

Is conservation triage just smart decision making?

Madeleine C. Bottrill¹, Liana N. Joseph¹, Josie Carwardine¹, Michael Bode¹, Carly Cook¹, Edward T. Game¹, Hedley Grantham¹, Salit Kark^{1,2}, Simon Linke¹, Eve McDonald-Madden¹, Robert L. Pressey^{1,3}, Susan Walker⁴, Kerrie A. Wilson¹ and Hugh P. Possingham¹

¹ The University of Queensland, The Applied Environmental Decision Analysis Centre, The Ecology Centre, Brisbane, QLD 4072, Australia

² The Biodiversity Research Group, Department of Evolution, Systematics and Ecology, The Institute of Life Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

³ Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD 4811, Australia

⁴ Landcare Research, Private Bag 1930, Dunedin 9054, New Zealand

Conservation efforts and emergency medicine face comparable problems: how to use scarce resources wisely to conserve valuable assets. In both fields, the process of prioritising actions is known as triage. Although often used implicitly by conservation managers, scientists and policymakers, triage has been misinterpreted as the process of simply deciding which assets (e.g. species, habitats) will not receive investment. As a consequence, triage is sometimes associated with a defeatist conservation ethic. However, triage is no more than the efficient allocation of conservation resources and we risk wasting scarce resources if we do not follow its basic principles.

Introduction

Analogous to the battlefields and trauma rooms from where the term ‘triage’ originated, conservation biology has been described as a crisis discipline: a mission-oriented science where decisions must be made quickly without complete information [1]. In an ideal world, there would be enough money to save everything [2,3], but instead we are faced with a growing list of species at imminent risk of extinction, declining habitat extent and condition, uncertainty about the likelihood of our investment success and inadequate conservation budgets [4]. Under these conditions, it is essential that scarce resources are allocated to maximise the persistence of valuable assets (e.g. biological features) that will disappear without treatment, that is, without conservation action. The use of the term triage in conservation arenas has been met with some apprehension. There is, however, an increasing body of prioritisation assessments that have applied the principles of triage to the allocation of conservation resources [5–8] by accounting for the benefits, costs and likelihood of success of investments. The need for further applications is pervasive over a much broader context, from prioritising management actions on the ground to strategic policy-level

decisions. Here we communicate the principles of conservation triage, highlighting the benefits of explicitly employing triage principles and its utility for all types of decision makers. We further make the case that, rather than being an ethical position, conservation triage is simply an unavoidable step in the process of efficiently allocating resources when budgets are constrained.

Defining conservation triage

Triage, derived from the French word *trier* meaning ‘to sort,’ is a process of prioritisation [9]. In a medical context, triage is used to allocate limited resources for the greatest good for the largest number of people [10]. The treatment of patients is prioritised by injury severity, the consequence of delaying treatment, net benefits of different treatments and the probability that the patient will recover with or without treatment [11]. Triage in a conservation context is the process of prioritising the allocation of limited resources to maximise conservation returns, relative to the conservation goals, under a constrained budget. This is achieved by explicitly accounting for the costs, benefits and likelihood of success of alternative conservation actions (e.g. protection, restoration, pest eradication, education, training, etc.).

Although triage provides a rational process to maximise the protection of human life in times of crisis, some are wary of its application in conservation contexts. It has been argued that the use of triage in conservation promotes defeatism when an asset is deemed too difficult to save [12–14], rendering it an ‘ethically pernicious’ approach to conservation [15] which will result in protection of only moderately diverse, moderately threatened biodiversity assets [16]. Opponents to triage also argue that urgency (e.g. extinction risk) is a catalyst for scientific innovation, and that scientists demonstrate their intellectual mettle when time is running out and extinction appears imminent [13,17]. Judged as a policy of convenience, the use of triage is viewed to be acceptance of the inevitability of extinction, providing an excuse to walk away and not take action for those species or places at greatest risk [15].

Corresponding author: Bottrill, M.C. (m.bottrill@uq.edu.au).

