CHAPTER 10

BENEFITING FROM COMPLEXITY THINKING

Principal authors:
Stephen F. McCool, Wayne A. Freimund and Charles Breen

Supporting authors:
Julia Gorricho, Jon Kohl and Harry Biggs

CONTENTS

IUCN WCPA WORLD COMMISSION ON PROTECTED AREAS Convention on Biological Diversity

PRINCIPAL AUTHORS

STEPHEN F. MCCOOL is Professor Emeritus in the Department of Society and Conservation at the University of Montana.

WAYNE A. FREIMUND is Arkwright Professor of Protected Area Studies and Chair of the Department of Society and Conservation at the University of Montana.

CHARLES BREEN is Fellow and Honorary Research Associate of the University of KwaZulu-Natal, South Africa.

SUPPORTING AUTHORS

JULIA GORRICHO is a PhD candidate at the Institute of Environmental Social Science and Geography, Albert-Ludwigs-Universität, Freiburg.

JON KOHL is Facilitating Coordinator of PUP Global Heritage Consortium.

HARRY BIGGS was program integrator, Adaptive Biodiversity Outcomes, with South African National Parks (SANParks), until he retired in 2014.

ACKNOWLEDGMENTS

The authors thank their many friends and colleagues for their inspiration over many years and challenging questions and observations about the complexity of social-ecological systems and their management. They also thank the reviewers for their keen observations and suggestions on making the chapter more readable and persuasive.

CITATION

McCool, S. F., Freimund, W. A. and Breen, C. (2015) 'Benefiting from complexity thinking', in G. L. Worboys, M. Lockwood, A. Kothari, S. Feary and I. Pulsford (eds) *Protected Area Governance and Management*, pp. 291–326, ANU Press, Canberra.

TITLE PAGE PHOTO

The symbolic intermixed complexity of an ancient rainforest tree's trunks, buttress roots and an accompanying liana, part of the Great Eastern Ranges corridor, Monga National Park, New South Wales, Australia
Source: Graeme L. Worboys

WCPA WORLD COMMISSION ON PROTECTED AREAS
BIOPAMA
UNEP WCMC
Australian National University PRESS
UNIVERSITY of TASMANIA
THE GREAT EASTERN RANGES connecting people...connecting nature

> The more we study the major problems of our time, the more we come to realise that they cannot be understood in isolation. They are systemic problems, which means they are interconnected and interdependent (Capra 1996:4).

Introduction

As our knowledge grows, technology advances, human populations increase and demands on our natural resources deepen and diversify, we realise that there is no longer an opportunity to avoid or ignore the complexity of protected area management, its governance and its role within the intersection of social-ecological systems. While we all engage complexity every day at a personal level, it is not a skill set that most of us are trained to use in a professional capacity. In fact, we spend considerable portions of our life learning how to simplify the overwhelming amount of information and complicated character of problems that come towards us in any given day. Small experiments that we conduct each day (known as trial and error) subtly guide us to the behaviours that will result in predictable outcomes. There are many ways in which we simplify our world and eventually those simplifications are instilled in us as habits. Those habits can actually inhibit the degree to which we learn, assimilate new information, adapt and perform as protected area managers.

In this chapter, we examine how our habits—which are functions of the mental models we discuss later in the chapter—can hinder our ability to sense change that is occurring around us in time for us to proactively and constructively attempt to influence that change. Sometimes these changes occur in large-scale societal shifts of perception that result in new pressures on governance systems. At other times they are more subtle and influence the way we interact with partners, colleagues, staff or community members. Still others are dramatic, visible and immediate. These changes come about because the complexity of the world is great, producing uncertainty and resulting in surprises for which our habits have ill prepared us.

In the following pages, we offer a way of thinking that views this complexity as an opportunity for benefit rather than as a source of overwhelming confusion. Systems thinking is the tool we use to first help us characterise complexity and then understand how we can simplify it when confronted. Systems thinking is a process by which we view a set of interrelated parts as a 'whole' rather than seeing them as unrelated components. By using this approach, we offer ways to recognise that in our simplifications we can still be strategic in understanding the changes occurring around us and how we can influence them both in governance and in management. Once we understand the basic characteristics of how a system operates, we can attempt to use its behaviour to our advantage and find places in that system where the resources we do have will result in the largest amount of influence. We benefit from this kind of thinking by building resilience into the social-ecological systems we manage and govern. We conclude by suggesting six practices to engage complexity that if used strategically will enable protected area managers to benefit from the complexity they engage with rather than being controlled by it. The key philosophical points in the chapter are outlined in Figure 10.1. We begin this journey by relating two stories of resource management and governance that we believe illustrate the importance of understanding complex systems.

Protecting the lowveld in South Africa

Historically, the low-lying land (lowveld) along the eastern border of South Africa was inhospitable. Malaria, trypanosomiasis, foot and mouth disease, horse sickness, swine fever and anthrax, among other diseases, largely protected the area from human influence and later from agricultural expansion that came with the settlers. These conditions made the establishment of the Kruger National Park (KNP) less contentious than it might otherwise have been. Together with concern for the loss of game that wandered out of the park in search of water and grazing during dry spells (Mabunda et al. 2003), these features provided justification for fencing the park to minimise the risk of transmission of animal diseases (Bengis et al. 2003). This was a policy decision that was to have many unforeseen and far-reaching consequences that would expose the inherent social-ecological complexity of the park.

Fencing prevented game animals accessing water in the wetter areas outside the park, particularly during droughts. And, as agriculture expanded, water was abstracted, reducing river flows through the park. The solution seemed so obvious and simple: force animals to become less dependent on water supply from outside the park by erecting dams and wind pumps to support wildlife during droughts. The architects of the policy believed it would ensure 'a healthy and productive environment which can accommodate long-term natural changes, is conducive to relative stability and which ensures population fluctuations of manageable proportions' (Pienaar 1983, cited in Gaylard et al. 2003:29).

Wildlife-proof boundary fence between Kruger National Park (left) and agricultural land

Source: Graeme L. Worboys

The first structures were built in 1933 after a dry spell and, by 1995, 365 boreholes and 50 earthen dams had been constructed (Gaylard et al. 2003). These changed the spatial pattern of water available to wildlife and set in motion a complex web of interactions that could not be predicted but which would have far-reaching implications for sustaining species diversity and heterogeneity in the park. Species such as water buck, zebra, wildebeest and impala that are usually found close to water could now live permanently in places that in the past could be used only during wet periods.

Herbivore populations increased, and grazing impacts became more homogeneous across the park, leaving little forage available during droughts. In short, the lowveld system was transformed from one in which natural forces dominated to one in which human influences moved the system from one developmental trajectory to another.

Crossing this threshold then led to a number of other concerns and impacts—none expected. Crowding around waterholes increased the opportunity for the spread of contagious disease and parasites between herbivores and carnivores (and among herbivores) (Bengis et al. 2003). The consequences became starkly evident during 1982–83 when drought resulted in herbivore population mortalities of 20–30 per cent in the park. In the neighbouring Klaserie Private Nature Reserve, which had a higher density of human-made water points, mortalities were estimated to be between 70 and 90 per cent (Bengis et al. 2003).

Fear of mortalities during droughts and increasing evidence of impact on vegetation around water points motivated yet another management response: culling during wet seasons (Freitag-Ronaldson and Foxcroft 2003). Elephants were one species targeted, and between 1966 and 2002, 16 666 were 'removed from the population' (Whyte et al. 2003:339), contributing to the emergence of strong political opposition to culling. In 1994, lobbying by animal-rights groups resulted in a moratorium being placed on further killing. A scientific assessment in 2006 concluded, among other things, that 'culling elephants alone may have ramifying

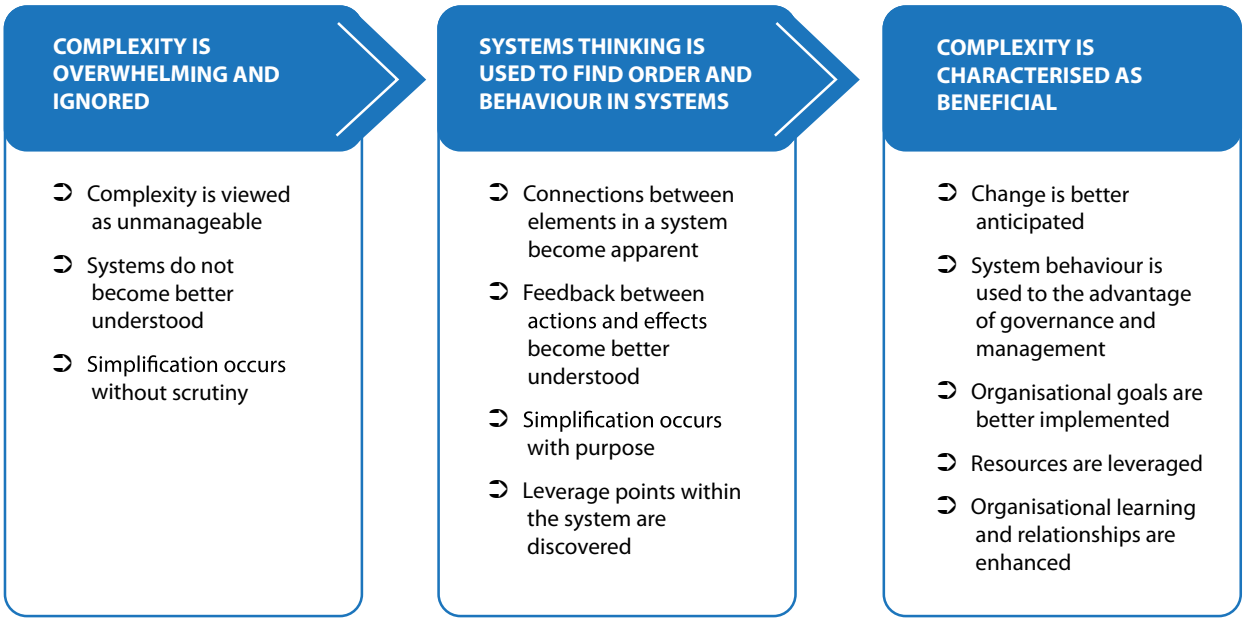


Figure 10.1 Key points in the chapter

White rhinoceros (*Ceratotherium simum*) and shallow constructed dam, Kruger National Park
Source: Graeme L. Worboys

African savannah elephant (*Loxodonta africana*), Kruger National Park
Source: Graeme L. Worboys

consequences' and that 'socio-political issues seem of more immediate concern than ecological ones, at least in the KNP' (Owen-Smith et al. 2006:393).

By simplifying and attempting to control the system, managers had actually made it more vulnerable to 'external' pressures and forces, thereby reducing its resilience. In 1997, the water-distribution policy was reversed (Pienaar et al. 1997): dams were breached and water points closed. Yet, the legacy lingers in appreciation for the social-ecological nature of protected areas, for their inherent connectedness, cross-scale interactions and complexity, and for the necessity of an adaptive approach to both management and governance.

Fire in the American west

On a turbulent summer afternoon in 1973, a thunderstorm spawned by a cold front advancing across the remote mountains of north-central Idaho in the United States produced a series of lightning strikes. One of those struck a conifer in the upper reaches of the White Cap Creek Drainage (in Fitz Creek), igniting a forest fire that eventually burned about 550 hectares of the Selway-Bitterroot Wilderness. In a historic reversal of a policy that had been in place since the 'Big Burn' of 1910, no firefighters descended on this fire, no shovels were lifted to throw dirt on flames and no slurry bombers were ordered to slow its advance.

The Big Burn took place over a period of two days in August 1910. It consumed 1.4 million hectares of forest in northern Idaho and western Montana, razing small towns and villages, scorching the earth with temperatures above 1000°C and killing at least 85 people. Following the Big Burn, the US Forest Service eventually adopted a policy of immediate suppression, calling for all wildland fires to be controlled by 10 am the day after their ignition. The agency was eminently successful in implementing this policy, with perhaps more than 98 per cent of all fires suppressed nearly immediately (Tidwell 2013). The new policy allowed the agency to monitor fires, allowing them to burn without interference in areas designated as wilderness under certain conditions.

If the Forest Service was so successful in achieving its goal of suppression and therefore prevention of damage, why did it change its policy in the early 1970s? Changing this '10 am' policy was not easy: many people—firefighters, scientists and managers within and outside the agency—fought the change, feeling that the risks of the new policy were not only great, but also largely unknown. So, why did it allow some wildland fires to burn? Was it a change in the natural environment? Or were changing knowledge, institutions and public preferences what led to this change?

The Forest Service policy towards management of wildland fire and South Africa's attempts at managing wildlife exemplify the content of this chapter. Institutions, public values and biophysical systems are in a state of constant change; uncertainty challenges managers of protected areas every day; surprises happen; knowledge is tentative; dynamic complexity permeates both the social and the biophysical worlds in which managers function; public values and meanings matter; and conflict confronts us at every juncture. With each choice a manager considers, risks—some known, many not—abound. Implementation leads to consequences that are both intended and unintended and may not be perceived for a long time. Six decades of fire suppression, for example, led to accumulation of fuels in forests where fire was a natural process, which science eventually acknowledged. Accumulated fuels, once ignited, caused fires to burn with greater intensity, increasing damage and accelerating suppression costs (wildland fire suppression costs in the United States now average close to US$2 billion per year). In short, the fire suppression policy led to more severe fires costing more to control.

And years of water point development led to not only increases in populations, but also their redistribution—consequences that were not anticipated. Attempts to simplify and control the system as another consequence led to other control-based actions, such as culling elephants, which resulted in international outcry, putting pressure on the South African Government to change its policy. Second and third-order effects across many scales were surprises to management, indicating how complex the system had become.

Engaging with this complexity using systems thinking, we argue in this chapter, allows managers to develop new and useful insights about the systems in which they function. Thinking and acting in complexity terms lead to strategies that retain their complexity and resilience, not to attempts to simplify and control.

Summary

The two examples reveal that social-ecological systems are inherently complex; that when we take governance action or make management decisions without understanding this complexity, surprises and unanticipated consequences frequently follow; that poorly informed responses to surprises inevitably lead to more problems, less resilience and to developmental trajectories that are more challenging to deal with. In this chapter, we suggest that when we understand and engage with this complexity, we become more aware of how effective our interventions and policies are, we develop better insights about the particular social-ecological system in which we function daily and use those new insights to make improved choices (Box 10.1). We also better recognise the risks associated with those choices.

We benefit from complexity thinking (the application of systems thinking to complex systems) by making systems more resilient, understanding the equity consequences of alternatives, and leave more options available for the future. Framing a protected area as a component of a social-ecological system helps deal with the inherent uncertainties facing managers that come from a variety of sources: 'Fundamental uncertainty is introduced both by our limited understanding of human and ecological processes, by the intrinsic indeterminism of complex dynamic systems (involving natural, human-made and human components), and by myriad of human choices and goals' (Gallopin et al. 2001:222).

