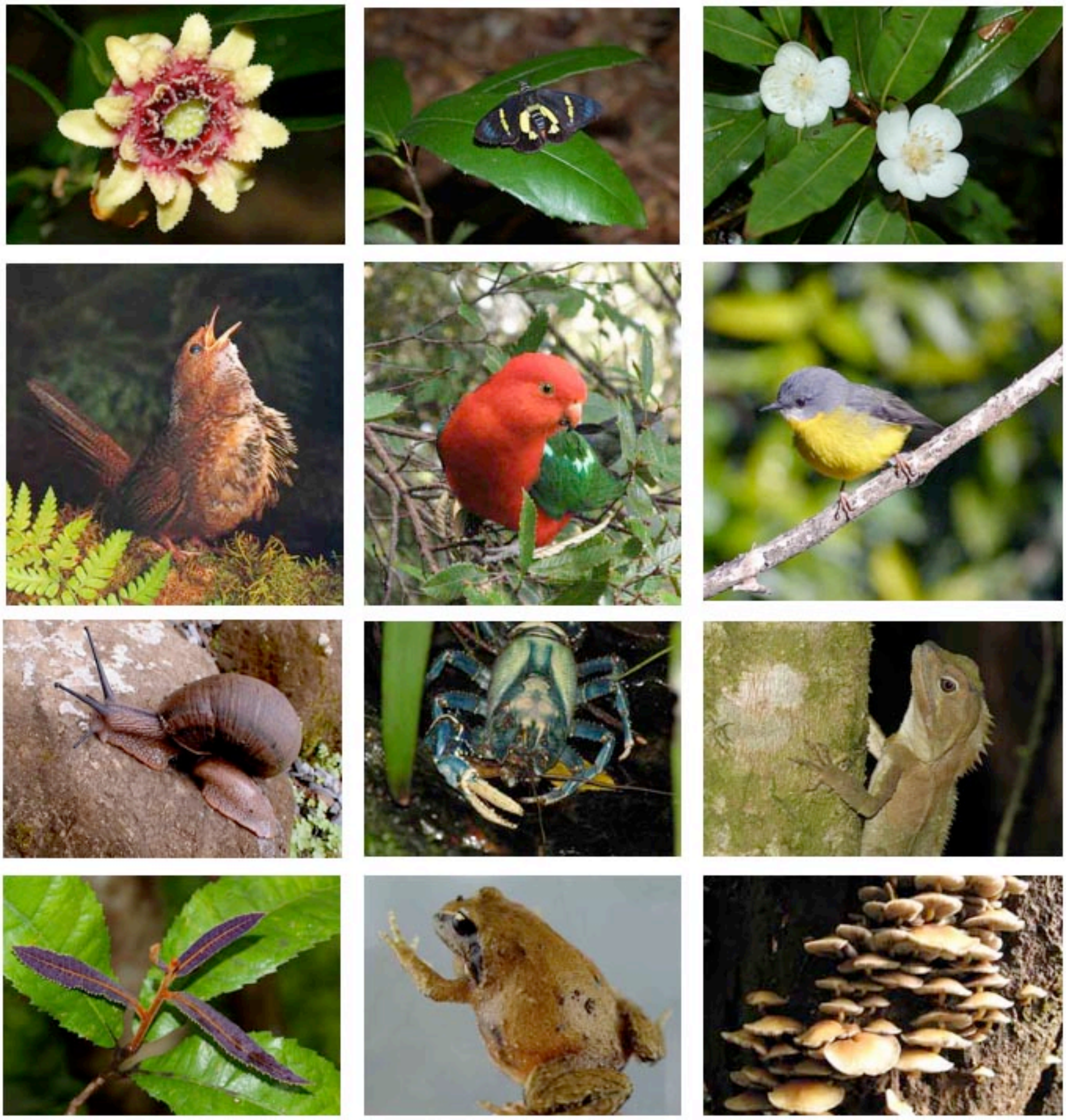
Principles and Guidelines

towards development of a

Queensland Biodiversity Strategy

A WORKING DOCUMENT



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FRAMEWORK AGREEMENT

PRIMARY POLICY OBJECTIVE

1. **Reverse the trends of biodiversity loss**
    a. **Bring extinction rates of species back to background levels; and**
    b. **Reverse the decline in species, populations, communities and ecosystems**

2. Increase resilience of natural ecosystems to withstand climate change and other pressures

MEANS TO ACHIEVING GOALS

2. **Address the major pressures responsible for biodiversity decline**
    a. **Loss, fragmentation and degradation of habitats**
    b. **Unsustainable exploitation of natural resources**
    c. **Pollution of the environment**

