# Why do we map threats? Linking threat mapping with actions to make better conservation decisions

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**Spatial representations of threatening processes – "threat maps" – can identify where biodiversity is at risk, and are often used to identify priority locations for conservation. In doing so, decision makers are prone to making errors, either by assuming that the level of threat dictates spatial priorities for action or by relying primarily on the location of mapped threats to choose possible actions. We show that threat mapping can be a useful tool when incorporated within a transparent and repeatable structured decision-making (SDM) process. SDM ensures transparent and defendable conservation decisions by linking objectives to biodiversity outcomes, and by considering constraints, consequences of actions, and uncertainty. If used to make conservation decisions, threat maps are best developed with an understanding of how species respond to actions that mitigate threats. This approach will ensure that conservation actions are prioritized where they are most cost-effective or have the greatest impact, rather than where threat levels are highest.**

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Biodiversity is declining rapidly, as human activities drive global-scale species losses and ecosystem changes (Pimm *et al.* 2014). Conservation actions are required to protect species and ecosystems from the processes that imperil their existence (Figure 1; Panel 1). To manage threats to biodiversity, scientists and decision makers often rely on spatial data – traditionally the distribution of at-risk biodiversity – for prioritizing conservation decisions (Wilson *et al.* 2006). Focus has recently shifted toward understanding and incorporating the distribution of threats (Allan *et al.* 2013), and the costs of managing them (McCarthy *et al.* 2012). Static visualizations of the spatial distribution, intensity, frequency, or seasonality of threats to biodiversity across a landscape or seascape are often referred to as "threat maps" (Figure 2; Neke and Du Plessis 2004; www.conservationgateway.org/Files/Pages/threat-maps.aspx). These maps are now regularly used to inform decisions about where to manage for biodiversity conservation and what actions to take (Figure 2; Salafsky *et al.* 2003), most notably identifying which regions to prioritize in terms of funding (eg Myers *et al.* 2000). But are threat maps the best tool for guiding conservation investment? Here we assess how threat maps have been used in the past, and how they should be applied in the future to maximize biodiversity outcomes.

### In a nutshell:

- Threat maps are spatial representations of the distribution, intensity, or frequency of threats to biodiversity across a landscape or seascape
- Threat maps can be useful for informing where and why biodiversity is at risk but may be insufficient for informing efficient management actions
- Using threat maps to guide conservation actions without clear management objectives linking to social, political, economic, or biodiversity outcomes can result in unintended consequences or misallocation of resources
- Structured decision making (SDM) helps to evaluate potential management actions that might be taken in a threatened area, and can lead to more cost-effective conservation decisions
- If applied to conservation-oriented decisions, threat mapping should be incorporated into SDM to account for the expected consequences of alternative strategies intended to promote biodiversity, so that the most effective threat-mitigating actions might be chosen

Threat maps influence much of the prioritization of conservation efforts by scientists, non-governmental organizations (NGOs), and governments (Brooks *et al.* 2006). For example, Conservation International raised over US$750 million for conservation in their priority hotspots of high habitat degradation and species endemism (Myers and Worm 2003), while The Nature Conservancy has focused activities around global "crisis ecoregions" that have extensive habitat loss and limited protection (Hoekstra *et al.* 2005). The use and influence of threat maps in the scientific literature is growing exponentially (from two papers in 1993 to more than 100 in 2013; WebPanel 1). Approaches to threat mapping range from mapping the past or current distribution of a single threat (eg Schmidt *et*

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***Figure 1.*** *Threats to biodiversity: (a) open-cut mining, (b) grazing, (c) oil palm production, and (d) coastal urban development.*

*al.* 2002), to identifying concentrations of endemic species that have experienced major threats in the past (eg hotspots; Myers *et al.* 2000), and more recently to additive scoring approaches for multiple threats, incorporating ecosystem vulnerability (Halpern *et al.* 2008).

