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BIRDS

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INTRODUCTION

With over 9000 species, birds are one of the most diverse and evolutionarily successful groups. They occupy almost every habitat on earth, often occurring in large numbers and in a great variety of forms, especially in the tropics. They range in size from the tiny bee hummingbird (*Mellisuga helenae*) of Central America, weighing just 2.0 g, to the ostrich (*Struthio camelus*) of Africa, weighing up to 130 kg. They are probably one of the easiest groups of animals to census, popular to study and are undoubtedly one of the most frequently observed and monitored of all taxa. While many species are sedentary, the power of flight enables others to exploit seasonal changes in food supply and migrate with extraordinary accuracy over thousands of miles each year.

Such attributes have given birds a special place in many human cultures and their fate, in the face of agricultural and industrial intensification, is of widespread concern. As a result, much research has been undertaken into the effects of agrochemical use on their populations. This has shown that birds are often at risk, either directly or indirectly from pesticide spray treatments, but that robust, low cost methodologies can be applied to monitor and assess the impact of pesticide applications in some cases. Indeed, this work has also demonstrated that some birds are good indicator species, revealing effects of pesticide spraying in their invertebrate or fish prey that would not otherwise have been detected. For example, changes in feeding rate, success and diet of pied kingfishers (*Ceryle rudis*) and little bee-eaters (*Merops pusillus*) showed that their prey – small fish and day-flying insects respectively – had been affected by spray treatments.

This aim of this chapter is to help the managers of agricultural projects or programmes, vector control programmes, plant protection divisions or wildlife and environment departments to decide which birds, if any, should be monitored during pesticide spray programmes, using which techniques, and to provide guidance on suitable methods for detecting pesticide effects on bird populations. Simple, low cost monitoring methodologies are described.

EFFECTS OF PESTICIDE TREATMENTS ON BIRDS

Pesticides may have direct and/or indirect effects on birds, with either lethal or sub-lethal consequences. Avicides (e.g. fenthion) are, of course, intended to kill bird species which are pests, such as quelea (*Quelea quelea*). However, routine pesticide spraying operations (for crop, forest or human health pests) will also kill non-target bird species as well, including birds of prey.

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Insecticides and acaricides primarily affect bird populations by reducing the availability of their arthropod prey, but the consumption of contaminated prey (e.g. ants contaminated with DDT, locusts contaminated with fenitrothion) may cause the deaths of insectivorous birds through acute poisoning or cause sub-lethal effects which will affect their behaviour or breeding success. Reduced abundance and/or availability of insect prey (see chapter 8) will result in lower feeding rates, loss of condition, breeding failure and, therefore, population decline. In addition, many insecticides are harmful to fish and thus piscivorous birds may also be at risk. The risk to granivorous species is generally lower although many species feed on insects (insectivorous) during the breeding season. Poisoning may occur when seeds dressed with insecticides are eaten. DDT, where it remains in use, presents a unique risk. The residues of this insecticide accumulate in birds of prey and cause eggshell thinning, which in turn will lead to breeding failure and ultimately population decline.

Herbicides may affect bird populations by reducing the availability of seeds for granivorous species; by reducing invertebrate abundance by the removal of the plants that the invertebrates depend upon for food or habitat; and by reducing cover for ground-nesting species. Such effects are becoming increasingly well documented and are of particular concern as herbicide use is rapidly increasing in many countries.

Impact indicators in bird studies will be the degrees of change to one or more of the following:

- feeding and diet
- condition
- behaviour
- breeding success
- numbers (relative abundance).

STUDY DESIGN

Having determined the scope of the proposed monitoring programme (see chapter 1), the manager should design the study and identify the resources needed, constantly bearing in mind the time available for any monitoring according to the needs of the proposed spray programmes.

Resources

The location, scale and duration of the spraying operation will determine the resources required to:

- replicate observations
- calculate the time required to collect data on pre-treatment or baseline conditions
- determine sample size
- estimate the duration of the environmental risk, and hence the available time for an effective sampling period.

Although some bird species are easy to identify and count, generally there will be a need to employ a trained field biologist with previous ornithological experience to carry out the studies described below.

Study species

Common, conspicuous, and sedentary species can be monitored with fewer resources than rare, secretive or migrant species. Indeed, it is usually impractical to attempt to monitor migratory species, and work on rare, secretive species will require the services of a professional ornithologist.

Study areas

At least *two* study plots should be chosen in the sprayed area and *two* outside the sprayed area, to reduce the risk that divergent changes observed between sprayed and unsprayed areas are not simply due to chance.