Characterising complexity

> The search for simple—if not simpleminded—solutions to complex problems is a consequence of the inability to deal effectively with complexity (Ackoff 1999a:252).

If the world is so complex, uncertain and contentious, why are we still here? If we have survived this long, why would complexity thinking benefit us both personally and professionally? The fact of the matter is, we deal with complexity at the personal level almost subconsciously (and most of the time well enough to get by) using models and simplifications that work in most situations, but we are challenged to function at larger social and spatial scales. But as Capra suggested at the start of this chapter, we have begun to realise that the socially and politically challenging problems of the time are connected; we cannot solve them one at a time.

To work in a complex world, we must first strive to understand it. Once we understand this complexity, we can develop approaches and methods to simplify it so we can apply our understanding to governance and management. Underlying this understanding is description, which is what we focus on in this section. We describe the world in which we work and live using the concepts, terminology and ideas of systems thinking. We begin initially by addressing our own personal experience in dealing with complexity and then enlarge the scale of discussion.

While we all have patterns in our daily routine, we seldom know all of the specific events that will greet us each day. In fact, for most of us, it is our routine that we depend on each day to help us meet the unexpected events we encounter. The behavioural patterns associated with routine provide us with the simplification we need to be able to make decisions, allocate our time, prioritise our activities and negotiate the unexpected events we inevitably encounter.

In our hard working lives, we may not take the time to consider what was needed for us to develop our routines. We may consider that our good judgment, experience, intuition or intellect are what guide us in our actions. All of these features of our personality are important but, in fact, what we do on a regular basis is to simplify an overwhelmingly complex set of stimuli into a series of relevant and actionable meanings. One of the ways we simplify on a personal level is to stereotype (generalising the specific to the general) people, situations and events in ways that reflect and reinforce our previous experience and beliefs. We filter new information through those beliefs and decide whether we should accept or reject its meanings for us. Another way is to defer our judgment on a situation to someone we perceive to be more of an authority on the subject than ourselves. For example, we hire trained forest or protected area managers to take care of special and complex places.

Further, we develop institutional structures such as a protected area management agency to organise the system of protected areas into a broader and easily comprehendible collection of places, all with rules and processes to make life simpler and more predictable. Those institutions adopt rules for our behaviour within our protected areas so that we can comfortably navigate how to engage nature's places.

We need to be able to describe a protected area system in a way that promotes our understanding so that when we do simplify, we do so acknowledging the consequences of simplification. The language of systems thinking helps us describe complexity, dispel myths and eventually formulate models which simplify that complexity in ways that promote learning. This is all the more important, given the changing assumptions about the world (Box 10.1).

The myth of stability

A protected area—including linkages with other elements, the people and organisations who manage it and interact with it—can be conceived of as a ball in a basin, which is a metaphor presented by Walker and Salt (2006). The forces and couplings both external to the system and within it define its shape and depth. The basin describes the set of possible states that a social-ecological system may have and still retain its structure and function. At any given point in time, the system will be in a particular state (see Figure 10.2 for depictions of the basin), represented by the position of the ball in the basin. The basin's shape and depth indicate the range of variability that normally occurs, and as long as the ball remains within the basin, any potential conditions could be described as 'normal'. Thus, ecosystems are not static, but ever-changing.

Within a basin (where the system has essentially the same structure and function, and the same kinds of feedbacks), the ball tends to roll to the bottom. In systems terms, it tends towards some equilibrium state. In reality, this equilibrium is constantly changing due to changing external conditions; however, the ball will always be moving towards it. The net effect is that one never finds a system in equilibrium—that is, with the ball at the bottom of the basin. The shape of the basin is always changing as external conditions change and so is the position of the ball. So the system is always tracking a moving target and being pushed off course as it does so. From a resilience perspective, the question is how much change can occur in the basin and in the system's trajectory without the system leaving the basin.

Beyond some limit (the edge of the basin), there is a change in the feedbacks that drive the system's dynamics, and the system tends towards a different equilibrium. The system in this new basin has a different structure and function. The system is said to have crossed a threshold into a new basin of attraction—a new regime. These differences can have important consequences for society, so some basins of attraction are deemed 'desirable', while others are not.

And it is not just the state of the system (the position of the ball) in relation to the threshold that is important. If conditions cause the basin to get smaller, resilience declines, and the potential for the system to cross into a different basin of attraction becomes easier. It takes a progressively smaller disturbance to nudge the system over the threshold.

Box 10.1. Changes in assumptions about the character of social-ecological systems

Since primary school, most park managers have learned assumptions about the world long before they realised that there were other ways to understand change. The conventional view, consequently, still controls how they manage change in protected areas. But with the increasing complexity and accelerating change of civilisation, the older view no longer gets the job done. We could characterise the old and new perspectives as a clash between the PLUS and DICE world views. PLUS, named after the simple mathematical operation, stands for 'predictability, linearity, understandability and stability', and infuses almost all tools and processes used today in protected areas. Because our 10 000-year-old civilisation emerged during a relatively stable climate and amid slow change on cultural, social and environmental fronts, modern society holds strong faith in its ability to predict or foresee the future. Indeed for most recent anthropological history, the future has looked very much like the past. By assuming a predictable future, managers formulate management plans with five-year or 10-year planning horizons, during which they predict conditions and offer solutions to management challenges well into the future. Isaac Newton himself taught that if we have enough information about a bouncing ball's velocity, angle of approach, composition, and so on, we can calculate exactly where it will bounce. Similarly, planners assume that if they can generate enough information, they too can calculate the future likelihood of events.

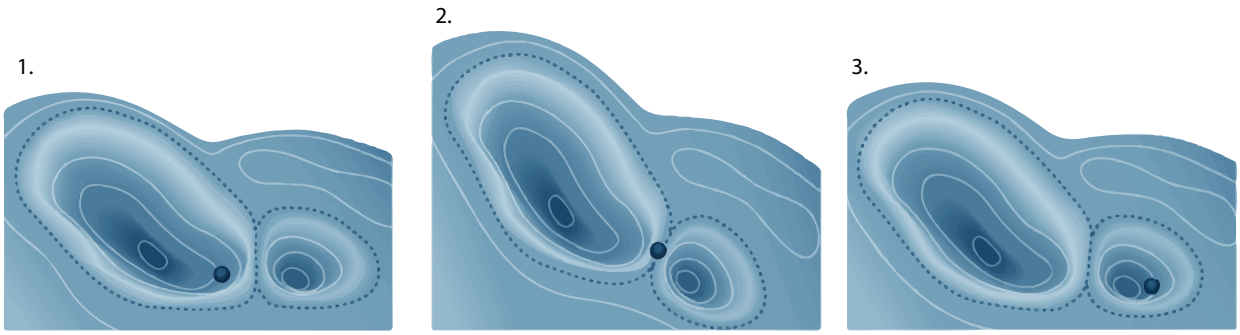
We are also taught very early about linearity, which assumes that the effect is proportional to the cause and that things occur closely in time and space. Many people, for example, assume that x amount of greenhouse gas emissions will produce x amount of warming, and when we start to truly see such warming, we can ease back on the gas and cool the planet in proportional fashion. Also, if we see a certain amount of poaching, managers must incrementally increase anti-poaching measures to mitigate the threat. Carrying capacity is the quintessential linear tool by which each additional person implies an incremental amount of additional impact: two people are twice as damaging as one. Further, managers need the world to be understandable. If they can comprehend the nature of a management problem—protecting an endangered species from a new virus—they can devise rational, quantitative solutions. Any limits to our understanding, the thought goes, must be attributable to a lack of money, time, personnel or information.

Predictability rests on stability. In the past, parents often expected conditions for their children to be largely the same as they were for themselves. As climate change, population growth, economic consumption, consciousness evolution and the Arab Spring show, moreover, forces of change continue to accelerate. Though management plans routinely extrapolate conditions at the time of planning into the future, the stability assumption grows risky in a world that increasingly boasts surprises. Since adherence to PLUS assumptions very often precipitates unimplemented plans, unyielding problems or problems that return after having been 'solved', many fields have promoted new theories: adaptive co-management, systems thinking, resilience thinking, organisational learning, high-resilience organising, limits of acceptable change, situational leadership, dialogue, holistic planning, mutual gains approach, integral theory, chaos theory, complexity theory, and evolutionary enlightenment. We can summarise these theories with the DICE world, a reference to the semi-random throwing of dice. This world view, in contrast with PLUS, is dynamic, impossible to completely understand, complex, and ever changing or evolving.

'Dynamic' refers to continuous change, activity or progress. A dynamic world undermines simplistic attempts to predict the future, such as estimating tourist arrivals, population growth curves and economic returns on investment. Of course the further into the future we look, the bigger are the risks of error. Dynamic worlds are nonlinear and dance to tunes of tipping points, thresholds and massive system changes.

In the DICE world, no matter how much information we have, we cannot completely know the future or even completely understand any problem. We can simplify complex social and ecological problems, but that does not make them simple. Things change too quickly and relationships prove too many to properly understand, so DICE means we need to decide with humility not overconfidence. 'Complexity' refers to an interconnected arrangement and interaction of parts, units, and so on, exhibiting behaviours that cannot be predicted by studying individual parts alone. Descartes showed us the power of reductionism for simpler questions, but for systems with lots of parts operating at different times, scales, places and objectives, the result should be awe not certainty. Last, the DICE world is ever changing and in many ways evolving to higher forms of self-organisation, interconnectivity and consciousness. To live in a DICE world means that managers need to be conscious of change, make decisions under stressful uncertainty, and learn apace with a world that will not stay still.

— Jon Kohl



1.

The ball is the state of the social–ecological system. The basin in which it is moving is the set of states which have the same kinds of functions and feedbacks. The dotted line is a threshold separating an alternate basin. In the alternate basin the system behaves differently (it has different function and feedbacks)

2.

A disturbance has pushed the ball over the threshold

3.

The above represents the system state having moved into an alternate basin, sometimes referred to as a regime shift

Figure 10.2 A system can be conceived of as a basin

Returning to the fire example, we see that the policy of fire suppression led to management interventions that changed the position of the ball (the state of the system) in the basin. As the system adapted to the absence of fire, it moved progressively towards the threshold of the basin and, had the practices persisted for long enough, it may have reached the threshold and overtopped the rim, passing into a basin characterised by the absence of fire. Had it done so, it would exhibit fundamentally different properties than in the previous 'basin'; however, the natural fire that was beyond our ability to control returned the ball to a state that was more consistent with the range of environmental variability to which it had adapted. This was complemented by a series of governance policy decisions relating to evolving unacceptable conditions, raising levels of risk from fire to both humans and their natural environment. While we cannot describe these actions as truly adaptive governance, they did recognise that thresholds were likely to be crossed without changes in policy, that a simplified fire environment threatened social-ecological systems and that uncertainty existed with respect to continued suppression. Under the revised policy and management practices, the ball is not being forced along a trajectory that takes it to the lip of the basin. The ability to retain system integrity—defined by Walker and Salt (2006) as the self-structuring capacity of systems) after disturbance (an imposed fire management regime)—is indicative of resilience.

Stability in the context of dynamic complexity, at both the personal and the larger scales, may be something we desire or seek, but complex systems are always changing because a shift in one element of that system affects others. This is particularly illustrated in the South African example, where placement of boreholes and dams shifted the distribution of animals, which then affected vegetation, but also increased the vulnerability of animal populations to drought. These social-ecological systems are complex, *adaptive* systems—that is, they respond to changes and processes and adjust to them by following a cycle of renewal and adaptation. In a very real sense, such systems show, more or less, the property of resilience. Resilience describes the ability of a system to retain its integrity and return to its developmental trajectory after disturbance (see Box 10.2 for further definitions).

Thus, stability is an impossible goal to achieve but resilience is something we most likely desire. Change is everywhere, and responding to it, as shown in Figure 10.2, requires different strategies, depending on the amount of change. Adaptation occurs when the system is subject to perturbations, but remains within the realm of natural variation—the basin in Figure 10.2. But at times and places, changes have been so dramatic that thresholds have been crossed and resulting conditions are untenable; in these situations, transformation to another or previous system is required. In the examples earlier, transformative processes were needed to return conditions to a more manageable situation. In both examples, governance systems were forced to act. In South Africa, governance was needed to direct management on the issue of elephant culling in response to untenable international relations. In the United States, Congress passes legislation and appropriates funding for treating hazardous fuels (by using fire and logging) near communities, thereby reducing risk of loss and fire intensity.

Box 10.2. What is resilience?

An oft-stated goal of managing complex social-ecological systems is to retain their resilience. But what is resilience? Walker et al. (2006:14) used this definition: 'resilience is the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity.' Folke et al. (2010:20) define resilience as '[t]he capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to change in order to maintain the same identity'.

Basically, what this means is the capacity of a social-ecological system to return to a previous developmental trajectory after being impacted by a perturbation or disturbance. For example, a typhoon may hit a small island country in the South Pacific, destroying transportation and other infrastructure, isolating the country for a while, and hindering efforts at poverty alleviation. A country that is resilient would be able to return to its previous developmental course without an irreversible impact to its former structure, function and feedback. Resilience does not necessarily mean returning to a pre-existing state. Systems are always changing, adapting and shifting in response to disturbances and ongoing processes. Retaining the system's ability to adapt is thus a major goal of the management of protected areas.

Sharing power and structuring decision-making processes are matters of governance that are key factors in building resilience, as is management. Adaptive governance requires devolution of some management decision-making authority to more local levels, engagement of multiple interests and sharing power among scales of policy (see Folke et al. 2005). Engagement of interests, the distribution of power and the structure of decision-making processes are also important elements in any characterisation of a complex system, as how they shift or remain the same influences relationships among elements of the system (see Chapter 7 for more discussion of how governance can facilitate resilience).

The direction and intensity of change are dictated by the nature of the relationships among the various system elements, and are subject to delays of varying lengths. Thus, in our daily lives, we interact at work with other individuals, with our interactions mediated through organisational rules and norms to produce plans and implement them. In a system, we cannot understand the function of parts without understanding their relation to other parts. If one of our co-workers takes ill and misses a meeting or an assignment, the effects on the whole depend on the co-worker's role and responsibility in the organisation and the nature of any specific task.

What makes a system complex?

