INTRODUCTION

The use of agrochemicals to increase food production in developing countries has intensified over recent decades. Industrial crops, such as cotton are also dependent on high inputs of fertilizers and pesticides to maintain or increase yields. Applied appropriately and judiciously, pesticides can assist in the control of plant and animal pests and help to alleviate human and livestock disease. Current trends show that the market for insecticides and herbicides in developing countries is growing and that they outstrip sales and use of fungicides, acaricides, nematicides and rodenticides. Apart from being used in the greatest quantities, insecticides and herbicides tend to have the most severe side-effects on the environment.

The amount of pesticide that actually reaches its target is frequently small, and much ends up as a contaminant in the environment. The environmental problems that can emerge from pesticide use and misuse include contamination of food and water, and adverse effects on non-target organisms and ecosystem function. The behaviour of pesticides and their environmental impact in agricultural and other ecosystems has mainly been studied in temperate countries. This implies that risk predictions based on temperate agricultural conditions are not altogether reliable when applied to other climatic zones and/or to biomes that are home to much of the world's biodiversity.

Ecotoxicology is a relatively new discipline that is itself a combination of at least three other disciplines: chemistry, toxicology and ecology. The science of ecotoxicology is not yet sufficiently developed to allow predictions of hazard and risk with the accuracy that we would like, particularly when answers are being sought under variable operational and environmental conditions. Nonetheless, methodological frameworks and databases have evolved that enable well researched risk assessments to be made, and it is environmental monitoring that underpins environmental assessment through the provision and strengthening of case study material.

Risk assessments are a tool to aid decision-making. They are used to present the available information about an intervention in a rational and communicable way that facilitates the decision-making process. A risk assessment is a predictive exercise about a change or an intervention (such as pesticide use) that is based on scientific data, judgements and assumptions. An assessment identifies significant hazards and estimates the likelihood of harm to individuals or the environment that might arise from those hazards. It also enables decisions to be made about ways to reduce or eliminate certain risks (risk management). Decision-makers and the public would wish to be presented with more precise information, but in many situations such information simply does not exist. The aim of a risk assessment is to determine as objectively as possible from the limited factual information available, the least damaging and reasonable option that will bring the benefits sought. It is where the balance of risk against benefit must be ascertained.

The primary purpose of this handbook is to strengthen the capacity of local and regional institutions to undertake meaningful monitoring and assessments of development interventions that involve significant pesticide usage. The transfer of appropriate methods and techniques for ecological monitoring enables institutions to undertake research, to assume more control and judgement over local pesticide use and to provide decision-makers in agricultural, natural resource, public health and environmental sectors with the tools and advice to resolve management questions. This handbook can assist staff in ministries, departments, district offices and NGOs to understand the rudiments and practice of pesticide impact monitoring and assessment. For operational purposes it is intended for use by field officers and assistants, but it will also be useful to managers and as an educational tool for students of ecotoxicology, ecology and natural resource management. This handbook is an aid to capacity building, but it will not enable ecotoxicological studies to be carried out entirely unassisted.

Specialist input will generally be necessary for planning and designing a pesticide monitoring programme, as well as for the interpretation of the data sets collected.

The handbook has been developed by researchers with extensive field experience of pesticide impact monitoring in tropical countries, where constraints of budget, remote working areas, electrical power and portability have driven the development of 'appropriate' methodologies. The result is a collection of robust ecological methods based on inexpensive equipment for the detection and measurement of change in population structure and ecosystem functions that are appropriate for use in tropical and sub-tropical biomes under various degrees of management (wild to cultivated). Methods requiring relatively sophisticated equipment are only mentioned in outline together with a bibliographic reference: method sheets for such study methods are not provided on the assumption that such methods will rarely be used without outside help.

Please note that although pesticides can have adverse impacts on plants, methods for monitoring vegetation are not covered in this handbook. The impact of pesticides on plants is a rather neglected area, but interested readers are directed to the following books which give the topic (especially in relation to herbicides) some coverage: Brown (1978) and Greaves *et al.* (1988). Ecological census methodologies for plants are given by Bullock (1996).

The methods provided in this handbook are by no means exhaustive. A selection of useful, generic methods are provided that fit the criteria outlined above. These will need to be adapted to local conditions and to specific constraints, including budgetary and logistical considerations. Of all the operational difficulties foreseen and discussed, the lack of taxonomic expertise is the hardest to overcome and so we have suggested ways of tackling initial difficulties, and then where and how to seek help later with faunal identifications.

REFERENCES

BROWN, A.W.A. (1978) *Ecology of Pesticides*. New York: Wiley-Interscience.