Despite their potential advantages over species-based approaches and their frequent application (see examples in Table 1), the use of threat maps to guide the spatial implementation of conservation actions has notable limitations (eg Wilson *et al.* 2006). Doubts have been raised regarding whether and how threat maps should be considered in conservation-oriented management plans (Mace *et al.* 2000). We argue that, while useful in certain contexts, threat maps – including simple spatial overlays of threatened species or threat "hotspots" – may be insufficient for making cost-effective conservation decisions. In many cases,

**Panel 1. Glossary of terms used in threat mapping and conservation decision making (Taylor 2013)**

| *Term* | *Meaning* |
|---|---|
| Actions | Committing resources to preserving or restoring biodiversity, or slowing declines thereof, usually following a choice |
| Alternatives | Optional courses of action (that provide ways to achieve objectives) from which a decision maker is expected to choose |
| Consequences | Results of a decision maker's action, which might be any defined (or ill-defined) outcome |
| Constraints | Situational factors that must be taken into consideration when an attempt is made to optimize a decision with respect to its key variables; these include policy, financial, and ethical constraints |
| Decision | Process of determining what action to take, including identifying a choice |
| Objectives | The intentions of the decision process that set out what is to be strived for or sought (also called aims) |
| Outcomes | Distinct events due to an action; a special case of consequences |

alternative approaches that do not rely on threat maps will be required to better inform such decisions.

## ■ Decision theory: a strategic approach to prioritizing threat management

Decision theory is a rational systematic framework for choosing between different strategies and optimizing decisions with uncertain consequences (Possingham 2001). Structured decision making (SDM) is a rigorous, transparent, and iterative approach, grounded in decision theory (Gregory *et al.* 2012), which brings stakeholders together to solve problems by:

(1) defining clear, quantifiable objectives and constraints related to the problem, and measurable attributes for each;
(2) identifying a set of alternative management actions;
(3) evaluating the consequences of alternative actions in terms of the objectives;
(4) dealing explicitly with uncertainty; and
(5) assessing trade-offs (Figure 3).

By explicitly identifying potential management actions and their outcomes, SDM aids in selecting actions that are expected to better achieve predefined conservation goals as compared with alternative actions. Historically, however, conservation organizations have often made management decisions based on threats rather than actions. For instance, Brooks *et al.* (2006) and Micheli *et al.* (2013) reviewed 21 different global or regional conservation prioritizations. While all considered the spatial distribution of threats or threatened species, none considered alternative actions or potential costs. In the absence of such considerations, it is impossible to identify species responses to actions and thus identify the optimal allocation of resources (eg conservation-oriented funding and personnel) between regions (Wilson *et al.* 2006). Although threat maps may serve as a useful public outreach tool to enhance funding opportunities for environmental organizations, there is often no explicit justification for using these maps to target (or ignore) certain threats or to inform conservation actions. Ultimately, conservation interventions should aim to deliver biodiversity outcomes. Decision-theoretic approaches such as SDM can identify actions that lead to the "best" outcomes (Polasky *et al.* 2011), rather than focusing on the locality of threats.

Here we adapt the steps of SDM to a threat mitigation decision problem (Figure 3; Gregory *et al.* 2012), highlighting where threat maps fit within the SDM framework and where they might fail to provide the information needed for action. We illustrate the differences between approaches that may or may not integrate threat maps with decision theory, and compare four different priority-setting approaches – where science was intended to inform decisions – for threatened species in Australia (WebPanel 2; [i] Australian Government 2003; [ii] Watson *et al.* 2011; [iii] Evans *et al.* 2011; [iv] Chadès *et al.* 2014). We use these examples to underscore potential flaws in the outcomes of threat-mapping approaches that did not formulate the decision problem from an SDM perspective (WebPanel 2, i–iii), and identify decision-theoretic approaches that can be used to maximize biodiversity outcomes (WebPanel 2, iv; WebTable 2).

