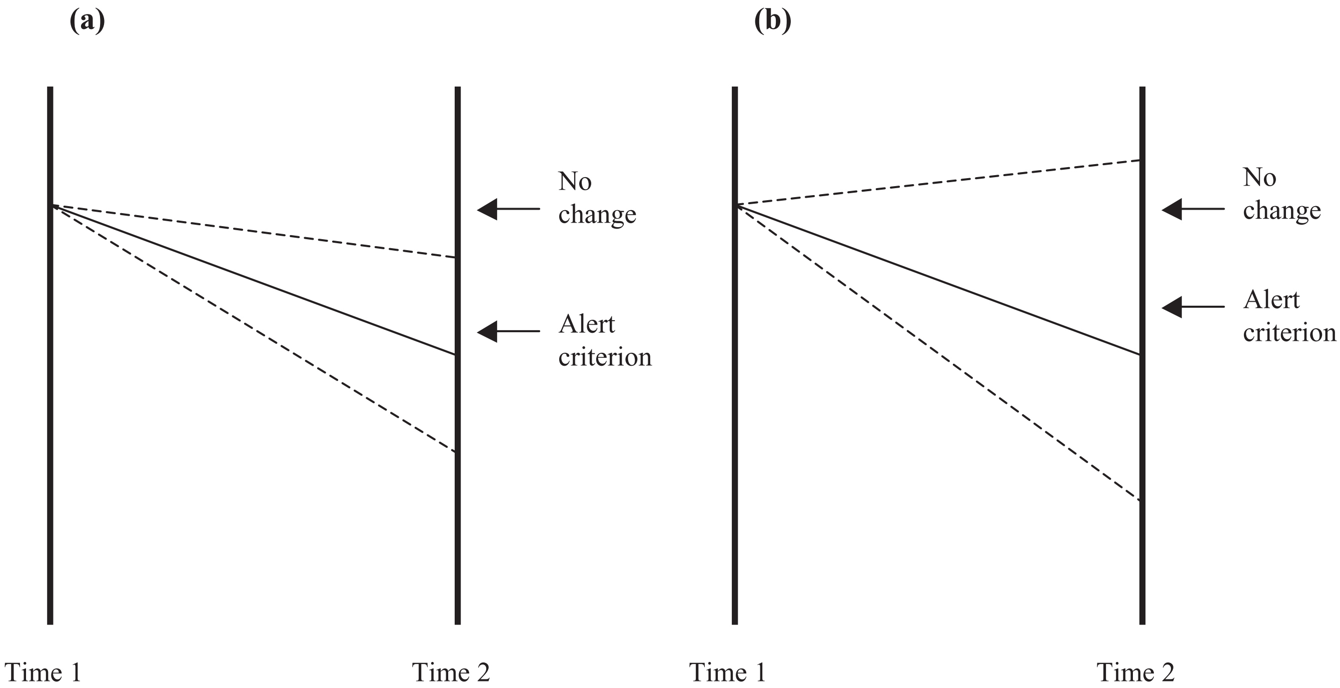

Figure 2.14 Alternative hypothesis tests for alerts. Vertical lines represent two occasions; continuous lines represent estimated population declines, with dashed lines representing confidence limits. The two cases illustrate declines of the same magnitude (exceeding the alert criterion) but the confidence limits are wider in (b) than in (a). If the null hypothesis used is that the population has not declined, the result is significant for (a) but not for (b), so no alert is triggered for (b). If the null hypothesis used is that the decline exceeds the alert criterion, the result is significant for neither (a) nor (b), so an alert is triggered for (b) as well as for (a).

alert, a decline of more than 50% to a Red alert. Under this system, the Lapwing *Vanellus vanellus* would have qualified for an Amber alert in both 1997 and 1999; but a Bayesian analysis assigned probabilities to Amber and to Red of 0.96 and 0.04, respectively, in 1997 but 0.55 and 0.45 in 1999, flagging up a substantial change in the evidence of the decline of this species between those two years (King *et al*. 2006). However, what the proponents of Bayesian methods would claim as a less constrained form of result than obtains under the traditional system is considered by others to be too complex to be placed in front of non-technical members of the community, who may prefer to be told simply whether there is or is not cause for concern over a species. On the other hand, non-scientists have proved perfectly capable of understanding the uncertainties of climate-change scenarios when these have been explained to them; there is no reason to suppose that they could not understand the uncertainties associated with ecological monitoring.

