Review

Strategic foresight: how planning for the unpredictable can improve environmental decision-making

Carly N. Cook[1,2], Sohail Inayatullah[3,4], Mark A. Burgman[2], William J. Sutherland[5], and Brendan A. Wintle[2]

[1] School of Biological Sciences, Monash University, Clayton, Victoria 3800, Australia
[2] School of Botany, University of Melbourne, Parkville, Victoria 3010, Australia
[3] Faculty of Arts and Social Sciences, University of the Sunshine Coast, Maroochydore DC, Queensland 4558, Australia
[4] Centre for Policing, Intelligence and Counter Terrorism, Faculty of Arts, Macquarie University, Sydney, New South Wales 2109, Australia
[5] Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, UK

Advanced warning of potential new opportunities and threats related to biodiversity allows decision-makers to act strategically to maximize benefits or minimize costs. Strategic foresight explores possible futures, their consequences for decisions, and the actions that promote more desirable futures. Foresight tools, such as horizon scanning and scenario planning, are increasingly used by governments and business for long-term strategic planning and capacity building. These tools are now being applied in ecology, although generally not as part of a comprehensive foresight strategy. We highlight several ways foresight could play a more significant role in environmental decisions by: monitoring existing problems, highlighting emerging threats, identifying promising new opportunities, testing the resilience of policies, and defining a research agenda.

Why should we think strategically about the future?

Environments globally face a range of existing challenges and it is inevitable that additional challenges will continue to emerge that add to this complexity. However, new opportunities will also arise that could benefit conservation. If decision-makers can identify forthcoming problems and opportunities they may react at the appropriate time to minimize damage or maximize benefits [1].

The value of early warning systems to recognize opportunities and emerging threats has long been recognized in warfare, business, and emergency preparedness [2]. Failing to identify emerging issues, such as introducing exotic species to supplement the fur trade and the global financial crisis, has had major negative impacts on the environment and society. Although most approaches to managing natural ecosystems are based on an understanding of ecological

Corresponding author: Cook, C.N. (carly.cook@monash.edu).
Keywords: alternative futures; conservation; causal layered analysis; conservation policy; decision-making; environmental futures; futures research; futures studies; strategic thinking.

0169-5347/
 http://dx.doi.org/10.1016/j.tree.2014.07.005

Glossary*

Backcasting: a tool for visualizing obstacles in achieving a goal and the steps needed to overcome those obstacles [16].
Black swans: unknown unknowns that can have large impacts on a system [21].
Causal layered analysis: a tool to expose hidden assumptions and help create a new narrative that facilitates the desired change [15].
Community of practice: a group of people who share knowledge about a particular field.
Delphi: an expert elicitation process to increase the accuracy of expert estimates through confidential voting over several rounds where participants can adapt their views based on the views of others [53].
Driver analysis: a tool for reviewing and assessing the most influential system drivers [27].
Emerging issues analysis: a tool to anticipate future developments by making connections between seemingly unrelated events [54].
Forecasting: predicting future conditions based on past trends.
Futures research: the academic discipline that includes strategic foresight.
Future studies: the academic discipline that includes strategic foresight.
Futures triangle: a tool to consider plausible futures based on past, present, and future drivers and trends [11].
Futures wheel: a structured brainstorming tool exploring the primary, secondary, and tertiary impacts of a trend or event [52].
Futurist: an expert in future studies.
Horizon scanning: a tool for collecting and organizing a wide array of information to identify emerging issues [14].
Issue-centered scanning: a tool for collecting and organizing a wide array of information to understand and track previously identified issues [14].
Issues tree: a tool to establish the logical sequence with which to address a question [27].
Modeling: using mathematical concepts to describe a system, study the effects of different components, and make predictions about system behavior.
Scanning: another name for horizon scanning.
Scenario analysis: used interchangeably with scenario planning or to describe the data analysis phase of a scenario planning exercise.
Scenario planning: a tool encompassing many different approaches to creating alternative visions of the future based on key uncertainties and trends [33].
Simulation: using a model to imitate the operation of a system over time to explore the effects of alternative conditions or actions.
Stakeholder analysis: a process to identify stakeholders with an interest in an issue [13].
Strategic foresight: a structured process for exploring alternative future states.
Visioning: a tool to envisage the most desirable future and a commitment to create that future [55].
Weak signals: the first indication of an impending change [20].

*More information about the foresight tools mentioned here can be found in the supplementary material online (Table S1), along with important references that describe the tools in more detail.

processes accumulated over time, forecasts generated from past conditions can be unreliable [3]. Human interference has altered the pace of environmental change, so historically derived perspectives may not represent an accurate guide for managing modified ecosystems, creating an incentive to develop forward-looking approaches [3]. Although managers can design surveillance systems to track known issues, they would also like to anticipate issues that would otherwise be genuine surprises that could destabilize systems [4]. There will still be genuine surprises (so called 'black swans'; see Glossary) that are unforeseen, but in reality most issues will be proceeded by some indicators (e.g., declining abundance of large herbivorous fish can indicate an impending abrupt shift from coral-dominated reef to algae-dominated reef [5]). The challenge is to reduce the number of foreseeable surprises. So how can we plan for an unknown future?

Strategic planning and foresight

Strategic planning systematically considers future conditions with the goal of ensuring current decisions are appropriate in the face of possible future challenges and opportunities [6]. It includes projection and forecasting (i.e., a quantitative process of extrapolating from the past to estimate future conditions), used by meteorologists to predict climatic conditions, and by ecologists to predict changes in populations [7]. Strategic planning also encompasses prevention and adaptation techniques (i.e., examining the consequences of present decisions through risk assessments), and exchange and dialog methods (i.e., stimulating creative discussion about future plans) [8,9]. Here, we focus on a form of strategic planning called strategic foresight, which is a shift away from being focused on forecasting a single future, toward an exploration of multiple alternative futures [6] (Box 1).

A robust strategic foresight process systematically considers a range of possible, probable, or desirable futures, the hidden assumptions that underlie these futures [10], their potential consequences for policies and decisions, and the actions that might promote more desirable futures. Strategic foresight attempts to prevent the past from unduly influencing how we think about the future, over medium or long-term (>25 years) planning horizons [6].

The academic discipline

The philosophy behind strategic foresight has existed since the 1950s and has grown into a multidisciplinary field. The World Futures Studies Federation (www.wfsf.org) recognizes 55 tertiary education institutions offering courses in strategic foresight, 16 academic (peer-reviewed) journals, seven popular magazines, and several academic societies and conferences (e.g., the Association of Professional Futurists).

Although strategic foresight has been widely adopted, there remains debate about the focus of the discipline. Foresight activities can be decision oriented (focusing on the processes needed to make good decisions) or question oriented (exploring possible decisions and their impacts over a specific time horizon). They can be normative (value-based exploration of desirable futures) or exploratory (open consideration of what is possible) [6]. These approaches are all considered valid, and can be combined to provide a robust foresight process. However, there remain deep divisions about whether foresight should be exclusive (conducted by experts alone) or inclusive (capturing the views of multiple stakeholders) and how to manage the influence of subjectivity within the process [11].

