A resilience approach to conservation and development

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Contents

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Introduction

All over the World, regions are caught up in the nexus between development needs, conservation goals and global changes (climate, the global economic system, migration, technology, social trends, new diseases coupled with rising antibiotic resistance, etc). As a consequence, the social and ecological systems upon which we all depend are changing rapidly in unfamiliar and unpredictable ways. A common response is a call for more resilience - a greater capacity to cope and to adapt to the uncertainty and change. There is, accordingly, a widespread and increasing interest in the concept of resilience as a basis for development and for conservation programs; for putting a “resilience lens” over existing strategies and plans, from local to regional and even global scales. The increase has arisen out of growing uncertainty about the future, and the failures of sectoral programs and projects that neglect broader systemic effects of development, notably their environmental and societal impacts.

The concept of social-ecological resilience recognizes the interdependence between people and nature and the importance of viewing and analysing the two as a linked, dynamic system, paying particular attention to the interactions between the social and ecological domains and across the various scales at which these systems function.

The global policy arena has embraced the concepts and the language of resilience thinking, adaptation and adaptive governance and management, and a ‘safe operating space for humanity’ (Rockstrom et al., 2009; Steffen et al 2015). The language now permeates new policy directions, and is captured through several Sustainable Development Goals.

There are, however, some outstanding challenges in taking the concepts beyond the stage of research and case-specific studies. There is a need for tools that bring together the concepts of resilience assessment with adaptation planning, and provide practical guidance to project developers. Recognising this gap, the Scientific Technical and Advisory Panel of the Global Environment Facility (STAP) commissioned the CSIRO in Australia to review and advise on leading practice methods for embedding resilience, adaptation pathways and transformation into the design of projects for investment in system interventions, and for deriving indicators for resilience, adaptation and transformation. The Resilience, Adaptation Pathways and Transformation Assessment (RAPTA) framework was developed in response to this commission. O’Connell et al 2015 reviews the theoretical background, and O’Connell et al 2016 provides the guidelines for using the approach in design of system interventions.

A characteristic of RAPTA is that it is readily configured for different settings and project aims. This paper demonstrates such a configuration, offering a condensed overview of RAPTA tailored for a general user community including those interested in sustainable development and conservation, and addresses what is required to operationalize the concepts for on-the-ground decision-making, planning and investment, as well as in the broader global policy arena.

What is “resilience”?

There are many definitions of the term ‘resilience’, and we use a definition that is appropriate for the assessment of social-ecological systems: resilience is the ability of a system to cope with shocks and to keep functioning in much the same kind of way. More formally it is ‘the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks – to have the same identity’ (Walker and Salt, 2012). It has four defining characteristics:

- the amount of change the system can undergo and still retain the same functions and structure – in other words, its ability to remain within the same stability domain, or ‘regime’;
- the degree to which the system is capable of self-organization;
- the ability to build and increase the capacity for learning and adaptation;
- the capacity to transform part or all of the system into a different kind of system when the existing one is in an irreversibly undesirable state, or on a trajectory towards such a state.

General resilience (adaptive capacity), specified resilience and transformation

Our use of the term “resilience” incorporates three distinct system properties:

- General Resilience: the capacity of the system to cope with all kinds of shocks and disturbances, and so be able to avoid crossing all thresholds, known or unknown, to an alternate regime or new kind of system. This incorporates, and is basically analogous to, the term ‘adaptive capacity’ used in some literature;
- Specified Resilience: resilience of a specified part of a system to an identified disturbance;
- Transformability: the capacity to change to a different kind of system, defined by different state variables, and governed by a different set of controlling feedbacks.

Here we view resilience, adaptation and transformation as a set of closely related concepts, consistent with the resilience literature where the capacity to adapt and transform is considered to be part of the framing of resilience thinking.

Rather than present a full account of resilience theory and practice we offer this summary. Deeper and more comprehensive accounts are presented in refereed journal papers in (amongst others) Ecology and Society (http://www.ecologyandsociety.org/), while Walker and Salt (2006, 2012) give a more non-technical account.