These arguments fail to acknowledge that the amount of money and capacity required to reverse the extinction rate for all biodiversity (i.e. to achieve ‘zero extinction’) is astronomical and far beyond the levels of current investment in conservation action [18]. If triage is defined as the process of prioritising conservation actions, then failure to employ triage deems it necessary that we save all biodiversity – every habitat, every species – and return extinction rates to natural levels. The Alliance for Zero Extinction, for example, states the goal of zero extinction at 700+ sites worldwide, which would require reducing extinction rates to natural levels of species and neglecting to factor in diminishing returns and the uncertainty of investment [19]. Human-induced extinction rates are up to 1000 times the natural extinction rate [20] and progress toward the 2010 biodiversity target to reduce significantly the rate of extinction [21] has been limited [22], despite six years of concerted conservation investment and action. Accepting that current conservation resources constrain the goal of zero extinction (and thereby acknowledging the need to prioritise conservation actions), the reality is that conservation triage is more commonplace than the degree to which it is explicitly discussed.

Indeed, the process of triage, as a necessity for prioritising investment of scarce resources, is implicitly applied on a daily basis by managers, policymakers, scientists and planners; this application is rarely explicit [14]. By not being explicit, however, decision makers are more likely to make inefficient choices. While resources are spent on

actions unlikely to succeed or costly to implement, a whole suite of other assets are likely to receive inadequate investment given a limited budget. The opportunity cost of conservation (i.e. what else could be achieved with the same resources or the opportunities that are lost) is rarely reported or evaluated. To support smart decisions, we must therefore consider information on values of biodiversity held by stakeholders, the benefit to biodiversity from an action, the probability that an action will succeed and the cost of action. In the remainder of this paper, we demonstrate that if applied explicitly, triage is simply a process of wise resource allocation.

Conservation triage as a resource allocation process

Using decision theory, conservation triage can be illustrated as a process of resource allocation. Decision theory guides decision makers in achieving explicitly stated objectives while acknowledging the constraints of the system (e.g. money, time and capacity) involved with the decision process [23]. Clearly articulating a conservation goal is fundamental for the efficient allocation of resources between conservation actions [2,24]. Goals are based on a desired state for the system, relative to scope and context, and underlie the identification, prioritisation, implementation and evaluation of conservation actions [25]. When using conservation triage for prioritising actions, the relative priority of alternative actions to achieve the stated goal should be determined by at least four parameters: values, biodiversity benefit, probability of success and cost