Box 1. Tools for thinking outside the box

An advantage of strategic foresight over alternative approaches to planning is that it facilitates the creative thinking integral to generating new ideas. Foresight shifts attention from one future to multiple possible futures [6]. Historical precedent can constrain thinking, whereas foresight encourages imaginative exploration of futures outside previous experience [8]. The past is not ignored but used to build a solid understanding of a system based on existing knowledge (Step 2; see Figure 1 in main text). This broad information base is often explored using traditional analytical tools (Step 3; see Figure 1 in main text). The influence of key uncertainties is investigated using tools such as simulation and futures wheel, promoting creative consideration of the primary, secondary, and tertiary impacts of trends or events [52]. When interpreting this information (Step 4; see Figure 1 in main text), the foresight process is designed to acknowledge assumptions that can bias how participants think about what is possible (e.g., scenario planning). Recognizing these limits helps participants to take a broader and more creative view of what the future may hold [33]. Scenario planning is an important tool for creative thinking because it encourages an exploration of how uncertainty in trends and events can lead to alternative and otherwise unforeseen futures [2].

Armed with a richer perspective on possible futures, the foresight process focuses on determining how to act to prevent undesirable futures and create the desired future (Step 5; see Figure 1 in main text). Backcasting is used to map a realistic path to a goal by shifting the focus from current conditions to a more distant future, allowing participants to envisage potentially radical change [56]. Breaking a problem down into smaller steps also helps counteract the view that challenges are insurmountable [57]. Single foresight tools can be valuable in promoting innovation but the full foresight process aims to turn this creativity into effective action.

Approaches to the practice of strategic foresight

Foresight processes can be structured in a variety of ways and use diverse tools [1,12] (Table 1), which has led to both confusion about what is actually involved and a tendency to use a single foresight tool, such as scenario planning (see below) and ignore the rest of the toolkit. Generally, strategic foresight involves six steps (Figure 1): (i) setting the scope; (ii) collecting inputs; (iii) analyzing the signals; (iv) interpreting information; (v) determining how to act; and (vi) implementing the outcomes. The objectives of any foresight process should be explicit and guide each of the steps outlined above. The choice of appropriate tools, and the skills and expertise required at each step, depends on the purpose of the exercise, whether that be identifying emerging issues or considering how future conditions might influence current and future decisions. The scoping stage often involves identifying key issues and who should be involved, at which point issues trees [1] and stakeholder analysis [13] can be useful. To identify important signals, information should be gathered from a wide range of sources, often drawing on tools such as horizon scanning (i.e., collecting and synthesizing diverse information to identify emerging issues), literature reviews and experts [1].

Review
Trends in Ecology & Evolution xxx xxxx, Vol. xxx, No. x

Table 1. The six steps of strategic foresight and how these steps relate to other descriptions of the process[a]

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Source
Setting the scope	Collecting inputs	Analyzing the signals	Interpreting the information	Determining how to act	Implementing the outcomes	As defined above: approaches to the practice of strategic foresight
Scoping	Gathering information	Spotting signals Watching trends	Making sense	Agreeing a response		Horizon Scanning Centre [27], [1]
Framing	Scanning	Forecasting	Visioning	Planning	Acting	[12]
Mapping	Anticipating	Timing	Deepening	Creating alternatives	Transforming	[58]

[a]The table contrasts the different ways in which the process of strategic foresight is described by different groups, relative to the approach outlined in Approaches to the practice of strategic foresight (above). The tools associated with each stage in the process are described in supplementary material online (Table S1).

Many foresight tools help analyze and interpret information (see the supplementary material online). Data-heavy exercises might include the use of statistical tools for identifying and modeling trends and highlighting uncertainties about the system that need to be considered. Horizon scanning [14] uses diverse information sources to anticipate future developments (Figure 2). Similarly, a range of inputs, including data and expert opinion, can be interpreted through scenario planning [2] and causal layered analysis [15] to integrate empirical and qualitative sources, expose hidden assumptions and critical uncertainties, and facilitate creative thought (Box 1). Once ideas about possible futures are clear, tools such as backcasting [16] can help generate strategies to overcome potential obstacles (Box 1). Step 6, implementing outcomes (i.e., taking action) is not always an explicit step in foresight

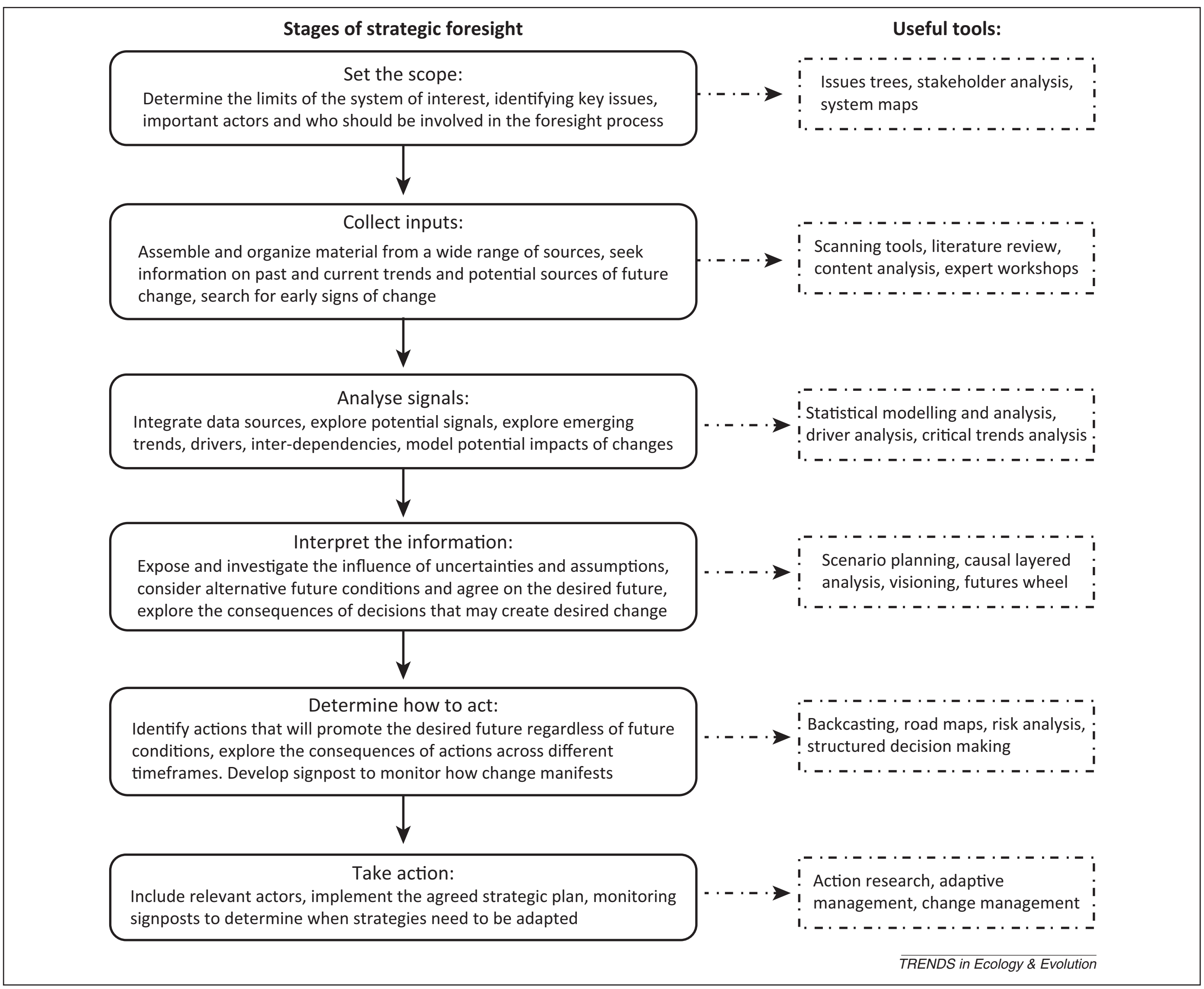

Figure 1. The six stages of the strategic foresight process and some of the many tools that can be used to assist at each stage. Descriptions of each of these tools and key references can be found in supplementary material online (Table S1).