Nine things to know about resilience

1. Resilience is the capacity of linked social-ecological systems to self-organize in response to shocks/disturbances and thereby maintain their system identity.
2. You cannot understand or manage an ecosystem or social-ecological system at one scale. All systems function at multiple (nested) scales, and interactions across scales affect resilience, adaptation and transformation. This is a major mistake made by policy and decision makers; they identify the focal scale, the scale of primary interest (which is valid) but fail to then focus on the interactions between the system at that scale and the scales above and below.
3. Resilience is neither ‘good’ nor ‘bad’. It is a property of a system. The broader sustainability goal defines what is desirable or undesirable.
4. Making a system very resilient in one way can cause it to lose resilience in other ways or at other scales—there are often trade-offs in managing resilience.
5. Resilience is not about not changing, or reducing variability. Trying to prevent disturbance and keep a system constant reduces its resilience. Probing the boundaries of a system’s resilience is necessary for maintaining and building resilience, including its capacity for adaptation and transformation.
6. Many losses in resilience are unintended consequences of narrowly focused optimization and ‘efficiency’ drives that remove currently ‘unused’ reserves and 'redundancies’. These so-called redundancies are often in fact expressions of response diversity – different ways of performing the same function, with different capacities for responding to different kinds of disturbances.
7. Understanding and managing resilience requires consideration of both ‘specified’ resilience (‘of what, to what’) and ‘general’ resilience (akin to adaptive capacity).
8. Adaptation and transformation are complementary processes— decision makers often need to transform a system at one scale in order for the system to maintain resilience at a higher or lower (embedded) scale.
9. When an undesirable regime shift has happened or is inevitable it calls for intentional transformational change.

A procedure for developing a resilience-based project for uncertain times

As depicted in Figure 1, a procedure we suggest for developing a resilience-based project for a social-ecological system involves six iterative components:

i) multi-stakeholder engagement, which proceeds iteratively throughout the project;

ii) change pathways;

iii) describing the system;

iv) assessing resilience in the system;

v) developing options and implementation pathways within an adaptive governance framework, and where necessary, enabling transformational change;

vi) learning, which permeates all the other elements, as well as being incorporated into the implementation and governance of the project.

This procedure emphasises the great uncertainties facing any project, and the need to make it adaptable to changing circumstances by keeping options open, learning through implementation, and expecting the unexpected.

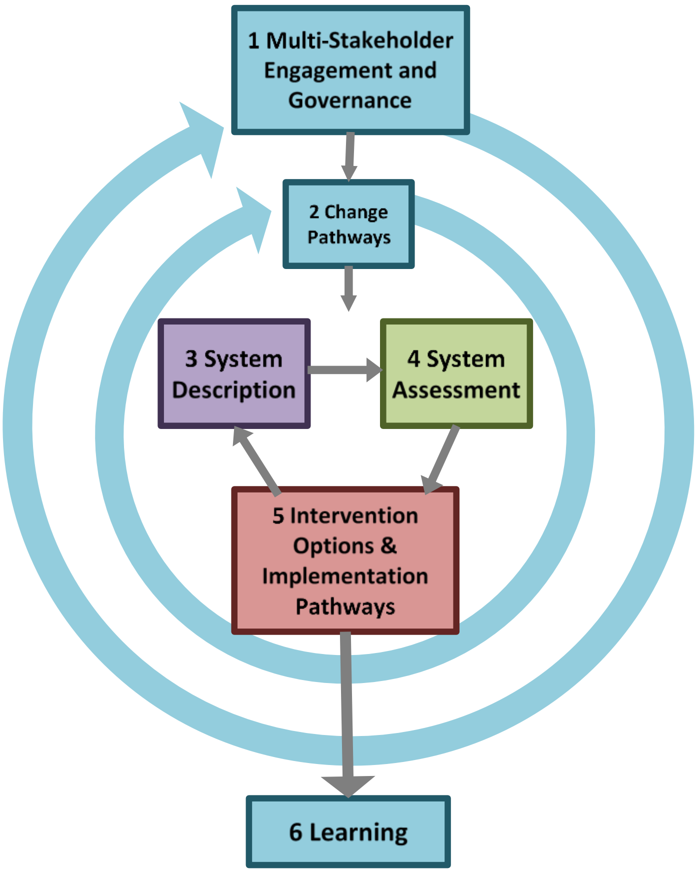

Figure 1 Proposed process for undertaking and implementing a resilience approach to a social-ecological systems. Note: this is a condensed version of the RAPTA diagram in O'Connell et al (2016).

