2.1 INTRODUCTION

If a monitoring programme is being planned, there are five basic questions that need to be asked and answered. Each question is important and should be answered before any monitoring begins; they essentially form a sequential set because a satisfactory answer to any individual question cannot be given until all questions higher on the list have been answered. The questions are:

1. **Purpose**: what is the aim of monitoring?
2. **Method**: how can this aim be achieved?
3. **Analysis**: how are the data, which will be collected periodically, to be handled?
4. **Interpretation**: what might the data mean?
5. **Fulfilment**: when will the aim have been achieved?

The aim of this chapter is to follow through these questions, discussing aspects of each that relate to the data being collected and the interpretations likely to be placed on these data. Many of the subsequent chapters address specific issues raised by these five broader questions.

2.2 PURPOSE

To some extent, the purpose will have been defined before consideration of the monitoring begins. The aim of the monitoring might be to estimate the annual size of a population: for example, how many bee orchids, *Ophrys apifera*, are flowering in the population in a nature reserve? (For many plants, however, the number of flowering spikes is a poor indicator of the population size.) It might equally be to estimate part of the population, such as the number of territories of the great tit, *Parus major*, in a farm woodland. It might be that the monitoring aims to establish a concentration by, for example, sampling air for its SO₂ concentration or a river for its NO₃ concentration or BOD (biological oxygen demand). Alternatively,
monitoring may aim to determine whether or not some event takes place, for example, much monitoring of the biota in river systems is designed to detect, a posteriori, if a pollution incident has occurred.

Two aspects of the monitoring should also be linked to its purpose. First, there is the intensity of monitoring; second, there is the frequency of monitoring.

2.2.1 Intensity of monitoring

Intensity is important if an estimate of the reliability of monitoring is required. It may be possible to count every bee orchid flowering in the nature reserve if the population is small both in number and area, but for many populations an estimate of the mean number of orchids per unit of area, together with a standard error of that mean, is required. Similarly for concentration, a mean and a measure of its reliability is required. Using the example of a concentration, the true mean \( \mu \) is estimated by a sample mean \( m \), and the true standard deviation \( \sigma \) by the sample standard deviation \( s \). The standard error of the mean is given by

\[
s / \sqrt{n}
\]

where \( n \) is the number of observations in the sample (such simple statistical calculations are described in all introductory texts to statistics, e.g. Bailey (1981), Campbell (1974) and Parker (1979)). Confidence limits for \( \mu \) are

\[
m \pm t s / \sqrt{n},
\]

where \( t \) is Student’s \( t \) with some defined probability level (2-tailed test); the confidence limits imply an interval around \( m \) within which the true, but unknown, value of \( \mu \) may be regarded as lying with a given degree of certainty. The true mean, \( \mu \), is the feature of the monitoring programme that is of particular interest.

Taking arbitrary standard deviations of one, two and four (\( s = 1, 2 \) and 4), Figure 2.1 shows how the 95% confidence limits become closer to the mean as the size of the sample increases; very small sample sizes have very wide confidence intervals whereas larger sample sizes have narrower confidence intervals. The data in Table 2.1 show how the confidence limits are reduced as the sample size is successively doubled. Although greater precision can be obtained by taking very large samples, in reality there has to be a trade-off between the accuracy of the estimate of \( \mu \) and the cost of taking and analysing the samples.

There are two problems with the practical application of the approach outlined in Figure 2.1 and Table 2.1. First, it was assumed that the samples were normally distributed, or at least approximately so. This is probably a reasonable assumption for estimates of a concentration but it is certainly not reasonable for counts of a species in quadrats, etc. These are at best likely to be Poisson (randomly) distributed, but more likely to show some kind of