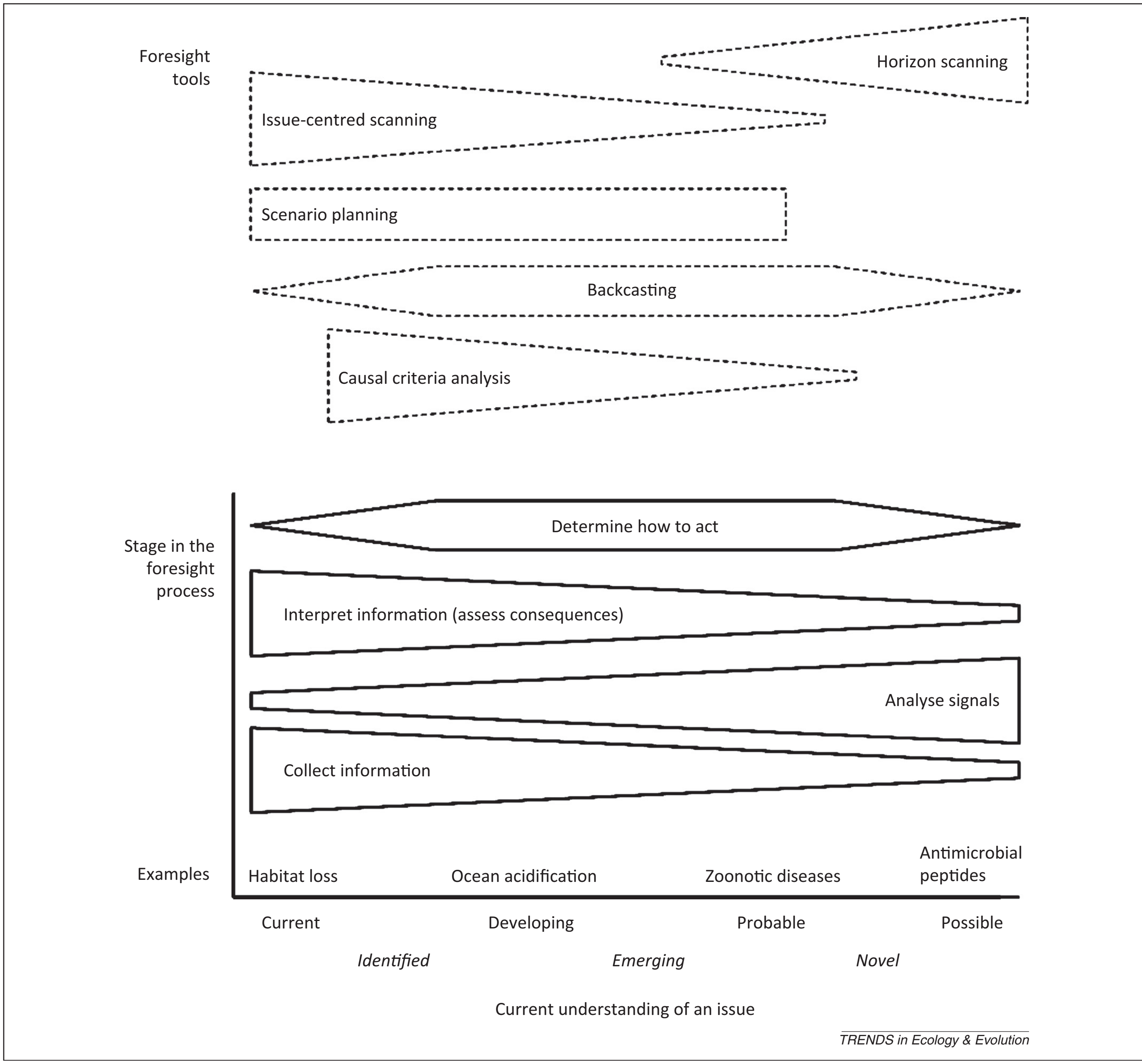

Figure 2. The continuum of our knowledge about potential issues and how this influences the choice of foresight tools and the emphasis placed on different stages in the foresight process. As understanding of potential issues changes from being considered only a possibility to being well understood, so does the choice of appropriate foresight tools (broken lines) and the emphasis placed on the different stages in the foresight process (unbroken lines) (see Table 1 in main text). When the focus is on identifying novel and emerging issues, horizon scanning can collect information and detect weak signals [1]. Issue-centered scanning is better suited to increasing our understanding and providing surveillance of identified and emerging issues in which assessing the consequences of issues and determining how to act is emphasized [14]. Scenario planning [33] is suited to structuring what we know about an issue while creatively exploring the consequences of issues that may develop under future circumstances and planning how to respond. Backcasting [57] is most useful when determining how to act on identified or anticipated issues, while causal criteria analysis helps interpret information and envisage a response to less well understood issues.

[12] (Table 1) but is a critical part of the process if the exercise is to influence the future.

Applications of strategic foresight

Strategic foresight is used by many organizations (Table 2) to examine the resilience of current policies to possible future conditions [17], identify unintended consequences of decisions [18], and develop actions that promote desirable futures [6]. Foresight is used by governments in Europe, North America, Australia, New Zealand, and Asia [17], in policy areas as diverse as defense, health, education, transport, biosecurity, and economics [14,17,19], to explore novel solutions to entrenched problems or emerging issues, such as new ways of dealing with organized crime (Table 2).

