of diversifying with some approaches becoming more frequent, such as area occupied and presence/absence approaches, while others have yet to be widely applied, such as risk-based monitoring and linking the results of monitoring directly to management decisions. It is important, therefore, that the objectives of any proposed population monitoring are clearly defined in advance (see Yoccoz et al, 2001).

Many sampling and analytical techniques are available for species and population monitoring (see Chapter 8) and are reviewed by Stork and Samways (1995) and specifically for CWR by Iriondo et al (2008).

Which attributes to monitor?

The attributes of species for which monitoring goal targets may be set include range, abundance, demography, population dynamics and habitat requirements (Tucker et al, 2005):

Quantity
- presence/absence;
- range;
- population size;
- frequency;
- number/density;
- cover.

Population dynamics
- recruitment;
- mortality;
- emigration;
- immigration.

Population structure
- age;
- sex ratio;
- fragmentation or isolation;
- genetic diversity.

Habitat requirements

Demographic monitoring

Demographic monitoring is the most common form of population monitoring, especially for rare or endangered species, and will often be found to be an appropriate approach for CWR where the focus is often on the maintenance of viable populations and their genetic variability.

Demographic monitoring is the assessment of population changes and their causes throughout the life cycle, and measures attributes such as germination and mortality rates, growth, size, density and distribution. It can also be used to help establish the factors determining the distribution and abundance of species and predict the future structure of populations. Demographic monitoring may involve frequent measurements or mapping if the necessary level of resolution is to be achieved (Given, 1994). The main demographic approaches are: (1) population and availability analysis; (2) single age/stage class investigations; and (3) demographic structure (Elzinga et al, 1998). Demographic approaches to monitoring are often time-consuming and expensive procedures and therefore not always feasible. Moreover, a demographic approach may not be appropriate for particular situations: Elzinga et al (1998), for example, caution against the inappropriate use of demographic monitoring for certain types of species, notably those with long-lived seed banks, dense vegetative reproduction, very short or very long lifespan, episodic reproduction, multiple stems and mat-like morphology, high densities and large populations in heterogeneous habitats (see Elzinga et al, 1998, Figure 12.13).

Genetic monitoring: What is it and when to use it?

The conservation of CWR focuses, as we have seen, on the genetic diversity found within the target species as a possible source of traits that may be used in breeding. But, at the same time, the long-term aim of *in situ* conservation of CWR is to ensure that sufficient genetic variation is maintained so as to ensure the survival of the species and allow the evolutionary processes to continue, thereby generating new variation that may allow the species to adapt to changing conditions. This is best done by protecting the environment and habitats in which the target species occur and controlling or limiting the threats that affect both the habitats and the species.

As we have seen, population monitoring can be a laborious and expensive exercise. The monitoring of genetic diversity can be an even more costly approach, especially if molecular methods are employed, so that its widespread use is not possible or even to be recommended. There may, however, be circumstances in which it is important to undertake genetic monitoring of high priority CWR. As already indicated when considering field ecogeographic surveying, information on the distribution of genetic variation in populations of CWR will normally have to be obtained through surrogate measures such as morphological (also 'visible') markers, which themselves are phenotypic traits or characters such as leaf shape, flower colour, growth habit, or through the use of biochemical markers (including allelic variants of isozymes detected through electrophoresis).

The circumstances in which genetic monitoring is likely to be used are discussed by Iriondo et al (2008, pp118–120), who give a series of examples. In particular it may be used:

- To assess the genetic diversity within the target populations in terms of total numbers of genotypes or alleles (richness) or the frequency of different genotypes or alleles (evenness). Such information on genetic diversity can be used to help to compare populations and determine which should be selected for *in situ* conservation and to decide which populations should be monitored so as to follow changes in genetic diversity over time.
- To estimate geneflow between populations, trends in the extent of inbreeding within populations and differentiation between populations or subpopulations.

Genetic analysis software

A wide range of software packages for undertaking genetic analyses is available. For a comprehensive alphabetical listing containing nearly 500 programmes see: *An Alphabetic List of Genetic Analysis Software*, currently maintained at North Shore Long Island Jewish Research Institute, New York, USA (2002 to date).[1]

Molecular markers for genetic analysis

An extensive range of molecular markers for use in genetic monitoring is available, but developments in this area are rapid and frequent so the reader should search the internet for the latest technologies. Molecular or DNA markers are loci (sites) in the genome of an organism at which the DNA base sequence varies among the different individuals of a population. They have the advantage over morphological or biochemical markers that they are not affected by environmental factors or the state of development of the plant.

Most of the reviews of molecular markers assume that the reader has a good level of knowledge of plant genetics and molecular biology; however, a very useful introduction to markers (and their use in marker assisted selection) for those with only basic knowledge has been written by Collard et al (2005).