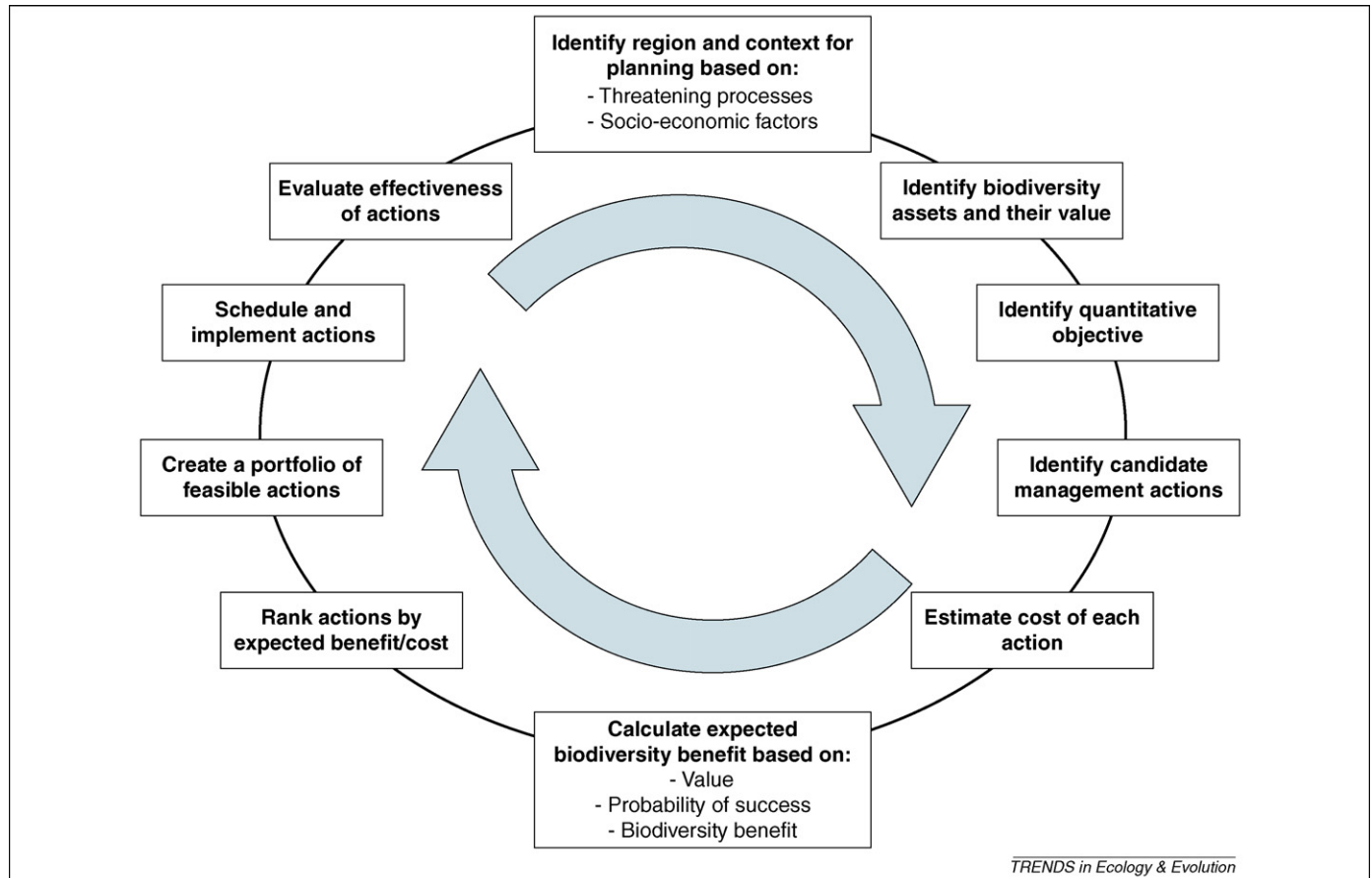


Figure 1. An operational model for allocating investment to different conservation actions to achieve a stated goal using the process of triage, which incorporates parameters of cost, value, probability of success and biodiversity benefit [2].

Box 1. Prioritising islands for eradication of introduced rats using conservation triage

A common dilemma faced by managers is that there is simply not enough time or money to undertake all conservation actions necessary to protect biodiversity. Below is a hypothetical scenario where conservation triage is used to prioritise actions to control introduced predators on a group of islands.

- (i) Introduced rats (Figure 1) threaten ground-nesting birds on five islands. As part of a conservation programme, a local manager is tasked to prioritise actions to remove the rats.
- (ii) The five islands are valued for their richness of endemic ground-nesting birds. Each island has its own set of endemic species. All islands are equally and absolutely threatened by rat predation; that is, it is assumed that all endemic ground-nesting birds will persist if the rats are eradicated, but will become extinct if they are not.
- (iii) The manager sets a conservation goal to minimise the loss of endemic ground-nesting bird species for a fixed budget of \$50 000 over ten years.
- (iv) The biodiversity benefit (b) of the management action for each island is a binomial value (0,1) related to protection of endemic bird species on an island. If eradication is implemented on an island, $b = 1$, and if it is not implemented, $b = 0$. The value (v) for each bird species is its phylogenetic diversity (PD), a measure of its relative evolutionary distinctiveness [39].

The probability of success, $\text{Pr}(\text{success})$, is the probability that the action will eradicate all rats on an island. There is assumed to be no inter-island migration of rats or transfer of rats from the mainland. Expected biodiversity benefit is therefore expressed as $\text{Pr}(\text{success}) * b * v$.

- (v) The manager then scores each island relative to the cost, benefit and likelihood of success of implementing eradication, which is expressed as

$$\frac{\text{Pr}(\text{success}) * b * v}{\text{Cost}}$$

The island with the highest score is where this action is likely to offset the greatest loss of phylogenetically distinct endemic species per unit cost.