CRITICAL OUTCOMES

3. **National Parks that are large, linked, adequately buffered and resilient,**
4. **Resource-use areas managed sustainably and for human well-being**
5. **Systems approaches used for assessing resilience to pressures or impacts on biodiversity**
6. **"Inclusive wealth" adopted as a better economic measure of sustainability**
7. **Good trend data, horizon scanning and safe boundary setting that is open and transparent**
8. **Required levels of resources for achieving policy objectives**
9. **Independent, timely performance reviews against policy objectives**
10. **Cross-government and sector commitment and coordination**
11. **Governance responsive to changing needs and monitoring outcomes**

Executive Summary

1. The Biodiversity Crisis

The world is facing the sixth great extinction crisis since life on earth began

Queensland has globally significant biodiversity and faces a tidal wave of extinctions

- **44% of nationally threatened species have negligible protection of habitats inside protected areas**
- **protected areas within national parks only represent less than 5% of Queensland**
- **threatened species with known trend records are all declining many orders above background rates**
- **climate change threatens many more species than are on current lists; and little is known about where species can survive or successfully move to under climate change**

2. The Root Cause

The root cause of this crisis is the expanding human footprint of resource use

- **All states aspire to a greatly expanding population whilst habitats are declining**
- **Queensland still has twice as much land clearing as the rest of Australia combined**
- **Resource consumption, pollution and urbanisation are intensifying and expanding**

3. Barriers to Reversing Biodiversity Decline

The key barriers to reversing biodiversity decline are:

- **Failure of communities to understand biodiversity and social-ecological systems resilience**
- **Failure of markets to value biodiversity (the public good)**
- **Failure of governance to protect biodiversity — i.e. avoid the "tragedy of the commons"**

4. Overcoming Barriers

To be effective the Strategy must address the above three key barriers:

Failure of communities to understand biodiversity and the essentials of 'systems resilience'

1 **Acknowledge the critical value of biodiversity and ecosystem services and the scale of the crisis**

2 **Acknowledge that "business as usual" approaches to arrest the decline are failing us**

3. **Adopt a "social-ecological systems" approach encompassing "resilience thinking"**
4. **Adopt new overarching goals of "systems resilience" and "reversing biodiversity decline"**
5. **Ensure that protected area systems are the cornerstone of an effective biodiversity strategy**
6. **Ensure adequate areas are protected, restored and functionally linked for ecosystem resilience**
7. **Commit to long-term monitoring as an essential basis for adaptive management**

Failure of markets to value biodiversity

8. **Address market-place failures that (a) ignore linkages between social and ecological systems, (b) inadequately or inappropriately value biodiversity and ecosystem services, and (c) result in insufficient allocation of financial resources or inadequate measures for biodiversity protection**

Failure of governance to avoid a "tragedy of the commons"

9. **Reform governance arrangements that will**

   (a) provide a whole-of-government, evidence-based, statutory, policy and implementation framework for long-term systems' resilience and the avoidance of cumulative impacts

   (b) require a minimum duty of care binding on all land and sea users

10. **Institute regular, transparent and accountable reporting of adaptive management and governance outcomes against policy objectives. The aim is to review and adapt our understanding of complex, often unpredictable systems, the ongoing appropriateness of goals and targets, and the rules adopted for access, use and management. Details of conceptual models adopted, underpinning assumptions, contingent and scenario-based risk assessment and planning, and the results of long-term monitoring should be freely available. Use horizon scanning for timely warning of new threats. Establish an Independent Commission on Biodiversity with adequate powers and access to expertise.**

1. The Biodiversity Crisis

Worldwide, we are in the early stages of the sixth great extinction of life on earth since it began 3 billion years ago, with rates already a thousand-fold higher than predicted background levels (SCBD 2006). Our threatened species lists continue to grow. Climate change compounds many other threatening processes. Threats are increasing while many new species are still being described (Chapman 2009).

Australia's unique mammal fauna has fared particularly poorly:
"Of the 305 non-marine mammal species present in Australia at European settlement, 85% were endemic, 22 are now extinct, 8 became restricted to continental islands, and 100 have been lost from at least one of Australia's 85 bioregions." (DEWHA 2009).

According to the 2008 Biodiversity Assessment (DEWHA 2009), the only formal status changes for threatened species from 2002–2007 were all declines. The threatened species list does not generally include subspecies, varieties or evolutionarily critical populations. It also doesn't recognise that seemingly common species can suddenly crash towards extinction.