The abundance of the species of interest and the sampling method selected will determine the size of the study plots. Clearly plots can be smaller if species studied are very common or if the sampling method or frequency is more intensive.

Where possible the sites chosen for monitoring should be close together to ease logistical arrangements for sampling and to reduce the risk that differences in bird populations will be due to ecological and climatic differences. The ecological conditions, habitats and land use of each of the study plots should be matched as closely as possible to reduce the risk that these variables will affect the results of the study.

However, great care should be taken not to position unsprayed study plots downwind of sprayed plots as spray drift can affect areas many kilometres downwind under suitable atmospheric conditions.

Study duration

The duration of the study is determined by the need to collect pre-spray baseline data, the nature of the impact and the predicted recovery period.

- If the impact is likely to be sudden and severe, but recovery is likely to be rapid, a short study lasting from a few days before the spray treatment to a few days after the impact of the treatment occurs can be planned.
- If recovery is slow, but the process apparent within the same season as the impact, then observations over a few weeks can be planned.
- If chronic effects are anticipated due to herbicide treatments or persistent pesticide residues then studies lasting from months to years may be necessary to ensure that normal seasonal and annual fluctuations in population size are understood and the recovery process is fully monitored.

It is important to decide on the study length as soon as information is received on when pesticide operations are planned.

Accuracy of observations

Variation in sampling methodology (e.g. by using different people to count the birds) during sampling may account for more variation in the population estimate than the effects of the pesticides themselves (Berthold *et al.,* 1986). Standardization of techniques and operator uniformity is, therefore, vital to ensure that statistically valid data are collected and valid results are obtained (Fowler and Cohen, 1986; Bibby *et al.*, 1992).

Bias can be reduced, and the accuracy of work improved, by following certain *operating rules.*

- The observers must be able to identify all bird species under study reliably.
- Provide training for observers if necessary, and in time.
- Try to retain the same observer to repeat any set of observations at a particular site.
- Use additional observers to sample extra sites, ensuring they have been well briefed and trained beforehand.
- Select sampling sites which are as similar as possible and where target species can be readily detected.

- Maintain the same sampling speed and effort throughout the study (standardize procedures) (see chapter 2).
- Conduct observations at the same time each day. Restrict observations to the 3–4 h period from sunrise, when birds are most active and light conditions are good.
- If the weather changes markedly on any day discard all observations for that day (be prepared to plan for such unforeseen happenings). If different observers are involved, do not mix data sets, and make sure that all data sheets are fully labelled.
- Report full details of the methodology used and field conditions (habitat type and condition, season and weather, etc.) at the time of monitoring.

Sample replication

Replication of observations is important to reduce the risk that any changes that occur are due to chance (see chapter 2). Monitoring should be carried out in at least *two* sprayed and *two* unsprayed areas, although in some instances this may prove impossible as comparable sites, or sufficient resources, may simply not exist.

Working at more sites will increase confidence in the final results, but will require more resources.

Keep accurate records of all procedures followed.

Residues analysis

Residues analysis is time consuming and extremely expensive and fieldwork linking exposure to effect is almost non-existent. There is no point measuring residue levels unless the associated risk can be interpreted. It is recommended, therefore, that residues analysis is not attempted. If field monitoring points to an adverse impact, the 'precautionary principle' should be adopted and safer control technologies recommended and implemented if possible.

An exception may be made in the case of birds exposed to DDT or other persistent organochlorine pesticide residues. However, residues analysis should be restricted to measurements of concentrations of the pesticide and its metabolites in the brain or whole body lipid.

Planning the fieldwork

Select study areas well in advance of spraying operations.

- If possible, avoid choosing unsprayed study areas downwind of the sprayed areas as spray drift can sometimes extend over many kilometres.
- Prepare data recording sheets, and be sure that there are sufficient for the entire programme of work.
- Use good binoculars (8 x 30 to 10 x 40), bird identification books (along with sheets 1–4 used to note features of unidentified birds in the field), clip-board, stop-watch, pencils, eraser, penknife and notebook for each observer.
- Mark sampling sites by painting stones, posts or trees with white water-resistant paint or aerosol spray paint.
- Test the methodology and competence of observers well in advance of spraying operations.
- Prepare a map of the study area showing important features such as trees, streams, tracks as well as transect lines or sample points.
- Use a global positioning system (GPS) for waypoints or a compass for direction.

