Chapter 11
Probability estimates in a scenario tree

“An expert is a person who has made all the mistakes that can be made in a very narrow field.”
Niels Bohr (1885–1962)

Scenario trees require many numbers. Each branch has a probability associated with it, and some nodes (risk category nodes) have three numbers for each branch. As we work along each limb in the tree, each probability is conditional on all the previous probabilities in that limb. Where do all these numbers come from and how do we make sure that they are correct? This chapter provides some guidance in finding the right parameters for a scenario tree.

**SUMMARY OF REQUIRED VALUES**

The purpose of a scenario tree is to calculate the sensitivity of a component of a surveillance system. Sensitivity is the probability that the surveillance system component will detect at least one infected animal, if the population is infected at the design prevalence. The result of the scenario tree analysis (sensitivity) is a probability; therefore all the branch parameters are also probabilities as well.

The probability values are different, depending on the type of node.

**Infection node**

An infection node has two branches: **infected** and **not infected**. The probability associated with the **infected** branch is the design prevalence ($P^*$). Prevalence is defined as the proportion of the population with a defined characteristic (in this case, the proportion that is infected). It also can be thought of as a probability: if an animal is drawn from the population at random, the probability that it will be infected is equal to the prevalence.

The approach to selecting an appropriate design prevalence was discussed in the section on page 44. To summarize, the way to choose a **design prevalence**, in order of preference, is:

- Use global standards (e.g. from the OIE code).
- Use regional standards (e.g. EU regulations).
- Check the requirements of your trading partners.
- Calculate based on your trading partner’s stated acceptable level of protection (ALOP) – this approach is rarely feasible.
- Determine based on the biology of the disease (e.g. the minimum expected prevalence if infection is established).
• Determine based on practical considerations (what level of surveillance is affordable).
• Make an arbitrary choice based on common values (1 percent, 5 percent or 10 percent).

**Detection node**
A detection node has two branches, representing \textit{detected} and \textit{not detected}. The probability associated with the \textit{detected} branch is a sensitivity. This is evident when the detection node refers to something like a laboratory test (e.g. a complement fixation test (CFT)). However, detection nodes are also often used to describe other complex components of a surveillance system, such as the probability that a farmer will call the veterinarian if they notice that an animal is sick. This may also be thought of as a sensitivity.

**Risk category node**
A risk category node is the most complex type of node in the scenario tree, as discussed in Chapter 9, as each branch has three figures associated with it.

**Relative risk**
The relative risk describes how some parts of the population are at higher risk than others. This is the only figure used in a scenario tree that is not a probability. It is a ratio that can take a value from zero to infinity. When adjusted (using the population proportion) to create the \textit{adjusted risk} (AR), it is multiplied by the design prevalence to give the \textit{effective probability of infection} (EPI) which, again, is a probability.

**Population proportion (PrP)**
The population proportion is used to change the relative risk to the adjusted risk. It represents the proportion of the entire population that is in the branch category. This is important as it allows the tree to take targeting into account.

**Surveillance system component proportion (PrSSC)**
This is the proportion of animals in the surveillance system that fall into the branch category. Targeting is expressed by the difference between the population proportion and the SSC proportion.

With some surveillance systems, the \textit{PrP} and the \textit{PrSSC} are the same.

**Example**
Consider surveillance based on a survey using random representative sampling. Twenty percent of the population are in a high-risk group. The representative sampling will ensure that 20 percent of the sample (the PrSSC) is also in the high-risk group. Representative sampling does not target high-risk groups, so scenario tree analysis will give the same result as simpler methods of analysis.
Example

A passive farmer reporting system may have coverage of the entire population, as every animal is owned by a farmer, and therefore every animal has a chance of being reported and detected if it becomes infected.

In this case, the PrSSC is the same as the entire population, so the PrSSC is the same as the population proportion. Surveillance systems that have complete coverage of the population therefore do not take different risk groups into account. However, they do take differences in the probability of detection into account, and thus scenario tree analysis is very useful for these situations.