Stakeholder Engagement

The outcome of the whole procedure will depend strongly on who is involved. Stakeholder Engagement is a process for ethically and transparently getting the right people involved, in the right way, at the right time - critical to the later development of appropriate interventions, their acceptance by stakeholders, and effective implementation. It also ensures the inclusion of knowledge and values that could otherwise be excluded, builds shared understanding of the multiple perspectives on problems and solutions, and establishes roles, responsibilities and accountabilities. As emphasized earlier, it is not separate from other elements and is embedded across all aspects of a project.

Irrespective of the approach used, the following questions are important:

- Who are the stakeholders?
    - Who should be involved? What could they contribute to the processes of Governance, Change Pathways, System Description, Resilience Assessment, and Intervention Options and Pathways? Are inclusions and exclusions of potential players justified?
    - Which government and non-government agencies should be represented, and by whom?
- What are the potential barriers and opportunities for engaging with stakeholders?
    - consider who can be in the room with whom, issues related to physical and social access, representation or leadership conflicts, and the timing of project activities in relation to stakeholders other commitments
    - pay attention to issues of gender and power
    - what incentives might encourage participation, what social or economic constraints might inhibit it, and how can these be countered?

In using this procedure two aspects of stakeholder engagement require particular attention:

- Where the amount of proposed change is high there is potential for conflict - some groups benefitting while others lose. Such cases call for a deliberate effort on ethics, conflict resolution and formal dialogue processes to reduce the likelihood for conflict and to manage it
- the key players needed to implement the proposed interventions need to be part of the stakeholder consultation and governance structure of the project

Change pathways (aka Theory of Change)

This initial step is designed to avoid coming up with partial solutions to the problem(s) at the heart of the program, and thereby failing to achieve the desired big-picture goals. It also ensures that assumptions about how project participants and stakeholders assume change will unfold as a consequence of the project's activities. The logic is captured in the following steps, in a process of working backwards from what is wanted:

Step 1: Assemble Key Stakeholders

Step 2: Explore stakeholder assumptions of changes needed to reach project goal

i) What is the long term goal / desired state for the system/ region? e.g. maintenance of healthy ecosystems and viable populations of their key (icon) plant and animal species, in ways that support livelihoods and wellbeing of people in the region.

ii) What are the necessary and sufficient intermediate outcomes needed to achieve i)? e.g. a) persistence of a hydrological regime that will allow the persistence of resilient ecosystems and key species in the component sub-systems/ rivers, b) levels of harvesting or otherwise reducing plant and animal populations, c) an effective common pool resource governance system that removes current incentives for over-harvesting.

Step 3: Develop change pathways to reach the project goal

iii) What actions/ interventions in the system, both at the focal scale of the problem and at scales above, are needed to achieve ii)? e.g. a) limitation of diversion of water flow in rivers for other purposes (agriculture, mining,--), b) prevention of illegal poaching of animals and harvesting of plant and fish species (?), c) limitation on conversion of natural ecosystems to agriculture/ forestry, c) new resource governance rules and institutions

iv) What sequence, or combination, of these interventions will constitute a successful program change? e.g. a) inter-country agreements on combined actions (?), b) changes in existing rules for using or protecting x and y, c) creation of alternate opportunities/ sources of income for the human populations (?), d ??

v) Who needs to be involved in order to develop answers to the questions i) through to iv)? (see 3.1. above)

Step 4: Anticipate what each of the RAPTA steps will do to contribute to the change pathways.

Step 5: Review and adjust these idealised change pathways as you learn from other RAPTA components, particularly the "Options and Pathways" component, where these questions are addressed in more detail.