- (vi) Using the score for each island, the manager decides on which island to implement eradication measures first. If funds are available, then funds are progressively invested on other islands with lower scores.

- (vii) The manager then continues to eradicate rats on other islands, working down the list of scores, within the limits of the budget and updating the scores as time passes.
- (viii) With rats successfully eradicated on the highest-priority islands, the conservation manager might argue for additional funds, which could be redirected from unsuccessful conservation programmes.

This process provides transparency about the opportunity costs of decisions and the tradeoffs between taking action on different islands. Further real-world complexities can also be addressed within this resource allocation model. These include (i) measuring complementarity between areas when they overlap in species composition; (ii) potential incomplete eradication and the need for additional and/or continuing investment for conservation [40]; (iii) per-unit area differences between islands in the cost of eradication due to habitat, topography and average rat densities; and (iv) interdependencies between costs, values, benefits and probability of success of alternative actions (e.g. fencing and baiting).



Figure 1. Black rat (*Rattus rattus*) eating a New Zealand fantail (*Rhipidura fuliginosa*) at its nest. Photo: D. Mudge.

[26] (Figure 1; also see Box 1 for application to a case study example). These parameters are used to define the relative contribution of each action to the stated goal. Conservation triage involves rationally combining these four parameters in a mathematically rigorous fashion: multiplying value, biodiversity benefit and probability of success, and then dividing by cost under resource constraints. This process delivers the expected cost efficiency of choosing any action over other actions, and makes it possible to rank the different options optimally.

Values

Underlying all decisions is a set of values and beliefs [27]. Value judgements between medical patients might appear morally difficult. However, in clinical practice, patients with greater expected healthy years are often prioritised, and young people are thereby given higher values as they are expected to live longer [28]. The opposite could be said to be true in biodiversity terms, with older, more phylogenetically distinct taxa often given priority for conservation [29]. The Zoological Society of London, for example, has recently launched a programme to raise awareness and develop conservation strategies for evolutionarily distinct and globally endangered (EDGE) taxa [30]. Values

associated with biodiversity include ecological, evolutionary, social, cultural and economic attributes, with higher value often given to charismatic species or places, or those features that provide functional support to ecosystems or people [31,32].

Biodiversity benefit

The benefit of an action is the amount gained from that action in progress toward the stated goal (e.g. avoided deforestation, persistence of endemic species). With respect to both the medical and conservation use of triage, everything else being equal, actions that provide the greatest benefits to human survival and biodiversity persistence are higher priorities. Net biodiversity benefits are measured as the difference in outcomes with and without the action taking place, therefore accounting for the relative threat facing each asset. If an asset is likely to persist without a particular action, then the action will have a low net biodiversity benefit.

Probability of success

The probability that an action will succeed should affect the decision of whether an action is implemented. All else being equal, an action likely to succeed will be a higher

priority than an action that is likely to fail [6,8,10]. The probability of success of actions can be estimated using data on threatening processes, biological potential of an asset to recover or persist, existing social or legislative conditions and the willingness or capacity of relevant social or management groups to facilitate the action. Uncertainty around whether an action will achieve its stated goal is arguably the most overlooked parameter in conservation investments [33]. As a result, resources can be wasted on impossible endeavours.

Cost

The cost of conservation actions is a crucial component of decision making but is nonetheless rarely considered explicitly [34]. Generally, all else being equal, a cheaper action should be prioritised over a more expensive action. Current conservation projects are constrained by limited budgets, which necessitate the consideration of prioritisation and scheduling of actions based fundamentally on the costs of conservation actions and funds available [2]. If costs are considered in planning, decision makers are aware of the opportunity cost of funds that are directed away from particular conservation actions, leading to greater returns on investment [35].

