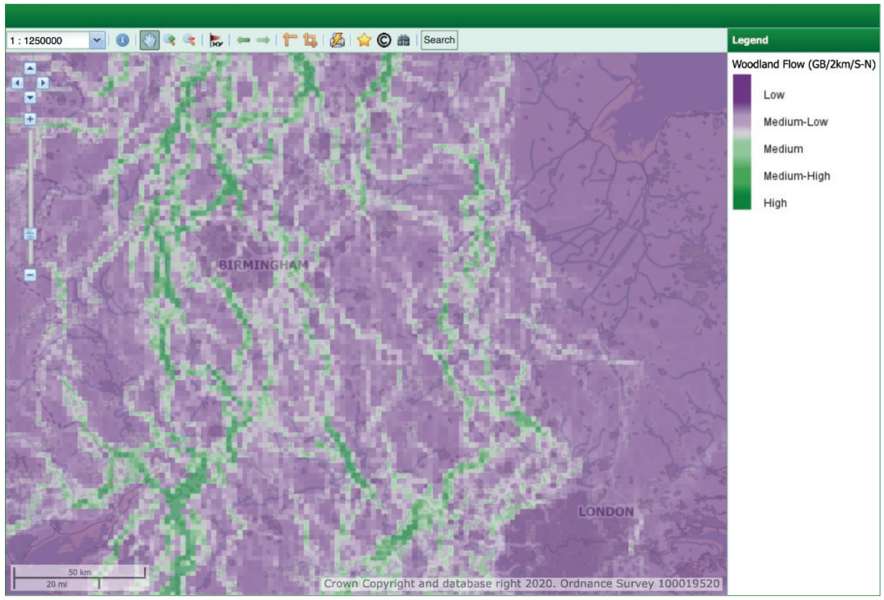

Figure 15.41 New building can be discouraged in habitats where the flow of species migrating to new habitats is greatest. The web service of a UK regional agency, Warwickshire County Council, comprising maps of important green infrastructure: http://maps.warwickshire.gov.uk/greeninfrastructure/. The layer of south–north flow of various species through woodland, calculated using the computer program Condatis, is shown overlain onto the UK Ordnance Survey map. It is a priority to preserve woodland, and hence discourage new building, in the routes where the flow is concentrated, for example both sides of Birmingham and in the Cotswolds to the south-west.

Based on this work, a computer program, Condatis, has been developed to help preserve and enhance connectivity in real world habitat networks (Wallis & Hodgson, 2018). An example is shown in Figure 15.41. A UK regional agency, Warwickshire County Council, have used Condatis, alongside a classic metapopulation connectivity measure (based on Hanski's models – see Section 6.7.4), to inform their work on 'green infrastructure', and in particular their decisions on whether to approve or reject planning applications. They also make the analysis results freely available online so that, for example, local community groups can use them to object to a planning application.

15.4.6 Decision analysis

In practice, many conservation decisions have to be taken in the absence of the sorts of dataset that are necessary to carry out a formal PVA. One way forward in such cases is to elicit the opinions of experts, often at meetings convened for the purpose, and to combine these where possible with such data as are available, using a variety of approaches described collectively as 'knowledge synthesis' techniques (Pullin *et al.*, 2016). These often incorporate, or are combined with, structured decision making processes referred to as 'decision analysis' techniques, especially multicriteria decision analysis (Adem Esmail & Geneletti, 2018), which allow analyses of the performance of alternative conservation strategies to be combined with the preferences and priorities of stakeholders in a transparent way that can therefore be discussed and, where appropriate, modified, perhaps in the light of additional information. One example comes from the conservation of an endangered species of salamander, *Ambystoma cingulatum*, in Florida, USA (O'Donnell *et al.*, 2017). A workshop was held, attended by conservationists and other biologists as well as representatives of United States Fish and Wildlife Service (USFWS), which has ultimate responsibility for the conservation of the species. The aim was particularly to consider the possible role of *ex situ* breeding programmes to supplement the declining populations, but also to consider how this might be combined with translocation of individuals and habitat