A popular use of strategic foresight is to anticipate future threats [17], detect weak signals [20], and identify potential surprise events (i.e., reduce the number of black swans [21]). Defense departments often use foresight methods for surveillance [17]. Reducing the frequency of black swans is appealing to social welfare planners and businesses seeking a competitive advantage [6]. Shell Oil famously used scenario planning (see below) to anticipate the impacts of significantly higher oil prices in the 1970s, providing a competitive advantage when the oil price rose

Review
Trends in Ecology & Evolution xxx xxxx, Vol. xxx, No. x

Table 2. Global examples of the use of strategic foresight in government and non-government organizations[a]

Organization	Use of strategic foresight	Refs
Organization for Economic Co-operation and Development (OECD)	Developed a toolkit to guide stakeholders in the use of foresight approaches, such as scenario planning, to improve educational outcomes by developing education strategies based on the needs of future generations	www.oecd.org/site/schoolingfortomorrowknowledgebase/[45]
Oxfam	Explored the links between enhancing democracy and eradicating poverty by examining possible futures of democracy and poverty	www.asiadialogue.org
United Nations Education, Scientific and Cultural Organization (UNESCO)	Considered the 'uses of the future' across culture, gender, and class, to see how different groups, the poor and rich, the weak and powerful, developed and developing, use the future in strategy and leadership development.	
International Center for Biosaline Agriculture	Anticipated new challenges in the futures of water and food, and in using visions to develop innovative policy and strategy, moving from a focus on water to one on vulnerable and marginal environments.	[59]
Interpol	Explored the alternative futures of policing and options for developing capacity throughout the world to 'get ahead' of crime, and move toward predictive policing, and the new threats and opportunities emerging from big data, genomics, gender equity, and the global harmonization of laws.	[60]
United Nations University Millennium Project	Produced the annual State of the Future report that lists the challenges and opportunities facing the world, with the goals of assessing change and using the future to create better policy today.	www.millennium-project.org/
Malaysian government	Guided policy development in all areas of government. For example, the Ministry of Higher education conducts workshops focused on ensuring that Malaysia creates an innovative model of higher education.	[61]
Singaporean Government	A nationwide horizon scanning network that uses causal layered analysis to analyze the data from its national conversation on alternative and preferred futures.	[62]

[a]Some of the ways strategic foresight has been used by organizations to address diverse and complex long-term strategic planning problems.

unexpectedly [22]. More than half of the Fortune 500 companies now use foresight to support strategic planning [23].

Despite many successes, there is a risk that strategic foresight exercises could be damaging to organizations if it leads them toward poor choices. At a minimum, foresight exercises that are not implemented waste time and resources that could be devoted to other activities. The challenge is to balance the effort allocated to current problems with the effort identifying and planning responses to issues that might not occur. Developing indicators to monitor change (Box 2) can enable the implementation phase of the foresight process to be adapted as the future unfolds.

Application of foresight to environmental problems

Traditional ecological research has identified many drivers and indicators of ecosystem change [24]. However, successful management requires integrating ecological, social, political, and economic factors [25]. Valuable ecosystem management tools could be developed by coupling existing knowledge with strategic foresight tools for collecting, analyzing, and interpreting relevant data, and planning when and how to act on emerging insights [24]. Some of the methods in Figure 1 may be familiar to ecologists (e.g., modeling, simulation, and Delphi), whereas others are less common in an ecological context (e.g., futures wheel, backcasting, and visioning). For environmental management problems, the two most commonly used foresight tools are horizon scanning and scenario planning. Generally, these tools are applied in isolation, rather than as part of a comprehensive strategic foresight process, although they often informally contain more than one step (e.g., Boxes 2 and 3).

Horizon scanning

As an effective metaphor for actively seeking information about the future, the term horizon scanning is used in many ways. Ecologists may be aware of the annual horizon scans of global conservation issues, reported in this journal [26] (Box 3). The term is also used to describe exercises that identify future priority research questions (e.g., the Scientific Committee on Antarctic Research – www.scar.org/horizonscanning) and as a synonym for the foresight process [27]. However, within the foresight literature horizon scanning is a tool for collecting and organizing diverse streams of information (Step 2; Figure 1) to identify emerging issues and to better understand issues already identified [14]. Once amassed, this information forms the basis of other steps in the foresight process, where different tools are used to analyze the signals, interpret the information and determine how to act (Figure 1). The breadth of the information collected and the use of experts (Box 3) and analysts (Box 4) to identify connections between seemingly unrelated pieces of information enables horizon scanning to identify emerging issues [28].

Scanning can be exploratory (generating hypotheses, seeking unknown unknowns – hereafter called horizon scanning) or issue centered (focused on issues previously identified – hereafter called issue-centered scanning) [14]. Horizon scanning is generally a one-off or annual scan, whereas issue-centered scanning tends to provide detailed exploration or continuous surveillance of specific topics. However, the two approaches to scanning occur along a

Box 2. Futures of the Wild

The Wildlife Conservation Society (WCS) established a Futures Group in 2004 to plan for the long-term future of the organization [63]. Although the Futures of the Wild exercise [63] was couched as scenario planning, it had many of the elements of strategic foresight and provides valuable lessons for organizations considering foresight to help prepare for future challenges.

The scope of the exercise was to consider how global dynamics and geopolitical, technological, economic, and environmental considerations might influence conservation strategies and activities. Inputs to the exercise were collected for predetermined elements (e.g., population growth) and important drivers of change (e.g., economic development) based on existing datasets [63]. This information was synthesized in white papers that discussed key sources of uncertainty about the future (e.g., the pace of change: slow and manageable or fast and disruptive). Participants were encouraged to think creatively about the scenarios by framing trends from the past 20 years in the context of uncertainty about the next 20 years. Scenarios were stories underpinned by data and analysis, embellished with creative details to illustrate key challenges and opportunities.

The process had several strengths, including support from senior management and a scenario planning expert with over 35 years of experience to guide the exercise. Staff members from across the organization participated, ensuring they developed ownership over the scenarios and could implement the outcomes. The process included the identification of indicators to monitor scenarios, and questions to help the organization consider how to respond to the outcomes [63]. However, the exercise did not assess which actions would be most effective across the different scenarios.

The exercise was considered a success because it helped staff consider the implications of alternative futures for the organization, which may have indirectly influenced the strategic direction of WCS. However, the indicators were not monitored, nor were the key questions formally considered (Kent Redford, personal communication), making it difficult to evaluate the impact of the exercise. Futures of the Wild was one of the earliest examples of scenario planning to guide conservation policy and it highlights the importance of the final stage of foresight (taking action) to ensure that the full benefits are realized.

continuum (Figure 2) and can be used sequentially to identify novel issues, explore those issues in more detail, and provide regular surveillance as part of routine management of a problem [14]. There is a trade-off between delaying action to improve confidence around an issue and losing the opportunity to act early. A related, but different trade-off involves balancing the risk of failing to act on a serious threat with that of spending resources on issues that may not eventuate [29]. Sequential use of horizon and issue-centered scanning can help manage these trade-offs by identifying novel issues that warrant further surveillance to identify early signs that action is justified [14].

The power of horizon scanning to identify novel threats or opportunities can be limited when the process or participant list limits consideration to issues for which sufficient information already exists to evaluate their significance [14,29]. For example, horizon scanning for emerging threats to biodiversity in the UK identified many issues that decision-makers were already aware of, although the exercise did increase their intention to act on some issues where resources were available [29]. This emphasizes the importance of building a broad information base and seeking analysts and participants with diverse backgrounds. There is also a need for a risk-based approach to selecting issues that are sufficiently well known to warrant immediate attention and those that require surveillance before determining whether to invest in action.