In Queensland we face a tidal wave of extinctions.

Arresting and reversing biodiversity decline requires both:
(1) effective *abatement* of threatening processes; and
(2) *rebuilding resilience* in interlinked social and ecological systems.

2. The Root Cause of the Biodiversity Crisis

The fundamental, root cause of the global biodiversity crisis is us — our vastly growing numbers, our unsustainable per-capita consumption of resources and production of waste that are undermining the resilience of both the earth's natural ecosystems and the social systems that depend on them (Dudgeon *et al.* 2006; Likens *et al.* 2009).

The number of humans inhabiting the earth has quadrupled over the last century and expected to rise to 8 billion by 2025. The technologies we use often compound impacts further. In all cases we substitute impoverished, degraded, modified or completely transformed landscapes or seascapes for the natural environment that once existed.

The WWF Living Planet report shows that Australians have the fifth highest ecological footprint in the world indicating a level of exploitation beyond the earth's regenerative capacity (WWF 2008).

Our burgeoning population and unsustainable consumption of resources and pollution from waste manifests in seven "Grand Challenges" recognised worldwide:

Threatening processes resulting from the root cause that must be addressed in an integrated way:

1. Unsustainable population growth especially that focussed in areas of high net primary productivity where biodiversity levels are highest (Luck 2007), and in areas where ecosystem resilience is already severely impaired;
2. Land-use practices leading to loss, fragmentation and modification of wildlife habitats and changes to essential biogeochemical processes;
3. Unsustainable natural resource consumption (e.g. forestry, fisheries, water extraction of ground and surface waters) ignoring complex ecosystem behaviour (Johnson *et al.* 2006; Walker and Salt 2006);
4. Pollution (all forms including chemical, visual, sound, and polarized light pollution);
5. Alien species and exotic pathogen invasions;
6. Inappropriate hydrological and fire regimes; and
7. Climate change, which also compounds impacts from the other threatening processes.

3. Barriers to reversing biodiversity decline

The inability to address these impacts or halt the decline of biodiversity arises from three key types of barriers (Loreau and Oteng-Yeboah 2006) or crisis precursors (Scott Taylor 2009):

(1) Failures of understanding (especially the fundamentals of resilience thinking)
(2) Failures of the market place (valuing biodiversity)
(3) Failures of governance — the tragedy of the commons

(1) *Failures to understand biodiversity and social ecological systems resilience*

Anthropocentric world view of biodiversity

There is no shared understanding that there *is* a problem, that we are the centre of the problem, and that past ways of thinking about the way social and ecological systems function and interact is exacerbating the problem and preventing us from finding solutions.

Generally we fail to understand that maintaining biodiversity is fundamental to the stability of the earth's ecological, economic and social systems (Worm and Duffy 2003, Veron 2008, Duffy 2009). Likewise, we generally fail to recognise that protected areas are vital for protecting biodiversity.

We fail to recognise the enormity of the global biodiversity extinction crisis, its causes and likely costs of amelioration (Jordan *et al.* 2009). We also fail to recognise the costs of inaction.

We generally fail to acknowledge that conservation of biodiversity is also an ethical imperative, not merely a policy option (World Charter of Nature 1982)[i].

We also fail to acknowledge that "business as usual" approaches of the past are failing to arrest biodiversity declines. However, new ways of thinking are never easy and will take time to achieve.

Our current approaches to dealing with biodiversity are largely utilitarian and depend on simplifying rather than embracing complexity and uncertainty in social and ecological systems. We assume predictable, linear relationships between cause and effects in essentially "equilibrium" systems. We try to optimise delivery of goods and environmental services by focussing on selected parts of social-ecological systems in isolation (e.g. maximum sustainable yield concepts for commodities).

Outdated ecosystem models

The "business as usual" approach to resource management, typically encompassing "command and control" instruments, aims to optimise returns on an isolated part of ecosystems through efficiency dividends, and is based on an equilibrium view of ecosystem behaviour. It assumes extinctions are part of natural processes, that ecosystems behave in a linear predictable manner (through cause and effect), that nature will recover regardless of the insults we throw at it, or that science and technology will come to the rescue through improved efficiencies or engineering fixes. Understanding a component of the system, controlling it to maximise its output, monitoring and minimally adjusting management for optimal cost-benefit returns is the norm. The characteristics of this approach are short-term timeframes, compartmentalisation, predictability, optimisation, efficiency. It does not lead to long-term sustainability either of the ecosystem 'parts' (e.g. timber, fish, water, grain, environmental amenity etc) or systems as a whole. In fact, this paradigm almost inevitably leads to crashes and loss of biodiversity. Use of panaceas or simple, easy fixes is dangerous and will not provide long-term solutions.