System Description

Different stakeholders bring different knowledge, experience and perspectives to a project. The System Description component is where these are drawn together in order to develop a shared understanding of what the system consists of and how it works. Multiple, conflicting perspectives of the system should be welcomed. The aim is a description that is robust to unresolved, differing perspectives; native people, farmers, hunters, ecotourism operators, conservationists and loggers would have very different views on how a tract of forest functions, how it should be used and managed, and by whom. This component is an opportunity to 'walk in another's shoes' and learn about others' understanding of the system.

The description should include the critical variables and their interconnections at the focal scale (the scale of primary interest) e.g. a fishery, a conservation reserve or agricultural region. It should also include interactions with variables at higher scales in the system, and within it (e.g. households). It also needs to include the effects of variables that are set outside the system but influence outcome within the system (e.g. government policy). Projects can easily get bogged down in detailed, complex descriptions with effort squandered characterising things that may not matter in terms of system behaviour and project goals. A useful system description includes only what is relevant to the project. We emphasize the importance of iteration, starting with simple descriptions that are revisited and revised throughout the project until a minimum but sufficient description of the system is produced.

The System Description is essential for underpinning the System Assessment and then the Interventions Options and Pathways components. Stakeholders will learn by implementing the project (Learning component) and these lessons should be used to modify the System Description.

The five necessary components for describing the system are presented below, but we emphasize that the procedure is not linear. It can begin with any of them and the important thing is to keep re-visiting them as the description develops. For example, in point 1 below, it may be easiest, and the stakeholders may prefer, to begin with the second dot-point.

Step 1. Explore stakeholders' views of the system, including what they value and why, and what stresses they anticipate.

This step gets to the problems at the heart of the project. It clarifies what stakeholders are seeking to make resilient, and what stresses/ shocks the system is likely to face: the "Resilience of what, to what".

- Begin by defining the focal scale of the system at/ within which lies the problem the project is intended to address. Define both the socio-economic and biophysical boundaries of the system. The two often don't coincide and the boundaries are unlikely to follow neat lines on a map. There may be, for example, local summer and remote winter habitats for migratory waterbirds, but the stakeholders are local; or perhaps some stakeholders may be only seasonal visitors. Then identify the scales above the focal scale that influence the system. For example, state or national government policies for development and for conservation. Then define the finer scales embedded within the focal scale that collectively give rise to the dynamics at the focal scale. For example a proposal to develop a conservation policy for a watershed may require some understanding of the dynamics and interactions of farming and forestry systems within the watershed.
- Identify what people value in the system now and potentially into the future (e.g. iconic species, the intrinsic value of an ecosystem, subsistence or sport hunting and fishing, agricultural production, timber, fuelwood, grazing for livestock, reliable high quality water supply, having a choice of options in the future).
- What are the 'drivers' of the system? ie, things that influence the system from 'outside' which are not influenced by the system. Common ones are markets and technologies,

national and international policies, and climate. Climate change scenarios for the region should show potential trends and the uncertainties. These can be related tentatively to the potential future distribution patterns of plants and animals, with major implications for the spatial distribution of conservation efforts.

- Identify previously experienced or potential future ‘shocks’ the system may face – economic, climate (a flood, a drought), diseases, a major policy change.

Step 2. Describe the social system and governance

- Describe the main social groups that characterise the social structure of the system, and if necessary stratify into relatively homogeneous groups (e.g. by demography, ownership, access to land, dependence on input or output markets, commercial versus subsistence versus sport hunting, etc.). Describe livelihood strategies, and the existing governance arrangements for the area, the extent to which power and decision making are hierarchical or decentralised, the formal and informal rules for resource access and use and the social processes and institutions for implementing them.
- Identify key decision-making groups, organisations and individuals that are critical to the project.
- Seek to understand how current values, knowledge and rules (i.e. laws, policies, traditions) may constrain or empower decisions, and assess the difficulty of changing rules when required.
- Assess the effectiveness and fairness of conflict resolution processes, and the extent to which levels of public trust in the governance system, and its openness to criticism will enable or impede implementation of the project.