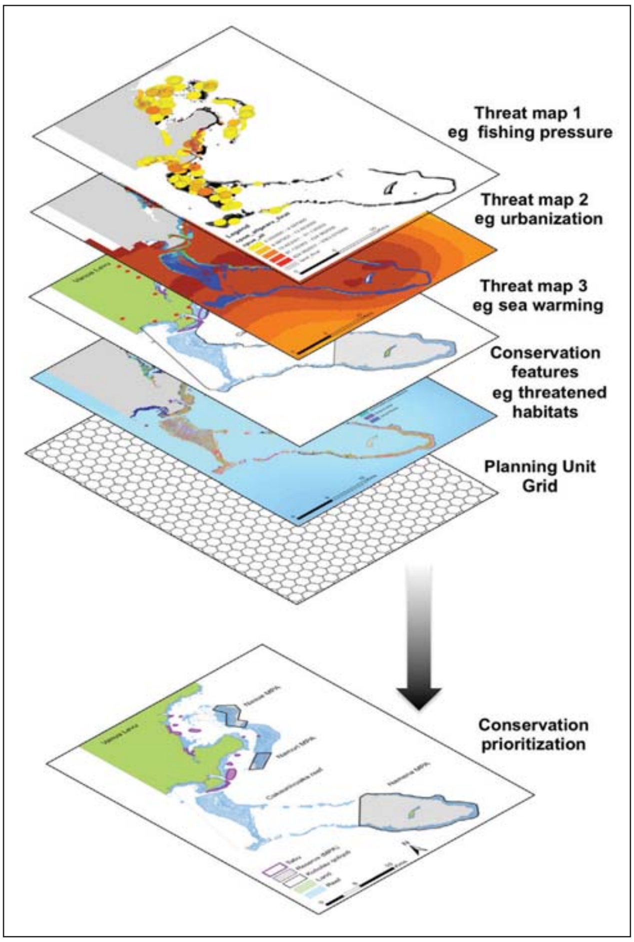


***Figure 2.*** *The different maps often used in conservation planning, based on a case study of planning for Marine Protected Areas in Fiji (Tulloch* et al. *2013b). Traditionally, one or more of these are overlaid with conservation features and used to prioritize areas for conservation. For threat hotspot mapping, the three threat maps might be added together to develop a cumulative threat map that shows highest or lowest values in areas where all three threats are present or absent, respectively. Rarely have these maps been linked explicitly with expected action outcomes to provide information on where and how threat mitigation might better protect or restore declining populations.*

## ■ Integrating threat management into an SDM framework

### *Step 1: set objectives, consider constraints, and assign measurable attributes*

The initial step in SDM is to set clear objectives related to the focal problem and the desired outcomes (Gregory *et al.* 2012). These are essentially value judgments. In conserva-

**Table 1. Typology of mapping approaches used to make decisions for threatened species and systems**

| *Output of approach* | *Species or ecosystem distribution* | *Threat distribution* | *Interaction between species and threat* | *Species response to threat* | *Species response to action* | *Applied examples* |
|---|---|---|---|---|---|---|
| Map of distribution of single species/ecosystem | ■ | | | | | Red List range maps of threatened species (IUCN 2013) |
| Species "hotspots" (areas featuring high species richness, endemism, or rarity) | ■ | | | | | Biodiversity hotspots (Mittermeier *et al.* 1998) |
| Species "hotspots" combined with threatening process | ■ | ■ | | | | Global hotspots of habitat loss (Myers *et al.* 2000) |
| Map of single threatening process | | ■ | | | | Distribution of invasive species (Sarre *et al.* 2012) |
| Map of single threatening process linked to affected species | | ■ | ■ | | | Poaching risk map (Sánchez-Mercado *et al.* 2008) |
| Map of multiple threatening processes (eg summed cumulative threat score/index) | | ■ | | | | Scores of cumulative threat from human influence (ie population, urbanization, roads, etc; Sanderson *et al.* 2002) |
| Map of vulnerability of species, systems, or regions to threat | ■ | ■ | ■ | ■ | | Vulnerability of species to climate change (Foden *et al.* 2013) |
| Map of impacts of multiple threatening processes on species/systems | ■ | ■ | ■ | ■ | | Cumulative threat impact score (multiple human threats) linked to ecosystem vulnerability (Halpern *et al.* 2008) |

**Notes:** Blue boxes indicate information used in the approach (see WebTable 1 for further details and additional references).

tion decision making, there are often multiple competing objectives related to social, political, economic, and biodiversity outcomes. Constraints associated with these objectives can affect management feasibility or outcomes. In SDM, constraints are considered during objective setting, with measurable attributes used to assess the consequences of different decisions (Martin *et al.* 2009), ensuring that decision making is driven by desired outcomes.