A system deals with a 'whole' and as such the system has properties that occur as a whole or, as Jackson (2003:3) observes, '[s]imply defined, a system is a complex whole the functioning of which depends on its parts and the interactions between those parts'. So, an automobile may be defined as a system, with the motor, front door, transmission and electrical pieces as several of its components. Each component has a function that can be defined only in relation to other components. And in a system, the properties of the whole (the automobile) cannot be derived from the properties of the parts. For example, we cannot describe what an automobile does if we only have a rear bumper in hand. And when we change a part, we change the system. Properties of the whole are termed *emergent* properties. So, if one of us decides not to come to work one day (say she is ill), the resulting work product will be different.

What makes some systems complex is that the relationships, or cause–effect interaction, among at least some of the parts are nonlinearly dynamic—that is, a little change in one component may lead to a larger change in another component (or vice versa) or in the system as a whole. For example, a casual conversation about a waterfall along the Rio Carabinani in Brazil's Jau National Park could lead to a dramatic increase in visitors at the waterfall, particularly kayakers desiring a first descent of a river. This in turn would spawn a number of other impacts, ranging from increased visibility of visitor-induced biophysical impacts to greater expenditures by visitors leading to more jobs for local residents, and increased uncertainty as to the long-term social and political consequences resulting from visitor use. Thus, while we do enjoy the occasional day in which everything goes as planned, we are clearly outnumbered in the ways that uncertainty can be introduced into the systems in which we are embedded.

While our routines of thinking or behaviour may become resistant to change, they are based on a flawed assumption that the past will predict the future. Dispelling that myth is truly our only hope for building personal resilience in the face of continuous change. If we go beyond accepting the importance and inevitability of the unexpected, to embracing it, learning, introspection and professional effectiveness can be improved. We develop better insights about the particular social-ecological system in which we function and understand how those insights help us

Skukuza research and management centre, Kruger National Park, South Africa
Source: Graeme L. Worboys

make improved choices. Rigid governance structures, policies and bureaucracies thus do not work well in a world of change. National-level policies may lead to disruptive equity issues at the local level or may impact resilience, threatening vulnerable biodiversity or human communities.

We note here that components of systems may be either tightly or loosely coupled. In tightly coupled systems, effects of changes in one component touch those immediately downstream—that is, cause–effect relationships are more or less deterministic and effects occur after only short delays. For example, since access to a protected area is often tightly coupled with government policy and funding, changes may lead to catastrophic financial losses to local businesses dependent on tourism, as was demonstrated in October 2013 in a funding dispute between branches of the US Government, leading to the closure of national park units.

Loosely coupled systems are characterised by longer delays between causes and effects, multiple causes leading to the same effects, slow feedback times, the number of linkages between causes and consequences, spatial discontinuities between causes and effects, and so on (Weick 1976). For example, changing climate causes uncertainty about the distribution of vegetation in some protected areas, such as Mexico's Monarch Butterfly Biosphere Reserve, potentially threatening scarce and vulnerable winter habitat for the butterfly. Social-ecological systems show both tightly and loosely coupled connections, but implicit assumptions that such systems are narrowly and rigidly defined as consisting of tightly coupled relationships tend to dominate the planning discourse because of the compulsion to reduce complexity to something that is (illusorily) manageable. As a result, many 'fixes' (management actions) often fail, or actually make things worse (Senge 1990).

An individual subsystem follows its own trajectory of adaptation and renewal in response to so-called outside influences (Walker et al. 2004; Walker and Salt 2006). These trajectories can be significantly changed in response to human or naturally induced disturbances, such as withdrawal of water from a river for irrigation, development of new tourism facilities, introduction of new animal or plant species, a meteorological event or change in climatic regime. Importantly, these events are not treated as variables exogenous to the protected area system but as endogenous and thus subject to some kind of managerial influence or response.

Box 10.3 Navigating complexity in and around Kruger National Park

Beginning to think about complexity

Science–management collaboration helped form the early basis for South Africa's Kruger National Park (KNP) being considered a leader in benefiting from complexity thinking. A long tradition of science-informed decisions, coupled with democratisation of the country in 1994 and the insights resulting from an adaptive focus on river management in a unique program in and around the park during the 1990s, laid the foundation for later seeing the park as primarily embedded within a complex social-ecological system (Berkes et al. 2000). A variety of other factors, such as realising the benefits of reflection (Biggs et al. 2011), long-term interaction with resilience and complexity scholars (Walker and Salt 2012; Cilliers et al. 2013), collaboration and testing of adaptive management ideas in catchments supplying water to the park (Pollard et al. 2014) as well as incorporation of the park into a larger trans-frontier protected area (Cumming 2004) reinforced this trend. As a consequence, decisions became better informed and more systemically founded, as can be seen, for instance, in the elephant management debate (Scholes and Mennell 2008).

Strategic adaptive management as a response

Park scientists and managers responded to the growing recognition that the park was part of a social-ecological system by developing a strategic adaptive management (SAM) approach to decisions. SAM involves a variety of management innovations, including wide contextual scanning (with a strong emphasis on surfacing the various deeply held underlying beliefs), co-construction of a requisitely simple version (Stirzaker et al. 2010) of the key interacting drivers that influence the system and development of specific, quantifiable objectives, thresholds of change that trigger management action and the feedbacks that allow adaptation and ongoing learning and reflection at multiple nested levels.

With the impetus from KNP, SAM expanded to other national parks in South Africa (Roux and Foxcroft 2011), and in doing so pointed out the role of organisational culture (Stirzaker et al. 2011) in building interest and support. Implementation of SAM also influenced other aspects of resource management, such as South Africa's post-apartheid *National Water Act*, which, *inter alia*, helps address catchment management for the rivers feeding KNP. Social-ecological systems thinking and/or the adaptive planning process from SAM is used as the basis for these and other strategies such as the Animal Health for the Environment and Development (AHEAD) initiative (Cumming 2004) developed in response to the World Parks Congress and several other research initiatives operating in the region (Coetzee et al. 2012). Many of these initiatives have incorporated important dimensions from the complexity dialogue that provide the conceptual grounding for interventions in such dimensions as sustainable economic development and poverty alleviation.

What has been accomplished?

One of the key realisations from applying complexity thinking is that, first, there are no panaceas for problems arising in complex systems, and second, it takes time to infuse, and to obtain the visible impacts of, such an approach to management. It engages scientists, managers, consultants, funders, administrators and citizens to be more comfortable with variation in time, space and operating culture, and to use better thought-through and more trans-disciplinary interventions as learning platforms. There is some evidence of a more strongly shared systemic view by several key players, and many examples of individuals and groups seeing themselves as part of a linked picture. These attitudes, along with the explicit values elicited in SAM, may lead us to a more sustainable future, in which science plays an important but value-contextualised role, rather than trying to lead alone.

Where is this all headed?

Some of the most exciting advances informed by complexity thinking include using trans-disciplinary social learning dimensions for communities in the Olifants River Basin and adapting institutional arrangements to help partly integrate multiple similar development projects in the Kruger to Canyons Biosphere (Coetzee et al. 2012). Together with several of the other initiatives mentioned above and emergent ones using similar frameworks, we hope pragmatic enthusiasts in the region will continue to learn together. This would help them navigate and manage the complex social-ecological system in which KNP plays a critical role. We begin to feel the benefit of complexity thinking and of a more systemic orientation, not in rejection of alternative (sometimes more conventional) approaches, but in complementing these by providing an overall jointly constructed and more defensible basis for making decisions and managing. Because the systemic view is often new and sometimes perceived as threatening to some participants, it requires sufficient mediation and emphasis, and an overarching position in the broader overall approach. Our experience in doing so makes us modest but optimistic.

— Harry C. Biggs

Complexity and leadership

In contrast with the quest for control, stability and predictability, bring to your mind someone who you think is a very good leader or protected area manager. Chances are that person will have a good repertoire of technical skills, but sets themselves apart through their ability to anticipate and understand changing social and ecological conditions. They likely have highly effective social skills that include respecting, listening, learning and validating the value of a variety of opinions and knowledge. They anticipate emerging challenges or threats and inspire others to coalesce around a vision for addressing those challenges. They ask good questions and have built a considerable network of advisors that also benefits from their insights. They provide good advice about when and where to act and their advice often shows considerable, visible effect. In other words, they use certain skills to benefit from the complexity around them and better contribute to management. They are aware of their place in a system and its context. They do not see problems as simple. They pay close attention to operations and suggest actions that result in large returns relative to inputs of staffing or other resources. They accept and learn from failure. They draw on and contribute to networks of knowledge that are broad and often challenging. They invest in relationships, often giving more than they appear to receive, and above all, continuous learning is a part of their routine. Consciously or unconsciously, they benefit from complexity.

Understanding complexity requires an acceptance of the inherent connectedness of the systems in which we are embedded. It further requires skills in experimentation, constructive thinking, sensing our surroundings, learning and adaptation, copying good examples, responding to uncertainty, communication, building support systems and imagining potential futures. Those skills increase capability for managing social and material relationships and for finding increased meaning in our lives. While we use these skills frequently, too often we do so unconsciously and do not challenge ourselves to refine them or draw greater advantage and personal comfort from seemingly chaotic environments.

When we fail to apply these skills, we can fall into what Peter Senge (1990) refers to as organisational learning disabilities such as allowing ourselves to be defined by our job descriptions, blaming negative results of change on an 'enemy out there', fooling ourselves about how much control over situations we have or failing to see the larger patterns of change that are occurring due to a fixation on events. Use of panaceas may also be promoted when governance does not act adaptively.

Some tools for characterising complexity

Our ability to characterise complex systems and to respond to perturbations is directly impacted by the tools we use. A number of tools are available that help us understand the components and relationships that exist in complex systems, as well as what policies might be robust in the face of uncertain change. First, the Resilience Alliance (2010) has created a useful workbook for identifying and assessing the various components of a social-ecological system that may be under stress. The workbook covers system dynamics, cross-scale interactions and governance as well as guiding the user through a process to identify actions.

Second, one may choose to use scenario planning as a method of identifying potential future conditions or states and then testing what policies might be robust across them (Peterson et al. 2003). Scenario planning for conservation is useful in situations with high degrees of uncertainty and little 'controllability'. Developing and examining scenarios with the engagement of constituencies provide them opportunities to discuss, engage and learn about how various policies may function in different potential future conditions.

Note that we suggest the term constituency rather than the more frequently used 'stakeholder' to represent those who have an interest in a protected area. A constituency represents those who are served by an organisation or benefit from a protected area. Stakeholders are those who have an investment or share in some thing. The term constituency is preferred to stakeholder because it implies a broader diversity of individuals and values affected by a protected area. We believe the term constituency is not only more inclusive, but also more appropriate for systems thinking.

A third tool that may assist involves mind-mapping—a process for uncovering how people see the connections and variables involved in a particular problem or issue and that reveals the underlying mental models (see next section) influencing governance, policy and management. Mosimane et al. (2013) used mind-mapping to expose critical factors affecting human–wildlife conflict in Namibia, finding that some ministries which on the surface seem uninvolved have a great deal of influence on such conflicts.

Section summary

Through acknowledging the nature of complexity, we have taken the first step towards being able to benefit from that complexity. At this point in the chapter, we have illustrated the following.

- We manage and govern protected areas in a context that is best described as dynamic, impossible to completely understand, complex and ever changing: the DICE world. Thus, managers needing to be conscious of change make decisions under stressful uncertainty, and learn apace with a world that will not stay still.
- We must strive to understand this complex world and our own behaviour in the way we engage with it. Through this understanding, we will see patterns in how we tend to simplify complexity at our personal, professional and societal levels. Simplification, while important, needs to be strategic if we are to consciously benefit from complexity.
- Systems thinking frees us from the myth of stability and gives us tools for understanding how systems are organised and ever changing. Insights gained from examining change enable us to better understand the causes of change and better anticipate the emerging conditions of the future.
- Concepts such as resilience assist us in engaging with the complexity of the system we have an interest in.
- What makes some systems complex is that the relationships, or cause–effect interaction, among at least some of the parts are not linear: a little change in one component may lead to a larger change in another component (or vice versa) or in the system as a whole. Further, lag times between cause and effect can be long and can disguise the fundamental relationships that are influencing change.
- Leadership within a context of complexity requires an acceptance of the inherent connectedness of the systems in which we are embedded. It further requires skills in experimentation, constructive thinking, sensing our surroundings, learning and adaptation, copying good examples, responding to uncertainty, communication, building support systems and imagining potential futures. Effective leaders are often those who know how to benefit from the complexity they are immersed within.

Simplifying complexity

> Simplicity does not precede complexity, but follows it (Perlis 1982:8).

If systems are so complex—and complicated—how is it possible not only to make our lives easier, but also to benefit from the insights that complexity thinking provides? If we recognise a system as complex, how do we function without overwhelming ourselves? In short, we simplify. But we simplify based on an understanding of the complex systems with which we engage. This is what we mean by getting to the other side of complexity. We engage that complexity by focusing on a few key variables, processes and relationships through the application of systems thinking. Gharajedaghi (2011:335) argues that '[s]ystems thinking is the art of simplifying complexity. It is about seeing through chaos. We see the world as increasingly more complex and chaotic because we use inadequate concepts to explain it. When we understand something, we no longer see it as chaotic or complex.'

We simplify the inherent complexity of a system to be able to better conceptualise, communicate about, understand and act on a forthcoming decision. When you think about it, we actually defer a great deal of our decision-making to experts, clergy, celebrities, institutions, family and friends or community leaders, scientists, biologists, planners, and so on. This process of simplifying the complexity of our world is remarkably effective and often reinforces our decisions quite positively—for example, the physician's recommendation worked. As we discussed with the myth of stability, there is a downside to our quest for a simplified, predictable and stable life. While simplification is necessary for us to function effectively, it comes with a risk that we assume predictability for which there may be little justification. When this occurs we are often surprised by events that we have not anticipated. Our stereotypes can be very counterproductive—for example, racism and sexism. Thus, it is highly valuable to build a contemplation of complexity into our routines so that we can better anticipate change and become more strategic in how we handle disruptions to our routine.

Models as methods of simplification

In applying systems thinking, we construct a *model* of our environment. A model is a simplified representation of the real world, the system in which we operate,

be it our household, community, transportation infrastructure, biophysical system or a large protected area. Models come in several forms: as ideas connecting one system component with another through some kind of relationship; as equations that predict an outcome from one or more variables or system components; or as figures depicting system components connected by relationships and feedback loops. What model we choose to represent any particular system is influenced by our own knowledge and needs, the importance of a particular system, the resources and capacities we have at our disposal, and the risks and consequences involved in choosing alternative approaches.

In developing a model, we are often confronted with the question of what to include in the model that represents a system. Donella Meadows (2008:97) argues that '[w]here to draw a boundary around a system *depends on the questions* we want to ask' (emphasis added). So in a very real sense, the protected area may be involved in a variety of systems, and thus there is no 'correct' or 'right' system depiction for governance and management of a protected area system. As a result, multiple mental models of the same system often abound, which result from different questions being sought and from the varying perspectives of protected area constituencies.