Step 3. Describe the biophysical system, focussing on key determinants of structure and function

The aim is to identify the biophysical components, their quantities (at least relatively to start with) and the processes that underpin the provision of whatever is valued in the system, and characterise current understanding of their dynamics.

- Distinguish between stocks and flows. For example, a population of a wild species may be large, but if recruitment is low the age structure may warn of an imminent crash. Or there may be a high volume of groundwater, but if the rate of groundwater extraction exceeds the rate of recharge this will reduce future groundwater availability.
- When key quantities that are of interest are not measurable, identify indicators that serve as proxies for them. A common example is using catch rates and fishing effort to indicate changes in a fish population, or the species composition of invertebrates to assess pollution levels of streams.
- Describe the influences on key biophysical quantities. This may be in the form of a spatially resolved quantitative description (e.g. results from a climate model or a catchment hydrological model), but the emphasis is on identifying existing descriptions and not

conducting new research. If new research is needed this can be identified for future action.

Step 4. Describe key relationships in the way the system functions

- Describe the relationships within and between the biophysical and socio-economic variables that influence their dynamics. Identify any known controlling variables – the relatively small number of variables that regulate the system through their direct effects and feedback loops, and maintain its resilience; e.g. ground cover that controls soil erosion, the area of habitat required to maintain a species, social norms and laws about resource access rights and extraction levels.
- Describe the social-ecological interactions that lead to both desirable and undesirable outcomes, such as logging that creates some employment but may preclude other options for use. Iterate with Step 1, resilience 'of what' (above).

Step 5. Review and revise the outcomes of Steps 1 to 4 to consider significant interactions across scales.

For example, national policy response to drought influences household decision-making, and in return there can be critical points at which household-level dynamics interact to trigger national-level change.

Step 6. Synthesize conceptual models, supported by evidence, from the previous elements

Various conceptual models, covering different aspects of the system, can be developed. There could be a conceptualisation for the decision making context, and a separate conceptualisation for climate, hydrology and vegetation dynamics. Alternatively the problem may call rather for a conceptual model of the interactive effects of climate and herbivores on vegetation dynamics. There is no requirement for all the conceptual models to be combined into one comprehensive model. Synthesising the various models might rather include identifying key interactions between them, and drawing attention to mutually inconsistent assumptions. For example, a conceptualisation of climate and land use interactions may have an overly simplistic representation of economic or demographic drivers of land use change, while a conceptualisation of land use change driven only by economic drivers may exclude climate or climate change effects. Both conceptualisations are useful, and do not need to be combined.

Establish a process to develop and share conceptual models of the system to foster an understanding of the different perspectives of the system among the key stakeholders. Again, there is no requirement for one 'right' system description, or one common, shared conceptual model, but the conceptual model, or set of conceptual models, needs to contain the set of core elements that enable a resilience assessment.

In summary, the System Description should comprise information about:

- **drivers and shocks**
- **actors**
- **main resource uses**
- **valued components and products of the system**
- **the (small number of) controlling variables**
- **known or suspected/potential thresholds on the controlling variables**
- **key interactions among variables at the focal scale**
- **key interactions between the focal scale and the scales above and below (within) the focal scale**

System Assessment, for general and specified resilience

Step 1. Current and possible future system states

A useful way to proceed is to address the following questions:

- What is the current state of the system (in terms of the System Description)? What other possible states could (might) the system could be in – both desirable and undesirable?
- Is the current state a 'desirable' one? Is it on a trajectory to one that is less desirable (for example due to increasing drought through climate change, or loss of a key conservation species through land clearing)?
- Does an identified 'desired' future state keep options open for future decision-makers (such as by maintaining a well-functioning and resilient biophysical system)?

A framework that is helpful in working through these questions is the "State and Transition" approach described by Westoby et al (1989), which has been tested in a variety of systems. It is also helpful in addressing step 3, below

Step 2. Assess general resilience (including adaptive or coping capacity for unknown risks, trends or shocks)

There are some system properties, like high levels of health and education in a population, and high biodiversity in an ecosystem, that confer a good ability to adapt and respond to a wide range of unexpected shocks and changes. To develop an appropriate set of such system properties, ask the following questions:

- What has conferred 'coping capacity' to the system in previous times of trouble? It can be helpful to pay particular attention to what allows effective connections between scales. For example, in times of disaster do different layers of government, community and private sector work well together?