Threshold system models

More realistic models recognise social and ecological systems as interlinked, dynamic, complex, adaptive systems involving multi-level feedbacks, with the potential to exist in more than one kind of regime with different structures, function and feedbacks (Walker and Salt 2006). Changes to any part of the system will produce feedback changes in other parts of the system. Shocks or disturbances (floods, droughts, fires, vegetation clearing, wars, market collapses) can drive systems unpredictably across thresholds into different (undesired) regimes, e.g. collapsed fisheries, forestries, coral reefs, lake systems etc. System recovery is not simply a matter of stopping activities causing the problem.

In complex adaptive systems emergent behaviour is impossible to predict from studying the parts separately. Resilience thinking provides powerful insights into how the real world works and is the key to practical innovative solutions. It differs from 'business' as usual approaches. The characteristics of threshold models are — linkages across many scales, unpredictability, redundancy, tipping points, alternative regimes, long-term thinking, resilience.

There are "off the shelf" frameworks of benchmarks and indicators for Social-Ecological Systems to facilitate analysis and problem-solving to reverse biodiversity decline (Ostrom 2007, 2009; Kenward *et al.* 2011; de Bello *et al.* 2010). These at least provide a starting point for adaptive improvements in systems analyses that benefits from learnings around the globe.

Practical criteria for identifying the characteristics of resilient Social-Ecological Systems (or a resilient world) have been proposed (Walker and Salt 2006):

1. *Diversity* (biological, landscape, social, economic)

   Diversity is the critical underpinning of resilience, the source of a system's capacity to respond to or resist change and disturbances. Diversity includes concepts of functional and response diversity which characterise the dynamics of complex interactive systems. Restoration of lost diversity may be essential for re-establishing resilience.

2. *Long-term variability*

   We need a better understanding of long-term natural cycles of change, accepting and living within these cycles rather than controlling them to suit our short-term social and economic demands.

3. *Modularity*

   Preserving and restoring modularity helps reduce susceptibility to shocks that would otherwise flow throughout over-connected systems. Modularity encompasses concepts of replication of protected areas to avoid total loss by disturbance events such as fire, cyclones or pollution.

4. *Attention to "Slow Variables"*

   "*Slow*" variables (including threatening processes) are the forces acting, sometimes imperceptibly, over longer timeframes that push systems past thresholds. If ignored even common species can suddenly disappear and apparently stable ecosystems collapse.

5. *Feedback loops*

   Maintaining and strengthening feedbacks enables better detection of thresholds before they are crossed. Currently, feedbacks are loosening at all scales and in all systems. Globalisation and homogenisation weakens signals of impending systems collapses.

6. *Social Capital*

   The promotion of trust, well-developed, cohesive social networks and knowledge leadership enable people to respond collectively and effectively to change and shocks to any system. The existence of strong penalties for 'cheaters' (naming and shaming etc) is important as well (Ostrom 1999, Brondizio *et al.* 2009).

7. *Innovation*

   Learning, experimentation, innovation, adaptive management, embracing change and complexity are hallmarks of approaches likely to achieve resilient systems. Governments provide subsidies to *not* change (drought and flood relief) rather than assistance for appropriate change to ensure long-term resilience. Crises are creative opportunities for change.

8. Overlap in Governance

Institutions need to include "redundancy" or overlap in their governance structures. Overlap measures (whole-of-government approaches) are likely to increase response diversity and flexibility to change and shocks to any system. Such arrangements also foster strong awareness and response to cross-scale influences (Ostrom 1999, Dietz et al. 2003).

9. Ecosystem Services

Development proposals and assessments should place a value on normally "unpriced" ecosystem services. Most ecosystem services (pollination, water supply and purification, nutrient cycling etc) are currently either unrecognised, considered "free" or ignored in purely market-driven economies. They are commonly lost under 'regime' change, and only then begin to be appreciated and valued. Valuing the environment must be science based (Ruffo and Kareiva (2009).