One fundamental purpose of modelling is to develop insights to create situational awareness. Endsley (2000:4) defines situational awareness as 'knowing what is going on around you'. A variety of factors affects situational awareness: experience, background, training, personal and organisational mental models and the context within which a planner, manager or constituency may be functioning. Each factor influences what cues are perceived, how they are interpreted and what meanings are assigned. For example, managing elephants in Kruger National Park in South Africa is now driven as much by animal-rights beliefs as by the ecology and reproductive character of elephant populations. Providing good stewardship of the Great Barrier Reef World Heritage Area in Australia requires as much understanding about human uses, values and preferences as it does about the relationship among reefs, rivers and currents.

How a manager or constituency describes a particular situation—what contextual variables are operative, what legal, policy and political factors are salient—influences the process used in framing problems and making decisions (Endsley 1995). The characterisation of a situation, developed through sense-making and awareness-building, is determined by mental models. Mental models are the 'internal representations of external reality that people use to interact with the world around them' (Jones et al. 2011:1). These mental models simplify our perceptions of how real-world systems behave (Nkhata and McCool 2012) and have a great influence on what things we attend to. Such simplified models are needed for humans to function effectively in a world of complexity—and many have been developed out of successful past experience.

The test of an appropriate model is its usefulness in making sense, building situational awareness, and enhancing learning and choosing among alternatives. In the systems in which protected areas are found, models will need to reflect the dynamic complexity, turbulence and contentiousness of those systems in order for managers to work effectively. While all models will always be wrong (Sterman 2002) in the sense that they are simplistic representations of reality, they will be more or less useful in the sense of the learning they stimulate (Box and Draper 1987). Thus, the test of an adequate model will be how well it furthers learning.

Constructing and adapting models are processes embedded in daily human life—done well in many cases, leading to unanticipated challenges in others. As the scale of the system grows, however, model-building becomes more difficult and needs to be more explicit, even if only in our own minds. The benefit of modelling a system, when we do it explicitly, lies not so much in the outcomes from using the model, but rather in the fact that it enhances and accelerates learning about the system we are modelling (Sterman 2002).

Protected areas as a component of a complex social-ecological model

Given the growing recognition of protected areas as a component of a complex social-ecological system, it is quite clear that more explicit models are needed for more effective management and governance. We state this because of rising conflicts, a growing diversity of expectations, increasing dependency on protected areas to preserve natural heritage and mounting hopes that they will become an important tool for raising incomes and alleviating poverty in nearby communities. Various constituencies may each carry their own mental models, which may appear to have little in common with one another.

Protected areas exist as one component of a social-ecological system nested within a larger social-ecological system, which can be succinctly stated as civil society and its interactions with the biophysical environment. For example, elephant management in KNP is now situated within a larger debate about animal rights,

vegetation dynamics and human–wildlife conflicts. Elephant management is influenced by society's perceptions and valuation of elephants perhaps more so than by scientific descriptions of their ecology. Society is the larger 'cloud' within which protected areas (including their governance and management) are embedded. As values, preferences and needs change in this cloud, the meanings, and thus management, of protected areas unfold as well.

The conceptualisation of a protected area as a component of a complex social-ecological system is distinctly different from the common conception that it is a geographical area defined by a visible and politically defined boundary, although permeable, which is assumed to be relatively independent of activities and processes occurring outside it. Because protected areas are established by society, they are systems embedded within larger systems that influence and impact the protected area, with systems within the protected area often impacting those outside it.

There are many ways to model and graphically characterise a social-ecological system. We choose to use a model prepared by Anderies et al. (2004) as it is one that matches our mental model of such systems and probably that of many protected area managers as well. In the following, we work through this model, discussing and exemplifying its applicability to protected areas.

The term social-ecological system denotes a social subsystem in which human interactions are mediated through connections (tightly or loosely coupled) with the ecological subsystem. Whereas the ecological subsystem refers to an interdependent system of organisms or biophysical units (at varying spatial scales), the social subsystem represents interdependent human relationships that develop at varying temporal, spatial and social-organisational scales. The social-ecological system consists of multiple subsystems that are embedded in multiple larger systems. Although both ecological and social systems comprise subsystems that appear independent of each other, each affects and is affected by other systems through coupled relationships.

The system depicted in Figure 10.3 consists of: a) the resource (in this case, a protected area—the values contained within it and the stock and flow of materials and biophysical-based processes) and the meanings attached to it by various constituencies; b) resource users (constituencies, such as visitors, tourism providers, companies that extract commodities and materials, residents who access the area for medicinal plants or fish, communities which use water flowing out of the protected area, groups who value various aspects of the environment—such as wildlife—and so on) who hold expectations and articulate demands for both what values are to be protected and how decisions about management are to be made; c) infrastructure providers

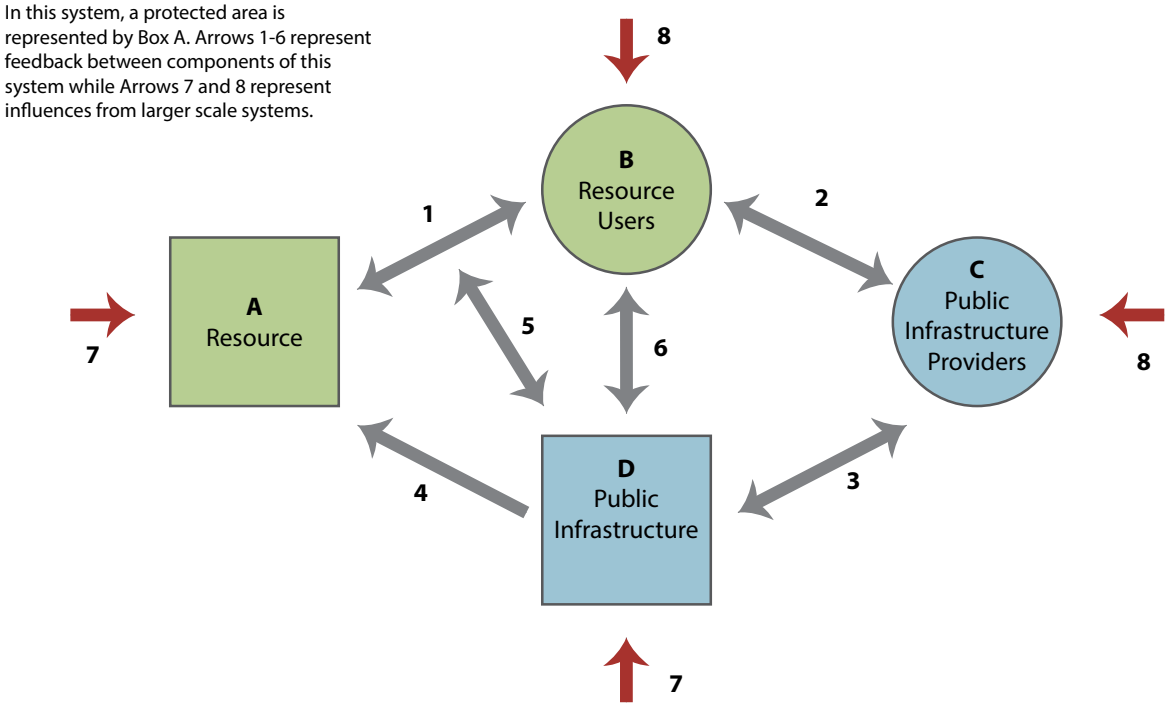


Figure 10.3 A simplified representation of a complex social-ecological system

Source: Adapted from Anderies et al. (2004:18)

(the protected area organisation and its staff and in many cases other land management or regulatory agencies, non-governmental organisations, laws and governmental policies about the environment, decision-making and governance); and d) public infrastructure (facilities, roads, policies that guide management, access, and decision-making processes).

The components of the system are coupled and exist at varying temporal and organisational scales. US Forest Service (public infrastructure provider) fire management policy changed over very long time scales (half a century and more) in response to enhanced knowledge about the effects of fire suppression on fuel accumulation, particularly in low-elevation dry forests that, previous to aggressive suppression, had burned relatively frequently with low intensity. Because the very definition of a system means coupling of components, changes in one component—for example, infrastructure provider policy established by some governance mechanism—impact other components, but there may be significant temporal delays or impacts could occur in another location. The successful implementation of the White Cap Creek fire management policy, for example, led to hundreds more decisions in many other places about letting naturally ignited fires in wilderness burn without interference. Another example is that a decision in Brazil by the central government prohibiting fishing in national parks impacts one group of resource users: local people living along a river.

On the other hand, drilling boreholes in KNP was built upon assumptions of control and simplification—assumptions that proved invalid at longer time scales. As the consequences of this policy became more apparent, occurring concurrently with a change in governance structure at the national level, management goals shifted to building resilience rather than controlling for stability.

Because the system is a nested hierarchy, changes occurring in the larger social-ecological system impact on processes and conditions at smaller scales and vice versa. For example, increased scientific knowledge about the role of fire in western North American forested ecosystems coupled with passage of the *Wilderness Act* in 1964 (which stated that a wilderness is to remain 'untrammelled', meaning that the wild character of natural processes was not to be interfered with) led to significant changes in attitudes towards naturalness and natural processes not only among the public (resource users), but also within the agencies (infrastructure providers). Changes in both interacted, leading to new demands, mental models, policies and management actions.

Positive and negative feedbacks (arrows 1–6 in Figure 10.3) among the subsystems shape the structure and function of a social-ecological system. The strength, coupling and character of these feedback loops are what make the four components a system. Changes in one component—for example, fire management policy—inevitably lead to changes in the other three components, often through a variety of feedback mechanisms with varying delays. As we noted earlier, the delay between the aggressive suppression policy implemented following the Big Burn and the accumulation of fuels in dry forests was measured in decades. The delay between noticing this accumulation, reflecting upon it, developing policy in response and implementing that policy was also lengthy. Such delays reflect knowledge differentials among resource users and infrastructure providers, delays in transferring knowledge from one to the other, ongoing resistance to framing fire in wildland settings as a beneficial process, and bureaucratic processes involved in assessing the consequences of framing fire in new ways.

The ecological subsystem interacts with the social subsystem through flows of information, energy and matter. The meanings that various resource users (constituencies) place on these form an important component of this process. For example, a large part of the debate about elephant culling in southern Africa has been influenced by shifting values and beliefs about elephants among constituencies living outside that region. And in the north-western United States in the 1990s, people opposed to timber harvesting commonly characterised old-growth forests as 'ancient forests' to build support opposing harvesting.

The social-ecological system in Figure 10.3 is susceptible to various inputs, as we have alluded to previously: biophysical (arrow 7) and in public infrastructure and socioeconomic conditions (arrow 8). These inputs may, however, be treated as disturbances or exogenous forces when our mental model is one of a smaller system. When including the cloud (society in general, for example), they are not disturbances but simply processes that exist at larger scales. This point is illustrated explicitly in Box 10.4, which uses the insights from complexity thinking to describe the apparently chaotic situation in Macarena National Park in Colombia.

Resource users or constituencies hold varying values and perspectives. These values and perspectives themselves are influenced by processes and forces occurring in the contextualising social-ecological system, such as demand for cocaine emanating in North America in the Macarena National Park case study, in shifts in attitudes toward animals occurring in Europe and elsewhere in the case

Box 10.4. Complexity and conflict in Macarena National Park, Colombia

The Sierra de la Macarena National Park covers 6200 square kilometres of ecologically unique territory in which the flora and fauna of the Amazon, Orinoco and Andes regions meet. Located in south-central Colombia, it boasts a large diversity of ecosystems and vast environmental resources, which are crucial for carbon sequestration and freshwater supply to massive subcontinental basins such as the Amazon. Due to its strategic geographic location, the Macarena mountain range has been at the heart of Colombia's armed conflict and illicit drug economy.

In the 1980s, Colombia's security situation deteriorated sharply with the emergence of large-scale illicit production and trafficking of cocaine, influenced greatly by drug demand emanating in other parts of the world. Powerful trafficking organisations and extreme right-wing paramilitary groups appeared, which led to violence and war with the conventional government. With time, all of Colombia's non-state armed groups became deeply involved in the illegal drug business (Pécaut 2001; ICG 2002, 2008). Macarena became the site of illicit drug production and military contest between these groups and government armed forces. The monetary income from this illicit economy attracted large numbers of landless settlers to the region.

The Colombian state has historically had only a small or no presence in the region. The Revolutionary Armed Forces of Colombia (FARC: Fuerzas Armadas Revolucionarias de Colombia) exploited this institutional weakness by building a 'virtual state within a state' (de Shazo et al. 2009), controlling the area and providing new physical infrastructure (such as roads, schools and health centres) and social infrastructure (such as rules for natural resources management and conservation), both of which have been incompatible with the national park's mission, thus showing the interests of different governance scales. Unregulated construction of makeshift roads especially has impacted on the unique ecosystems through fragmentation. While the FARC-controlled roads encouraged more colonisation around and inside Macarena, law enforcement by park rangers was almost impossible. Fishing in the rivers surrounding the park and wildlife hunting were regulated by FARC through 'gunpoint conservation' (Álvarez 2003), which included the use of banned antipersonnel mines and curfews. Consequently, the park is today one of Colombia's protected areas with the largest number of planted landmines.

The National Park Service of Colombia faced the daunting task of developing effective management strategies for this protected area. How could this be achieved? The first step consisted of understanding the different components and relationships of this particular social-ecological system. This exercise, carried out in a 2002 evaluation, revealed that many of the challenges and threats Macarena was facing were linked to the broader conflict and political context.

It became clear that a range of complex issues related to national security and transnational drug trafficking impacted on the dynamics around Macarena's natural resources, their users and the different stakeholders providing infrastructure. This situation required a new intervention model that would be different from the way Colombia's national parks had been managed thus far—that is, as independent and isolated units. Rather, the National Park Service of Colombia needed to use the power of networks and reach out to other sectors of the government and civil society to look for joint solutions. This was facilitated through the establishment of a governance arrangement bringing together different state institutions and civil society organisations.

The role played by Colombian National Parks in this endeavour was crucial. First, having been among the few government institutions with a continuous presence in the region, its work was perceived by people in Macarena, including FARC, as neutral and trustworthy. This leverage point was essential to empower local settler organisations by encouraging their active participation, which was important in and of itself in a setting characterised by violence and armed conflict.

Second, Colombian National Parks emphasised the importance of environmental management of the territory, advocating, for instance, for a comprehensive approach to relocating settlers outside the park. A major thrust was to identify areas where the relocation of these families would not have a negative ecological impact. Interventions were also needed to provide people with much needed infrastructure, such as legal access to land and productive activities. This required coordination between a range of central, regional and local government institutions, including the Ministry of Agriculture, the agency in charge of rural development, the Ministry of Defence and local municipalities.