Box 3. Horizon scanning for global conservation issues

Annual horizon scanning exercises are conducted to identify emerging threats to biodiversity globally [26]. The approach utilizes the conceptual framework for strategic foresight [1] including Steps 1, 2, and 3 (see Figure 1 in main text), to identify issues while still close to the horizon (see Figure 2 in main text). Inputs are collected from a wide range of sources including experts (e.g., actively consulting over 369 people) and literature searches. The issues identified are analyzed at expert workshops akin to a Delphi approach, whereby the most significant 15–25 threats are selected via a confidential, iterative scoring process [64]. Some possible limitations of this approach include that the experts selected can heavily influence the results [14], making it important to draw on a wide range of individuals to capture issues currently unknown to conservation professionals. The global scope of the exercise may influence the issues identified by discounting issues with the potential to have significant local or regional consequences.

Horizon scanning is generally used during Step 2 in the foresight process, with the information collected then considered during the other four steps (see Figure 1 in main text). The later steps most relevant to decision-makers are not part of the horizon scanning process. However, there have been some high profile successes with a range of issues identified that have since become mainstream (e.g., high latitude volcanism and fracking). The exercise held in 2007 [65] identified many elements of the agenda that has since become mainstream, such as biofuels, synthetic biology, and large scale restoration. The main use by practitioners has been to identify which issues need consideration in the short term and which require surveillance [29].

Participant selection. The ability of horizon scanning to identify unacknowledged or unanticipated threats and opportunities can depend on the participants in the process. This is especially true for expert workshops (Box 3), where the diversity (e.g., different disciplines, professional and cultural backgrounds) and creativity of the participants in the process, and the degree to which the forum encourages those qualities, has the potential to significantly influence the outcome. Diverse participants in foresight exercises provide different knowledge, worldviews, and experience that often lead to more robust outcomes [30]. This is particularly important because perceptions about what is considered possible can be highly subjective, and including multiple participants can help to counteract this subjectivity [31]. More work is needed to understand fully the impact of the diversity of participants and their skills on the outcomes of strategic foresight exercises. Nevertheless, horizon scanning represents a major advance on planning approaches that consult few experts with highly specialized knowledge and rely on extrapolating recent trends.

Scanning for intelligence on existing threats. Although the aim of horizon scanning is to detect emerging issues, issue-centered scanning provides surveillance of relatively well-defined issues, using existing research to help interpret the signals detected [32]. Many issue-centered scanning systems search all open-source content on the Internet using web-crawlers (Box 4). Information gathered

Box 4. Scanning software

Software has been developed to efficiently accumulate intelligence around specific issues from a wide range of sources [28]. These tools use algorithms and structured search terms to identify relevant information from the huge volume of literature, news reports, social media (e.g., Twitter), databases, and blogs available online, although currently they cannot search audiovisual material [14]. Search terms should identify all relevant material without attracting too much irrelevant information, a considerably easier task for issue-centered scanning than horizon scanning. Searches can be refined over time based on a human review process that filters the information or by using automated systems that assign relevance to items [28]. Fully automated systems are relatively inexpensive, automatically translate sources, and alert users to important intelligence, but can benefit from a human review process to interpret information [28]. Non-automated systems can be better at identifying important signals but are more costly, requiring multiple experts to dilute individual biases [14].

Some scanning software uses a 'community of practice' to provide expert analysis [24]. HealthMap (www.healthmap.org), an issue-centered scanning tool, provides real-time intelligence of emerging infectious diseases, combining incidents of disease and information about the drivers of disease (e.g., encounters with wildlife) with data and analysis contributed by users (i.e., crowd-sourcing) [32]. This approach has reduced the average time taken to detect a disease outbreak [32]. Aquatic Animal Health (www.aquatic.animalhealth.org) is a tool for detecting aquatic animal diseases as part of the international IBIS disease network. The site uses the 'community' to refine search terms, provide analysis for systems reports, and forecasts disease outbreaks and trends [28].

Scanning tools can collect both official (e.g., media reports) and unofficial (e.g., social media) records, which provide more realistic estimates of the extent of poorly reported threats, such as illegal trade in wildlife [66] and invasive species [67]. Species and location specific information assist to identify trade routes and target protection activities [66]. An existing body of research can help identify weak signals, generate hypotheses and provide context for the data collected [28]. The disease detection scanning tool PREDICT uses pathogen physiology, routes of transmission, and information about disease behavior to contextualize information and identify signals [68] (Figure I). Likewise, Aquatic Animal Health collects information about aquaculture and fisheries to identify drivers of aquatic diseases and contain outbreaks by identifying specific threats [28].

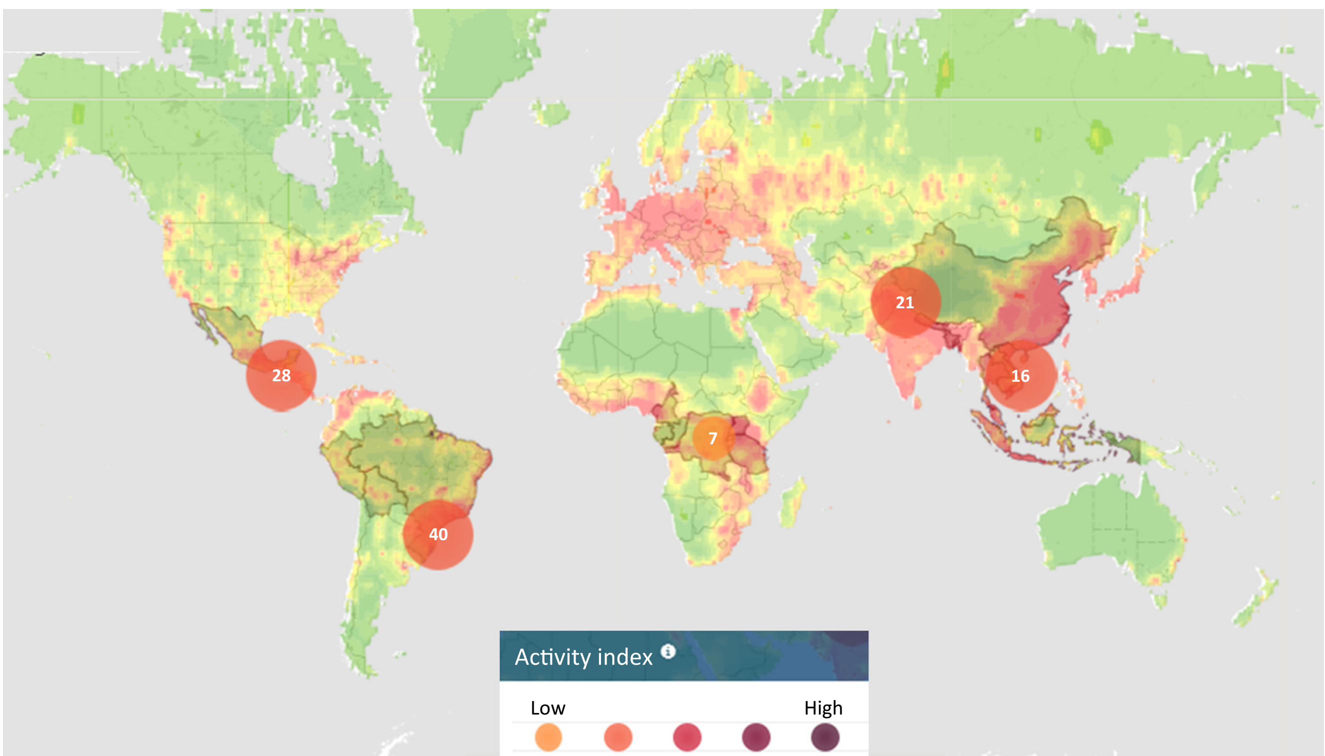

Figure I. A map of the world displaying incidents of infectious diseases captured by the PREDICT issue-centered scanning tool. The marker color reflects the noteworthiness of events at a particular location during the selected time window (22 April 2014 – 20 May 2014). The degree of noteworthiness of an event is based on the significance rating of the alert provided by HealthMap users. In the absence of user ratings, the system assigns a composite score based on the disease importance and the news volume associated with the alert. If the marker of a location has multiple alerts, the color associated with the most prominent alert is used. Only country-level alerts are shown on this map.