(2) Failure of the market place to value biodiversity

Differences in social and private benefits associated with natural resource use result in classic market failure (Jack et al. 2008). The market place fundamentally operates on principles of efficiency, optimisation and short timeframes that consistently undervalue biodiversity. The premise is that values without property rights, that are not marketed or wealth generating, tend not to be protected or supported. It is based on economic rationalism, which assumes that an individual's incentive to protect nature is based on self-interest (e.g. profit). The consequence of market place failures is a lack of funding for biodiversity protection and management, and severe inadequacies in environmental impact assessment. In the long term, costs of remediation become extremely or prohibitively high. The US Everglades and the Murray Darling system are good examples of the immense future costs of inaction (Walker and Salt 2006).

When problems arise, the level of past investment to optimise returns or survive financially (sunk costs), also acts as a major impediment to long-term planning and decision-making.

Governments often impose perverse incentives or subsidies operating in the short term that encourage overuse of resources. For example, government hardship payments to drought-stricken farmers on marginal land or lands that have lost their resilience, can push these systems towards irreversible collapse (Walker and Salt 2006). Subsidies that favour unsustainable systems (fishing, forestry, agriculture…) should be replaced by incentives to change in ways that favour long-term sustainability and resilience.

Where the costs of acquiring complete information about complex problems are high, decision-makers commonly use simple heuristics or act intuitively (Perrings 2007). These make sense when decisions are routine and the benefits of determining the optimum are small. It makes no sense when decisions involve high and potentially irreversible costs. At present there is fundamental uncertainty about both the structure of coupled systems and measures of their performance.

Market-based instruments for environmental management include price-, quantity-, and market friction-based tools. Their use needs to be continually evaluated in terms of their capacity to assist achievement of long-term biodiversity goals. The effectiveness of market-based instruments is determined by (a) the extent to which they attract participants and influence their behaviour, and (2) the extent and nature of biodiversity that is conserved as a result. Potential improvements, where appropriate, include:

a. Adapt short-term principles of *efficiency* and *optimisation* in resource management to include those of long-term systems resilience (Walker and Salt 2006, Walker *et al.* 2010)
b. Address problem of *externalities* and *perverse subsidies* (Jack *et al.* 2008, Walker *et al.* 2010)
c. Include currently unpriced *ecosystem services* in all development assessments and approvals; "inclusive wealth" metrics provide one means of doing so (Arrow *et al.* 2004; Walker *et al.* 2010). This stocks-based approach uses market and non-market prices as measures of human, manufactured and natural capital, the net value of which should remain constant over time.

d. Improve ability of consumers to make wise market decisions that reward sustainability and systems resilience by e.g. appropriate *certification* and *labelling* of all products that better inform consumers.

The relative effectiveness of market-based instruments and democratic political processes that could best address issues with a moral, ethical and long-term dimensions of the public good must be assessed.

(3) Failure of governance to protect biodiversity — The tragedy of the commons (Harden 1968)

The tragedy of the commons (Harden 1968) is a useful paradigm to symbolise inadequately regulated overuse and degradation of natural resources (Ostrom 1999, Crepin and Lindahl 2009). Overuse of resources (consumption) and resulting environmental degradation largely result from a failure of governance (Young et al. 2007). Traditional focus on single-species resources in fisheries, aquaculture and forestry creates organisational and institutional structures with compartmentalized decision-making processes leading to narrow policy instruments that create incentives for policies and actions that undermine sustainability. This type of governance is ill-equipped to respond to the complexity of dynamic ecosystems or build adaptive capacity for coping with change and uncertainty (Ostrom 2007). These traditional approaches to resource management are often overwhelmed by global economic drivers and cannot address complex threshold dynamics of linked social-ecological systems (Olsson et al. 2008). Failures in governance (inadequate institutional structures, laws etc) result in cumulative, compounding impacts that can ultimately result in regime change and irreversible loss of biodiversity.

It is important also to strengthen commitments to and implementation of existing international agreements. These include

It is vital to recognise there are no universal solutions or panaceas to problems of overuse or destruction of natural resources. A systems approach and adaptive management are essential. Planning frameworks must require concurrence agencies to evaluate linked and cumulative impacts across scales within a multi-systems approach.

A Social Ecological Systems Framework

As a starting point, standardised frameworks for a Social Ecological Systems such as those proposed by Ostrom (2007, 2009), Kenward *et al.* (2011) or Francesco de Bello and colleagues (de Bello *et al.* 2010) should be tested as a matter of urgency. The Ostrom framework is a multi-tiered approach adaptable to any issue or system across any relevant multiple scales. It provides a model to be reviewed and further developed based on experience and the results of adaptive management. Her proposed Framework provides benefits from a vast mass of published and reviewed learnings from around the world.