BULLOCK, J. (1996) Plants. pp. 111–137 In: *Ecological Census Techniques. A Handbook*. Sutherland, W. J. (ed.). Cambridge: Cambridge University Press.

GREAVES, M.P., SMITH, B.D. and GRIEG-SMITH, P.W. (eds) (1988) *Field Methods for the Study of Environmental Effects of Pesticides. BCPC Monograph,* No. 40. Thornton Heath: British Crop Protection Council.

HOW TO USE THIS HANDBOOK

The primary purpose of this handbook is to assist staff in national and local institutions to understand the rudiments and practice of pesticide impact monitoring and assessment. However, pesticide impact assessment is complex and this handbook cannot hope to provide the comprehensive instruction in the disciplines that the assessments must draw upon. The handbook should be used as an aid to undertaking focused monitoring and assessments of development interventions that involve significant pesticide usage. The book will not provide adequate information to allow all institutions/groups to undertake all aspects of a pesticide impact monitoring programme without technical assistance. Aspects of programme planning, design, data analysis and interpretation will require guidance from qualified technical personnel to ensure secure recommendations.

The handbook is laid out in such a way as to guide the reader through the steps necessary to plan and design an environmental monitoring programme with the aims of:

- assessing pesticide impacts
- selecting ecological processes or wildlife groups to monitor
- selecting appropriate sampling or monitoring methods
- processing and analysing the data collected
- interpreting the information.

The first chapter outlines the preparatory stages necessary for planning and designing an environmental monitoring programme. The desk assessment outlines the type of background data that it is necessary to collect in order to decide which faunal groups are most at risk and should, therefore, be monitored. The various tables which follow will also assist with this decision. Once key fauna and/or processes have been identified, it will then be necessary to consult the appropriate chapter(s) to decide which sampling or monitoring methods to use in order to collect the most appropriate data for the key groups or processes. It may be advantageous to monitor several groups or processes, in which case it will be necessary to consult several chapters.

Once the non-target organisms and appropriate methods for their monitoring have been identified, it will be necessary to go on to chapter 2 on 'Basic Statistical Issues and Methods'. This chapter outlines key elements of experimental design that are needed to ensure appropriate collection and management of data that will provide a statistically valid assessment of a hypothesis. Consultation with a statistician/biometrician at a local college or university is highly recommended at this stage as it will minimize the danger of collecting inappropriate data.

Reading through the Worked Example will also help by taking you through the process from data collection, processing and analysis through to interpretation of the results.

Each chapter outlines the sampling or monitoring methodologies that are most appropriate for the particular faunal group by habitat and pesticide type, application mode and for assessing impacts by pesticide group. Important considerations in the choice of techniques include the availability of equipment: will this be available locally, or can it be made locally? Are the staff numbers needed for the particular method available? Do those staff have the necessary skills or will outside experts need to be called in? Are laboratories necessary to carry out processing of any samples collected and, if so, are these available? Questions such as these should be carefully considered at this stage.

The method sheets for individual field monitoring or sampling techniques need to be read through carefully during the planning phase of the monitoring programme. They outline factors that are necessary to consider

both in preparation for the technique and its implementation. The method sheets are printed on durable, waterproof paper as it is intended that they are taken to the field as an *aide-memoire*. Check the *Don't Forget* section before departure on field visits.

Other than skills in environmental assessment and ecotoxicology, the most likely area where trained staff will be required at some stage is that of taxonomy. In many cases, experts on particular taxa will be required to provide or check the identification of the biota. Such assistance should be relatively easy to find for both mammals and birds from members of local (or national) wildlife groups, NGOs and departments responsible for parks and wildlife. Local or national universities/museums can provide or suggest experts in the taxonomy of insects, spiders, fish and aquatic invertebrates, amphibians and reptiles and general invertebrate zoology.

Note: If going to the field for extended field visits to carry out monitoring using more than one sample method, it is recommended that the whole handbook is taken along, not just the method sheets. This will help in making decisions on sample site selection, sample processing, data collection, sample preservation and storage, etc.

Suggestions for effective presentation of data and results is provided in the section of chapter 1 on the 'Analysis and Assessment Phase'. These should be considered carefully as they may influence your selection of methods. This is followed, at the end of chapter 1, by a Worked Example which should be read again before data analysis and presentation begins.

NB: Since original publication, a number of the authors involved in writing the handbook and methods sheets have moved from NRI. Their updated contact details are included as footnotes to chapters, wherever this is possible. Many of the chapter authors are now part of the NR Group and can be contacted via the group website (www.thenrgroup.net).