- Refer to published lists of indicators of general resilience or adaptive capacity that have been developed in other, related systems. Adaptive capacity confers a higher level of general resilience upon systems, so if the system displays many of the characteristics of high adaptive capacity, then the general resilience is likely to be high. At the highest level, general resilience comes from system properties that
    - enable quick and effective response to a diverse range of shocks
    - enable the maintenance of reserves or buffers
    - allow options to be kept open in the face of uncertain futures.

More specifically, assess the following attributes:

- diversity, both functional diversity (e.g., different species that perform different functions) and response diversity (different species that perform the same function in different ways, with different responses to disturbances)
- openness – allowing both emigration and immigration
- reserves
- feedbacks
- modularity
- social capital
- levels of financial and physical assets.

An understanding of general resilience can also emerge through multiple specified resilience assessments (Step 3). If the system is resilient to multiple specified shocks, then general resilience is usually high.

Step 3. Assess specified resilience

Specified resilience assessment is about characterising the resilience of particular parts of the system to specific kinds of shocks.

- Where possible, identify known or suspected thresholds and the likelihood of them being crossed, or recognise where a threshold might exist but more evidence or knowledge is needed to understand if there is a threshold, and if so, how close the system is to it.
- Assess whether there are critical points of no return that prevent recovery from shocks, and whether there are system properties that help recovery from shocks, such as refuges that shelter a remnant population from fire and enable the species to recover subsequently.

A helpful way to proceed is to ask, in the context of the State and Transition approach referred to in 1, if any of the identified transitions are likely to be irreversible, or to exhibit strong non-linear reversibility effects?

Stpe 4. Identify the potential benefits of i) managing the resilience of the system so it remains in the current regime, or ii) shifting to a different regime within the same system, or iii) transforming to a different kind of system with different outputs and controlling variables (a different identity).

If the system is currently satisfying stakeholders' needs and aspirations (it is in a desirable system regime) and the chance of an unwanted regime shift or transformation to a different kind of system is judged to be sufficiently low for the time being, then investing in a mix of specified and general resilience measures is a prudent option (e.g. investment in insurance, building up reserves, communication systems for rapid coordinated response across scales and sectors). Alternatively, if the current regime is precarious or not meeting the needs of stakeholders, an option is to make a planned shift to a different regime within the same system e.g. switching from intensive fishing of one species to a multi-species strategy. If no such option is available, then intentional transformation to a different, system (e.g. eco-tourism) may be the wisest course. The benefits, costs, risks and uncertainties of each of these options would be appraised using the understanding gathered to this time.

Step 5. Synthesize 1 – 4 in an overall resilience assessment.

Intervention Options and Implementation Pathways

It is useful to think about the set of interventions that will be implemented as forming an adaptive pathway into the future. Its course cannot be fixed because circumstances will change, so the pathway must be readily adaptable and designed to cope with the unexpected. Potential interventions emerging from the Resilience Assessment are developed and assembled into a pathway in partnership with stakeholders in the four-step process described below.

Step 1. Develop intervention options

Useful considerations when selecting and developing interventions include:

- Measures to prevent irreversible change in a controlling variable should usually take priority over actions to manage output. For example, if rapid clearance of wildlife habitat is happening at the same time as over-hunting, controlling the former is the first priority. Similarly, soil conservation is generally preferable to increasing application rates of chemical fertiliser. By managing a controlling variable you have a long-term effect on the outputs that it controls.
- People do not like fundamental change, so it is difficult to develop options for a regime shift or for transformational change. When information challenges beliefs and local knowledge, it tends to be rejected – as for example with the causes and impacts of climate change on species abundance and distribution, or the possibility of changing resource access rights. Options for radical change should therefore be explored and developed through a process which is ethical, carefully planned and skilfully facilitated, because it is likely to generate conflict (Stakeholder Engagement Step 4).