Detection category node

A detection category node is used to divide the population into groups that have different probabilities of being detected. The branches of a detection category node are associated with the proportions of the surveillance system component that fall into that category.

Often, we will also need to note the population proportion for detection category nodes, so as to determine how good the sensitivity of our surveillance is compared to representative (non-risk-based) sampling.

Group category node

The group category node is similar to a detection category node in that it uses the surveillance system component proportion, but will often have the population proportion recorded for comparison purposes.

In summary, the values that may be required for node branches include:

- relative risk
- sensitivity
- surveillance system component proportion
- population proportion

Sources of estimates

Sometimes figures for the probabilities are already available. Sometimes they are not, but data that allow the figures to be calculated or estimated are available. And sometimes, nothing is available. How do we deal with these different situations?

Sensitivity

Sensitivity is the probability of getting a positive test result if the animal tested truly is infected. Sensitivity is used in detection nodes. Where a detection node refers to the use of a laboratory test, sensitivity estimates may be available. For more complex detection nodes (for instance, the probability that a sick animal will be noticed by the farmer, or the probability that a veterinarian will take samples for laboratory analysis), there are unlikely to be existing estimates.
**Laboratory tests**

*Existing estimates for validated tests*

In some cases, there are published studies in which a laboratory test has been validated, and the sensitivity and specificity have been calculated.

Even when this information has not been published, internal validation studies may have been carried out by a laboratory, and the figures may be available directly from that source. When these figures are available, it is reasonable to use them in the scenario tree model. However, there are a couple of considerations that need to be taken into account, and these are as follows:

- Sensitivity varies due to a variety of factors, including laboratory techniques and factors associated with the population under study. If validation studies have been carried out in another part of the world and on different populations, the values for sensitivity may not be directly applicable to the local population.

- Where the key factors that influence sensitivity are known, these should appear in the model as detection category nodes. In this case, different values for sensitivity should be used for the different categories of animals. It is relatively rare for studies aimed at estimating sensitivity to calculate different values according to a range of influencing factors – instead they tend to estimate an average sensitivity across the population studied.

- Often, sensitivity estimates are published as point values (for instance, 93.5 percent). However, these estimates were calculated using sampling approaches, and there is therefore some element of random error associated with the estimates. Ideally, this should be reported along with the estimates, in the form of a 95 percent confidence interval (for instance, in the form 93.5 percent [87.2 percent – 98.5 percent]). Where confidence intervals are not available, it may be possible to calculate them based on the sample size used to make the sensitivity estimate. The confidence interval describes the uncertainty around an estimate, which can be incorporated into the model, as described in Chapter 12.

*Generating new estimates*

Where no published information or internal estimates for a laboratory test are available, an alternative solution is to undertake studies to generate the required estimates. The traditional study would involve identifying a number of truly positive animals (based on the use of a ‘gold standard’ test), and subjecting them to the test that needs to be validated. The sensitivity is the proportion of these animals that have a positive test result.

A newer, alternative study design (latent class analysis) makes it possible to estimate sensitivity and specificity without necessitating the use of a gold standard test. While this design requires the use of at least two different tests and two populations with different disease prevalence levels, it does not require the true status of individual animals to be known. Occasionally, large volumes of historical laboratory records are available to meet these requirements. It **may be possible to analyse** this data relatively quickly and cheaply, in order to produce good estimates of the test performance.

Both of these approaches pose a number of particular problems. Both the high cost and the time involved in conducting a study often make it impractical. However, more importantly,
the reason for the sensitivity estimate is to support surveillance to demonstrate that the infection is not present in the country. If the country is free from the infection, there are no infected animals to test (and artificially infecting animals would be very dangerous). In fact, this creates a paradox: in order to estimate the sensitivity of the test correctly, it should be evaluated on the animals of interest (the local population), but when the population is free from infection, the test cannot be evaluated.

Normally, we are forced to use estimates from areas where the disease is present, either historical data in the country of interest (if the disease has been eradicated), or from other countries with roughly similar populations.