Indicators

In the present context, indicators are summary measures based on the populations of various species that are considered to show how things that people may regard as important are faring. Thus the ‘Wildbird Indicator’ is used by the British government as an indicator of quality of life, partly on the basis that people like to see birds themselves and partly because the numbers of birds

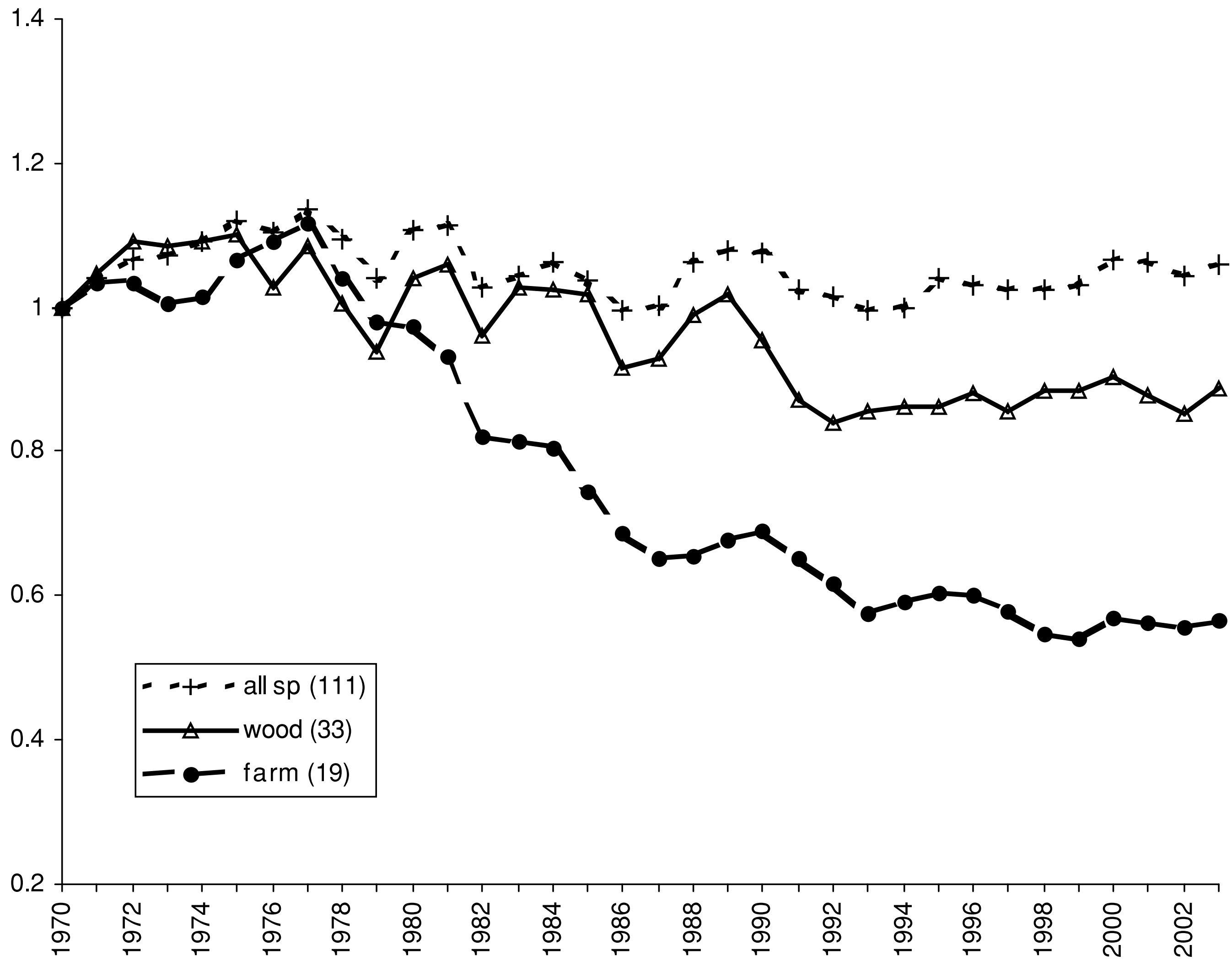

Figure 2.15 The UK indicators for wild birds. Figures in parentheses are the numbers of species on which each indicator is based. (Source: British Trust for Ornithology, Royal Society for the Protection of Birds, Defra.)

in the country may be an indicator of wildlife more generally (Figure 2.15). A similar indicator is used by the European Union (www.ebcc.info).