The basic outline of this framework (Ostrom 2007, 2009) is illustrated in Figure 1.

4. Overcoming barriers

Practical steps to overcome or address barriers

(1) Failure of the community to understand biodiversity or resilience thinking

1. Acknowledge the critical value of biodiversity to sustainability of ecological, social and economic systems and the enormity of the crisis and the effort that is needed to ameliorate it. This includes acknowledging the following:
   - the sixth global biodiversity extinction crisis, its magnitude and causes
   - uncontrolled growth of the human footprint, the chief cause & measures that must be taken to address this primary cause of the biodiversity crisis
   - existing extinction debt and overshoot of tipping points
   - global greenhouse gas emissions tracking above IPCCs 2001 'worse case' scenario
   - maintaining biodiversity is fundamental to stability of social-ecological systems

- conservation of biodiversity is an ethical imperative, not merely a policy option (See Endnote)

2. Acknowledge "business as usual" approaches of the past are failing us and that a changed approach is needed
    - recognise we exist in linked social and ecological systems: change in one part affects others
    - recognise ecosystems can be pushed past thresholds into new undesirable regimes
    - recognise "resilience" is the key to sustainability
    - acknowledge past implementation failures (some listed on www.onlyoneplanet.com.au). These include:
        - inadequate biodiversity inventories (e.g. inland aquatic and wetland ecosystems)
        - failure to achieve truly comprehensive, adequate and representative protected area networks (e.g. inland aquatic and wetland ecosystems under-represented)
        - inadequate understanding, inventory and baseline data of biodiversity (including inadequate taxonomic capacity)
        - grossly inadequate levels of funding to achieve biodiversity protection and management
        - failure to utilise specific but flexible time-bound, quantifiable targets and actions as part of milestone monitoring associated with adaptive management
        - failure to clearly establish jurisdictional responsibilities for funding, monitoring and assessment programs to monitor progress towards policy outcomes.
        - failure to implement coordinated inter-agency and inter-governmental strategies

3. Agree to develop a "social-ecological systems" approach with a key focus on achieving "resilience". As a first step, explore the development of standardised Social-Ecological Systems frameworks of benchmarks and indicators as suggested by 2009 Nobel laureate Elinor Ostrom and her colleagues (Ostrom 2007, 2009), Kenward *et al.* (2011) or Francesco de Bello and colleagues (de Bello *et al.* 2010).

4. Adopt goals of "systems resilience" and "reversing species decline" by 2035. Centre adaptive management for "systems resilience" around the 9 goals or indicators developed by the Resilience Alliance (Walker and Salk 2006).

5. Recognise that protected area systems are the cornerstone of an effective biodiversity strategy.
    - 5.1 Acknowledge that a science-based, resilient reserve system, large wilderness areas, and sympathetic off-reserve management are fundamental principles of a Biodiversity Strategy (Likens *et al.* 2009); that "biodiversity is best conserved in its natural state" and "ecosytems are complex systems capable of non-linear dynamics with threshold and unpredictable behaviour" (Walker and Salt 2006).
    - 5.2 Give equal emphasis to protection of marine ecosystems. Oceans cover 70% of the Earth's surface, harbouring one million species on coral reefs alone and up to 10 million in deep seas, most of which have not been catalogued or identified. Less that 1% of oceans are protected.
    - 5.2 Increase the national park system to represent 15% of the state area by 2020 based on the essential attributes of resilient Terrestrial and Marine Protected Area network design outlined in Tables 1 and 2.
    - 5.3 Set targets to accelerate leasehold and state forest conversions to national parks
    - 5.4 Set targets, based on urgency and need, to save critical habitat and ecosystems
    - 5.5 Build a capital fund to at least $100 million by 2014 to ensure achievement of the above targets

6. Rebuild long-term social and ecological systems resilience at multiple scales.
    - 6.1 Restore depleted ecosystems and linkages across multiple scales to achieve functional connectivity and resilience, setting time-bound targets and prioritising according to most urgent need (Tables 3 and 4)

7. Rebuild social capital needed to understand and deal with resilience of social-ecological systems (See Resilience Criterion 6)