**Expert opinion**

If suitable estimates of test sensitivity are not available from any source, it may still be possible to obtain appropriate figures for use in the scenario tree. Even if the test has not been formally validated, it is likely that many scientists have used it in different situations for some time. These people are likely to have a reasonably good understanding of the performance of diagnostic tests. Formal approaches to gathering and analysing expert opinion offer a method for collecting sensitivity estimates when no other information is available. These approaches are discussed in detail in the next section.

**Other detection probabilities**

Detection probabilities that are not associated with a laboratory test are most commonly found in trees using some aspect of passive reporting. A typical ‘detection cascade’ in a passive farmer reporting system may look like this:

- Infected animal shows clinical signs.
- Farmer notices animal with clinical signs.
- Farmer contacts veterinary services.
- Veterinarian examines animal.
- Samples taken for analysis.
- Samples tested for disease in question.

This is normally followed by one or more laboratory tests to detect and then confirm the infection.

Other non-laboratory detection probabilities may be associated with activities such as abattoir meat inspection.

**Existing estimates**

The probabilities listed above have rarely been explicitly studied or quantified. The exception is perhaps the sensitivity of abattoir meat inspection for the detection of various diseases. It is unlikely that other useful information will be available in the published literature.

However, some figures could be available. For example, the first in the list, the probability that an infected animal shows clinical signs, is likely to be included in general descriptions of the epidemiology of the disease, and could be included in both textbooks and published papers.
Generating new estimates

Unlike the evaluation of laboratory tests, estimating the probabilities associated with these non-laboratory detection nodes may be feasible, even where the disease does not exist. One of the key advantages of a scenario tree is that it explicitly identifies the various probabilities involved in the detection system, and each of these can be studied separately.

Some of the probabilities listed on page 105 may be calculated from existing records. For instance, veterinary visit records may indicate how often a veterinarian collects samples for analysis from cases with a certain collection of presenting signs (consistent with the disease in question). Similarly, it may be possible to determine the probability that a sample submitted from a possible case is tested by examining laboratory testing records. While accessing and analysing these data sources may be difficult, they offer an approach to getting realistic probability estimates for some of the required parameters.

However, for others (e.g. the probability that a farmer would notice clinical signs, or that they would contact the veterinary services), no records are likely to exist. It may be possible to conduct small studies to directly measure these probabilities. One approach would be to convene a number of farmer meetings in different areas. At each meeting, farmers would be shown a series of photographs or videos, and asked to answer a number of questions. The videos could include a combination of scenes in which all the animals are healthy, and one or more animals are showing signs of the disease. The questions posed may be:

- Do you notice anything unusual about this group of animals?
- If yes:
  - What is unusual?
  - Would you take any action as a result of this observation?
  - What action would you take?

Such meetings should be conducted without giving any prior information to the participants (for instance, do not invite them to a meeting using a form of words which indicates that the purpose of the meeting is to study the detection of classical swine fever).

Clearly, while responses to questions that are posed in a formal setting, such as a public meeting, may not accurately reflect people's actual behaviour, such responses nevertheless provide some indication of behaviour, and this information may be usefully applied in the scenario tree.

Expert opinion

The previous example showed how a study of farmer behaviour could be analysed in the same way as other surveys, with the precision of the estimate being related to sample size (the number of farmers included in the study). If a structured study such as that described is not feasible, expert opinion may provide an alternative source of data. While similar in some ways, gathering expert opinion is fundamentally different to a study such as that described. In a traditional study, each participant provides a single observation. On the other hand, however, when expert opinion is solicited, individual experts are likely to present quite different observations, based on their experience.

In many cases, the “expert” who is gathering expert opinion is assumed to be some respected, well-educated person – a laboratory scientist, university professor etc. The explicit probabilities required by a scenario tree model show that the appropriate experts may be
very different for the different questions. For instance, the experts considering a farmer’s ability to detect animals with disease may be either a number of farmers (with experience of the behaviour of their peers), or, alternatively, may be just one individual who has extensive daily contact with farmers, sees their animals and hears about their observations of disease; such an individual may be a field veterinarian, a paraveterinary worker, or a trader. In order to address each question, a different expert is likely to be required.