is filtered by knowledgeable individuals, often relying on a community of interested users to interpret information. Automated systems are currently less capable than humans at dealing with complexities [28], so expert analysis, with its inherent biases, is needed to combine disparate information sources [24]. Successful examples of issue-centered scanning systems exist in many disciplines (Box 4).

Scenario planning

Scenario planning is a foresight tool used to interpret information (Step 4; Figure 1), relying on a broad knowledge base and a clear understanding of system drivers and trends built up during the foresight process. It is a systematic method for thinking creatively about the dynamics of a system, which might generate different possible futures [33], and how different futures affect current decisions [2].

The process identifies and challenges assumptions about how a system behaves, moving beyond forecasting to create new perspectives [2]. Participants create multiple scenarios, rather than attempting to generate a single accurate prediction, allowing them to capture important elements of uncertainty [33]. Robust scenario planning involves developing a strategy or strategies that perform well across a broad range of scenarios, prior to deciding how to act and implementing the outcomes of the process (Steps 5 and 6; Figure 1).

Scenario planning can be purely qualitative, creating stories about how the future may evolve [2], or quantitative, using empirical models and simulations to explore uncertainty. Some applications combine qualitative and quantitative elements, underpinning narrative descriptions with quantitative models and expert knowledge [34]. The diversity of approaches and versatility of scenario planning make it useful for complex environmental problems, such as the climate change scenarios developed by the Intergovernmental Panel on Climate Change [34], which in turn inform ecological models of climate impacts [35]. The Millennium Ecosystem Assessment used scenarios to identify actions to improve the condition of the ecosystems of the world [30]. Scenario planning has also been applied to sustainable land use [36], water management [37], climate change adaptation [38] and forest management [39], and has proved useful partly because it considers the ecological, social, and economic aspects of the problem [33].

Scenario planning can add value to existing decision-making tools. Landscape-futures analysis [40] aims to inform landscape-scale decisions by considering the impact of different policy options under a range of possible future states. This approach combines conservation planning tools with scenario planning to incorporate spatial and other data sources [40].

Despite the potential value for decision-makers, scenario-planning exercises often fail to influence decisions when the objectives of the exercise are not clearly articulated [6] or built in to the broader planning process [41] (Box 2). The Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) is planning to develop scenarios of how global drivers of change will influence natural systems, along with policy-support tools to disseminate outputs to decision-makers (www.ipbes.net [42]). This process presents an opportunity to demonstrate the power of scenario planning within a broader foresight process by focusing data collection, modeling, and analysis on achieving maximum policy impact and robustness. For IPBES assessments to be policy-relevant a key challenge will be identifying shared visions and desired endpoints among diverse stakeholders at relevant geopolitical scales. Strategic foresight could make a useful contribution to facilitating this process.

Selecting the appropriate scale of a scenario-planning exercise is important. The Millennium Ecosystem Assessment influenced some international conventions, but lacked general impact because the scale was too coarse to be relevant to most decision-makers [43]. Alternatively, exercises can be focused on a local issue relevant to stakeholders, such as climate change adaptation within the Hudson River Valley, USA [44]. Including stakeholder groups in scenario development (i.e., participatory scenario planning) can provide robust scenarios by capturing more relevant social, political, and economic dimensions of a problem than expert analysis alone [30]. Participatory approaches need to balance the value of inclusivity for giving stakeholders sufficient ownership over the scenarios and potential actions developed, with the increased complexity, cost and time associated with participatory process [45]. Large exercises can become unwieldy and need to balance the views of different and sometimes competing groups. Stakeholder analysis can be valuable to identify relevant groups and ensure representation is not biased [13], but facilitators must be conscious of the potential for vested interests and entrenched views to constrain scenarios.

The future for the use of strategic foresight in environmental decisions

Strategic foresight could play a more significant role in guiding long-term planning for environmental decisions, including: (i) monitoring existing problems; (ii) highlighting emerging threats; (iii) identifying promising new opportunities; (iv) testing the resilience of policies; and (v) defining a research agenda.

Monitoring existing problems

Scanning software tools have been effective at gathering intelligence on diseases or illegal activities (Box 4), demonstrating the power of foresight tools for clearly defined problems. Forms of digital surveillance that rely on crowd-sourced information can also be used to monitor known but poorly documented phenomena, such as protected area downgrading (reduction in protection status), downsizing (reduction in size), and degazettement (removal of protection) (PADDD) [46]. The PADDDtracker surveillance tool (www.PADDDtracker.org) identifies affected protected areas to analyze patterns and drivers of change in protection and the consequences of changes for biodiversity conservation. Prioritizing what to monitor within a surveillance system should rely on clearly stated monitoring aims and a plan for how monitoring data will be used [4]. Ideally, the need for monitoring should be identified from a strategic foresight process (e.g., based on horizon scanning and scenario planning) that has systematically identified likely issues of future concern or opportunity that need careful surveillance in order to facilitate timely action.

Detecting emerging threats

By their nature, emerging threats are poorly documented, making them difficult to identify using scanning approaches that rely on conventional information sources available in the public domain [14]. The likelihood of early threat detection may be increased through the use of a comprehensive foresight approach, based on a range of different foresight methods (Table 1). The Australian Department of Agriculture uses foresight planning together with scanning software to detect new and emerging biosecurity threats. Department analysts using an issue-centered scanning tool detected an emerging threat to aquatic species in Australia. They intervened and eliminated the pathway for this hazard by requiring sterilization of secondhand aquaculture equipment [28]. This was made possible by monitoring a broad evidence base, including information related to known drivers of aquatic diseases. The knowledge needed to recognize emerging issues often already exists in other disciplines and knowledge domains. Strategic foresight can help unlock this knowledge by structuring the search for diverse streams of information, embracing expertise to highlight connections between seemingly unrelated pieces of information [28], and by forcing participants to make the assumptions and biases that may limit their ability to recognize relevant information explicit.

Identifying new opportunities

Foresight can be used to help recognize the technological advances that can revolutionize conservation science and management practices. For example, in molecular biology, amplifying and analyzing genetic sequences to estimate species diversity without specialist taxonomists has become routine and relatively inexpensive, allowing the detection of rare, cryptic, and invasive species in samples of biological material, soil, and water (e.g., environmental DNA or meta-barcoding) [47]. Applying similar technology to detect molecular signatures in environmental pollutants may soon make it possible to identify and prosecute environmental polluters [48]. It is not clear where the next big advance in environmental management may come from, but the sooner these opportunities are identified, the sooner their benefits can be realized.