There have been many challenges. Fundamentally, Colombian National Parks has been overstretched by this broadening of its fundamental conservation mission. Although it was not its responsibility to secure access to land, housing and alternative livelihoods for families living in the park, its leadership was crucial for coordinating with other agencies. It has done this, however, without appropriate funding and has been challenged with trying to exert leadership without risking damage to its good reputation among local communities.

These interventions sent a strong message that colonisation of land in the park would not be tolerated. At the national level, Colombian National Parks took a lead in adopting a planning approach to protected areas management involving a range of central and regional government entities. This has called attention to the need for a broader definition of *conservation* than simply management of biodiversity in a complex social-ecological system characterised by weak institutions.

— Julia Gorricho

of elephant management in southern Africa, or in rising expectations of indigenous peoples in Brazil's Amazon for greater autonomy in conservation governance.

Understanding these demands, the constituencies expressing them and how they evolve over time requires 'sensing' mechanisms that monitor changes in the social and political contexts. It means that managers interact with constituencies on a regular basis both consciously and unconsciously (Pimbert and Pretty 1995). Sensing changes in constituency preferences and values has been difficult in the past because some constituencies (such as indigenous peoples, minorities and women) were given few opportunities to have a voice or to be heard in some societies. Also, conventional models of planning and decision-making privilege scientific and technical knowledge over experiential sources (see, for example, Yankelovich 1991 and his discussion about the 'culture of technical control'). New models of governance (developing in the larger social-ecological system) require organisations to advance and manage networks to attend to relationships, listen and respond to a wider variety of voices, and at times become more than biodiversity conservation agencies.

Constituencies act to maintain or change policies developed and implemented by infrastructure providers. In Kruger National Park, for example, animal-rights constituencies exerted influence not only on the SANParks organisation to change its elephant culling policy but also on the larger South African Government. Constituencies also lobby parliaments for funding programs that will benefit their interests.

We always simplify. But making our simplification explicit helps us ask if we really understand what the system is and why it works the way it does (Ackoff 1999b). To provide useful insights, models then must be built upon knowledge of how something works—the characterisation of a complex system. Once we have knowledge and understanding, we can engage with the complexity we face every day.

Let us also consider that no matter how hard we try to simplify 'our' system, we are always connected to other people, each of whom will be constructing a different simplification as they try to make sense of their world. They engage with it differently and apply their personal forms of simplification to understanding it. They will have their own stereotypes operating to filter new information. As a result there are multiple meanings associated with any given situation, and information that challenges rather than reinforces a particular belief is likely to be contested when they collide in resolving competing demands.

We seek authorities such as scientists, spiritual leaders and those with more experience to simplify situations for us, to construct governance that reflects our understanding of how the system is structured and functions. We may want to copy the approaches other professionals have used or offer as best management practices. Within these contested settings, some voices will be louder than others and some may have more real power than others—for example, political or financial voices. We may fall into our own routines of understanding and learning and fail to hear important voices because we do not appreciate the legitimacy of their authority. We may also fail to anticipate change, recognise how contexts are developing or appreciate the loosely coupled nature of causes and consequences. Inversely, we may become so convinced that we can direct change that we take too long to accommodate it. In sum, while we are trying to solve problems in a contested and complex environment, we are likely to be contributing to new problems that may not emerge in obvious ways. In other words, we may be doing our job well but are not providing needed leadership for something as complex as managing and governing protected areas.

Section summary

After we acknowledge the complexity and character of the system, we can quickly see how to go about simplifying complexity into a set of meanings and practices that are manageable. Some of the common methods we use to make sense of the world can lead to oversimplification or be driven by the intensity of issues or voices that emanate from a small portion of the system. In this section, we analysed common practices used to constructively simplify systems. Insights that emerge from that process are as follows.

- When we understand something, it no longer seems as complex.
- We simplify the inherent complexity of a system to be able to better conceptualise, communicate about, understand and act on a forthcoming decision.
- While simplification is necessary for us to function effectively, it comes with a risk that we assume predictability for which there may be little justification. When we focus on prediction rather than understanding, we are often surprised by events that we have not anticipated.
- In applying systems thinking, we construct a model of our environment based on our understanding of linkages, components and contextual influences. A model is a simplified representation of the real world and the system in which we operate.

- Models connect one system component with another through some kind of relationship. What model we choose to represent any particular system is influenced by our own knowledge and needs, the importance of a particular system, the resources and capacities we have at our disposal, and the risks and consequences involved in choosing alternative pathways.
- A model should help you describe and bound your system, as well as help you find leverage points among the relationships within it. Leverage points are those places within the system where a small amount of change can lead to larger changes in other parts of the system.
- Modelling assists us in developing insights to create situational awareness, which is a key practice for benefiting from complexity. When you know where and how to look, it is much easier to know what is going on around you.
- The mental models within us are how we make sense of the external reality with which we interact. These mental models simplify our perceptions of the real world and have a great influence on what things we attend to and of which we are aware.
- Numerous models are available to help us understand the system properties and relationships inherent in the management and governance of protected areas. These models help us see the broader picture of the complex social-ecological system we are operating within. Seeing how the system works, we are able to assess our own mental models and processes for simplification relative to a broader context. This assessment provides a check and balance on our own decision-making, ensuring that we have not oversimplified a situation or are only listening to the voices emanating from one part of the system.

Engaging complexity

> Human beings, viewed as behaving systems, are quite simple. The apparent complexity of our behavior over time is largely a reflection of the complexity of the environment in which we find ourselves (Simon 1996:110).

How can we avoid the dangers of simplification and put ourselves in the position of engaging complexity effectively? Sterman (2002:504) cautions us that we also need to get away from 'the narrow, event-oriented, reductionist world view most people live by' if we are to be successful in governing and managing protected areas. In other words, we must simplify to understand, but not 'oversimplify', which would repeat the ineffective approaches of the past to complex problems.

Acting in the complex world of protected area governance and management requires that we engage the complexity we have characterised and modelled. Engaging complexity requires wisdom that has been developed out of the knowledge and understanding created through characterising and simplifying complexity. Wisdom, Ackoff (1999b:16) stated, is the 'ability to perceive and evaluate the long run consequences of behavior'. In this section, we discuss six 'complexity practices' that we believe build wisdom while enhancing governance and management when viewed through the lenses of complexity and systems thinking. The practices are not limited to the resource providers; we would recommend all constituencies deploy them.

1. Building situational awareness

Being a keen observer of the situation

Managers operate in an era of change, uncertainty and surprise. Our strategy for functioning in this context is to heighten awareness so that we sense the unexpected early and prepare to manage in ways that help sustain resilience (Weick and Sutcliffe 2001). In other words, managers who have well-developed situational awareness make continuous adjustments that prevent errors from accumulating and enlarging (Weick and Sutcliffe 2001).

One does not have to spend long among animals in the wild to appreciate the evolutionary significance of situational awareness for both animals and humans. Perhaps what separates humans from most other animals is our ability to reflect on and consciously fabricate situational awareness. We are able to create rules that order behaviour, making it easier for us to interpret and respond to what we observe so that we can better cope with the complexity that attends our lives. For example, driving in city traffic has been made more predictable through the development and enforcement of rules that guide behaviour. Road users learn what to expect, the signals to look out for and how to respond, transforming potentially chaotic situations into ones that are ordered, consistent, more predictable and less confusing. The rules 'simplify' complexity and reduce uncertainty, allowing us to build situational awareness appropriate to the context. When we arrive at work, although the context changes, we are guided by other rules and signals. For example, in a meeting, we pay close attention to body language or tone of voice in order to plan how and when to respond to emerging issues; we reflect on previous experiences

with participants to interpret their responses and guide our behaviour. When we set out to consciously build situational awareness, we better draw on lessons from past experiences, shape our response to the present and plan for the future.

How do we build situational awareness skills?

A first step is to appreciate how situational awareness plays a determinative role in our daily activities and that because we live in a changing world, awareness is largely a consequence of how we gather information, reflect and learn. Because the 'rules of the game' we adopt as we progress through life can be so effective in simplifying complexity, we easily become insensitive, perhaps even resistant, to signs and information that do not accord with current preferences and understanding. When this happens surprises become more frequent and may reach serious levels before we become willing to acknowledge them. So, we have to change our habits, consciously building and sustaining learning relationships, characterising the system, modelling it and encouraging acceptance of complexity. Rather than feeling threatened by different understandings people hold of system structure, function and change, we should view them as learning opportunities. Because of the uncertainty that is associated with complex, changing systems, we cannot expect ideas or understandings to be clearly expressed; we have to be patient, inquisitive and encouraging if new shared understandings are to emerge and provide a foundation for collaboration and collective action appropriate to the emerging conditions.

The history of protected areas has its origin in strong conviction of the need to protect natural heritage. Not surprisingly, early approaches to governance of many national parks fostered a culture characterised by protection, exclusion and control, often with a passion that polarised citizenry and management. This culture helped define the context in which governance was exercised, establishing orderliness in roles and routines that simplified complexity and provided a filter for information; information that conformed was accepted and that which did not was rejected. This made the system, and more particularly the people in it, resistant and slow to change. Paul Cilliers (2008) drew attention to the need for 'enduring structures' if a complex system is to retain its identity. He went on to argue that while systems must change if they are to continue to exist, they must also resist some change if they are to retain a recognisable identity. Building situational awareness helps us prepare for and manage the tension between the need for stability and identity in conservation and the imperative for change.

Here are some specific things that we can do to build situational awareness: draw others into dialogue; encourage the sceptics and listen attentively so that the exchanges become learning opportunities; because we all experience the world differently, search for and be open to alternative frames of reference; pay attention to interpersonal skills so that others feel safe raising concerns and new ideas; and welcome others into your thought processes by thinking out loud. Because social learning through interactions with family, friends and colleagues enables us to benefit, we need to invest in developing and sustaining personal relationships.

2. Invest in personal relationships

In the previous section of this chapter, we illustrated how the system in which protected area governance and management occurs includes many actors. Within that system the various actors serve as resource users, public infrastructure providers and numerous others indirectly related to those two functions. Thus, how the relationships among those actors are developed, nurtured, encouraged and maintained will be a critical ingredient of the success of protected area governance.

Important considerations include both the nature of the relationship among parties within the system and the structures that provide the platform for those relationships to occur (control, governance, coordination mechanisms, norms, contracts, monitoring routines, and so on). These structures between organisations and among individuals can provide consistency and predictability within the relationships. Over time, these structures also enable the environment for learning, creativity and building trust and respect. Interpersonal relationships assist us in building relational capital and social cohesion that can adapt and remain resilient in the face of challenge or change. When we view our job as partly one of managing relationships (McCool et al. 2013), we position ourselves well to construct the collaborative forms of governance that may have a higher probability of long-term success when we are functioning within a nested hierarchy of social-organisational scales. Collaboration from this perspective can be viewed as a behavioural approach to governance that is guided by a belief that a variety of components working together will provide benefits beyond what would occur in unilateral decision-making. Working together, especially if it occurs over a lasting time frame, reduces transactional costs, enhances performance and develops greater social-ecological resilience.

How does systems thinking lead to beneficial relationships?

Due to the complexity of governance systems, we also know that these relationships occur at several scales. Panarchy is often referred to as a structure in which system elements at various scales are not only interlinked, but are also adapting together within a non-hierarchical system. We can think of these scales as being nested one inside the other, but of varying value and importance to the behaviour of the system. We can also think of the scales occurring across time frames. Thus, a manager needs to think about the relationships they must maintain within a system in a four-dimensional sense. There are the obvious relationships that are necessary within the same scale: colleagues, partners, and so on. The manager also must be thinking about relationships that go higher in government than where he or she works, as well as the relationships to be maintained with those who are affected by the decisions made.

Further, managers must realise that some of the issues they deal with today result from relationships that occurred in the past. Likewise, the results of the decisions they make today may not materialise until some time in the future. While we easily identify the formal relationships we must maintain amongst organisations and institutions, we must also consider interpersonal relationships with the individuals who make those organisations and institutions work (Nkhata et al. 2008).

How does managing relationships help us engage with complexity? First, taking a good look at the system as described in the 'Characterising complexity' section of this chapter enables us to see who is involved in the system and better understand how existing relationships are the legacies of previous interactions or lack of interaction. Second, being aware of the system we are working within may lead to a better understanding of the need for relationships that may actually seem counterintuitive. For example, managers may find it quite advantageous to the natural heritage of protected areas to build a functional relationship with key staff within companies who represent extractive interests associated with the protected areas they manage. While at some moments the goals of these two parties may seem at odds, in other situations it may be quite possible to complement one another's agendas.

Relationships, like other components of complex systems, are always changing. Further, those changes are not likely to be linear in direction or development. Thus, one cannot expect that relationships with colleagues will automatically improve through more interaction. Rather, as we see in our closest family ties, evolution in the strength of our relationships often occurs when the relationship is tested and challenged. Nkhata et al. (2008) recently used Holling's adaptive cycle to illustrate how changes in relationships can be anticipated and how those changes can test the relationship's resilience. In their paper, the authors argue that collaboration can best occur when there is a high degree of relational connectedness and a high potential for relational capital. In other words, if two or more parties are clearly forced to engage and do so with the benefit of solid relationships, their opportunity for creative collaboration is high. If, however, their degree of connectedness is high but they do not have the benefit of constructive relationships, they are much more likely to operate in an adversarial-type relationship. It is not uncommon for a relationship that has been collaborative for some time to quickly lose relational capital and descend into an adversarial structure. While there are often many reasons for these changes that are beyond the control of managers, there are many things a manager can do on an interpersonal level to nurture and maintain a good environment for collaborative relationships.

How do we develop and maintain positive relationships?

Suggestions as to how to maintain healthy relationships are many. While the success or failure of many strategies will depend on the context of an interaction, there are some basic ideas that do tend to transcend humanity. For example, in Malcolm Gladwell's book *Blink* (2005), he describes the work of psychologist John Gottman. In Dr Gottman's career of examining the success or failure of interpersonal relationships, he developed several universal predictors of success. Among the most significant are to sincerely provide five positive interactions for every negative interaction in a relationship. This principle suggests that as humans we react more strongly to negative encounters than positive. Some negative encounters are worse than others. For example, showing signs of contempt for or superiority over a party within the relationship is a sure sign of hard times to come. Unfortunately, it is not uncommon to see exactly this form of interaction on issues related to protected area management. Contempt is often displayed towards those embracing differing sources of information and knowledge, having differing levels of authority relative to land management, or who are expressing values that are not shared by the other party. It is incumbent on us as protected area managers to rise above these forms of interaction.