Details on the use of expert opinion are discussed in the next section.

**Proportions**

In a scenario tree, branch probabilities for category nodes are based on proportions. They all require the proportion of animals in the surveillance system component that fall into the category represented by the branch, but it is generally useful to know the population proportion as well (and this is also required for risk category nodes).

**Proportion of herds or proportion of animals?**

It is important to note that the proportions used in category nodes refer to the units in the infection node immediately following. For instance, consider the following example list of nodes for a scenario tree used to analyse brucellosis surveillance:

The two infection nodes (Herd and Animal) have been highlighted. The first three nodes (Region, Herd type and Herd size) are all category nodes; therefore, their branches require proportions. As these three nodes are placed before the herd infection node, the proportions refer to the proportion of herds that fall into each group. For instance, if there are 10 000 herds in the country, and 4 000 of these herds are in Region 1, 3 500 in Region 2 and 2 500 in Region 3, then the probability for the Region 1 branch of the Region node is 40 percent. In the Region 2 branch it will be 35 percent, and in Region 3 it will be 25 percent.
The herd size node also refers to the proportion of herds because it is placed before the herd infection node.

The recently aborted node, however, is placed before the animal infection node, and therefore refers to the proportion of animals that have recently aborted. The vaccination node refers to the proportion of animals vaccinated.

After the animal-level infection node, any detection category nodes refer to the animal level as well. Thus, the area node (remote or not remote) in the node list on page 107 refers to the proportion of animals that are in remote areas, or are in not remote areas. It would also have been possible (and maybe simpler) to place the area detection category node ahead of the herd node, as it is the herd that is located in a remote or not remote area. Even though the node relates to detection of individual animals, it can be placed at higher points in the tree if it is logical to do so.

**Conditional proportions**

Remember too that all of these proportions are conditional on the previous nodes, depending on which limb the node appears on. For instance, the branch probabilities for the area node (remote and not remote) are conditional on region, herd type, herd size, recently aborted and vaccinated. In most cases, however, some of the nodes may be considered independent of previous nodes. For instance, the probability that an animal is in a remote area possibly depends on the region (some regions have more remote areas than other regions), but it may not be related to the animal’s vaccination or abortion status, as these are independent of geographic remoteness.

In practice, to determine the population proportions for the area node, one could:

1. Obtain a map of the country.
2. Identify the three regions.
3. Calculate the number of herds in each region (this provides the data for the branch probabilities for the region node).
4. Identify on the map those areas that are remote and those that are not. (This may be simply done by marking a line at a given distance from the diagnostic laboratories (buffering). A more sophisticated approach would be to calculate ‘travel time contours’ based on road distance and speed – these are lines joining points that take the same time to travel to/from the laboratory).
5. Based on region and area, divide the country into six areas (remote and not remote in each of the three regions).
6. In each of these six areas, calculate the total number of animals.
7. The category proportions can then be calculated.
   a. For region 1, remote, this is the number of animals in the remote area of Region 1 divided by the total number of animals in Region 1.
   b. For region 1, not remote, it is one minus the proportion of animals in the remote area.

This example shows how the area node was only conditional on one of the previous levels and could be considered independent of the others. For each node, it is necessary to determine on which of the previous nodes the node is conditional, and for which it is independent.

For example, recently aborted is probably conditional on herd type (beef or dairy) and may also be conditional on region. Laboratory abortion investigation records may provide some
information about whether there are more abortions in one region than another—although the difference may be due to bias because of different reporting rates between regions; therefore, such data must be interpreted with caution.

The **VACCINATED** node is likely to be conditional on **REGION** and **HERD TYPE**, and it should be possible to estimate the population proportion by using veterinary service vaccination records or vaccine sales records. It may also be conditional on **AREA** (remoteness), in which case **AREA** should be placed higher in the tree.

### Population and surveillance system component proportions

The previous examples focused on the use of official statistics or other records to provide information about the population. SSC proportions are often simpler to calculate, as we normally have data about the animals that are included in our surveillance.