Too often in conservation contexts, there is only one objective: reduce or avoid threats. For example, three recent conservation priority-setting approaches all set different objectives to reduce threats to biodiversity in Australia (WebPanel 2, i–iii), and all prioritized different areas of the landscape. However, threat reduction is not a biodiversity outcome per se. By selecting threats to target before setting conservation objectives, organizations have a preconceived notion of how the species or system should be managed, and may cling to objectives (and actions) driven by information about the threat alone, rather than by the ultimate objectives. This mismatch can lead to the overall conservation objective being undermined. For instance, expanding protected areas because there are multiple threats and threatened species present in that area (WebPanel 2, ii) does not ensure positive outcomes for biodiversity, if there are threats that will continue despite that decision. Narrowly focused, threat-based objectives at best might achieve only the reduction of a single threat, and at worst may fail to minimize biodiversity loss because of unabated threats, action in inappropriate areas, or a lack of consideration of other socioeconomic or political constraints. In another example, to prioritize actions for conservation of rhinoceros species (black rhinoceros *Diceros bicornis* and white rhinoceros *Ceratotherium simum*) imperiled by illegal hunting, conservation programs set threat-based objectives such as "reducing poaching" (eg Zimbabwe Parks and Wildlife Management Authority 2003) using maps of recent poaching activities to increase militarized enforcement (eg www.stoprhinopoaching.com/statistics.aspx). However, focusing on actions that only try to mitigate the threat ultimately restricts supply of rhino horn, despite increasing market demand (Biggs *et al.* 2013). This raises the price of horn and provides incentives for poachers, resulting in perverse outcomes for biodiversity; many species, including rhinos, are still being poached at an increasing rate.

Outcome-oriented objective setting explicitly considers constraints such as time (eg over what temporal extent will costs and benefits be accrued), political context, governance (eg multi-jurisdictional issues), and budget limitations (eg minimizing costs or maximizing income) – factors usually overlooked in traditional threat-based approaches (eg WebPanel 2, i). SDM facilitates decisions that achieve positive outcomes by fully exploring the values and objectives of all stakeholders, typically in a stakeholder engagement process (eg WebPanel 2, iv; Gregory *et al.* 2012), rather than focusing on threat-based objectives alone. Importantly, by considering constraints, SDM ensures that objectives are feasible given the political, cultural, or economic context; in extreme cases some potential actions will be impossible to implement.

Objectives need to be quantitative and unambiguous, and should represent all aspects of the conservation problem to be managed. For the rhino example, an outcome-oriented SDM objective might be to maximize the number of breeding rhinos, such as in the Namibian Government's black rhino Conservation Strategy (Martin 2010). A measurable attribute could be rhino population viability after 20 years, which is linked directly to the desired outcome instead of the threat. Applying an SDM process might also identify human welfare as important; an additional objective might be to minimize income loss to local communities responsible for poaching. Examining outcomes, measurable attributes, and values thus helps to avoid the mismatch of objectives.

Finally, decisions based on threat maps are inherently scale dependent (Boyd *et al.* 2008); thus, international and national priorities guiding large-scale threat map development (such as WebPanel 2, i–iii) may not transfer to smaller-scale conservation decisions due to different species assemblages or policy settings (Guerrero *et al.* 2013). Because SDM can be scale independent, this problem can be overcome by matching the objectives (and associated actions) to the scale of the problem (eg WebPanel 2, iv).