A systems approach instructs us that losses in relational capital can have devastating effects on our ability to be effective in protected area management. Moving out of adversarial interaction styles requires a reorganisation

Wildlife and human interaction in Yellowstone National Park, USA
Source: Graeme L. Worboys

of the relationships within the system and often the development of a new vision for moving forward. Thus, the manager should think carefully about how much change this area can absorb before they dismiss the concerns of those who are disagreeing with them.

3. Appreciate the power of networks

What is a network?

The complex systems in which protected areas are embedded are composed of many separate entities that are connected at various scales that create a system with a purpose that is larger than the sum of its parts. Networks are what hold systems together. They provide mechanisms and pathways for communication, exchange among actors and development of shared or disparate visions. Using networks composed of people helps build in the various perspectives needed to characterise and simplify complexity. Ormerod (2012) describes three types of networks. Scale-free networks are those in which most people are not connected but a small portion within the system is tightly connected to many people. These are the type of networks that can be easily understood through ideas such as six degrees of separation, which suggests that most people within a system can find acquaintance with another with no more than six people between them. Thus, the readers of this book may be from all over the world but with careful analysis may be able to find the people who link them in common. In many cases, it will take far fewer than six people to make the connection. For example, if you work in protected areas, no matter the country, you probably know somebody who knows somebody who knows the other readers of this book.

The second type of network is termed a small-world network. Rather than a small number of people being highly connected to many people, these are overlapping sets of acquaintances or friends. Thus, while the leverage points of influence are less obvious in these types of networks, the potential for adoption of ideas is still quite high. In fact, in small-world networks it is less demanding to spend the time finding the connecting people who are critical to scale-free networks. Much social media that guides the way we communicate today could be characterised as small-world networks. This is often the way videos, pictures, incidents or stories can quickly go viral and enjoy global consumption. In small-world networks, attraction to popular items has a disproportionate effect on people's choices. For example, if a video of a game ranger chasing an elephant is posted on YouTube and becomes 'popular' or 'trends',

many people will see it simply because of its popularity. The more novel, provocative or interesting the item is, the more likely it is that it will continue to progress through networks of friends until it has reached across what in this case can be a global system.

The third type of network referred to is a random network. In these networks, behaviour is transmitted through random conductivity within the system. This type of system can often be compared to the transmission of a virus. For example, you may be unlucky enough to sit next to somebody on a train who has a cold and catch it. Then as you move through your day you transmit the same virus to other people who were equally unlucky to come in contact with you. Once enough people come in contact with others, this cold can infect an entire system. Or we may sit next to a person on a plane who happens to share an interest in protected areas and who also is an important stakeholder. That random network then may be converted to a small-world network.

Why is using networks important for engaging complexity?

Ormerod (2012:153) tells us:

> The crucial challenge for policymakers is to understand and take account of the fact that networks are becoming more and more important in the social and economic world. The Internet revolution in communications technology is obviously a key factor. But the entire second half of the 20th century featured the massive rise in globalisation, a huge increase in travel, and a greater and greater proportion of the world's population living in cities, exposed to many more people, many more networks than they would be in the confines of the village.

Thus, since the scale and scope of the systems we are dealing with are global, behaviours and pressures in this system may occur in ways we would never anticipate and come from places that are far from our day-to-day mindsets. For example, we pointed out earlier that international animal-rights groups can now have an impact on management policy within any given country. Depending on the types of networks that are operating, those international reactions to an issue can be almost instantaneous and overwhelming. Thus, we must consider the way networks affect not only the behaviour of individuals, but also the forces that are affecting the social-ecological systems in which we are engaged.

When confronted with complexity and the desire to simplify it, one mechanism is to copy the actions of others (Ormerod 2012). When doing so, we assume that others may be more informed than we are on any given topic. Accessing examples or tools to copy can be one of the most powerful benefits of engaging networks. In fact, we organise considerable opportunities for training, higher education, mentoring and various certifications to enhance our awareness and understanding of tools and concepts. When combined with positive personal relationships, as described in the previous section, these networks can help us increase our capacity (intellectual, financial or workforce) and address complexity.

Networks, however, can generate their own behaviour. This can occur, for example, when numerous people begin to copy one another, all thinking the other is more informed, leading to a herd mentality; dissemination may be all but instantaneous and rapid change can occur with unpredictable consequences. We see examples of this behaviour in financial markets and in recent political protests and rebellions assisted by digital social networking platforms.

Exploiting networks

From a protected area perspective, we can think of many ways that networks are formed. For example, consider a protected area such as Yellowstone National Park, which receives more than three million visits per year, with as many as 30 000 of those visitors in the park on any given summer day. Each has the opportunity to interact with the others and may have many kindred interests that would make those interactions likely. Through their interactions, they can inform one another of the locations of wildlife sightings, how to find good campsites or where to find good meals in the park. Ormerod would consider these positive links, in which the network takes on its own behaviour, leading to mutually beneficial results for people connected in a network. With the easy access of digital communication technology, those 30 000 people can also be interacting with many more people who are outside Yellowstone through small-scale networks. By updating their Facebook pages, YouTube or Twitter accounts, they can form a much larger network focused on the park. If an incident were to occur, such as a tragic human–wildlife interaction, that incident is likely to reach thousands of people and be resubmitted to thousands more before management has the opportunity to craft a communication to either the visitors or the broader society. This is an example of how small-world networks are changing the relationship management has with society and illustrating how limited managers may be in controlling events.

So what does all this mean for governance and management? First, we need to recognise the importance of networks within the systems in which we are embedded. In many cases, the people within those networks may have more influence on the system than the policy we may be proposing. In all types of networks, decision-making is often based on relatively superficial understandings, with great faith given to copying other people. Thus, popularity has a disproportionate influence on the dissemination of ideas, behaviour and support for or resistance to policy. Anticipating this, it is critical that we engage networks rather than ignore or avoid them. The authors have often heard discourse among management that rejects the emergence or importance of information technology and social networking systems. Thus, smart phone apps, Facebook pages or interactive websites are often considered trivial, inauthentic or inappropriate for a protected area setting. We reject these at our own peril. Society is moving in this direction and without the capacity to engage these networks constructively we give up what little influence we do have on how they are connected to our protected areas.

Second, by engaging networks, particularly scale-free networks, we can find opportunities to gain considerable leverage through expanding resources, influencing public opinion or designing and implementing policy. By taking the time to understand who within a given network seems to be connected to everybody else, and investing in relationships with those individuals, we can not only learn considerable lessons about what the people they know think, we also have an increased opportunity to influence the system we are embedded within.

Third, by analysing a network, particularly a scale-free network, we can understand who within it is the most connected and therefore would possibly be a good ally or source of information. For example, if you are working in a community, there are probably several people who know everybody and also have considerable influence. Thus, gaining their insight on goals, visions and interventions may have a disproportionate effect in a large portion of the community. The importance of networks has been illustrated by the International Seminar on Protected Area Management (Box 10.5).

4. Identify and use leverage points

Children playing on a seesaw in a park quickly learn the relationship between action and reaction, between cause and effect, and between source and outcome, even though they may have little understanding of the physics of levers. They know where and how to act to bring about (to leverage) change to achieve a preferred outcome. When cause and effect are linearly related and tightly coupled, it is relatively easy to identify points of leverage. It is much more difficult in complex systems because of the way effects are propagated through networks, being weakened or strengthened, arising unexpectedly and sometimes after long delays. Yet, because society depends on preferred sets of benefits from ecosystems, management is directed towards identifying leverage points that can be applied to either sustain or bring about this preferred set.

A leverage point is a place in a system where managers can intervene to change conditions or trajectories of system development. We seek leverage points because we detect, most often, a failure in achieving a goal or a problem that has arisen and now has become a major challenge.

Consider a protected area manager confronted with rising visitor use at a popular, but sensitive site within a national park, such as the Victoria Falls World Heritage Property along the Zambezi River astride the Zimbabwe–Zambia border. Myriad choices await the manager because doing nothing would endanger the very values for which the protected area was established. These choices involve many domains: identifying specific goals for visitor and tourism management, constructing alternative management actions or interventions, deploying personnel, securing funding for implementation, choosing indicators to monitor implementation and outcomes, measuring consequences to the local business community, defining at what point impacts become unacceptable, understanding how to incorporate and exploit various forms of knowledge in the decisions to be made, convincing politicians to support actions that may impact negatively on the local economy in the short term, and determining what opportunities for visitor experiences exist and are appropriate. What action has the greatest leverage in addressing impacts?

In addition to selecting among many avenues of intervention, managers commonly operate in settings where available information is inadequate, understanding is superficial, research provides ambiguous, even conflicting, interpretations, and levels of uncertainty are high. If intervention seems necessary, focusing on identifying points of leverage not only helps decide where and how to intervene but, importantly, it allows the logic that was used to make the decision to be recorded in a meaningful way. Revisiting the logic allows us to learn from experience and is an important process in adaptive management.

Box 10.5 The International Seminar on Protected Area Management as network-building

The power of networks as a change agent is illustrated by the International Seminar on Protected Area Management, a training program conducted annually since 2000. More than 400 managers have cycled through the three-week intensive program in its 15 years. Over that time, the authors of this chapter, who also are involved in directing the seminar, have seen it serve as a force involved in changing one of the conventional paradigms of protected area planning from one of command and control or fences and fines to one of greater inclusiveness. This conventional paradigm regarded the utmost possible protection of nature from human intervention as the principal means of biodiversity conservation.

Over the past decade of the seminar, however, we have seen a dramatic movement away from conventional approaches to greater enthusiasm for adoption of more community-based management paradigms that seek ways for the benefits of conservation to be shared with local people and to demonstrate the direct positive and beneficial connections between conservation and their lives. Seminar participants often engage in dialogue challenging conventional paradigms while seeking approaches to conservation involving communities, as they see these as simply more effective.

It is clear to us as instructors, however, that the general understanding of what it means to engage communities is highly superficial. Participants in our seminar will quickly comment that engaging communities is essential to conservation. But when asked basic questions about how to engage communities or even to find them, responses are limited and quite varied. This demonstrates how a change in the fundamental perception of what protected area management is occurs not because managers are deeply steeped in theory, analysis or experience, but rather because discourse about protected area management has rapidly included the need for community engagement. People in the management community are adopting that language with a limited understanding of what it really means.

This example illustrates that networks at different scales may operate very differently with vastly different consequences. So while a global network of protected area managers may build awareness of new approaches, challenges or opportunities, smaller scale networks are probably better suited to building competencies and confidence. This adoption of a new management paradigm is one example of what Ormerod (2012:127) refers to as 'a world characterized by the psychology of the society of individuals each of whom is endeavoring to copy the others. A world in which the optimal decision can never be known … And a world in which the unexpected happens all the time.' Depending on your perspective, of course, whether this change towards community conservation is positive or negative will be based on how you filter this new information through your existing world view. The point here, rather, is that even those who resisted increased access for local community members for much of their careers have quickly changed their mind and moved towards what is emerging as an increasingly popular idea.

Why focus on leverage?

Interventions are how systems, conditions and processes are changed. We focus on leverage because we want our interventions to be not only effective but also efficient. We want to achieve the maximum change with the minimal effort. We often search for leverage points in determining how to achieve goals or change the system. These searches are often popularised by the notions of the 'silver bullet', 'magic number' or 'getting the biggest bang for the buck'.

It may not be intuitively clear where to intervene in the system, how to intervene and what interventions would lead to the greatest positive or negative consequences. Given that protected area goals are usually vaguely defined and at least partly competing, the situation is muddled if nothing else. Protected area systems have both negative and positive feedback loops, and choosing where to intervene can result in unanticipated consequences and even lead to effects completely the opposite of what was intended.

Donella Meadows (1999) identified a number of places where interventions in a system may occur. These are shown in Table 10.1. What is clear in this table is that managers must understand the nature of the system in which they are functioning in order to choose interventions that will work and have leverage on changing conditions.

Table 10.1 Points at which to intervene in a system, ordered by increasing leverage

Places to Intervene in a System	Example of How These Places Could Be Used to Manage High Levels of Visitor Use
Constants, parameters, numbers	Change length of stay
Sizes of buffers and other stabilising stocks relative to their flows	Reduce size of parking facility
The structure of material stocks and flows (such as transport networks, population age structure)	Construct additional trails to disperse visitor use
Lengths of delays relative to the rate of system change	Monitor use and impacts more frequently
Strength of negative feedback loops, relative to the impacts they are trying to correct against	Make access more difficult, for example, by charging fees based on visitor group size
Gains around driving positive feedback loops	Provide more visitor education about the importance of natural heritage values
Structure of information flows (who does and does not have access to what kinds of information)	Provide timely information to visitors about temporal patterns of visitation
Rules of the system (e.g. incentives, punishments, constraints)	Charge differential visitor use fees by time
The power to add, change, evolve, or self-organise system structure	Revise management plan to address visitor-induced social and biophysical impacts
Goals of the system	Change objectives with respect to visitor experiences
Mindset or paradigm out which the system arises	Reframe the purpose of the protected area
Power to transcend paradigms	Consider alternative ways of administering the protected area (e.g. contracting the park, allowing private sector administration, prohibiting visitor use)

Source: Meadows (1999)

Figure 10.4 Using root-cause analysis

Source: Adapted from Thwink (2014)

Enhancing use of leverage

There are a number of ways that leverage can be used and enhanced. We note that identifying and implementing leverage points may be neither obvious nor easy. The further down in Table 10.1 we move, the more costly the interventions become. The further down we go, however, the more likely is change to occur and the more likely it is our actions will elicit fundamental rather than symptomatic change. A process to help identify leverage points is identified in Figure 10.4. One begins first with root-cause analysis, which attempts to identify the fundamental causes of the problem.

This is sometimes conducted by simply asking why five times. Each time the why is answered, the answer is subjected to why. So, for example, if the impacts of visitor use are high, one would ask why? If the answer is 'too many people', one would ask why again, repeating until a fundamental cause or causes are identified. By progressing to causes that seem to be fundamental, we are positioned to identify leverage points that are more likely to effect change that will lead to the preferred state.

A word of caution: because of the networked nature of protected area systems, coupling may be loose such that an outcome can arise through alternative pathways and take a long time to manifest, or it may be tight such that effects immediately arise upon implementation of an action. Observed change can be a result of a sequence of management decisions, each of which on its own may seem inconsequential. Under these conditions it becomes difficult, even impossible in some situations, to trace a 'root cause' that provides a locus for leverage. And because we may feel the need to show decisiveness, we willingly accept simplification, thereby raising the risk of selecting a leverage point and making a decision that aggravates the problem and compounds the difficulty of finding a better approach. The situation is not hopeless.