Ideally, surveillance data should contain a record for each animal in the surveillance system component, and each record should contain information on each of the nodes included in our tree. For instance, for each animal, the dataset should contain the following information:

- a herd identifier linked to herd information, including:
  - the region the herd is in
  - the type of the herd (beef/dairy)
  - the number of animals in the herd
  - whether the herd is in a remote area or not
- whether the animal has recently aborted or not
- whether the animal has been vaccinated or not
- the results for the RBT and SNT

If this information is available, the dataset can be quickly summarized to provide all the SSC proportions required. Another approach to using this type of complete dataset will be discussed in Chapter 13.

Often, this type of complete data is not collected as part of the surveillance, and therefore some values have to be estimated. One approach to estimating the SSC proportions is to assess whether there was any targeting or bias related to that factor (normally in discussion with the surveillance designers or field teams). For instance, did they attempt to preferentially collect samples from animals that had recently aborted, or did they try to avoid vaccinated animals? If not, then the population proportion can be used, on the assumption that without targeting for these factors, the animals would be roughly representative. If there was targeting, an estimate of the level of targeting will be required to calculate the SSC proportion.

### Relative risk

Risk category nodes require estimates of the relative risk for each of the categories. These probably represent the most difficult values that are needed for a scenario tree.

For well-known risk factors, specific risk factor studies may have been carried out, thus providing reliable estimates of the relative risk for different categories. As with published sensitivity estimates, it is important to consider confidence intervals when using published estimates of relative risk.
In most cases, however, little information will be available. It is very difficult and expensive to carry out risk factor studies to measure the relative risk (such studies can only be conducted when the disease is present). Expert opinion is usually necessary in order to estimate relative risks.

**EXPERT OPINION**

The use of expert opinion as a method of estimating parameters (such as the sensitivity of a test, or a relative risk) has often been viewed as undesirable and unreliable. This may be due to the common misconception that the approach is based on asking an expert (a wise person who is respected in their field) what they think the answer is, and the expert then makes a guess at the answer.

The appropriate use of expert opinion is very different. Philosophically, it is based on the same type of approach as scenario tree modelling to demonstrate freedom from infection. To demonstrate freedom, we aim to use all available sources of evidence, even if they are complex and even if alone they do not contribute very much evidence. The principle is not to say that the evidence is imperfect, and therefore to reject it, but to carefully understand the limitations of the different data sources, and to use that which is good (risk-based surveillance), and take into account that which is bad (the presence of bias).

Expert opinion is appropriate when no data based on direct structured observation are available. It may also be used to supplement information from small or potentially biased studies. The principle of the use of expert opinion is to acknowledge that, even if no study exists, there are usually a number of people who have a great deal of experience with the question of interest. Rather than say this experience is not as well structured or as easily captured as an objective study, we try to capture the experience, while at the same time making sure that any limitations are clearly taken into account.

The three main rules for expert opinion are:

- Ask the right experts.
- Ask them specific questions in a way that enables them to provide specific answers.
- Always capture uncertainty.

No matter how experienced experts are, there is a significant chance that they will give an incorrect answer. This does not matter too much if the answer is close to the correct answer, but it could be important if it is a long way from the correct answer. Capturing uncertainty involves asking the experts not only to say what they think the answer is, but also to indicate how confident they are about their answer. This is normally done by asking them to provide a confidence interval. If their estimate is wrong, the confidence interval indicates the range in which they are very sure the true estimate lies.

This approach is the same as that used with other parameters of the scenario tree that may be uncertain. For instance, a sensitivity estimate from a validation study is based on a sample of animals and therefore has a confidence interval that is related to the sample size. When we explicitly include confidence intervals in our scenario tree model, we accept that the result may be wrong, but we can offer a range in which we are very confident that the correct result lies. Chapter 12 provides a detailed description of how to incorporate uncertainty into a scenario tree model; therefore, for the moment, we just need to ensure that experts provide confidence intervals.
A great deal of research into collecting and using expert opinion has been carried out, but this discussion will only address a small number of common approaches that are generally practical and suitable for eliciting the required parameters for scenario trees.