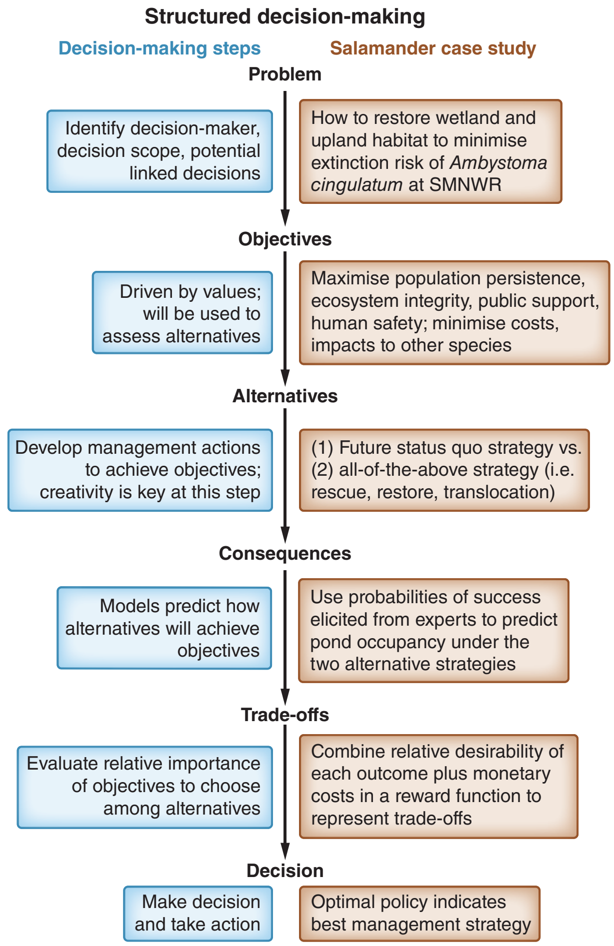

Figure 15.42 Conservation decisions are often taken, ultimately, as the end point of a structured decision-making process, incorporating both the elicitation of expert opinions and the analysis of data. The general process is shown to the left and its application to the conservation of the salamander, *Ambystoma cingulatum*, at the St Marks National Wildlife Refuge (SMNWR), Florida, USA is shown to the right. *Source*: After O'Donnell *et al.* (2017).

restoration. The stages of the structured decision-making process are outlined in Figure 15.42. The process starts with an explicit statement of the underlying problem and the objectives that flow from that. Next comes a listing of the available alternatives and an assessment of their chances of success, guided both by expert opinion and available data. This then leads to an assessment of both the desirability and costs of those alternative outcomes, such that the trade-offs between, say, cost and the chance of success can be analysed – is it, for example, worth doubling the cost for a marginal improvement in the likely outcome? And finally, a decision is made. In the case of the salamander, a wide range of actions was implemented, including the development of captive breeding protocols, the establishment of captive populations and habitat modification, but also programmes to collect additional data that the workshop agreed were necessary for better informed decisions to be made.

decision trees – the Sumatran rhinoceros

Clearly, a key step for the salamanders and in many other cases is the analysis of an optimum strategy in the light of the expert evidence. Decision trees are a technique that may be used to weigh up and then choose between alternatives. To illustrate the approach, we can take a classic example from a workshop on the Sumatran rhinoceros, *Dicerorhinus sumatrensis* (Maguire *et al.*, 1987). At the time, the species persisted only in small, isolated subpopulations in an increasingly fragmented habitat in Sabah (East Malaysia), Indonesia and West Malaysia, and perhaps also in Thailand and Burma – its range has further contracted since. There were only a few designated reserves, which were themselves subject to poaching, and only two individuals were held in captivity. A decision tree for arriving at a conservation strategy is shown in Figure 15.43, based on the estimated probabilities of the species becoming extinct within a 30-year period (equivalent to approximately two rhinoceros generations). The workshop was designed to generate a consensus among the experts on these probabilities. The tree was then constructed in the following way. The two squares are decision points: the first distinguishes between intervention on the rhinoceros' behalf and non-intervention (status quo); the second distinguishes the various management options. For each option, the line branches at a small circle. The branches represent alternative scenarios that might occur, and the numbers on each branch indicate the probabilities estimated for the alternative scenarios. Thus, for the status quo option, there was estimated to be a probability of 0.1 that a disease epidemic would occur in the next 30 years, and hence a probability of 0.9 that no epidemic would occur. If there was an epidemic, the probability of extinction in 30 years (pE) was estimated to be 0.95 whereas with no epidemic the pE was 0.85. The overall estimate of species extinction for an option, E(pE), is then given by: (probability of first option × pE for first option) + (probability of second option × pE for second option), which, for the status quo option, was 0.86. The values of pE and E(pE) for the various intervention options were estimated in a similar way. The final column in