Unlike mechanical systems, social-ecological systems are loosely coupled, which means there is always 'slack' in the system that allows time for reflection. And, if we conduct ourselves with heightened situational awareness so that we become more conscious of small changes and early warnings, we can experiment with and learn from change.

One can also conduct a problem-solving process. For example, Mosimane et al. (2013) asked why human–wildlife conflicts were growing in Namibia despite significant, and growing, investments in management to prevent them. They reported that the mental models of conflict included the Ministry of Agriculture and Lands because that ministry identified land suitable for farming that regularly included wildlife habitat. This analysis thus suggested that working with this ministry could be a key leverage in reducing conflict.

5. Employ different forms of knowledge

What do we mean by knowledge?

Knowledge is, as Russell Ackoff (1999b) argued, knowhow, or information about how systems work. Knowledge of how to do things is critical to planning, implementing and monitoring interventions to retain or restore system structure, function and pattern, in determining if a system is close to an important threshold, or in identifying leverage points. In contemporary Western society, we typically think of knowledge as being sourced from science. Managers often proclaim there are not enough data to indicate what alternative to choose, how to assess consequences or to determine what and how a species might be impacted by a particular intervention. But knowledge as knowhow is not restricted to that developed by scientists. Knowledge accumulates from experience, either that formally constructed from scientific experimentation and research or that constructed from other kinds of experience. Our experience may be direct or we may learn from others—the whole point of formal education—either directly or indirectly. We also accumulate knowledge in other ways such as through informal interactions with friends and colleagues and from rituals, norms and behaviours of our or others' culture. In dealing with the complex systems in which protected areas are embedded, most of our knowledge will actually come from others. US Forest Service fire managers had little direct experience with accumulating fuels, for example, but relied on measures of accumulation by others and on theories of plant succession formulated by others.

In addition to scientifically/technically based knowledge, there has been increased interest in indigenous knowledge as important in managing complex social-ecological systems. Berkes et al. (2000:1252) define this kind of knowledge as 'as a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment'. Such indigenous knowledge can play important roles in making decisions about interventions, particularly when other forms of knowledge are deficient.

Why should we use different forms of knowledge?

To survive in a world of ever-changing challenge, people rely on knowledge and mental models of the systems in which they are embedded. We have noted how these mental models are influenced by our own experience, background and other factors. Mental models are neither right nor wrong, but are more or less useful. For a long time, management of protected areas was dominated by reliance on formal systems of knowledge, which we generally term scientific or technically based. This reliance was influenced by a mental model of planning based on the perceived efficacy of expertise in solving problems. The result was an approach often termed 'rational-comprehensive planning', which relied on and thus required enormous—and expensive—amounts of data for decisions.

Yet, a close examination of the underlying assumptions of rational comprehensive planning reveals important limits. For example, it assumes a single objective about which there is a consensus. Further, it assumes a comprehensive search for alternatives, requiring huge amounts of information for evaluation, despite the reality that rarely do the budget, time or political willingness to permit this exist. Perhaps most importantly, it implicitly treats problems as technical and value-free—and thus subject to technical-rational analysis and resolution—when increasingly, the value-based, political nature of such problems is acknowledged as the primary driver: views that are built upon the assumptions of the PLUS world. And what kind of knowledge we need is based on understanding answers to the 'why' questions we noted earlier. For example, in the decade-long controversy over management of snowmobiles in Yellowstone National Park, the kind of knowledge managers seek to resolve this issue now also includes a greater emphasis on underlying beliefs and values about the purpose of the park and the role of snowmobile access in that purpose.

Other forms of knowledge, such as those based in personal experience and cultural values, are often as useful as scientific knowledge in making decisions. Such knowledge involves descriptions and uses of plants, animals and minerals, the spatial and temporal distribution of the availability of these, and a social frame of reference concerning the way in which people use, allocate and manage these attributes as resources within the context of their experience and cultural norms (Johannes 1993).

By incorporating diverse forms of knowledge, our mental models become more useful in creating insights about how something works, and eventually developing wisdom, our *understanding* of a complex system, particularly its purpose, and how it relates to other systems. This understanding moves concerns about interventions from the realm of efficiency to those of effectiveness and equity.

6. Learn continuously

Why we need to learn

It is quite clear that governing and managing protected areas must be based on a diverse knowledge base while at the same time recognising that knowledge is tentative, that science and other forms of knowledge evolve and lead to new discoveries, insights and understandings, and that learning is an essential strategy for managers and constituencies embedded within protected area social-ecological systems. Given the dynamic complexity of these systems, surprises occur, unintended consequences happen and impacts may be greater or lesser than anticipated. As we apply new knowledge, we begin to reduce the risk of these outcomes. And as diverse sources of knowledge are also applied, we begin to enhance the capacity of protected area managers to better understand the systems and structures underlying this complexity, and thus increase the capacity of organisations and constituencies to anticipate, absorb and respond to both slow and fast processes affecting the protected area.

What is learning?

Building system resilience requires new ways of thinking about learning, governance, management and planning (Garmestani and Benson 2013). By framing goals as part of building system resilience, we begin to ask new and insightful questions about how and why we learn, what is the objective of learning and what role do protected area managers, scientists and other constituencies play in enhancing learning. By considering the notion of a system, we ask questions about delays and leverage points—both important characteristics of protected area systems (Meadows 1999).

Learning may be defined as the detection and correction of error (Argyris and Schon 1978) or the acquisition of information, knowledge or wisdom (Ackoff 1999b). We learn by making mistakes, reflecting on those mistakes, understanding their causes and correcting them with actions. We learn by being confronted with alternative perspectives and viewpoints, reflecting on them and assessing their relevancy and validity in the system being discussed. We learn through conflict and contention when we attempt to resolve competing demands. We learn when we take action, consider the outcomes and revise the action to make it more effective, efficient and equitable.

Learning requires the ability to sense the contextualising environment (in a number of different domains), to understand the changes occurring, to reflect on and evaluate them and then act appropriately. Doing so leads to single-loop learning—a process of detecting errors and correcting them. This style of learning is what we are most comfortable dealing with and it is what we have generally been taught. The feedback loop is tight in the sense that monitoring a management action and reflecting on the results can provide relatively immediate information as to the consequences of it.

In the complex world of protected areas, however, a number of 'governing' variables—such as the design of a conservation organisation, its cultural norms or the mental model of its mission—operate and make learning more challenging. By attending to larger scale relationships and conditions that provide the context for smaller scale management actions, we learn about the factors that may question whether the standard or norm is the most appropriate one. Argyris and Schon (1978) term this 'double-loop' learning. Double-loop learning is particularly important in eras of change, uncertainty and complexity, when the systemic causes of errors may be difficult to uncover.

For example, shifts in the preferences and values of society in the 'cloud' may call into question a protected area's mission that is defined solely as biodiversity conservation. Such a mission would likely eliminate human uses of resources that historically had occurred. Action to prohibit extraction of a resource—say, thatching grass—could be tested to see how effective the prohibition is. This would represent single-loop learning. The result of this adaptive management implementation might be that local people continue to violate the prohibition. Examining the organisation's mission, however, might

reveal that a reframing of the mission to integration of biodiversity conservation and enhancement of local residents' lives would gain more influence over biodiversity conservation by developing ownership of the management of thatching-grass harvesting by the local community and thus reduce impacts on biodiversity more than a complete prohibition on that activity.

Encouraging learning

There are a number of ways we can encourage managers to learn; we briefly present three of them.

Monitoring the implementation of management action

Monitoring may be defined as the periodic and systematic measurement of key variables reflecting the outcomes of a specific management action. Monitoring provides the means by which management may detect error and affords the foundation by which correction of the error may occur and be monitored. Too often, however, monitoring is viewed as an action external to actual management, with many protected area agencies indicating they have no funding for monitoring.

Reflection and evaluation

To learn, we must detect errors, mistakes and unanticipated consequences. This means we not only explicitly monitor the results of a management action, but we also reflect on the outcomes and evaluate them in light of the objective of the action—for example, reduce impacts from thatching-grass harvesting. We reflect on the data developed from monitoring implementation. If outcomes are not as expected, we need time for reflection and evaluation to identify the causes of error and ways in which to correct them that are efficient, effective and equitable.

Focus on developing, adapting and revising models

Sterman (2002:521) noted that the primary benefit of explicating models is that focusing on 'modeling rather than on the results of any particular model speeds learning and leads to better models, better policies, and a greater chance of implementation and system improvement'. This learning is fundamental to adaptation. Without the learning, our adaptation is simply trial and error.

Section summary

If we are to be successful in governing and managing protected areas, we must simplify to understand, but not 'oversimplify' the system in which we are immersed. We suggest six practices that, if worked into our routines, will aid us in balancing our need for simplification with our need to progress within a complex environment. Following these practices, governors and managers will be better prepared to benefit from complexity.

- Situational awareness enables us to better see and understand the system in which we are embedded. Understanding our role within the system helps us to better see the effects of our decisions and anticipate change.
- Leverage points are the places within the system where we can have the greatest effect. Finding and focusing on leverage points will take the greatest advantage of the resources we have to prioritise our energy to those areas where we can realistically have the greatest impact.
- Systems thinking helps us see that relationships are a fundamental component within a system. Focusing on these relationships will help us leverage our resources, and sense change, issues, emerging demands and concerns within the social system that affects us. By proactively focusing on the relationships among individuals, agencies and organisations that are central to our mission, we build relational capital during the good times that is indispensable amid times of challenge.
- Social systems are largely characterised by networks. Understanding how networks function and how information is used within different types of networks is an emerging skill required for effective management. Only by understanding network effects will protected area managers or those governing protected areas be able to proactively engage networks to assist in relationship building and situational awareness.
- Modelling the complexity of the system quickly illustrates a variety of relationships that occur between protected areas and their social context. While quite different, each of those varying relationships illustrates the opportunity to gain knowledge and wisdom about the system. Thus, we can no longer rely on the power of science, academic education or policy to accurately understand the nature of the system. We must employ and take advantage of a variety of knowledge forms to truly benefit from the complexity of the systems with which we are engaged.
- The rapid pace of change we are experiencing now illustrates that today's knowledge is clearly tentative and that what we learned yesterday may not be what we need tomorrow. Thus, specifically building learning into our routine is more important now than ever.

Conclusion: Governing and managing adaptively

In complex systems in which protected area governance and management occur, uncertainty looms large, knowledge is tentative at best and likely incomplete, and consequences are routinely temporally and spatially discontinuous. There is no option but to manage protected areas adaptively. By this, we mean that a culture of reflection, learning and adaptation permeates the conservation organisation. Mistakes and problems are inevitable, and as quantum mathematician David Deutsch (2011) promises, they are also solvable. And thus we manage adaptively, at both the personal and the organisational levels. To do otherwise is to facilitate our demise. Certainly, the US Forest Service found that full suppression of fire did not lead to fewer and less-damaging wildland fires and it could not 'stay the course' in light of this knowledge.

Governance creates the environment in which management can be adaptive, but to truly create that environment, it must itself reflect the adaptability that it expects of management. Adaptive governance processes are designed to allow for strategic dialogue and negotiations around societal beliefs and values represented by diverse constituencies, which then are formally expressed through mandates, policy and multi-level institutions. When governance creates this environment, we benefit by the variety of perspectives expressed and debated, thus enabling the opportunity to address resilience.

Managing adaptively means that we decide, monitor, reflect, learn and decide again. And again. Managing adaptively means that we move towards expanding understanding and developing wisdom—both forms of learning geared towards the future, not focused on the past. Managing adaptively means that organisational cultures and institutions must in many cases also change, away from perceiving conservation as a routine, and towards being ever changing. Sometimes it takes a while for this conclusion to develop, as with the US Forest Service and its fire management policy.

Organisations will need to be agile if they want to manage adaptively. Organisations will need to be functionally fit—holding the capacities needed to manage adaptively, employing the personnel who can think critically and encouraging leaders who promote the culture of reflection and learning that is fundamental to managing adaptively.

The world is complex; it is filled with uncertainty, and it is nearly always contentious. These are the facts of life, so the principal question for protected areas is how can we more effectively operate in such a world? We can do so by first characterising the complexity that confronts us, then simplifying based on that knowledge and then engaging it. As a result, we move towards resilience, and we benefit. The key to understanding and operating effectively is to accept the necessity for simplification while retaining a healthy reluctance to simplify. We integrate these two considerations when making decisions, knowing that they are a way of testing our simplified interpretation, of experimenting, learning and adapting. In this approach, we make smaller, less disruptive and less uncertain decisions more frequently and large decisions that are potentially very disruptive and more uncertain less frequently.

Characterising complexity requires knowledge, which is about how things work. Simplifying complexity is about understanding, which is about why things work the way they do. Engaging complexity is about wisdom, which is about sensing long-term consequences. By thinking in terms of complexity, we benefit from that complexity.

We have illustrated how complexity enriches our lives and how we learn to cope with it. And so it is with governance and management of protected areas. They are embedded in complex social-ecological systems. When we accept that complexity, simplify after developing knowledge and develop situational awareness, we are better at building relationships that widen our circles of learning, helping us to pick up and make sense of early warning signs pointing to the loss of resilience. We are better prepared for surprises and become less reactive and more reflective and willing to accept human fallibility. We allow the trajectory of change to shape our approach to management so that the system retains identity while changing; we are able to intentionally manage in ways that promote resilience.

Mount Painter, Arkaroola Protection Area, South Australia: the very top of this mountain features an ancient (Permian) valley with geological evidence of geothermal activity similar to the modern geysers and hot pools of Yellowstone National Park. The surrounding rocks contain many rare and outstanding geological minerals, structures and petrological features including some evidence of uranium mineralisation. It is a geological hotspot of immense value for geologist field survey training and despite the complexity of past mining leases and political processes, the privately owned area has been permanently protected by the South Australian Government.

Source: Graeme L. Worboys

The Eastern Grey Kangaroo (*Macropus giganteus*) is found free-ranging in Eastern Australia and in many protected areas. It has benefited from a predator-free environment and many populations have outgrown the capacity of their home reserves to support them. For urban and near-urban areas in particular, the issue of managers undertaking any culling of kangaroos (for the sake of other species survival in reserves) is often highly charged and complex and has included high-level political intervention.

References

 Recommended reading

Ackoff, R. L. (1999a) *Re-Creating the Corporation: A design of organizations for the 21st century*, Oxford University Press, New York.

Ackoff, R. L. (1999b) 'On learning and the systems that facilitate it', *Reflections: The SoL Journal* 1(1): 14–24.