SAMPLING METHODS

POPULATION SIZE

Monitoring relative abundance is appropriate when there is a risk that mortality or emigration/immigration associated with spraying will take place within the duration of the study. A variety of methods are available. Their suitability depends on:

- the scale of the spraying operation
- the habitat type sprayed
- the bird species of interest: their visibility and behaviour
- resources (material and financial) available for completing the monitoring.

Timed point counts (sometimes called point counts)

This is a useful method for assessing the relative abundance of common, sedentary, non-flocking bird species in wooded or bushed habitats. Large sampling areas are usually needed (at least 20 km^2). The observer monitors numbers of the species of interest, seen or heard, at a series of sample points. Sample points may be selected at random or regular intervals, or systematically, along roads, which are identified before beginning the observations. Systematic selection may be made where birds of a particular habitat are of interest, otherwise use randomly chosen sites.

Whichever method is used, sample points should never be less than 200 m apart to avoid the risk of overlapping observations. Observations at each point are made within a pre-determined radius of up to 50 m from the central point chosen. They are made over a fixed time period of 2–5 min. The actual counting time allocated for each station must be the same, although it will vary with habitat and the abundance of birds. Therefore, the time estimated to monitor 20 points (stations), assuming 10 min to complete observations and move to another station, will be about 3.5 h. Sample points are numbered clearly with coloured plastic tags, or rainproof paint.

It is recommended that *two sets* of 20 points are monitored *in the spray treatment area*, and *two similar* sets in the *untreated area*, to allow comparison of changes in treated and untreated areas. Using a vehicle, 20 points can be conveniently sampled in 2–3 h work. If no vehicle is available, allow about 1.5 h to complete 10 sample points. (This allows 8 min to move between each sample point and includes the time taken to reach the next point.)

The impact of spraying on the relative abundance of each species, or feeding guild (group of birds), is compared *within* and *between* treatments (i.e. within sprayed and within unsprayed areas, and between sprayed and unsprayed treatments). If relative abundance declines with spraying in both treated sample sets, but increases or remains constant in both untreated sample sets, an effect of spraying may be concluded (Douthwaite, 1980, 1995).

Limitations Data from a large number of samples are required, each of which must be chosen at random. The accuracy of the counts will vary with the time of day, weather, season, habitat and observer. Results are highly dependent on observer experience. Not a good method for open habitats, where birds may flee from an observer.

Fauna sampled Small to medium-sized, relatively common, non-flocking, sedentary species (e.g. flycatchers, shrikes, some ploceids). Good for songbirds, less appropriate for shy species.

Processing Direct recording of occurrence or observation on to the data sheet.

Resulting data Species lists, frequencies, species relative abundance curves or ratios, and detection rates, according to the spray treatment.

Sampling period At least 4 days of observations should be made at each set of sample points before spraying, and 4 more days shortly after spraying (i.e. 32 days fieldwork). More time will be necessary if the weather is changeable.

Equipment Binoculars and stop-watch.
Staff required 1–2 skilled observers, with vehicles.

Analysing the data from timed point counts

- Sum the counts for each species to give totals for each census.
- Draw up a contingency table showing the highest count of each species by sample area and sample period (i.e. pre- and post-spray).
- Fewer than 20% of the cells in the table should have expected frequencies <5, and none should be <1. If this occurs, combine data for the less common species by diet type (frugivorous, insectivorous, etc.), method of feeding and by site. If this cannot be done, discard the species from further analysis.
- Compare frequencies of occurrence before and after spraying within treatments by using the chi-squared test. If the data are homogeneous combine counts within treatments and compare frequencies between treatments. If the data are homogeneous the risk of an effect of spraying is low.
- If the data are heterogeneous, spraying may have affected relative abundance. Examine the data by species to detect the source of heterogeneity and note especially those species that showed no decline in abundance in both unsprayed areas, but declined in both sprayed areas.
- From a knowledge of the ecology of these species, consider whether an effect of spraying seems likely.
- If an effect is probable, monitor the species through other, more intensive, methods in future spraying operations.

Fixed strip transect counts

This is a useful method for sampling the relative abundance of relatively common, medium to large, conspicuous and sedentary species in open, uniform or species-poor habitats such as bushed or wooded grassland (see Mullie and Keith, 1993a). It requires less space than timed point counts but requires more than territory mapping. More than 10 km^2 of pesticide-treated area are required, plus *an equivalent* untreated area which should (wherever possible) lie adjacent to the treated area and be of similar habitat type and topography.