The realities of using triage for conservation decision making

Choices about how and where to invest conservation resources are frequently much more complex than the example in Box 1. Decision makers are faced with reconciling potentially conflicting and/or complementary benefits and values with multiple actions having different costs at various scales. They also face the challenge of finding consensus among multiple stakeholder groups, including scientists, donors, industry and local communities (Box 2). Decision-making parameters used to decide which actions to take might be quantified in different currencies (e.g. dollars, staff retention rates, public willingness, political leverage) [36], which might inform the extent of a tradeoff given for a particular action. Some actions (e.g. building stakeholder capacity) might not contribute directly to an immediate and quantifiable benefit to biodiversity, but instead facilitate conservation opportunities that influence long-term biodiversity persistence. This scenario might be represented as a type of leverage in a resource allocation process, which could be incorporated as either a reduction in the cost of an action or added to future budgets. Conservation triage provides a useful process for reconciling and evaluating multiple choices despite such complexities.

The benefit of using triage for allocating conservation resources is that the consequences of choosing among different actions are explicit. Transparent reporting of conservation investments is essential, so tradeoffs might be evaluated *a priori* and future decisions improved by retrospective assessments. It would be naïve, however, to ignore the fact that conservation investment is often driven by other sociopolitical realities [37], and there is uncertainty whether rational approaches will be awarded equivalent funding as those projects directed toward charismatic taxa [38] or emotive causes. We argue that if decision makers demonstrate a rational process to allo-

Box 2. Conservation triage in a complex world: setting global investment priorities

Here we describe and analyse a real-world application of conservation triage, where global regions are prioritised for conservation investment using a complex set of criteria in a resource-limited situation.

- (i) In 2005, the World Wildlife Fund–US, an international conservation organisation, initiated a strategic assessment for the allocation of its available resources to measure progress of conservation efforts in 15–20 of the world's 32 most important ecoregions, given limited resources, context-specific opportunities and capacity constraints [41]. WWF used a triage approach to decide upon which regions to focus their immediate attention because they could not work in all regions. Allocation of resources to each ecoregion would provide multiple benefits (e.g. ecological, economic and institutional) to regional programmes and provide global benefits by reducing biodiversity loss and minimising the impact of global drivers of threat.
- (ii) WWF identified three broad criteria to be used in their decision-making process: biological values, benefits from transforming the effects of threats and feasibility (Table I). Within each broad criterion, several subcriteria were identified and weighted ($W_1 - W_n$) by a team of experts to reflect their relative importance. Regions were scored for each broad criterion (high, medium, low) by adding a weighted sum of each of the subcriteria (a,b,c):

$$Score = \sum_{site=i} W1.ai + W2.bi + W3.ci...$$

- (iii) The choice of priority regions for WWF was informed by the scores using a threshold approach: regions that scored high in biological criteria were then evaluated for transformational and feasibility criteria in a hierarchical process. For example, WWF has multiyear funding grants in the Namib-Karoo ecoregion; once through the biological filter, this region scored highly in feasibility criteria. Using this process, 19 of the 32 ecoregions were identified for investment within the resource limitations of WWF.

By outlining criteria for allocating decisions, the process performed by WWF has demonstrated that decisions can be structured under complex scenarios, even when parameters might not always be numerically quantifiable. The step-by-step decision process employed and made available online provides some transparency and accountability.

By not explicitly considering the cost of 'measurably conserving' biodiversity in each region, however, this process misses a key component for supporting efficient investments [42]. The cost of conservation in a region can be estimated by the financial and other resource requirements of the actions that will contribute to the overall goal. The investment potential or 'leverage' of each region, if estimated quantitatively, could be subtracted from this overall cost, or could be used to generate benefits elsewhere. The use of thresholds and scores by WWF also hinders efficiency, as it leads to low values in one criterion or subcriteria diluting high values in another. Finally, WWF relied on intuition rather than quantitative and explicit approaches to ensure that the regions selected covered a broad range of biodiversity. An approach that quantitatively addresses costs, leverage and integrated multiple criteria would provide a more objective justification for the selection of some ecoregions over others.

cating resources, such as one based on principles of triage, then greater awareness of tradeoffs (at a minimum evaluated internally) will lead to more strategic and defensible outcomes and potentially heightened public confidence and stakeholder buy-in. Where there is flexibility in allocating resources, which is true for many investment portfolios of international conservation organisations and multilateral agencies, an explicit and economically rigorous triage