- Intervention options are unlikely to fall into mutually exclusive categories of 'building resilience of the current system', or 'domain shift' or 'transforming to a new system'. Interventions of all of these sorts may be appropriate at different times or spatial scales. For example, building resilience at the regional scale could mean supporting transformational change at finer scales. In this way the option to incrementally build resilience at the regional scale can include building options for transformation at more local scales.

Step 2. Build Pathways and Sequence the Intervention Options

An Adaptive Implementation Pathway is a strategy for grouping and sequencing the implementation of interventions, as well as identifying critical review points in the future. Some interventions should be implemented before others, some will be best held in reserve, others will be discarded or modified as circumstances change and understanding improves. Table 1 provides criteria that help to achieve this.

Table 1 Criteria for choosing and sequencing interventions

Criteria	Description
Is it a foundational intervention?	Some interventions must be implemented if other interventions are to work e.g. changes in governance, such as resource access rights; landscape scale management of vegetation cover, water flows and soil erosion; health, training and education; new roads.
Is it an intervention to prevent a threshold being crossed?	The System Description and System Assessment components identified potential thresholds on controlling variables. Crossing some of these may be necessary for achieving food security, but others may mark an irreversible shift to an unwanted domain e.g. a decline in soil depth that leaves land useless for anything except unproductive grazing, a fall in the water table that makes water inaccessible, or loss of wildlife habitat to charcoal-making. The sequencing of interventions that prevent the crossing of such thresholds depends on how imminent the danger is.
Is the intervention resilient or robust to a wide range of potential stresses or shocks?	It is wise to prioritize interventions that will work despite a wide variety and range of magnitudes of shocks, e.g. a bridge on a road to a market can be built to cope with extremely large floods that might occur if future rainfall variability increases (a robust intervention). The investment may not be justified if extreme floods do not occur. A resilient intervention might be to build a smaller bridge which can be affordably rebuilt if destroyed by a flood.
Will the intervention impact on other options?	A resilient system is one that keeps a wide range of options open for the future. This is because we cannot know what the future will bring, so the system will be more adaptable if, wherever possible, we avoid interventions that close off future options – clearing vegetation for farming is an example. Of course there are trade-offs – such interventions may be beneficial in other ways – but these should be considered explicitly, so that options are kept open as long as possible.

Will there be a long delay between intervention and effect?	Some interventions will only begin to take effect long after implementation begins e.g. planting trees, increasing skills and building social capacity for governance. Also in this category are interventions that need to be delayed while further research into their benefits and costs is carried out. Other things being equal, interventions with long lead times should be initiated before interventions with less delayed effects.
Is the intervention necessary but not currently feasible?	Some interventions necessary for reliable agricultural or fish production or long term wildlife conservation are not immediately feasible because they are blocked by current laws or policies, or prevailing social norms and values e.g. inheritance or resource access laws, norms about the roles of women, and absence of infrastructure or educational facilities. Changing laws or policies may require prior interventions such as strengthening stakeholder relationships with politicians and public servants. Changing cultural norms may require prior investment in participatory social processes to co-develop a socially acceptable intervention. These prior interventions become part of the pathway, and when they are successful the interventions that were previously blocked can then be reconsidered and incorporated in the pathway.
Is it fair and will it build social cohesion?	Interventions that build social cohesion should be implemented early because cohesion will often facilitate other interventions. In general, interventions having negative impacts on fairness and cohesion would get lowest priorities.

The provisional sequence together with a deepening understanding of the system can now be used to set implementation triggers. These are decision points along the pathway that indicate it is time to implement interventions that have until then been deliberately delayed. Hypothetical examples are:

- the flow volume of a stream below which irrigation is not feasible, or a particular fish species cannot persist
- the density of tree hollows in which an endangered species breeds
- the recruitment rate of a forest tree species
- the frequency of wildfires
- the capacity of a community above which it is ready to adopt more complex interventions.

These triggering criteria are specific to the context of the project. They are set during this design stage, but should be revised as circumstances change.