Species of interest seen or heard within strips of known width are counted as the observer walks slowly along a fixed transect route. Transects may be of any length (an ideal length would be 1000 m), which can then be sub-divided into fixed lengths of between 100 m and 1000 m, as this will make analyses easier.

Parallel transects should be 150–200 m apart in *closed* habitats or 200–500 m apart in very *open* habitats. The distance chosen **must** be adhered to throughout to avoid the risk of double counting. Transect width should be in the range of 10–100 m to either side of the observer, depending on the habitat and ease of observation; 20 m is an easily estimated width. Birds seen or heard outside the transect should **not** be counted. Assuming the observer moves at about 2 km h^{-1}, some 10–20 ha of habitat can be sampled during each morning. As a rule of thumb, 40 recordings (records) of any particular species will be necessary to provide a reasonable estimate of density. It is recommended that bird densities are monitored along at least two transects in the sprayed area, and two similar transects in the unsprayed area.

Transect counts can be made from vehicles provided the species of interest are conspicuous and there is sufficient road in the sprayed and unsprayed areas to give reasonable sample sizes. This method has been used to monitor relative abundance of diurnal raptors, sparrow-weaver colonies (Douthwaite, 1992a), and nightjars (McWilliam, 1994).
Limitations Variations in observer's abilities during the fieldwork. Procedures must be standardized as far as possible to reduce any subjective bias especially when using a number of different observers (every observer will

tend to do things differently unless clear procedures are explained beforehand). About 40 observations of any particular species are necessary to provide enough information and a reasonable estimate of density. The accuracy of the counts will vary with the time of day, weather, season, habitat and observer.

Fauna sampled Relatively common, medium to large, conspicuous and sedentary birds (e.g. tits, thrushes, woodpeckers, grassland/thicket inhabiting warblers).

Processing Direct recording of occurrence or observation to the data sheet.

Resulting data Species lists, frequencies, densities, species relative abundance, or abundance ratios by between the spray treatments.

Sampling period At least 4 days repeated observations along each transect before spraying, and 4 days afterwards. The timing of counts should be related to the expected severity and duration of spraying impact.

Equipment Binoculars and a watch (or stop-watch) are necessary.

Staff required 1–2 skilled observers.

Analysing the data from transect counts

- Plot changes in species abundance by count and transect sub-section.
- Combine sub-section counts to ensure at least 40 individuals of a species or feeding guild were sampled (on average) in the pre-spray series of samples.
- Make a table of the number of every species seen or heard along each entire transect.
- Calculate *B* Index for each species, using the following equation:

$$B = [(N/C) \times ((N_{1/2} + 1/C) \times 100)] + A$$

where N = number of transect sub-sections during which the species was recorded during the first hour
$N_{1/2}$ = the number of transect sub-sections during which the species was recorded during the first 30 min
C = number of surveys
A = the sum of the abundance ratings (AR) >1.

Abundance ratings are estimated as:
AR 1 = 0–5 birds; AR 2 = 6–10 birds; AR 3 = >10 birds.

- Use the Spearman Rank Correlation Coefficient test (see chapter 2) or Wilcoxon matched-pairs test to determine the significance of differences between results of transect counts in sprayed and unsprayed areas.
- Consider the evidence that changes in abundance following spray treatment were due to spraying.

Territory mapping

This is the most accurate method for monitoring population size, suitable for use in any habitat, and requiring the smallest study plots. However, it is also the most time consuming method and its applicability is limited to territorial species during the breeding season. Males sing to identify and defend their territories, which are often clearly defined. The territories of species of concern are mapped. A code will need to be generated for each species encountered, examples are given in the Appendix on page 242. Once designated, species name abbreviations must not be changed. Analysis of the data collected is quite complicated and for those interested in using this method, it is strongly recommended that reference is made to Bibby *et al.* (1992), pages 42–65, before embarking on a study using this technique.

Detailed large-scale maps of at least a scale of 1:2500 are used to plot the location of singing or displaying individuals, and their movements. All obvious features such as distinctive trees, ponds, streams or tracks should be marked on the map of the study area **before** beginning the census. Study plots should ideally be round or square, long plots are not suitable because of the very high edge to area ratio. Relatively small study areas should be chosen, with plot size depending on ease of coverage, but varying from 10–20 ha in fairly tight canopy woodland to 50–100 ha in farmland or open wooded grassland.