Desirable features of DNA markers that have been suggested by various authors (e.g. Joshi et al, 1999; Iriondo et al, 2008) include:

- highly polymorphic in nature;
- co-dominant inheritance (determination of homozygous and heterozygous states of diploid organisms);
- frequent occurrence and scattered throughout the genome;
- selectively neutral behaviour (can be focused on expressed genes);
- readily available;
- easy to use, rapid assay and cheap;
- high reproducibility; and
- data can be easily and reliably exchanged between laboratories.

Unfortunately, no single marker type matches all these criteria, although some come close such as SSRs (simple sequence repeats).

A comparison of four molecular markers: inter-retrotransposon amplified polymorphism (IRAP); retrotransposon-microsatellite amplified polymorphism (REMAP); sequence-specific amplified polymorphism (SSAP); and amplified fragment length polymorphism (AFLP) for genetic analysis in *Diospyros* L. (Ebenaceae) in terms of information value and effectiveness is given by Du et al (2009). A comparison of molecular markers for genetic analysis of *Macadamia* in terms of the type, amount and cost-efficiency of the information generated, using data from published studies, is given by Peace et al (2004).

A summary of 'dos' and 'don'ts' regarding the user of molecular markers is given by Iriondo et al (2008):

- *Do not* plan to do molecular population genetic monitoring first in any *in situ* conservation assessment.
- *Do not* undertake molecular population genetic assessment/monitoring without very good reason, or without specific questions to answer, and until other proxy genetic assessments have been fully examined.
- *Do not* necessarily plan for routine sequential population genetic monitoring.
- *Do* use molecular population genetic assessment as a last resort and for fine-tuning to:
  - select the most suitable and fittest populations for *in situ* conservation;

- – measure inbreeding/outbreeding in a species as a pilot survey;
- – monitor populations or critical situations;
- – select for conservation among candidate populations of inbreeding species;
- – select the 'best' small isolated populations for protection;
- – determine the effects of a severe drop in actual population size on genetic diversity;
- – establish whether gene flow is occurring between fragmented populations.

Habitat monitoring

Habitat/protected area monitoring can be defined as 'the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective' (Elzinga et al, 2001).

Habitat monitoring (sometimes known as ecosystem monitoring) involves making repeated recordings of the condition of the target habitats or ecosystems so as to detect or measure changes from a predetermined standard, target state or previous status (Hellawell, 1991). It may cover the range and distribution of habitat types and the area occupied and often their species composition and, in some cases, abundance. It may also provide information on the status of some of the components of the habitat such as species or populations and has been suggested as a cost-effective substitute for the simultaneous monitoring of several species (Gottschalk et al, 2005).

The features of a habitat that may be monitored, including aspects of quantity, structure, function or dynamics (Tucker et al, 2005) are:

Quantity
- area;
- quality: physical attributes;
- geological (e.g. presence of bare rock or deep peat);
- water (e.g. presence of open water or depth of water table).

Quality: composition
- communities;
- richness or diversity;
- typical, keystone or indicator species;
- presence–absence;
- frequency;
- number or density;
- cover;
- biomass.

Quality: structure
- inter-habitat (landscape) scale (e.g. fragmentation, habitat mosaics);

- intra-habitat scale;
- macro-scale;
- horizontal (e.g. plant community mosaics);
- vertical (e.g. ground-, shrub- and tree-layer topography);
- micro-scale;
- horizontal (e.g. patches of short and tall vegetation);
- vertical (e.g. within-layer topography).

Quality: dynamics
- succession;
- reproduction or regeneration;
- cyclic change and patch dynamics.

Quality: function
- physical and biochemical (e.g. soil stabilization, carbon sinks;)
- ecosystem processes.[2]

Habitat monitoring covers a wide variety of approaches. The traditional way of acquiring information on habitats is through field recording and mapping of vegetation, plants communities or habitat types. More recently, remote sensing which uses computer-aided interpretation and visualization of satellite imagery has been applied (Turner et al, 2003). Aerial photography may be used in either approach.

Developing a monitoring programme

Whatever the object of monitoring – species, habitat or policy – a monitoring programme or strategy should be prepared that sets out: the objectives; the methodology to be employed for each feature to be monitored; a sampling strategy, if appropriate; a review of the resources and equipment needed; a review of any legal aspects such as licences that may be necessary; a system and methodology for recording and storing data; a process for analysing and interpreting the data; and an implementation schedule.

It is important to ensure that monitoring programmes are properly designed, the baseline established and the sampling is adequate; otherwise, it will be difficult to detect trends accurately. There is evidence that much of current practice is far from satisfactory (Yoccoz et al, 2001; Noon, 2003; Kull et al, 2008).