### Step 2: develop management alternatives

Many hypotheses, each of which could be linked to one or more potential management-related actions, may explain observed declines in biodiversity. In SDM, a set of all possible actions is developed, and constraints are considered; from the total list of potential actions, a subset is selected for further attention. By exploring alternative actions rather than a single action, managers may be better able to judge the pros and cons of each as they relate not only to biodiversity outcomes but also to ancillary political or socioeconomic outcomes (eg sustaining livelihoods; Pullin and Knight 2001). Managers can also better understand the benefits of multiple action strategies (Chadès *et al.* 2014). In the absence of such a comparison, it is impossible to assess potential trade-offs between different actions, a fundamental principle of cost-effective decision making. In the rhino example, SDM allows the supply-chain effects to be described because it canvasses alternative options such as new policies or actions to decrease demand; this might lead to poaching being identified as an unstoppable threat that can be addressed only in combination with other alternative actions (such as intentional dehorning, education, or legalized harvesting; Figure 4; Biggs *et al.* 2013).

In WebPanel 2, the first example (i) failed to meet its objective to increase awareness of cost-effective conservation action because it did not link alternative actions or their costs to threats, an issue that can be resolved

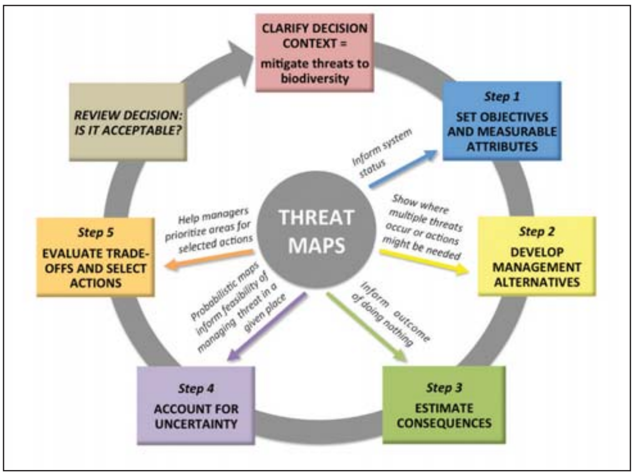


***Figure 3.*** *A structured decision-making framework. We modified the approach of Gregory* et al. *(2012) by explicitly accounting for uncertainty. There is implicit uncertainty in all steps (eg in objectives, in the choice of alternative actions), but by including it as a separate step we ensure that decision makers can rigorously account for all of these uncertainties. We also highlight some examples of how threat maps can be used within this framework to guide decision (colored arrows and associated text inside the process cycle).*

through decision-theoretic approaches (eg Joseph *et al.* 2009). The second approach (ii) is an improvement, given that the cost of protection was accounted for, but alternative actions were not developed. In the third example (iii), which still used a threat map, alternative actions were explored; this allowed for more cost-effective evaluation of outcomes. In the final case (iv), explicit consideration of costs and actions using an SDM approach enabled cost-effective investment in multiple actions, without utilizing threat maps.

Threat maps may be useful in identifying actions linked to threats (eg deforestation maps might inform actions such as conserving forest regrowth, promoting revegetation of previously forested lands, or enacting legislation to protect remnant vegetation). However, as in objective setting, decision makers relying on threat maps solely to manage direct threats risk implementing actions that only reduce a particular threat (such as expanding the spatial extent of existing protected areas; WebPanel 2, ii). There could, however, be many threats to biodiversity that are not mitigated by this action (Mora and Sale 2011). Without considering portfolios of actions, constraints, and consequences, a threat-based approach could – perversely – prioritize management efforts in inappropriate (due to displaced, diffuse, or unstoppable threats) or impractical (due to political, social, or economic reasons) areas or in locations degraded to such an extent as to render those efforts ineffectual (Figure 4; Game *et al.* 2008). Similarly, mapping the cumulative threats within a landscape or seascape (eg Halpern *et al.* 2008) may help to illustrate where actions are needed but cannot show which action should be taken. Furthermore, maps of unstoppable threats (eg ocean warming from cli-