Scanning software (Box 4) could be used to detect advances by searching the academic literature, blogs, forums, and other sources of information for speculation about new relevant tools. Similarly, new ideas may emerge from assembling experts from a wide range of disciplines to consider which knowledge or technology from elsewhere could help to solve environmental problems. Crowd-sourcing approaches could also be applied in this context, whereby specific challenges are proposed to a broad audience using design competitions (e.g., designing wildlife crossing structures; www.competition.arc-solutions.org) or games (e.g., the intelligence game; www.intelgame.acera.unimelb.edu.au). Engaging large numbers of non-specialists in this way has solved problems that have eluded scientist for decades [49].

Testing the effectiveness of policies under future conditions

Many current drivers of environmental change, such as climate change, will continue to operate in the future and existing stressors may become more important in ways that are not easily foreseeable. Decision-makers should therefore consider the likely consequences of present decisions under a range of future scenarios [17] and identify policies likely to be most effective under the broadest range of future conditions. For example, Fernandez [50] has demonstrated that failing to consider both socioeconomic and ecological factors when planning protected areas can create conflicts that undermine the success of these areas, whereas more positive social and ecological outcomes can be achieved by considering both factors *a priori* [51]. Futures wheel can be useful for considering the consequences of decisions. It is a structured approach to brainstorming the possible implications of a decision, first considering the direct (primary) consequences, and then any ripple effects to the secondary and tertiary consequences [52]. Applying foresight tools within existing conservation planning frameworks, such as landscape futures, also allows decision-makers to consider the potential effects of land management or policy options before they are implemented [40].

Defining a research agenda

An important part of the strategic foresight process is highlighting key knowledge gaps and uncertainties that need further exploration. Likewise, where emerging threats or opportunities are identified, these will require research to determine what, if any, action should be taken [29]. Embarking on strategic foresight is likely to help define a research agenda that generates new opportunities and helps shape future environmental management. It may help to define medium and long-term research priorities and identify policies that are robust to a range of possible future outcomes.

Concluding remarks

Decision-makers benefit from early warning of emerging threats, and timely recognition of opportunities to increase the effectiveness of conservation actions. Strategic foresight provides a diverse toolkit to help decision-makers structure attempts to think creatively about the future and make decisions that create a more desirable future. The flexibility in the diversity of tools available to support the strategic foresight process means that the details are crucial to success. Early applications of foresight methods to environmental problems have been relatively naïve, often using one tool in isolation or elements of established methodologies (e.g., horizon scanning and scenario planning). Therefore, some of the attempts to integrate strategic foresight into environmental decisions have failed to influence decision-makers, especially when implementation was not an explicit part of the process. Although social and political context can sometimes be an impediment to implementation, a rigorous foresight process that uses tools such as backcasting to help overcome resistance to taking action should yield better outcomes. It is encouraging to see the increasing recognition of the power of foresight tools, but it is important to ensure their application is based on a rigorous foresight process. Applying these lessons and utilizing specialists in the foresight discipline could maximize the value of strategic activities for environmental management.

Acknowledgments

This research was conducted with the support of funding from the Environmental Decisions Hub of the National Environment Research Program. BAW is supported by an ARC Future Fellowship. WJS is funded by Arcadia.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tree.2014.07.005.