A series of up to 10 visits may be necessary to establish the boundaries of all bird territories before spraying begins, and a similar number should be made afterwards. The number of visits required will vary with the duration of the visits and the degree of species richness information (with more visits required the higher the species richness) recorded during them. Where there is no real seasonality (marked differences in climate and/or photoperiod at different times of the year), timing of visits will need to be planned during the periods when many species tend to breed (e.g. during or just after the rains). It will be more difficult to observe birds when the trees are in leaf.

On each visit, the observer should walk slowly around to within approximately 50 m of the boundary at every part of the plot, noting the identity and activity of all individuals of interest and recording the observations through coded entries on the map. The observer should concentrate on the location of individuals of the same species that can be seen or heard simultaneously. Attempts to flush individuals, and the playback of tape-recorded song, will help to demarcate territorial limits. If territories extend beyond the limits of the study area, it may well be necessary to map territories that extend beyond the limits up to about 100 m in all directions, so the map will need to extend beyond the selected study area accordingly.

A separate map should be prepared and used for the records collected during each visit to the study plot (see example territory map in Figure 12.1 below). Although an early morning start will yield information more quickly (it may in fact not be possible to record information due to the large numbers of birds calling), the time of day and weather are less critical than with timed point or transect counts. It is important to mark the location of birds accurately. The duration of the visit depends upon the stamina of the observer; in any event every part of the plot must be visited at least once at each visit. Every bird encountered and its associated activities are entered on the map using the symbols prepared before the observations begin (examples of bird behaviour that will require coding with examples are given in the Appendix on page 242 and these codes must also be strictly adhered to). This method is suitable for use in any habitat type. In forested habitat only about 2 ha can be surveyed per hour while in open habitat this may increase to 15–20 ha per hour.

Fieldwork and analysis of territory mapping are *very* time consuming, but the work results in more accurate estimates of population size than either transect or timed point counts. This method is suitable for single species studies, provided the species are territorial (e.g. thrushes, chats, warblers).

Ideally, *two treated* and *two untreated* study plots should be monitored. *This method does assume that birds live in pairs and in territories that do not overlap*. This method is unreliable when birds are present in high densities.

Changes noted after spraying may well be represented by a marked decrease in the number of bird species present, or by changes in their behaviour when compared with an unsprayed area.
Limitations This method is very time consuming and, therefore, expensive. It is not useful for colonial species or those living in loose groups. The method assumes that birds live in pairs in discrete, non-overlapping areas, which is often not true. Even if standard guidelines are used, it is rather a subjective measure and heavily affected by the observer. It becomes less accurate at high bird densities, and is really only suitable for breeding birds. The method is thus subject to seasonal territoriality.
Fauna sampled One to a few territory holding species (e.g. warblers, chats, shrikes).
Processing Sightings are recorded directly on to maps. Concentrate on mapping unambiguous records (e.g. territorial disputes) and minimize collection of ambiguous ones (e.g. re-registering the same bird in another part of the study area after contact has been lost). Symbols will need to be devised for all species to be encountered

and separate symbols used for their behaviour. This may result in a lengthy list of different symbols (see the Appendix on page 242).

Resulting data Maps of territorial boundaries before and after spray treatment, or between treatments. Data can be complicated to analyse, depending on bird numbers in the different areas (see Bibby *et al.*, 1992, prior to any study). Territory mapping will show how the effects of pesticide treatment will affect the numbers of birds and their resultant territorial boundaries. If there is a dramatic effect on insect species, then young birds may also die through starvation, and nests may also be deserted.

Sampling period Allow for up to 10 site visits in the 3 weeks before spraying, and 10 visits afterwards (i.e. plan for visits every second day for 3 weeks).

Equipment Binoculars, a tape recorder and maps are needed.

Staff required 1–2 trained but otherwise unskilled workers, provided they are good at finding birds and can plot records accurately on maps. No vehicle is required, except for initial delivery to the site to be sampled.

Analysing the maps produced

The data collected are transferred at the end of each day to individual species maps, and each set of data maps is referred to as A, B, C, etc. This shows the chronology of the observations. Each species is represented on one map. The field map will look very complicated, but its complexity is reduced with the single species map (Marchant, 1983). All the edge territories should be included within the plot, and it is perfectly acceptable to venture a short way out of the plot if edge territories have been encountered.

Analysis of territory maps will require the input from someone who is experienced in this technique, especially when it comes to analysing the edge territories.