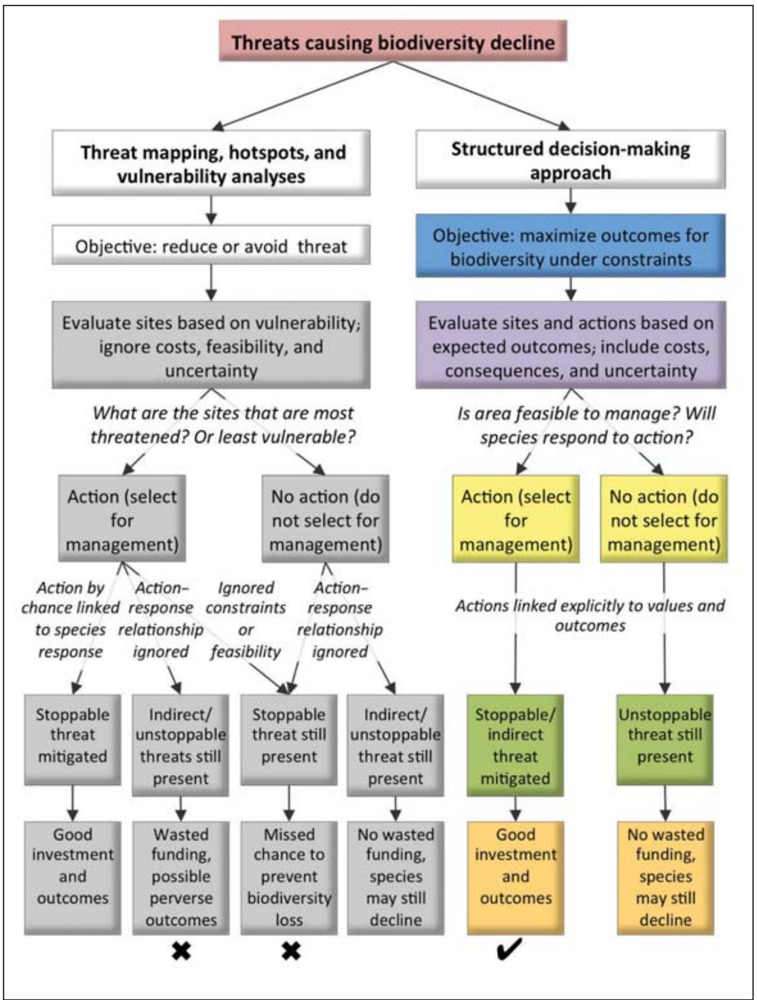


***Figure 4.*** *Simplified flowchart of decisions made with a threat-mapping focus as compared with an example of structured decision making (SDM, which may or may not integrate threat maps). The flowchart of threat mapping on the left demonstrates both the errors in decisions and the costs that might be incurred due to a focus on threats only (the "x" marks highlight the pathways and outcomes for our rhino example where "reduce poaching" was the objective), whereas using an SDM process (right side of the flowchart, colors matched to steps in Figure 3) allows decision makers to make informed investments and avoid wasted funding (the check mark highlights the pathway possible for our rhino example using SDM).*

mate change) are able to highlight only where direct action would be wasted (because local action cannot remove these threats; Figure 4); such maps should not be used to set priorities. By listing actions rather than threats, SDM automatically avoids addressing unstoppable threats and instead directs resources toward actions that encourage positive biodiversity or socioeconomic outcomes (Figure 4).

### *Step 3: estimate consequences*

Once Steps 1 and 2 have been completed, SDM practitioners must identify how outcomes contribute to the desired objective. This step requires understanding how biodiversity features and associated threats may respond to an action (including its spatial extent, intensity, frequency, or duration) but also understanding what would have happened in the absence of an action (ie estimating "additionality"; Maron *et al.* 2013). For biodiversity objectives, benefits are most often measured in terms of biodiversity outcomes (eg increases in population growth rate or population size); by way of comparison, economic-related benefits are measured in currency and threat-related benefits are measured in terms of how much the threat was mitigated.