**Gathering expert opinion**

**Working with experts**

**Choosing experts**

As discussed previously, the right experts are not necessarily scientists and professors, and they are almost certainly not the person who is building the scenario tree. The right experts are individuals who have direct and significant experience in an area related to the specific question being asked, which means that the right experts will differ depending on the issue at hand.

Experts’ estimates are more likely to be applicable to the population of interest if they have a broad knowledge of that population. This means that it is much better to have access to a group of experts, as opposed to just one or two experts. While such a group could comprise as few as five individuals, it could equally comprise hundreds – although there is a point when the exercise stops being the solicitation of expert opinion and instead becomes a survey (for example, a survey of farmer behaviour).

**Interaction between experts**

Group dynamics can play an important role in the estimates provided by experts. Two main approaches are commonly used.

The first involves working with each expert independently. This may be achieved by a one-on-one interview (conducted by telephone or by e-mail), or by asking experts in a group setting to consider the question and provide written answers without conferring with the other experts. The main advantage of using this approach is that individuals’ opinions are not influenced by the opinions of others in the group, thus allowing the full range of experience to be captured. As well as avoiding the danger of having one or two dominant personalities in a group exerting too much influence on the opinions of others, the ‘independent’ approach provides one response per expert, which can be used to assess the variation in responses, and thus as a measure of uncertainty.

The other option is to work in a group setting. The group is asked to discuss the question together. At the end of the discussion, you may ask the group to produce a single estimate based on consensus (with a confidence interval), or ask each expert to record their own estimate, in the light of the group discussions. Some of the advantages of the group approach include:

- Discussion that takes place in a group setting ensures that there is a common understanding of the question at hand, whereas when questions are answered by individuals separately, there is a risk that some respondents will interpret the question slightly differently.
- Discussion also often prompts the memory of others within the group, and allows the question to be considered from a variety of points of view.
- It is an efficient way to gather estimates rapidly.

The best approach may vary for different situations and different expert groups.
Questions
The way in which a question is asked has an important impact on the answers that may be received.

Ensuring that the question is understood
It is very important that the experts fully understand the question that is being asked. This is not always as simple as it seems. For instance, when asking experts to estimate relative risk, it is possible or even likely that not all experts will be familiar with the concept of relative risk. This problem can be addressed in two ways.

First, there may be a need for training and explanation. This is generally a good idea in any case, but it is even more important when the questions incorporate technical concepts. Relative risk is a common concept among epidemiologists, but it may be poorly understood by many others involved in animal health. A brief explanation of what a relative risk is, how it is calculated, and how it is used will improve the quality of responses. However, it may also be valuable to provide a list of examples of relative risks for known risk factors, which may be used as a comparison. Those who are inexperienced in the calculation of relative risks may think that values of 10 or 50 appear reasonable, without realizing that most risk factors for many diseases have relative risks which are much lower than these (often in the range of 1.2 to 3).

The second approach is to ask questions in terms that are already understood by the experts. If the experts are not familiar with relative risks, then ask them for estimates that would enable a relative risk to be calculated. For instance:

"Imagine two groups, each comprising 100 animals. Group 1 has the risk factor, and Group 2 does not have the risk factor. If the disease is present in the area, how many animals in Group 1 would you expect to have the disease? How many animals in Group 2 would you expect to have the disease?"

The two prevalence estimates from the previous question can be used to calculate an estimate of the relative risk.

Confidence intervals
For each question, it is important to capture the experts’ uncertainty. This is normally done in two stages:

1. "What do you think is the correct value?"
2. "If you are wrong, what is the lowest possible value that could be correct, and what is the highest?"

This approach will provide a range in terms of the minimum and maximum possible values, with the most likely value somewhere in between. This is the most common approach used in expert opinion. In statistics, a 95 percent confidence interval is usually used, but this tends to be more difficult for many experts to imagine and to estimate.