An indicator based just on farmland birds is used by the British government to assess its success in achieving its target of reversing the decline in farmland birds by 2020. Such habitat-specific indicators can also throw up general problems in the management of particular habitats. Thus the steeper decline of farmland birds than of woodland species (Figure 2.15) has signalled general problems of the management of farmland (Chamberlain & Vickery 2002) as opposed to the more varied problems facing some woodland species (Fuller *et al*. 2005).

An indicator will be useful only if the species included within it are chosen for their relevance to what the indicator is meant to indicate. For example, a farmland indicator should comprise only those species for which farmland is a major habitat. (Because species' habitat preferences may vary geographically, the list of relevant species may vary from country to country.) It is important that the criteria for inclusion are seen to be objective because the information provided by indicators is often politically sensitive.

For general monitoring purposes, rare species should be excluded. They tend to have particular habitat requirements, which make them poor general indicators. They are often the subjects of special management, which makes them poor indicators of the more general management of an environment. Also, their rarity may mean that their populations may be imprecisely monitored (unless they are so rare that their whole population is readily counted). Care needs to be taken in respect of species that were once common enough to include in the index but which have declined in population so much that they can no longer be properly censused. Simply removing them from the index introduces serious bias. The alternative is to assign some arbitrary low value to their populations if they have become too rare to be censused.

Data from various species can be combined in various ways. A method of giving each species equal weight is to divide its population in each year by the population in the first year (for which the index is thus 1.0 in all cases), and then take the average of these indices in each year as the indicator for that year.

The arithmetic mean of such species indices is not a useful indicator. Consider an indicator based on two species, one of which doubles in number between the first and second years, while the other halves. The two indices in the second year are thus 2.0 and 0.5, the mean of which is 1.25. Yet a doubling and a halving should cancel out. The geometric mean (Box 2.19), which has a value of 1.0 in the second year in this case, is a better measure.

Box 2.19. **Calculating a geometric mean**

If your statistics package does not provide this function (e.g. GEOMEAN in Excel®), proceed as follows.

Take the logarithm (natural or base 10) of each of the numbers.
Calculate the arithmetic mean of the logs.

The geometric mean is then the exponent (antilog) of the arithmetic mean of the logs.

	Number	$\log_e$(number)
	1.05	0.049
	0.82	–0.198
	3.17	1.154
	1.34	0.293
	1.25	0.223
	2.03	0.708
	0.99	–0.010
	0.38	–0.968
Arithmetic mean	1.38	0.156
Geometric mean	1.17	

Multi-species population indicators tend to give all species equal weight and to treat all increases as desirable and all decreases as undesirable. But there are some species whose presence may be regarded as indicating deterioration in the 'quality' of a habitat, such as those species characteristic of other communities or invasive aliens. In principle, each such species can be incorporated in the indicator by taking the inverse of its index each year. Thus, if it is twice as abundant in year 10 as in year 1, one uses 0.5 as its contribution to the index in year 10, instead of 2.0.

Planning and managing a monitoring programme

Planning

The first step, which must not be rushed, is to decide one's objectives. Because monitoring, once one goes beyond mere surveillance, is a process that draws in an array of interested parties, it is essential that all those parties participate in discussions about objectives.

Some broad issues must then be addressed, such as what particular failures to achieve targets are likely to be of greatest concern and what actions are likely to be taken should those targets not be hit. The answers to those questions will influence the design of the monitoring programme, particularly the surveillance.

Statistical design issues must be addressed. One must identify the design that is most efficient, providing the most precise estimates given the resources available, while avoiding undue bias. It is important not to be too precious about design, for a perfect design might not be practically possible; so long as one thinks carefully about the likely scale of bias (both when planning and when interpreting the results), it is almost always better to have biased surveillance than no surveillance at all. Various aspects of the design may conflict. For example, one may have a choice between using highly standardised methods implemented by a small number of professional fieldworkers or less standardised methods implemented by a large number of volunteers. Results from the latter approach will be more precise (because of the greater sample size) but potentially more biased (because of the looser standardisation). Careful thought is required as to what is needed for one's particular purpose.

The principles outlined in this chapter are not the only ideas to be used in the planning process: the practical experience of those running similar programmes will be of particular value, as will pilot studies to test out the methods and to provide information that is useful in deciding on final details of the design.

The most important principle of planning is to do it. The second most important principle is not to spend so much time planning that the start of the programme is significantly delayed. With rare exceptions, you will be unable to gather information about the present population in future, so each year's delay in starting is a permanent loss to the long-term programme.

Reviewing

Any long-term programme should be kept under review, to discover whether the methods can be improved in the light of practical experience (which may expose deficiencies), changing circumstances (such as public attitudes or resources), changing objectives and improved theoretical