The effectiveness of actions to ameliorate threats will vary. Although informing the likely outcome of inaction, threat maps fail to inform decision makers about the consequences of various actions. Without understanding consequences, decision makers cannot judge the relative benefits of implementing alternative actions. Indeed, threat maps might lead to threat mitigation in areas considered the most threatened rather than in areas where actions will be most effective. For the rhino example, linking population viability to the level of mitigated poaching allows decision makers to predict whether reductions in poaching might achieve a desired outcome, as compared with how new policies, such as legalized harvesting, might affect supply and demand (Biggs *et al.* 2013). Prioritizing rhino conservation in areas with the greatest number of known poachers may not lead to desired outcomes if the demand for horn has not declined.

Species' populations may respond positively, negatively, or neutrally – in terms of increasing, decreasing, or unchanged abundance – to certain threats and actions (Díaz *et al.* 2013). Most threat maps assume additive responses to multiple threats (eg Halpern *et al.* 2008); however, antagonistic or synergistic interactions and responses are possible (Brown *et al.* 2013). By choosing an ineffective management action, managers may squander limited funding (Walsh *et al.* 2012) while failing to understand why biodiversity continues to decline (see Figure 4). For example, establishing protected areas (WebPanel 2, ii) will not counteract species losses due to trophic effects of invasive animals (WebPanel 2, iii); this requires different management actions, such as introducing population control measures through intentional poison bait campaigns. Determining relationships – between threats and conservation actions, between actions and biodiversity outcomes, and between outcomes and money invested, as well as the links among these relations – is vital for selecting cost-effective actions (Carwardine *et al.* 2012).

A range of approaches can be used to describe the consequences of a conservation action (see examples in WebTable 2). These may or may not link spatially to the distributions of threats, depending on whether this information can be derived. Process models that describe biodiversity responses to management approaches (eg population models and viability analysis; WebTable 2; Possingham *et al.* 1993) are frequently used in SDM (eg Mitchell *et al.* 2013) but are more likely to be linked to species distributions rather than threats (eg Falcucci *et al.* 2009). Increasingly, return-on-investment thinking that uses empirical data on benefits and costs of actions (WebTable 2; Murdoch *et al.* 2007), or expert elicitation of the likelihood of successful management of species where empirical data are lacking (WebTable 2; Joseph *et al.* 2009), is used to predict consequences of alternative management actions (see also WebPanel 2, iv). After calculating the consequences of mitigation, it is more useful to target distributions of biodiversity than distributions of threats (eg Maggini *et al.* 2013). Predicting such consequences will ideally identify actions that would minimize the likelihood of extinction and clarify the mechanisms driving species responses.

### *Step 4: address uncertainty*

In threat management, uncertainty – our lack of knowledge about which species to protect and where – pervades every decision. The amount of information we are missing (parameter uncertainty), or the likelihood that our understanding of the system is incorrect (model uncertainty), may be difficult to quantify (Regan *et al.* 2005; Gregory *et al.* 2012). By explicitly accounting for the uncertainties pervasive in decision making, decision-theoretic approaches such as SDM make it possible to maximize the expected return in the face of uncertain parameters and models, or to minimize the consequences of the worst-case scenarios (Regan *et al.* 2005). Assigning a feasibility value to outcomes (to account for the likelihood of an action being successful), or a certainty weighting to expert-elicited data (to elucidate how confident we are in the information), allows further exploration of the risks of different decisions. Setting upper and lower bounds on parameters can highlight the best-case and worst-case scenarios rather than a single outcome. Failing to associate uncertainty bounds with the presence and intensity of threats to biodiversity prevents decision makers from comparing the expected return on alternative investments and essentially from making informed decisions (Wilson *et al.* 2006; Visconti *et al.* 2010). Although consideration of uncertainty is inherent in SDM (Figure 3), few threat-mapping prioritizations address this issue (however see Carvalho *et al.* 2011). If not explicitly incorporated in all stages of the mapping and decision-making process, uncertainty will increase costs as well as the probability of selecting an unsuccessful conservation action (Figure 4).