Table I. A resource allocation process used by WWF, an international conservation organisation

	Representativeness	Species richness	Higher-level endemism	Ecological phenomena	Intactness	Gains in value from action	Reduced impact of global drivers	Staff capacity	Strategic leadership	Regional partnerships	Existing donor relationships	Governance	Investment risk	Investment potential
Subcriteria	a	b	c	d	e	f	g	h	j	k	l	m	n	p
Broad criteria ^a	Biological (Value)					Transformational (Biodiversity benefit)		Feasibility (Probability of success)						
Weights ^b	W ₁	W ₂	W ₃	W ₄	W ₅	W ₁	W ₂	W ₁	W ₂	W ₃	W ₄	W ₅	W ₆	W ₇
Ecoregion for investment														
Amur-Heilong River														
Anatolia Freshwater														
Atlantic Forest														
...														
...														
...														

^aTerms in brackets (...) relate each broad criterion to parameters of a triage approach to resource allocation.

^bWeights within each broad criterion (biological, transformational and feasibility) add to a total of 1.

approach will likely lead to greater returns on investment than if the process of triage was ignored or implicit.

Conclusions

Efficient resource allocation relies upon clear goals for what we hope our actions will achieve for biodiversity conservation. Decision making based on the principles of triage provides a defensible, rational and repeatable approach to prioritising conservation investments. By explicitly acknowledging the use of triage as a process for efficient resource allocation, we are able to clearly understand and scrutinise the tradeoffs resulting from investing in one action over another, thereby increasing confidence in investments. If doctors are willing to use triage in allocating resources to save human lives, why would conservation biologists be squeamish?

Acknowledgements

This work emerged from a workshop on conservation planning hosted and funded by the Applied Environmental Decision Analysis (AEDA) Centre at the University of Queensland, Australia. This work was supported by AEDA, which is funded by the Commonwealth Environmental Research Facility Programme and also the Australian Research Council for H.P.P. and S.K., eWater CRC for S.L. and Landcare Research, NZ for S.W. We thank Carissa Klein, Taylor Ricketts, Barry Brook and two anonymous reviewers for useful comments that improved the manuscript. We also thank John Innes for assistance in acquiring images.

References

- Soulé, M.E. (1985) What is conservation biology? *Bioscience* 35, 727–734
- Possingham, H.P. *et al.* (2001) Making smart conservation decisions. In *Conservation Biology: Research Priorities for the Next Decade* (Soulé, M.E. and Orians, G., eds), pp. 225–244, Springer
- Balmford, A. *et al.* (2000) Integrating costs of conservation into international priority setting. *Conserv. Biol.* 14, 597–605
- James, A.N. *et al.* (1999) Balancing the Earth's accounts. *Nature* 401, 323–324
- Wilson, K.A. *et al.* (2007) Conserving biodiversity efficiently: what to do, where, and when. *PLoS Biol.* 5, e223
- McBride, M.F. *et al.* (2007) Incorporating the effects of socioeconomic uncertainty into priority setting for conservation investment. *Conserv. Biol.* 21, 1463–1474
- Costello, C. and Polasky, S. (2004) Dynamic reserve site selection. *Resour. Energy Econ.* 26, 157–174
- Hobbs, R.J. *et al.* (2003) What happens if we cannot fix it? Triage, palliative care and setting priorities in salinising landscapes. *Aust. J. Bot.* 51, 647–653
- Random House (1997) *Webster's Unabridged Dictionary*. Random House
- Kennedy, K. *et al.* (1996) Triage: techniques and applications in decision making. *Ann. Emerg. Med.* 28, 136–144
- Repine, T.B. *et al.* (2005) The dynamics and ethics of triage: rationing care in hard times. *Mil. Med.* 170, 505–509
- Mittermeier, R.A. *et al.* (1998) Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conserv. Biol.* 12, 516–520
- Pimm, S.L. (2000) Against triage. *Science* 289, 2289
- Marris, E. (2007) What to let go. *Nature* 450, 152–155