(2) Failure of markets to value biodiversity

8. Address market-place failures that (a) ignore linkages between social and ecological systems, (b) inadequately value biodiversity and ecosystem services, and (c) result in insufficient allocation of resources for biodiversity protection (Arrow *et al.* 2004).
    - 8.1 Adapt principles of *efficiency* and *optimisation* in resource management to include those of systems resilience based on longer time frames (Walker and Salt 2006)
    - 8.2 Address issues of *sunk-cost and poverty traps*, *externalities*, and *perverse subsidies* (Jack *et al.* 2008)
    - 8.3 Include currently unpriced *ecosystem services* in all development assessments and approvals via *shadow pricing* or other appropriate tools such as InVEST developed at Stanford University (http://www.naturalcapitalproject.org/InVEST.html)
    - 8.4 Improve ability of consumers to make wise market decisions that reward sustainability and systems resilience by market-based incentives directed at reducing market friction e.g. appropriate *certification* and *labelling* of products that better inform consumers (Whitten *et al.* 2004)
    - 8.5 Continually review the relative effectiveness of market-based instruments or political processes to achieve protection of the public good such as biodiversity.

(3) Failure of governance to protect biodiversity (Tragedy of the Commons)

9. Reform governance arrangements that will (a) provide an integrated statutory and policy framework for science-based adaptive management of terrestrial, marine and aquatic social-ecological systems to achieve long-term systems resilience; (b) require a minimum duty of care binding on all land and sea users; and (c) ensure transparency, accountability and intergenerational equity.
    - 9.1 Trial an "off the shelf" Social-Ecological Systems framework (Ostrom 2007, 2009) as a useful standardised system of resilience benchmarks and indicators. Use learnings from various countries therein as to what works when.
    - 9.2 Consider institutional "*redundancy*" c.f. *efficiency*, within governance structures (Resilience Criterion 8) to improve response diversity and flexibility to change and unpredicted shocks or surprises.
    - 9.3 Review and reform policy and legislation to align with requirements for systems resilience and the avoidance of threshold-exceeding cumulative impacts.
    - 9.4 Strengthen commitments to and implementation of existing international agreements
    - 9.5 Require a minimum duty of care binding on all land and sea users

10. Ensure transparency and accountability in performance, reporting and review by adopting a whole of government program logic model based on adaptive management.

    - 10.1 This would integrate goals, target setting, risk assessment, ecological and financial need assessment, planning, implementation, long-term monitoring and progressive improvements.
    - 10.2 Analyses must be based on hard evidence and sound science.
    - 10.3 Institute annual or biannual forums with the conservation sector to review performance (e.g. associated with annual Ministerial Roundtable) and underpinning assumptions (a joint science council or workshops); build in timely reviews of NRM plans

    Independent , fully funded Biodiversity Commission, with independent performance auditing powers (WA WWF proposal)

5. Addressing threatening processes in the short-to-medium term

Seven "Grand Challenges" are recognised worldwide as the key threatening processes arising from the Root Cause (unsustainable human numbers consuming natural resources and ecosystem services, and polluting and degrading the environment). (See Section 2.)

Recognising that complexity, uncertainty and the multi-scale nature of social ecological systems presents difficult challenges for already overstretched natural resource managers dealing with day-to-day crises, it will take time to develop and implement the necessary policy, statutory and strategic and monitoring framework. However, it is important to still be able to act urgently in areas less prone to uncertainty (Lawler *et al.* 2010).

Additions to the protected area estate (Tables 1 and 2), increasing ecological connectivity, removing invasive species, restoring habitats and natural flow regimes, preventing or removing pollution, are all areas where urgent proactive action is needed within short- to medium timeframes (Tables 3 and 4).

Tables 3 and 4 list the broad short- to medium-term threat abatement strategies and activities for terrestrial and marine off-reserve environments (and reserve environments where relevant).

Time-bound Goals, Targets and Audits, that are regularly reviewed for relevance and urgency, need to developed as milestones for these specific resource management activities but within the broader framework described above that is designed to address the causes of past failures and the complexity and uncertainty of linked social and ecological systems.

End Note

The National Biodiversity Strategy (1996) and the *World Charter of Nature (1982)* state that:

i. *"There is in the community a view that the conservation of biological diversity has an ethical basis. We share the Earth with many other life forms that warrant our respect, whether or not they are of benefit to us. Earth belongs to the future as well as the present; no singe species or generation can claim it as its own"*; and

ii. *"Every form of life is unique, warranting respect regardless of its worth to man, and, to accord other organisms such recognition, man must be guided by a moral code of action"* (World Charter of Nature 1982)

Table 1. Essential attributes of a resilient, Terrestrial Protected Area (TPA) network design