References

1 Sutherland, W.J. and Woodroof, H.J. (2009) The need for environmental horizon scanning. *Trends Ecol. Evol.* 24, 523–527
2 Schoemaker, P.J.H. (1995) Scenario planning – a tool for strategic thinking. *Sloan Manag. Rev.* 36, 25–40
3 Carpenter, S.R. (2002) Ecological futures: building an ecology of the long now. *Ecology* 83, 2069–2083
4 Wintle, B.A. *et al.* (2010) Allocating monitoring effort in the face of unknown unknowns. *Ecol. Lett.* 13, 1325–1337
5 Nyström, M. *et al.* (2000) Coral reef disturbance and resilience in a human-dominated environment. *Trends Ecol. Evol.* 15, 413–417
6 Glenn, J.C. (2009) Introduction to the futures research methods series. In *Futures Research Methodology – Version 3.0* (Glenn, J.C. and Gordon, T.J., eds), The Millenium Project
7 Ma, S. and Seid, M. (2006) Using foresight methods to anticipate future threats: the case of disease management. *Health Care Manag. Rev.* 31, 270–279
8 Deshler, D. (1987) Techniques for generating futures perspectives. *New Dir. Adult Cont. Educ.* 1987, 79–92
9 Wollenberg, E. *et al.* (2000) Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests. *Landsc. Urban Plann.* 47, 65–77
10 Inayatullah, S. (2007) *Questioning the Future: Methods and Tools for Organizational and Societal Transformation*, Tamkang University Press
11 Inayatullah, S. (2006) Anticipatory action learning: theory and practice. *Futures* 38, 656–666
12 Hines, A. (2006) Strategic foresight: the state of the art. *Futurist* 40, 18–21
13 Reed, M.S. *et al.* (2009) Who's in and why? A typology of stakeholder analysis methods for natural resource management. *J. Environ. Manag.* 90, 1933–1949
14 Amanatidou, E. *et al.* (2012) On concepts and methods in horizon scanning: lessons from initiating policy dialogues on emerging issues. *Sci. Public Policy* 39, 208–221
15 Inayatullah, S. (2004) *The Causal Layered Analysis Reader: Theory and Case Studies of an Integrative and Transformative Methodology*, Tamkang University Press
16 Robinson, J. (2003) Future subjunctive: backcasting as social learning. *Futures* 35, 839–856
17 Van Rij, V. (2010) Joint horizon scanning: identifying common strategic choices and questions for knowledge. *Sci. Public Policy* 37, 7–18
18 Leigh, A. (2003) Thinking ahead: strategic foresight and government. *Aust. J. Public Admin.* 62, 3–10
19 King, D.A. and Thomas, S.M. (2007) Taking science out of the box – foresight recast. *Science* 316, 1701–1702
20 Hiltunen, E. (2008) The future sign and its three dimensions. *Futures* 40, 247–260
21 Taleb, N.N. (2007) *The Black Swan: The Impact of the Highly Improbable*, Random House
22 Wack, P. (1985) Scenarios: uncharted waters ahead. *Harv. Bus. Rev.* 63, 72–89
23 Schoemaker, P.J.H. (1993) Multiple scenario development: its conceptual and behavioral foundation. *Strat. Manag. J.* 14, 193–213
24 Galaz, V. *et al.* (2010) Can web crawlers revolutionize ecological monitoring? *Front. Ecol. Env.* 8, 99–104
25 Arlettaz, R. *et al.* (2010) From publications to public actions: when conservation biologists bridge the gap between research and implementation. *Bioscience* 60, 835–842
26 Sutherland, W.J. *et al.* (2014) Horizon scan of global conservation issues for 2014. *Trends Ecol. Evol.* 29, 15–22
27 Foresights' Horizon Scanning Centre (HSC) (2014) *Exploring the future: tools for strategic thinking*, The Government Office for Science (http://hsctoolkit.bis.gov.uk/index.htm)
28 Lyon, A. *et al.* (2013) Using internet intelligence to manage biosecurity risks: a case study for aquatic animal health. *Divers. Distrib.* 19, 640–650
29 Sutherland, W.J. *et al.* (2012) Enhancing the value of horizon scanning through collaborative review. *Oryx* 46, 368–374
30 Bengston, D.N. *et al.* (2012) Strengthening environmental foresight: potential contributions of futures research. *Ecol. Soc.* 17, 10
31 Kerr, N.L. and Tindale, R.S. (2004) Group performance and decision making. *Annu. Rev. Psychol.* 55, 623–655
32 Chan, E.H. *et al.* (2010) Global capacity for emerging infectious disease detection. *Proc. Natl. Acad. Sci. U.S.A.* 107, 21701–21706
33 Peterson, G.D. *et al.* (2003) Scenario planning: a tool for conservation in an uncertain world. *Conserv. Biol.* 17, 358–366
34 Carter, T.R. *et al.* (2007) New assessment methods and the characterisation of future conditions. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Parry, M.L. *et al.*, eds), pp. 133–171, Cambridge University Press
35 Pearson, R.G. and Dawson, T.P. (2003) Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? *Global Ecol. Biogeogr.* 12, 361–371
36 Kass, G.S. *et al.* (2011) Securing the future of the natural environment: using scenarios to anticipate challenges to biodiversity, landscapes and public engagement with nature. *J. Appl. Ecol.* 48, 1518–1526
37 Carter, J.G. and White, I. (2012) Environmental planning and management in an age of uncertainty: the case of the Water Framework Directive. *J. Environ. Manag.* 113, 228–236
38 Baron, J.S. *et al.* (2009) Options for national parks and reserves for adapting to climate change. *Environ. Manag.* 44, 1033–1042
39 Newton, A.C. *et al.* (2009) Toward integrated analysis of human impacts on forest biodiversity: lessons from Latin America. *Ecol. Soc.* 14
40 Bryan, B.A. *et al.* (2011) Landscape futures analysis: assessing the impacts of environmental targets under alternative spatial policy options and future scenarios. *Environ. Model. Software* 26, 83–91
41 Molitor, G.T.T. (2009) Scenarios: worth the effort? *J. Future Stud.* 13, 81–92
42 Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (2014) Initial scoping for the fast-track methodological assessment of scenarios and modelling of biodiversity and ecosystem services. http://www.ipbes.net/images/K1353373-en.pdf
43 Tallis, H.M. and Kareiva, P. (2006) Shaping global environmental decisions using socio-ecological models. *Trends Ecol. Evol.* 21, 562–568
44 The Nature Conservancy (TNC) (2009) *Rising Waters: Helping Hudson River Communities Adapt to Climate Change Scenario Planning 2010-2030 Final Report*, The Nature Conservancy Eastern New York Chapter
45 Iversen, J.S. (2005) Futures thinking methodologies – options relevant for 'Schooling for Tomorrow'. (www.oecd.org/site/schoolingfortomorrow knowledgebase/futuresthinking/scenarios/37246348.pdf)
46 Mascia, M.B. and Pailler, S. (2011) Protected area downgrading, downsizing, and degazettement (PADDD) and its conservation implications. *Conserv. Lett.* 4, 9–20
47 Taberlet, P. *et al.* (2012) Environmental DNA. *Mol. Ecol.* 21, 1789–1793
48 Ji, Y. *et al.* (2013) Reliable, verifiable and efficient monitoring of biodiversity via metabarcoding. *Ecol. Lett.* 16, 1245–1257
49 Schrope, M. (2013) Solving tough problems with games: online communities are using the power of play to solve complex research problems. *Proc. Natl. Acad. Sci. U.S.A.* 110, 7104–7106
50 Fernandez, P.R. (2007) Understanding relational politics in MPA governance in northeastern Iloilo, Philippines. *J. Coast. Res.* 23, 38–42
51 Porter-Bolland, L. *et al.* (2012) Community managed forests and forest protected areas: an assessment of their conservation effectiveness across the tropics. *For. Ecol. Manag.* 268, 6–17
52 Glenn, J.C. (2009) Futures wheel. In *Futures Research Methodology – Version 3.0* (Glenn, J.C. and Gordon, T.J., eds), The Millennium Project
53 Gordon, T.J. (2009) The Delphi method. In *Futures Research Methodology – Version 3.0* (Glenn, J.C. and Gordon, J.T., eds), The Millennium Project
54 Molitor, G.T.T. (2003) *The Power to Change the World*, Public Policy Forecasting
55 Groves, C.R. *et al.* (2002) Planning for biodiversity conservation: putting conservation science into practice. *Bioscience* 52, 499–512
56 Cinq-Mars, J. and Wiken, E. (2002) Using science, technology and innovation in support of conserving Canada's ecosystems and habitats. *Forestry Chronicle* 78, 133–136
57 Manning, A.D. *et al.* (2006) Stretch goals and backcasting: approaches for overcoming barriers to large-scale ecological restoration. *Restor. Ecol.* 14, 487–492
58 Inayatullah, S. (2013) Futures studies: theories and methods. In *There's a Future: Visions for a Better World* (Gutierrez Junquera, F., ed.), pp. 36–66, Banco Bilbao Vizcaya Argentaria Open Mind

59 Inayatullah, S. and Elouafi, I. (2014) The alternative futures of the International Centre for Biosaline Agriculture: from salinity research to greening the desert. *Foresight* (in press)
60 Inayatullah, S. (2013) The futures of policing: going beyond the thin blue line. *Futures* 49, 1–8
61 Inayatullah, S. (2012) Universities in Malaysia in transformation. *J. Future Stud.* 17, 111–124
62 Centre for Strategic Futures (2013) *Causal Layered Analysis Project: An Inter-agency Project to Explore the Socio-economic Aspirations of Singaporeans*, Office of the Prime Minister, Public Service Division, Government of Singapore
63 Wildlife Conservation Society (WCS) and Bio-Era (2007) *Futures of the Wild. A Project of the Wildlife Conservation Society's Futures Group*, Wildlife Conservation Society and Bio-Era
64 Sutherland, W.J. *et al.* (2011) Methods for collaboratively identifying research priorities and emerging issues in science and policy. *Methods Ecol. Evol.* 2, 238–247
65 Sutherland, W.J. *et al.* (2008) Future novel threats and opportunities facing UK biodiversity identified by horizon scanning. *J. Appl. Ecol.* 45, 821–833
66 Sonnericker Hansen, A.L. *et al.* (2012) Digital surveillance: a novel approach to monitoring the illegal wildlife trade. *PLoS ONE* 7, e51156
67 Suiter, K. and Sferrazza, S. (2007) Monitoring the sale and trafficking of invasive vertebrate species using automated internet search and surveillance tools. In *Managing Vertebrate Invasive Species: Proceedings of an International Symposium* (Witmer, G.W. *et al.*, eds), USDA/APHIS/WS, National Wildlife Research Center
68 Morse, S.S. *et al.* (2012) Prediction and prevention of the next pandemic zoonosis. *Lancet* 380, 1956–1965