- 15 Noss, R.E. (1996) Conservation or convenience. *Conserv. Biol.* 10, 921–922
- 16 Mittermeier, R.A. *et al.* (2005) *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. Conservation International
- 17 Watts, R.J. and Wilson, A.L. (2004) Triage: appropriate for prioritizing community funded river restoration projects, but not for advancing the science of river restoration. *Ecol. Manage. Restor.* 5, 73–75
- 18 James, A. *et al.* (2001) *Can we afford to conserve biodiversity?* *Bioscience* 51, 43–52
- 19 Ricketts, T.H. *et al.* (2005) Pinpointing and preventing imminent extinctions. *Proc. Natl. Acad. Sci. U. S. A.* 102, 18497–18501
- 20 Pimm, S.L. *et al.* (1995) The future of biodiversity. *Science* 269, 347–350
- 21 Balmford, A. *et al.* (2005) The convention on biological diversity's 2010 target. *Science* 307, 212–213
- 22 European Environment Agency (2007) *Europe's Environment: The Fourth Assessment*. European Environment Agency
- 23 Clemen, R.T. (1996) *Making Hard Decisions: An Introduction to Decision Analysis*, Duxbury Press
- 24 Wilson, K.A. *et al.* (2006) Prioritizing global conservation efforts. *Nature* 440, 337–340
- 25 Noss, R.F. (1999) Assessing and monitoring forest biodiversity: a suggested framework and indicators. *For. Ecol. Manage.* 115, 135–146
- 26 Joseph, L.N. *et al.* Evaluating costs, benefits and probability of success for threatened species management: a project prioritisation protocol. *Conserv. Biol.* (in press)
- 27 Noss, R.F. (2004) Conservation targets and information needs for regional conservation planning. *Nat. Areas J.* 24, 223–231
- 28 Shickle, D. (1997) Public preferences for health care: prioritisation in the United Kingdom. *Bioethics* 11, 277–290
- 29 Johnson, C.N. (1998) Species extinction and the relationship between distribution and abundance. *Nature* 394, 272–274
- 30 Isaac, N.J. *et al.* (2007) Mammals on the EDGE: conservation priorities based on threat and phylogeny. *PLoS ONE* 2, e296
- 31 Shrader-Frechette, K.S. and McCoy, E.D. (1994) Biodiversity, biological uncertainty and setting conservation priorities. *Biol. Philos.* 9, 167–195
- 32 Walker, B.H. (1992) Biodiversity and ecological redundancy. *Conserv. Biol.* 6, 18–23
- 33 Ferraro, P.J. and Pattanayak, S.K. (2006) Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLoS Biol.* 4, 482–488
- 34 Bode, M. *et al.* (2008) Cost-effective global conservation spending is robust to taxonomic group. *Proc. Natl. Acad. Sci. U. S. A.* 105, 6498–6501
- 35 Naidoo, R. *et al.* (2006) Integrating economic costs into conservation planning. *Trends Ecol. Evol.* 21, 681–687
- 36 Schneider, S.H. *et al.* (2000) Costing non-linearities, surprises and irreversible events. *Pac. Asian J. Energ.* 10, 81–106
- 37 Pressey, R.L. *et al.* (2000) Using abiotic data for conservation assessments over extensive regions: quantitative methods applied across New South Wales, Australia. *Biol. Conserv.* 96, 55–82
- 38 Metrick, A. and Weitzman, M. (1996) Patterns of behavior in endangered species preservation. *Land Econ.* 7, 1–16
- 39 Faith, D.P. (1992) Conservation evaluation and phylogenetic diversity. *Biol. Conserv.* 61, 1–10
- 40 Morrison, S.A. *et al.* (2007) Facing the dilemma at eradication's end: uncertainty of absence and the Lazarus effect. *Front. Ecol. Environ.* 5, 271–276
- 41 Dillon, T. *et al.* (2005) *Priority-Setting at WWF-US: Towards a Conservation Portfolio*, World Wildlife Fund
- 42 Murdoch, W. *et al.* (2007) Maximizing return on investment in conservation. *Biol. Conserv.* 139, 375–388