Step 3. Build the understanding gained from all components into an implementation plan

The next step is estimating the benefits and costs of interventions before assembling them into an implementation plan. The following are helpful points in developing these estimates.

- Benefits and costs can be economic, social or environmental and encompass a diversity of values, and they are not usually distributed equally among stakeholders or between genders.

- Many important benefits cannot be quantified – governance capacity for example. It is important to ensure that quantified benefits are not automatically assumed to be more important than qualitative ones.
- The adaptation pathway as a whole should have an expected net ecological/ social benefit, but a net loss may be acceptable during the early years.
- Uncertainty means that a generous amount of funding needs to be allocated for contingencies.
- Systems subject to threshold changes can display very large and often irreversible changes in benefits and costs if thresholds are crossed. It is wise therefore to make clear and prominent statements about the consequential benefits and/or costs of crossing a threshold.

Step 4. Action the implementation plan

The provisional order of implementation, and often the options themselves, will change as the pathway is adapted to unexpected setbacks, growing knowledge and new opportunities. Funding will change; drought or flood can disrupt plans; costs and prices may change unexpectedly; government's priorities may shift and key stakeholders may leave; etc. Also, the project will implement some interventions to remove blockages to other potential interventions, some of which would join the implementation sequence when they become feasible.

The implementation of interventions will reveal gaps in understanding of the system, such as the existence of unexpected thresholds, or stakeholder consultations may prove inadequate.

Learning (Monitoring, Assessment, and Knowledge Management)

"Monitoring and assessment", "lessons learned" and "knowledge management" are increasingly recognised as essential components of most projects, but the overarching "learning" element is more fundamental to a resilience approach than to other approaches. As the world faces changes at unprecedented speed and scale, for which there are no tested solutions, "learning by doing" must be central to any approach, and RAPTA is designed to provide such a structured learning and adaptive process.

The focus on learning, on testing assumptions and improving the knowledge base sets a resilience approach apart from traditional approaches to project development and implementation. This focus is aimed at helping stakeholders find new ways of addressing chronic problems, break with ineffective policies of the past, and set social-ecological systems on resilient new pathways. But it requires a strong commitment to learning and building the knowledge systems and a learning culture to support this shift. It requires governance that encourages a diversity of ideas, is willing to experiment, and that includes monitoring, evaluation, information management and a culture of acting upon feedback from the system.

Concluding Remarks

These concepts are not a set of scientific theories that can be developed and tested in controlled conditions. There are no off the shelf, tried-and-tested recipes for resilience. The context of each application requires a tailored approach, which must be flexible and able to adapt to novel, uncertain and rapidly changing circumstances. The RAPTA approach supports the design of actions which can help guide linked social and ecological systems into the future, informed by sound science, underpinned by a structured learning process to gather and analyse evidence, followed by continual adjustment of actions based on what has been learned.

We emphasize that the process is essentially iterative, moving through three main phases. The first involves initial scoping and planning with a 'light pass' through the process, emphasizing multi-stakeholder engagement, description and learning. The second is a more substantive assessment of resilience, options and pathways, where all components are done in a thorough manner. The third phase has a focus on implementation and adaptive management of options and pathways, and is where the multi-stakeholder engagement and governance, and the learning components receive more emphasis.

The people and stakeholders involved through these phases change, and the numbers involved increase, as it proceeds. The first is likely to involve a few key stakeholders, the initiators of the project and a few key technical experts. The next pass through the process involves a wider array of stakeholders, including key government agencies, and a wider array of scientists and people with knowledge of the system, both biophysical and social. Those involved in phase 3 will depend on the particular project but may well involve private enterprise and industry representatives in addition to key decision makers and the core technical group.

The process we have outlined is still being developed and tested. We do not expect it to be implemented just as described, because practitioners will need to adapt the approach to local circumstances, and because they are likely to find ways of improving the approach (which we would like to hear about). We advocate only that practitioners engage early with stakeholders, promote listening, questioning and learning, build adaptive management into the project, and apply the 'Nine Things to Know About Resilience' when developing their own approaches.

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