- Check the maps as soon as possible upon return to the office to make sure that all symbols are clear; transpose records for each species to separate transparent overlays. Make sure they are properly labelled.
- In re-plotting the information, change the species code to a visit code.
- Use the species overlays for consecutive visits to map territorial boundaries.
- Decide whether you have enough evidence to plot territorial boundaries with confidence, or whether further field visits should be made.
- At the end of the study, examine territorial changes and determine whether changes in the sprayed plots differed substantially from those in the unsprayed plots.
- Statistical tests can be used to test changes in the number of territories occupied in each area by the same species (use chi-squared tests).

OTHER METHODS FOR ESTIMATING ABUNDANCE

A modified timed point count-territory mapping method was used to monitor relative abundance of white-headed black chats (*Thamnolaea arnoti*) along roads within and beyond areas sprayed for tsetse fly control in Zimbabwe (Douthwaite, 1992b). Tape-recorded song was played back at regularly spaced points, 250–500 m apart, along roads and the response (and counts) of that species within 2.5 min noted.

Nest density

The method is suitable for areas that are treated with persistent insecticides or annually treated with insecticides or herbicides and where chronic effects on bird populations are suspected. This method is suitable for birds making obvious nests such as raptors, crows, weaver birds, colonial bee-eaters, herons or egrets. It is of *no* use where nests are camouflaged or hidden by the birds. Unless the nest is highly visible and readily identified, or