The development of monitoring programmes is often considered a step-wise process (e.g. Elzinga et al, 1998; Noon, 2003). As summarized by Noon (2003):

- specify goals and objectives;
- characterize system stressors;
- develop conceptual models of the system;
- select monitoring indicators;

Box 13.2 The main steps involved in a monitoring programme

1 Complete background tasks.
2 Develop objectives.
3 Design and implement management.
4 Design monitoring methodology.
5 Implement monitoring as a pilot study.
6 Implement and complete monitoring.
7 Report and use results.

Source: Elzinga et al, 1998

- establish sampling design;
- define response criteria; and
- link monitoring results to decision-making.

Elzinga et al (1998) give an overview of the steps involved in setting up a monitoring programme for plant populations (see Box 13.2). Each of the steps can, in turn, be broken down into a series of sub-steps, thus the background tasks comprise:

- completion and review of existing information (see Chapters 6 and 8 of this manual);
- review of planning documents of the relevant land management/conservation agencies to ensure the monitoring is in harmony with their established goals;
- identification of priority species and/or populations (see Chapter 7 of this manual);
- assessment of the resources needed and available for monitoring – management support, people with appropriate skills, suitable equipment both low-tech, such as vehicles and measuring instruments, and high-tech, such as GIS, GPS and satellite imagery;
- determination of the scale of the monitoring actions – what part of the range of the species or populations;
- determination of the intensity and frequency of the monitoring;
- review what is being proposed with the management agency(ies) and seek external review if appropriate.

Details of the methodologies involved in each step for population monitoring are given by Elzinga et al (1998) and specifically for CWR by Iriondo et al (2008: Chapter 4).

Selection of monitoring sites

One of the key decisions that must be made is how many and which populations of CWR will be targeted, thus influencing the sites to be selected for monitoring. The selection of sites will depend on the nature, pattern and extent of the habitat, as well as the number, size and distribution of the populations of the target CWR and on the availability of resources for the monitoring programme.

Selection of indicators for populations and threats

In the species management plan for a CWR, the key components are the actions proposed to combat, mitigate or eliminate the threatening processes. These will have been identified during the ecogeographic survey stage (see Chapter 8). When undertaking monitoring of the effectiveness of these management actions, appropriate indicators need to be devised.

Sampling

A census may be undertaken of the populations to be monitored, although this may not be feasible or practical in a species with very large numbers of individuals. In cases where information is needed on the overall habitat or population but where it is not practical to conduct all the individual measurements this would imply, sampling can be employed. Basically, sampling is a means whereby a part of the habitat, population or other unit is selected so as to provide an overall assessment of its status, nature or quality. Questions regarding the sampling design, sampling objectives, size of the sampling unit, population parameters, such as the number of individuals (population size), density and cover, number of features of the plant, such as leaves and flowers and confidence limits are discussed by Elzinga et al (1998) and by Iriondo et al (2008, Chapter 8).

Timing and frequency of monitoring

Accurate monitoring of results will depend, to a large degree, on the timing and frequency of the monitoring. This will depend partly on the life history of the plant, its phenology, its growth form and the season when it is most easily measured. Life form also affects the frequency of monitoring needed, as will the rate at which population and habitat change is occurring. The more threatened a population, the more frequently it may need to be monitored. If the timing of monitoring is not appropriate to the circumstances, valuable information may be missed.

Reporting

A monitoring report may take many forms but is likely to include:

- an executive summary;
- background information on the project;
- maps, illustrations, photographs or drawings showing locations of the baseline monitoring locations;
- monitoring methodology employed and any standards used;
- equipment used and calibration details;
- parameters monitored;
- monitoring locations;
- frequency and intensity of monitoring;
- date, time, frequency and duration;
- results of monitoring;
- analysis; and
- conclusions and recommendations.

Costs of monitoring programmes: Involving the local population

Monitoring programmes, as we have seen, range from simple field surveys to complex procedures that can involve very considerable costs to cover staff salaries of professionals and significant material and/or equipment such as permanent sampling sites, satellite imagery, remote sensing, advanced computing facilities, data analysis and interpretation. However, the budgets normally allocated by countries to biodiversity conservation are limited; the use of professionals alone is seldom possible and use must be made of volunteers coordinated by the experts. In addition, it is important to involve local stakeholders.

Every effort should be made to involve local people and organizations in monitoring, as they have a vested interest in the areas and the species concerned. The CBD guidelines for creating a management plan (2008) note that local groups will be more likely to collect information which they can analyse and use themselves in managing the ecosystem. This information can be complemented by other monitoring activities. However, in practice, as Danielsen et al (2009) comment, 'most of the literature on methods of natural resource monitoring covers an externally driven approach in which professional researchers from outside the study area set up, run, and analyse the results from a monitoring programme funded by a remote agency'.