It is impossible to account for all the uncertainties associated with different threats; however, quantitative maps that link multiple threats with the probability of successful management (see WebTable 2) might allow evaluation of total management costs and an exploration of the distribution of effort required across a landscape (Auerbach *et al.* 2014). This directly links with Steps 2 (evaluating alternatives) and 5 (assessing trade-offs) of the SDM process (Figure 3).

### *Step 5: assess trade-offs and select decision*

To resolve conservation problems, SDM practitioners assess trade-offs between stated objectives to prioritize and ultimately select appropriate actions. The assessment process is iterative and must simultaneously consider costs, feasibility, and benefits (Wilson *et al.* 2010). Actions are then prioritized based on the likelihood of achieving multiple objectives, such as maximizing species abundance while minimizing costs (WebPanel 2, iii and iv). Threat maps alone are insufficient to account for trade-offs inherent in conservation decision making. For instance, referring to a threat map with additively combined information on individual threats would not allow decision makers to consider trade-offs that might exist between particular threats and their associated actions. By determining the consequences of all alternative actions rather than focusing on threats, decision-theoretic approaches (see WebTable 2 for examples) avoid this dilemma, as they allow for multiple solutions. By using an SDM framework it is possible to determine how to manage interacting species simultaneously; in cases where managing one species differentially affects other species, multiple objectives might be required (eg maximizing the persistence of one species while minimizing population losses for another; Díaz *et al.* 2013; Tulloch *et al.* 2013a). For highly migratory species, it may not be feasible to mitigate threats outside of managed areas that are characterized by different governance and political contexts (Nicol *et al.* 2013). Weighting values, consequences, and objectives helps assess trade-offs in multi-action decision making (eg Multiple Criteria Decision Analysis; WebTable 2; Walshe and Burgman 2010), and ensures that societal preferences or constraints are accommodated.

## ■ Threat maps are not a panacea: improvements to using threat maps for decision making

To ensure that decisions are made quickly and effectively and to avoid costly mistakes when prioritizing conservation efforts, we have shown how and when threat mapping might be applied in conservation decision making. By understanding the limitations of threat maps, decision makers can decide whether it is more important to learn about what is happening in a landscape (when threat maps are most useful) or to implement management actions (when threat maps are not always useful).

Several emerging decision-theoretic techniques for informing conservation decisions may account for threats and their inherent uncertainty without using fine-scale, spatially explicit data, as is the case in traditional single or additive threat maps (see examples in WebTable 2). If threat maps are to inform management decisions, spatially explicit response curves linking actions directly with threats could be useful; however, these are difficult to develop due to the high level of parameterization and resolution required (Kelly *et al.* 2012). Recently, population models have been coupled with species distribution models and threat distribution to investigate expected responses by populations to changing threats and likely actions (eg Regan *et al.* 2012). Alternatives to the conventional approach of additive threat mapping depend on the problem scale and constraints. Furthermore, the actions required will influence the analytic approach used to inform decision making: some management options will be a one-off action (eg buying land) and are relatively simple to solve through the use of systematic conservation planning and static threat maps, whereas other options will require ongoing action (and costs) and therefore represent more complex temporal approaches (eg managing disease spread using Markov Decision Processes) (WebTable 2; Chadès *et al.* 2011).

Although important, threat maps are insufficient for choosing which action to take in a given location. SDM can include the use of threat maps but also considers other factors vital for effective threat management. Given increasingly limited conservation funds, incorporating threat mapping into decision-theoretic frameworks will lead to improved management outcomes by accounting for uncertainty and species responses, in addition to the cost, feasibility, and consequences of actions. The use of an SDM framework to solve complex conservation problems will ensure not only transparency and accountability of decisions but also that actions are prioritized in locations where the best outcomes for biodiversity can be achieved.

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