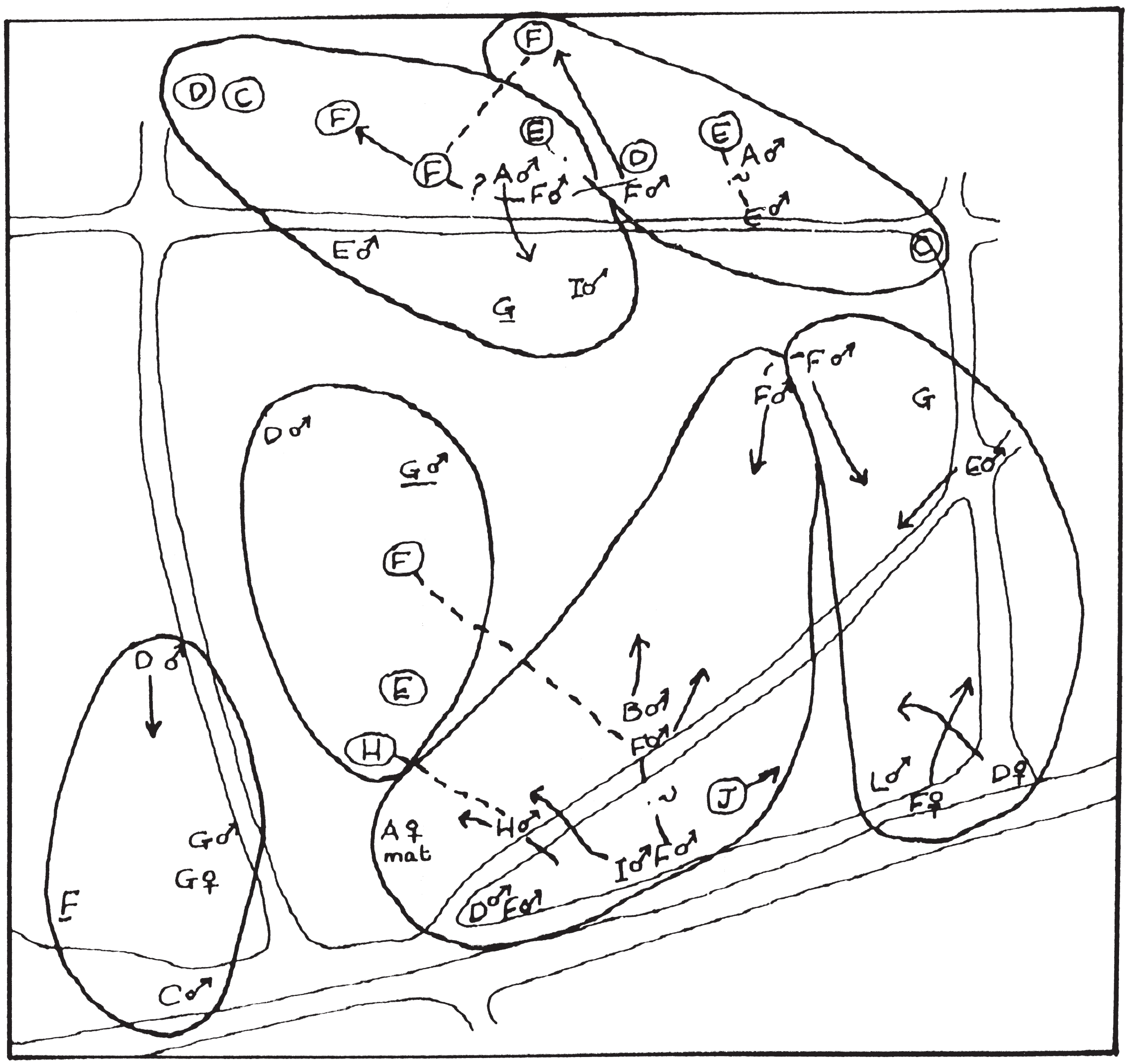

Figure 12.1: Example of a territory map compiled from numerous visit maps (see method sheet) (From *Bird Census Techniques* by Bibby, C.J., Burgess, N.D. and Hill, D.A. (1992) British Trust for Ornithology and Royal Society for the Protection of Birds, reproduced with permission of Academic Press, London.)

located easily by searching well defined habitat, the method is likely to be time consuming and unreliable. Before this technique is attempted an initial assessment of the area should be carried out to determine its suitability.

Number of nests per colony, or number of nests per square kilometre of land or kilometre of river bank or lakeshore can be checked in sprayed and unsprayed areas at any time during the breeding season. However, local assistants can often be recruited to look for nests. If local assistants are used, it is very important to impress upon them the importance of not causing damage or disturbance to the nests, as birds with eggs may readily desert. A further limitation is that the work can only be done during the breeding season so that new nests can be distinguished from old ones by the freshness of materials used or their occupancy.

Interpretation of the results must also be done with care. Habitat suitability may vary between adjacent areas and may affect nest densities (Douthwaite, 1992a; Hartley and Douthwaite, 1994), while a high density of active nests may indicate previous breeding failure rather than good conditions (Douthwaite, 1992c).

Limitations Dependent upon the ability to identify and estimate the age of nests.

Fauna sampled Species with conspicuous nests.

Processing Map nest location and record its condition and contents.

Resulting data Nest densities by spray treatment.

Sampling period Dependent upon the magnitude of pesticide effects expected and the duration of impact. For acute effects, detailed searches should be made 2–3 weeks before spraying and 2–3 weeks afterwards. For chronic effects, annual surveys are only of any real value during the breeding season.

Equipment Binoculars. Tree- or rock-climbing equipment is required to access nest sites for some species (e.g. birds of prey, some starlings or pigeons). Be aware that climbing trees or rocks should only be undertaken by experienced personnel.

Staff required Semi-skilled, but with appropriate training.

Methods for counting leks and nests in colonies are covered in Gibbons *et al.* (1996).

Analysing the observations for nest density

- Estimate the area of suitable habitat searched in the sprayed and unsprayed areas.
- Calculate the density of nests per square kilometre (or, if nests are in colonies the number of nests per colony and/or colony density per square kilometre).
- Compare the density of nests in the sprayed and unsprayed areas, or (if the nests are in colonies) average colony size, using the chi-squared test.
- If differences are apparent, consider the possibility that they were caused by habitat differences between sprayed and unsprayed areas. From observations made at nests, consider also whether they were due to greater breeding failure in one or other area.

Feeding behaviour and diet

Pesticide impacts sometimes arise indirectly, through effects on food supplies. The effects of spraying on the food supply may alter foraging success, feeding rate and diet. For monitoring purposes, the species of interest must be sedentary and easily observed and should feed on large food items in the air or on a perch so that success can be observed. The little bee-eater and pied kingfisher have both been successfully monitored using this method in the past (Douthwaite, 1982; Douthwaite and Fry, 1982). If the species feeds on the ground or in cover, or on small prey items, or ranges widely, continuity of observation will be lost and the method cannot be used.

Provided prey items are large, diet can be determined crudely by direct observation. More detailed analysis requires the examination of regurgitated pellets which contain bone, fur or arthropod exoskeleton. Shooting of birds for gizzard content analysis, may be undertaken if deemed essential and given the appropriate approval. This drastic approach should only be undertaken if it is really considered that valuable, otherwise inaccessible data will be provided. Although a skilled fieldworker can readily locate pellets on the ground, the development of a reference collection of pellets and the resultant pellet analyses, is laborious.

The aim should be to observe the feeding behaviour of a few individuals of a common insectivorous or piscivorous species in a sprayed area and make simultaneous observations in an unsprayed area nearby. Observers need not be ornithologists provided they can identify the species of interest and are good observers.