Causes of monitoring failures

In practice, monitoring often fails to meet expectations. For example, an assessment was undertaken by Kull et al (2008) of 63 plant monitoring schemes from

Europe (collected into a database, DaEuMon), and 33 schemes found through a literature search, covering 354 vascular plant species in total, of which 69 are listed in Annex II of the European Union Habitats Directive. They found that current schemes collect insufficient data, particularly on the dynamics of the extent and distribution pattern of species, and concluded that the quality and general effectiveness of monitoring programmes would be improved if the publication of monitoring data was planned when designing a scheme. Another aspect that needed to be given strong emphasis in developing monitoring schemes was taxonomic diversity and the integration of different scales, as well as the context of different types of sustainable management.

A summary of the most common causes of failure of monitoring are given by Elzinga et al (2001), including technical reasons such as poor project design, use of multiple observers or unreliable data collectors, poor analysis of results and institutional problems such as lack of support to monitoring programmes or analysis of data, and failure to implement results.

Monitoring and climate change

As Lepetz et al (2009) note:

> *it is generally difficult to predict long-term biological responses, as we have little knowledge concerning lag-times between a given effect and its related responses. To show and understand climate change impacts on biodiversity, it is essential to monitor individuals/populations/species over a long time period, usually spanning several decades, as effects are detectable only after many years.*

A critical issue that will arise as climate change takes hold is the alteration in the dynamics of the habitats in the protected areas, the migration patterns of some of its component species and possibly of target CWR themselves, as discussed in Chapter 14. Monitoring requirements might therefore include habitat change and population movements. This is discussed in more detail in Chapter 14.

Experience from Armenia, Madagascar and Uzbekistan

Armenia

A monitoring system was developed in 2007 and then jointly tested and fine-tuned in 2008 with the protected area authorities. The system was applied to monitoring the state of the populations of four target species – wild relatives of wheat, namely *Triticum boeoticum* Boiss., *Triticum urartu* Thum. ex Gandil., *Triticum araraticum* Jakubz., *Aegilops tauschii* Cosson. – within the Erebuni State Reserve. The following factors were selected for regular observations and recording:

- climate;
- soils (contamination);
- natural and human-induced disturbances;
- phenological observations;
- population size and area occupied;
- pests and diseases;
- invasive species.

Protocols and field forms were developed for each of the above factors. In addition, a stand-alone software tool was developed to record and store the monitoring data, developed in Visual Basic 6.0, using MS Access as a database. Either viewing or editing modes can be chosen. Although developed for the Erebuni State Reserve, it can be easily customized for any other protected area. The modules on *phenological observations*, *population size and area occupied*, and *pests and diseases* are currently linked to the target species; however, the number of species can be increased.

The procedures adopted for monitoring of wild cereal species in the Erebuni State Reserve are given in Annex II.

Technical difficulties

Certain difficulties were encountered in mapping the distribution of target species within the protected areas and, subsequently, calculating the area occupied. The distributions of *T. urartu* and *A. tauschii* are not uniform. They occur in small patches that are not spatially static but vary from year to year. However, their identification is possible only after close on-site inspection by an expert; sometimes further examination in the lab is required. As for *T. araraticum* and *T. boeoticum*, they are more abundant and more uniformly distributed within the protected area; however, there are certain areas where none of the species of interest can be found. These areas are rather small and can only be identified after intensive field-work by qualified experts during the spike-bearing stage. To solve these problems, a sampling methodology was developed using GIS software functions: it was successfully tested.

Madagascar

Dioscorea spp. population monitoring protocols have been established and tested by national partners. Monitoring is being carried out jointly with park personnel, forest commission from local community and CWR national partners.

Uzbekistan

The monitoring methodology was developed in the framework of the CWR Project. Pilot plots measuring 37m by 83m were established in areas with high CWR distribution for four priority target species: wild almond in the Chatkal Biosphere Reserve, wild pistachio in Pistalisay, and wild apple and walnut in Aksarsay. Three pilot plots were established in each location and monitoring was

Figure 13.1 *General review of pilot plot 2 (walnut) – strictly protected territory. Ugam Chatkal National Park, Uzbekistan*

Figure 13.2 *Walnut population on pilot plot 2 – strictly protected territory. Ugam Chatkal National Park, Uzbekistan*

carried out. Results were then provided to the management authorities of the Ugam Chatkal National Park, where these CWR species occur. Monitoring will be carried out every five years in both spring and summer. The results of the monitoring exercise are available online (www.cwr.uz) in Russian and are being translated into English.

Sources of further information

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Notes

1. http://linkage.rockefeller.edu/soft/.
2. Tucker et al (2005) warn that such processes are difficult to define and even more difficult to assess and monitor so that it may not be practical to use them to monitor habitat conditions.

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