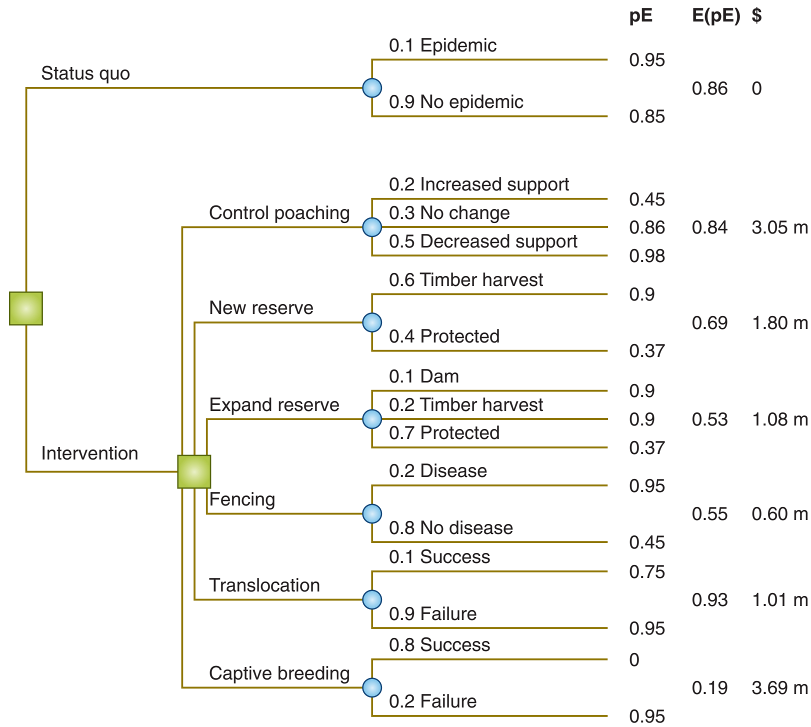

Figure 15.43 A decision tree for the management of the Sumatran rhinoceros gives rise the probability of extinction if various alternative actions are taken. Within the tree, the large green boxes indicate decision points, and the blue circles indicate random events. Probabilities of random events are estimated for a 30-year period; pE, probability of species extinction within 30 years; E(pE), expected value of pE for each alternative. Costs are present values of 30-year costs discounted at 4% per year; m, million. *Source*: After Maguire *et al.* (1987).

Figure 15.43 then lists the estimated costs of the various options.

evaluating management options

Consider two of the interventions. The first was the establishment of a captive breeding programme. Animals would have to be captured from the wild, increasing the pE if the programme failed to an expected 0.95. However, the pE would clearly drop to 0 if the programme succeeded (in terms of the continued persistence of the population in captivity). The cost, though, would be high, since it would involve the development of facilities and techniques in Malaysia and Indonesia (around $2.06 million) and the extension of those that already exist in the USA and Great Britain ($1.63 million). The probability of success was estimated to be 0.8. The overall E(pE) was therefore 0.19.

An alternative was to control poaching, either with more, less, or no change in the level of support. As Figure 15.43 shows, the E(pE) was much higher, 0.84, and the estimated cost not much less than the captive breeding programme.

Which was the best management option? The answer depends on what criteria we use to define ‘best’. Suppose we wanted simply to minimise the chances of extinction, irrespective of cost. The best option would then appear to be captive breeding. In practice, though, costs are most unlikely to be ignored. We would then need to identify an option with an acceptably low E(pE) but with an acceptable cost. In fact, $2.5 million was spent catching Sumatran rhinoceroses for captive breeding, but three died during capture, six died postcapture, and of 21 rhinoceroses taken into captivity none gave birth (Caughley, 1994). The latest IUCN Red List assessment (van Strien *et al.*, 2015) describes limited ongoing attempts at breeding programmes and still only two captive births with support for and coordination of anti-poaching teams being the primary conservation action.

We see from this, therefore, the strengths and weaknesses of subjective expert assessments and the techniques, like decision trees, that they use. The approach makes use of available data, knowledge and experience in a situation when a decision is needed and time for further research is unavailable. It explores the various options in a systematic manner, and it does not duck the regrettable but inevitable truth that unlimited resources will not be available. But in the absence of all necessary data, the recommended best option may simply be wrong, as it seems to have been for the Sumatran rhino. The experts seem to have been far too optimistic about the chances of success of captive breeding. Techniques for weighing up options are improving. An analysis of the decision tree that incorporates uncertainty around the estimated probabilities highlights the particular sensitivity of captive breeding to such uncertainty and downgrades its 'utility' accordingly (Regan *et al.*, 2005). Nonetheless, looking forward, decisions based on opinion rather than hard data will be inevitable – as will the mistakes that equally inevitably accompany them.