A vehicle, motorcycle or bicycle should preferably be available as it increases the observers' range and ability to find enough birds to monitor.

Limitations Ability to monitor feeding behaviour and success closely. Behaviour and success will vary with individual, time of day, weather, season and habitat.

Fauna sampled Single common, sedentary, relatively tame, insectivorous or piscivorous species (e.g. little bee-eater, pied kingfisher, drongos).

Processing The sum of records for a period (e.g. morning/afternoon/date), analysed by feeding attempt, outcome and prey type.

Resulting data Feeding rate, feeding success and diet according to spray treatment. Data will also be available for before and after treatment effects.

Sampling period A few days before and a few days after any anticipated impact.

Equipment Binoculars and a stop-watch are necessary.

Staff required Unskilled but trained, motivated observer, with transport.

Analysing the observations for feeding behaviour assessment

- Add the total duration of observations, the number of feeding attempts, the number of successful feeding attempts and items of prey by type for each observation period.
- Calculate the rate of feeding attempts, the rate of feeding, the proportion of successful attempts, and the proportions of different prey in the diet for each observation period. Express the results with, and without, the 'unknown' data, to indicate the precision of sample estimate.
- If the samples are small, combine observations on a daily basis.
- Plot the results against time and assess whether any marked changes occurred in the sprayed area shortly after spraying which exceeded variation in the pre-spray period and did not occur in the unsprayed area.
- Use contingency tables and chi-squared tests to assess the statistical differences in the various data between sprayed and unsprayed areas.

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APPENDIX EXAMPLES OF SPECIES AND ACTIVITY CODES

SPECIES CODES

An example of some codes (in the format as used in the UK) are given below for some common East African birds. You may easily design your own, but keep a hard copy of any identification codes which you use and/or invent to ensure that you do not inadvertently duplicate the abbreviations.

WFY	=	White-eyed Slaty Flycatcher	LBR	=	Lilac-breasted Roller
HT	=	Hartlaub's Touraco	H	=	Hoopoe
PK	=	Pied Kingfisher	YbH	=	Yellowbilled Hornbill
LBe	=	Little Bee-eater	GH	=	Ground Hornbill
SM	=	Speckled Mousebird	CW	=	Cardinal Woodpecker

ACTIVITY CODES

The following are some suggested descriptions required for bird activities (modified from standard British Trust for Ornithology symbols (Bibby *et al*., 1992) for which codes are required. For any activities not mentioned below, codes can be easily devised by the observer. These *activity codes* are used in combination with the unique *species code* used to identify each species encountered.

- Sight records with age, sex or, if appropriate, number of birds. Do not forget to record using the code the number of obvious pairs seen. (species code prefixed by its sex and number seen)
- Juvenile with either one or both parents in attendance. (species code followed by 'fam')
- Adult calling. (species code underlined)
- Adult giving alarm calls (not singing), which may have a territorial significance. (species code with double underline)
- Adult in full song. (species code encircled)
- Aggressive encounter between two birds. (species codes close together surrounded by broken circle)
- An occupied nest (do not bother to mark unoccupied nests). (species code prefixed by '*')
- Adult bird sitting on nest. (species code prefixed by '*' with 'on' after species code)
- Adult bird carrying nesting material. (species code followed by 'mat')
- Adult bird carrying food. (species code followed by 'food')
- Adult bird carrying faeces. (species code followed by 'fcs')
- A calling adult in flight. (species code with arrow through code, if calling then also underline the code)
- A singing bird seen perched but which then flies away and not observed to land. (species code encircled followed by a horizontal arrow)
- A male bird flying into the observation area and landing. (a horizontal arrow pointing to the species code followed by male sign)
- Adult bird moving between two different perches – if you are sure it is the same bird. (species code with a horizontal arrow pointing to the same code)
- Two adults in song at the same time. (codes encircled and separated by dotted lines)
- Single bird in song from different perches. (codes encircled and, if certain that they are the same birds, then the joining line is solid)
- Two different records of possibly the same bird, which may be the situation when the census route revisits an area already covered. (species codes are encircled and the adjoining lines broken by a '?').

On the daily record map, it is also important to record the wind speed (e.g. W3), using the Beaufort scale or anemometer (see chapter 5 on environmental parameters), date and time of survey locality and observer name. (From *Ecological Census Techniques. A Handbook.* (1996) Sutherland, W.J. (ed.) reproduced with permission of Cambridge University Press.)