Álvarez, M. D. (2003) 'Forests in the time of violence', *Journal of Sustainable Forestry* 16(3–4): 47–68. <doi: 10.1300/J091v16n03_03>

 Anderies, J. M., Janssen, M. A. and Ostrom, E. (2004) 'A framework to analyze the robustness of social-ecological systems from an institutional perspective', *Ecology and Society* 9(1): 18. <www.ecologyandsociety.org/vol9/iss1/art18/>

Argyris, C. and Schon, D. (1978) *Organizational Learning: A theory of action approach*, Addison-Wesley, Reading.

Bengis, R., Grant, R. and de Vos, V. (2003) 'Wildlife diseases and veterinary controls: a savannah ecosystem perspective', in J. T. du Toit, K. H. Rogers and H. C. Biggs (eds) *The Kruger Experience: Ecology and management of savanna heterogeneity*, pp. vi–vii, Island Press, Washington, DC.

Berkes, F., Colding, J. and Folke, C. (2000) 'Rediscovery of traditional ecological knowledge as adaptive management', *Ecological Applications* 10(5): 1251–62.

 Biggs, H. C., Breen, C., Slotow, R., Freitag, S. and Hockings, M. (2011) 'How assessment and reflection relate to more effective learning in adaptive management', *Koedoe* 53(2): 1001. <doi:10.4102/koedoe.v53i2.1001>

Box, G. E. P. and Draper, N. R. (1987) *Empirical Model-Building and Response Surfaces*, Wiley, Hoboken, NJ.

Bourque, J., Inglis, J. T. and LeBlanc, P. (1993) 'Preface', in J. Inglis (ed.) *Traditional Ecological Knowledge: Concepts and cases*, pp. 349–69, International Development Research Center, Ottawa.

Capra, F. (1996) *The Web of Life: A new scientific understanding of living systems*, Random House, New York.

Christensen, N. L., Agee, J. K., Brussard, P. F., Hughes, J., Knight, D. H., Minshall, G. W., Peek, J. M., Pyne, S. J., Swanson, F. J., Thomas, J. W., Wells, S., Williams, S. E. and Wright, H. A. (1989) 'Interpreting the Yellowstone fires of 1988', *Bioscience* 39(10): 678–85.

Cilliers, P. (1998) *Complexity and Postmodernism: Understanding complex systems*, Routledge, London.

Cilliers, P. (2008) 'On the importance of a certain slowness', *ECO* 8(3): 106–13.

Cilliers, P., Biggs, H. C., Blignaut, S., Choles, A. G., Hofmeyr, J. S., Jewitt, G. P. W. and Roux, D. J. (2013) 'Complexity, modeling, and natural resource management', *Ecology and Society* 18(3): 1. <doi org/10.5751/ES-05382-180301>

Coetzee, M., Biggs, H. C. and Malan, S. (2012) *Sharing the benefits of biodiversity: a regional action plan to nurture and sustain the contribution of biodiversity and ecosystem services to livelihoods and resilient economic development within the Kruger to Canyons Biosphere*, Report first officially presented 16 November 2012, Nelspruit, South Africa. <www.kruger2canyons.org/consolidatedtechnicalreportvfin.pdf>

Cumming, D. H. M. (2004) *Sustaining animal health and ecosystem services in large landscapes—2nd draft*, Concept for a program to address wildlife, livestock and related human and ecosystem health issues in the Greater Limpopo Transfrontier Conservation Area. <www.wcs-ahead.org/documents/gltfca_cumming.pdf>

Department of Water Affairs and Forestry (DWAF) (2007) *Guidelines for the Development of Catchment Management Strategies: Towards equity, efficiency and sustainability in water resources management*, Department of Water Affairs and Forestry, Pretoria.

de Shazo, P., McLean, P. and Mendelson, J. (2009) *Colombia's Plan de Consolidacion Integral de la Macarena: An assessment*, CSIS Americas Program, Washington, DC.

Deutsch, D. (2011) *The Beginning of Infinity: Explanations that transform the world*, Penguin Press, New York.

du Toit, J. T., Rogers, K. H. and Biggs, H. C. (eds) (2003), *The Kruger Experience: Ecology and management of savanna heterogeneity*, Island Press, Washington, DC.

Endsley, M. R. (1995) 'Toward a theory of situation awareness in dynamic systems', *Human Factors* 37(1): 32–64.

Endsley, M. R. (2000) 'Theoretical underpinnings of situation awareness', in M. R. Endsley and D. J. Garland (eds) *A Critical Review in Situation Awareness Analysis and Measurement*, pp. 3–28, Lawrence Erlbaum Associates, Mahwah, NJ.

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T. and Rockström, J. (2010) 'Resilience thinking: integrating resilience, adaptability and transformability', *Ecology and Society* 15(4): 20. <www.ecologyandsociety.org/vol15/iss4/art20/>

Folke, C., Hahn, T., Olsson, P. and Norberg, J. (2005) 'Adaptive governance of social-ecological systems', *Annual Review of Environmental Resources* 30: 441–73.

Freitag-Ronaldson, S. and Foxcroft, L. C. (2003) 'Anthropogenic influences at the ecosystem level', in J. T. du Toit, K. H. Rogers and H. C. Biggs (eds) *The Kruger Experience: Ecology and management of savanna heterogeneity*, pp. 391–421, Island Press, Washington, DC.

Gallopín, G. C., Funtowicz, S., O'Connor, M. and Ravetz, J. (2001) 'Science for the 21st century: from social contract to the scientific core', *International Social Science Journal* (168): 219–29.

Garmestani, A. S. and Benson, M. H. (2013) 'A framework for resilience-based governance of social-ecological systems', *Ecology and Society* 18(1): 9. <doi.org/10.5751/ES-05180-1801099>

Gaylard, A., Owen-Smith, N. and Redfern, J. (2003) 'Surface water availability: implications for heterogeneity and ecosystem processes', in J. T. du Toit, K. H. Rogers and H. C. Biggs (eds) *The Kruger Experience: Ecology and management of savanna heterogeneity*, pp. 171–88, Island Press, Washington, DC.

Gharajedaghi, J. (2011) *Systems Thinking: Managing chaos and complexity. A platform for designing business architecture*, Butterworth-Heinemann, Boston.

Gladwell, M. (2005) *Blink: The power of thinking without thinking*, Little, Brown & Co., New York.

Hanson, T., Brooks, T. M., da Fonseca, G. A., Hoffmann, M., Lamoreux, J. F., Machlis, G. and Pilgrim, J. D. (2009) 'Warfare in biodiversity hotspots', *Conservation Biology: The Journal of the Society for Conservation Biology* 23(3): 578–87.

International Crisis Group (ICG) (2002) *Colombia's Elusive Quest for Peace*, International Crisis Group, Bogotá and Brussels.

International Crisis Group (ICG) (2008) *Latin American Drugs I: Losing the fight*, International Crisis Group, Bogotá and Brussels.

Jackson, M. C. (2003) *Systems Thinking: Creative holism for managers*, John Wiley & Sons, Chichester, UK.

Johannes, R. E. (1993) 'Integrating traditional ecological knowledge and management with environmental impact assessment', in J. Inglis (ed.) *Traditional Ecological Knowledge: Concepts and cases*, pp. 33–40, International Development Research Center, Ottawa.

Jones, N. A., Ross, H., Lynam, T., Perez, P. and Leitch, A. (2011) 'Mental models: an interdisciplinary synthesis of theory and methods', *Ecology and Society* 16(1): 46. <www.ecologyandsociety.org/vol16/iss1/art46/>

Mabunda, D., Pienaar, D. J. and Verhoef, J. (2003) 'The Kruger National Park: a century of management research', in J. T. du Toit, K. H. Rogers and H. C. Biggs (eds) *The Kruger Experience: Ecology and management of savanna heterogeneity*, pp. 3–21, Island Press, Washington, DC.

McCool, S. F., Nkhata, B., Breen, C. and Freimund, W. (2013) 'A heuristic framework for reflecting on protected areas and their stewardship in the 21st century', *Journal of Outdoor Recreation and Tourism* 1(1–2): 9–17.

Meadows, D. (1999) *Leverage Points: Places to intervene in a system*, The Sustainability Institute, Hartland, VT.

Meadows, D. (2008) *Thinking in Systems*, D. Wright (ed.), Chelsea Green, White River Junction, VT.

Mosimane, A. W., McCool, S., Brown, P. and Ingrebretson, J. (2013) 'Using mental models in the analysis of human–wildlife conflict from the perspective of a social-ecological system in Namibia', *Oryx* 48(1): 64–70. <doi:10.1017/S0030605312000555>

Nkhata, A. B. and Breen, C. M. (2010) 'A framework for exploring integrated learning systems for the governance and management of public protected areas', *Environmental Management* 45(2): 403–13.

Nkhata, A. B. and McCool, S. F. (2012) 'Coupling protected area governance and management through planning', *Journal of Environmental Policy and Planning* 14(4): 394–410.

Nkhata, A. B., Breen, C. M. and Freimund, W. A. (2008) 'Resilient social relationships and collaboration in the management of social-ecological systems', *Ecology and Society* 13(1): 2. <www.ecologyandsociety.org/vol13/iss1/art2>

Ormerod, P. (2012) *Positive Linking: How networks can revolutionize the world*, Faber & Faber, London.

Owen-Smith, N., Kerley, G. I. H., Page, B., Slotow, R. and van Aarde, R. J. (2006) 'A scientific perspective on the management of elephants in the Kruger National Park and elsewhere', *South African Journal of Science* 102: 389–94.

Pécaut, D. (2001) *Guerra contra la sociedad*, Espasa, Bogotá.

Perlis, A. J. (1982) 'Epigrams on programming', *ACM SIGPLAN* 17(9): 7–13.

Peterson, G. D., Cummings, G. S. and Carpenter, S. R. (2003) 'Scenario planning: a tool for conservation in an uncertain world', *Conservation Biology* 17: 358–66.

Pienaar, D., Biggs, H., Deacon, A., Gertenbach, W., Joubert, S., Nel, F., van Rooyen, L. and Venter, F. (1997) *A Revised Water-Distribution Policy for Biodiversity Maintenance in the KNP Kruger Park Management Plan. Volume 8*, South African National Parks, Skukuza, South Africa.

Pienaar, U. de V. (1970) 'Water resources of the Kruger Park', *African Wildlife* 24: 180–91.

Pimbert, M. P. and Pretty, J. N. (1995) *Parks, People and Professionals: Putting 'participation' into protected area management*, Discussion Paper No. 57, United Nations Research Institute, Geneva.

Pollard, S. P., Biggs, H. C. and du Toit, D. (2014) 'A systemic framework for context-based decision making in natural resource management: reflections on an integrative assessment of water and livelihood security outcomes following policy reform in South Africa', *Ecology and Society* 19(2): 63. <www.ecologyandsociety.org/vol19/iss2/art63/>

Resilience Alliance (2010) *Assessing Resilience in Social-Ecological Systems: Workbook for practitioners*, Version 2: 54. <www.resilience.org>

Roux, D. J. and Foxcroft, L. C. (2011) 'The development and application of strategic adaptive management within South African national parks', *Koedoe* 53(2): 1049. <doi:10.4102/koedoe.v53i2.1049>

Scholes, R. J. and Mennell, K. G. (eds) (2008) *Elephant Management: A scientific assessment for South Africa*, Wits University Press, Johannesburg.

Senge, P. (1990) *The Fifth Discipline: The art and practice of the learning organization*, Double Day, New York.

Simon, H. A. (1996) *The Sciences of the Artificial*, 3rd edn, MIT Press, Cambridge, MA.

Sterman, J. D. (2002) 'All models are wrong: reflections on becoming a systems scientist', *System Dynamics Review* 18(4): 501–31.

Stirzaker, R. J., Biggs, H. C., Roux, D. J. and Cilliers, P. (2010) 'Requisite simplicities to help negotiate complex problems', *Ambio* 39: 600–7. <doi:10.1007/s13280-0100075-7>, PMid:21141779.

Stirzaker, R. J., Roux, D. J. and Biggs, H. C. (2011) 'Learning to bridge the gap between adaptive management and organisational culture', *Koedoe* 53(2): 1007. <doi:10.4102/koedoe.v53i2.1007>

Thwink (2014) Process Driven Problem Solving. <www.thwink.org/sustain/glossary/ProcessDrivenProblemSolving.htm>

Tidwell, T. (2013) Wildland fire management, Statement of Tom Tidwell, Chief, USDA Forest Service, before the Committee on Energy and Natural Resources, US Senate, Washington, DC.

Turner, M. G., Romme, W. H. and Tinker, D. B. (2003) 'Surprises and lessons from the 1988 Yellowstone fires', *Frontiers in Ecology and the Environment* 1(7): 351–8.

United States Agency for International Development (USAID) (2013) *Resilience in the Limpopo Basin Program (RESILM): Olifants catchment*, USAID, Washington, DC. <www.usaid.gov/sites/default/files/documents/1860/RESILIM%20O%20Fact%20Sheet.pdf>

Walker, B. and Salt, D. (2006) *Resilience Thinking: Sustaining ecosystems and people in a changing world*, Island Press, Washington, DC.

Walker, B. and Salt, D. (2012) *Resilience Practice: Building capacity to absorb disturbance and maintain function*, Island Press, Covelo, CA.

Walker, B. H., Gunderson, L. H., Kinzig, A. P., Folke, C., Carpenter, S. R. and Schultz, L. (2006) 'A handful of heuristics and some propositions for understanding resilience in social-ecological systems', *Ecology and Society* 11(1): 13. <www.ecologyandsociety.org/vol11/iss1/art13/>

Walker, B., Holling, C. S., Carpenter, S. R. and Kinzig, A. (2004) 'Resilience, adaptability and transformability in social–ecological systems', *Ecology and Society* 9(2): 5. <www.ecologyandsociety.org/vol9/iss2/art5/>

Weick, K. (1976) 'Educational organizations as loosely coupled systems', *Administrative Science Quarterly* 21: 1–9.

Weick, K. E. and Sutcliffe, K. M. (2001) *Managing the Unexpected*, Jossey-Bass, San Francisco.

Whyte, I. J., van Aarde, R. and Pimm, S. L. (2003) 'Kruger's elephant population: its size and consequences for ecosystem heterogeneity', in J. T. du Toit, K. H. Rogers and H. C. Biggs (eds) *The Kruger Experience: Ecology and management of savanna heterogeneity*, pp. 332–48, Island Press, Washington, DC.

Yankelovich, D. (1991) *Coming to Public Judgment: Making democracy work in a complex world*, Syracuse University Press, Syracuse, NY.

This text taken from *Protected Area Governance and Management*,
edited by Graeme L. Worboys, Michael Lockwood, Ashish Kothari, Sue Feary and Ian Pulsford,
published 2015 by ANU Press, The Australian National University, Canberra, Australia.