Combining expert opinion
When a group approach is used to collect expert opinion, and the group is able to provide a single consensus estimate of the value (and of the confidence interval), these values can be used directly in the scenario tree. However, when experts provide values independently,
there will be a number of different estimates and confidence intervals. We need an approach to combine or summarize these, in order to determine what should be used in the model.

**Uncertainty and variability**

There are two reasons why an expert may not be able to give a precise single estimate of a value (for instance, a prevalence).
- They may not know the correct answer (they are uncertain).
- There may not be a single correct answer, as the prevalence may be different in different situations (there is variability in the answer).

The approach to combining estimates from different experts differs depending on whether the main reason for the confidence interval is uncertainty or whether it is variability. Of course, in many cases, both will be present.

**Uncertainty**

When the variability in estimates is due to uncertainty, it implies that there is a single correct answer. Estimates from experts can be thought of as samples from a population of experts, each with some random error, but distributed around the true value.

Figure 11 shows an example of the results that 20 experts may provide, estimating the sensitivity of abattoir inspection for detecting bovine paratuberculosis.

- If it is considered that there is one true value for the sensitivity, and it is assumed that the estimates of the experts are not biased, then we could summarize the results by taking the average of the estimates as an estimate of the true value. In this case, the average is 0.37.
- There are two methods that we could use to describe the uncertainty. The first is to consider that any of the estimates could be correct, and to use the lowest and highest estimates as the minimum and maximum possible values. This is the most conservative approach and would provide the widest range. The confidence interval is shown on page 114. This is based on a beta-PERT probability distribution, as discussed in the next chapter.
- The second method would be to consider the confidence intervals provided by the experts, and to take the mean of the lower ends and the mean of the upper ends of these intervals. Depending on the width of the experts’ separate confidence intervals, this may produce an overall confidence interval that is wider or narrower than the one shown on page 114.
Variability
If differences in expert opinion are considered to represent varying correct values for the parameter under different conditions, then the summary of the experts’ views should retain these differences. Using the average is no longer appropriate. A common approach is to consider each expert’s estimate and confidence interval as a distribution, and build up a composite distribution based on the views of all the experts. The details of how this is done will be discussed in the next chapter, but Figure 13 illustrates an example of the output. Each expert’s opinion has contributed to the shape of the final curve.

Rinderpest example
In a scenario tree for analysing livestock and wildlife surveillance for rinderpest, vaccination was considered an important factor. Vaccination had ceased at different times in the areas being considered, but, for the purpose of this example, the last vaccination was administered six years before the surveillance. Animals less than six years old were certain not to have been vaccinated, while animals older than six years may have been vaccinated.
Age was used as a risk category node with two branches: less than six years, and greater than or equal to six years. The surveillance targeted younger animals; therefore, it was necessary to estimate the population proportion and the SSC proportion of animals less than six years old.

After discussion with local experts (13 field veterinarians with extensive experience of each of the relevant species), it was agreed that it would be very difficult to directly estimate the proportion of each species less than six years old. Instead, an indirect approach was used.

Experts were asked to describe the age structure of each species in terms of a survival curve. For each one-year age bracket, they were asked to estimate the proportion of animals born that survived to that age group. Table 14 is an example of the information gathered from one expert.

As it was assumed that there was a single correct survival curve for each species, the estimates from each expert were averaged. This produced the following survival curves.

The uncertainty around each of these curves was calculated based on the standard deviation of the estimates. The proportion of animals less than six years old is the area under the curve left of the six-year point on the x-axis, as a proportion of the total area under the curve for that species. Figure 15 on page 116 shows the estimated proportions.

This example illustrates how it may be possible to gather the required estimates for a scenario tree by asking questions in a form that is easier for the experts to understand. Although the true survival curves for the different species in the study area are not known, the results in Figure 14 are certainly biologically believable and are consistent with expectations.

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FIGURE 14
Estimated survival curves based on the means of 13 experts' estimates

FIGURE 15
Estimated proportion of animals of different species less than six year of age, based on expert opinion