Attribute	Design parameters
Size	Large connected areas are generally better (Laurance 2001; Luck 2007; Keddy *et al.* 2009) but small areas of high productivity can be vital to protect areas of extremely high biodiversity and these require special buffering strategies (Luck 2007)
Shape	Minimize perimeter to area ratio to reduce edge effects (Laurance and Curran 2008) and maximise buffering against sharp edges (Nascimento *et al.* 2006)
Comprehensiveness and adequacy	Ensure viable examples of all bioregional ecosystems and species habitats are adequately reserved through integrated and systematic bioregional strategies (Sattler and Taylor 2008). Include at least 30% of every bioregion and each major ecosystem, with greater levels (where possible) for vulnerable or threatened ecosystems. An interim target of 10% should be reached by 2020. At least 80% of reserved ecosystems should be protected within IUCN class 1–IV reserves, the remaining 20% within IUCN class V–VI reserves and other governance arrangements. Draw on regrowth or restore vegetation where insufficient remnant vegetation remains. Restore and include endangered ecosystems and threatened species habitats to the point they are no longer at risk of extinction. Ecosystems targeted must include freshwater and wetland ecosystems and associated stygofauna (i.e. lakes, mound springs, cave systems, streams, rivers, floodplain wetlands and groundwater-dependent ecosystems) and encompass protected catchments and freedom from major in-stream barriers (Zedler and Kercher 2005; Stein 2007).
Risk spreading	*Replication*: protect sufficient (at least five or more viable replicates) samples of each terrestrial habitat type (regional ecosystem) to capture geographic variation of species and their genetic diversity within regional ecosystems
	Spread: ensure that replicates are spread out in space to reduce the chances they will be affected by the same disturbance event or lost in one catastrophe
	Select TPAs in a variety of bioclimatic regimes based on modelling to ameliorate the risk of sensitive ecosystems succumbing to thermal and hydrological stresses caused by climate change. Cloud forests and palaeoendemic refugia require priority protection because of their vulnerability.
Critical areas	Identify and protect ecologically important or critical areas, such as climate and edaphic refugia (topographically complex mountain areas and chains, calderas, ravines, centres of high endemism, hotspots of species diversity), and areas of high net primary productivity (Luck 2007)
	Protect altitudinal and latitudinal gradients and areas of topographic diversity most likely to survive or mitigate the effects of climate change. Buffering mechanisms allowing the long-term persistence of climate change must be protected (intact canopies, water tables, aquifers)
Connectivity	Ensure functional or habitat connectivity between network components (Fahrig 2003; Malanson 2003; Starzomski and Srivastava 2007; Gaston *et al.* 2008; Awade and Metzger 2008) by taking into account movement and dispersal patterns of organisms based on their habitat requirements and using, where feasible, appropriate, tested modelling tools and theories, e.g. graph or percolation theory (Chetkiewicz *et al.* 2006; Starzomski and Srivastava 2007).
	Abrupt changes in resilience occur when habitat loss results in loss of connectivity between local patches; landscape models using percolation theory suggest a threshold in loss of connectivity occurs with loss of approximately 40% of the original area (Starzomski and Srivastava 2007)
	For species to move across landscapes as part of regular migrations, for gene flow, and for range shifts to adapt to climate change, habitat restoration may be essential to re-establish linkages.
Maintain ecosystem function and resilience	Ensure ecosystem resilience by (1) maximising the protection or restoration of all functional groups (and response diversity within each functional group), as well as the keystone, foundation or ecological engineer species; (2) ensuring the integrity of biotic and abiotic ecosystem processes (pollination, dispersal, competition, facilitation, predation, biogeochemical cycling etc); (3) identifying critical thresholds to alternative stable states and ensuring key drivers and state variables remain at safe distances from these thresholds; and (4) increase the area, where necessary, of core areas, buffers and linkages through scientifically based and adequately funded restoration programs (Gaston *et al.* 2008)
Social Ecological Systems-based management, monitoring and reporting	Embed Terrestrial Protected Areas within broader landscapes with complementary management that maximises functional connectivity and ecosystem resilience to threatening processes across relevant multiple scales. Focus on eliminating shade tolerant invasive species that can destroy forests (Martin *et al.* 2009). Integrate management of terrestrial, freshwater and marine (including estuarine and subterranean) ecosystems where functional linkages occur.
	Give priority to abatement of threatening processes likely to cause shifts to undesirable alternative stable states that are difficult to reverse.
	Establish long-term environmental monitoring sites that provide precise and unbiased measures of trends in biodiversity at the local, regional and state levels using leading edge technologies (remote and *in situ*) at ecologically meaningful spatial and temporal scales.
	Publish tri-annual audits within the program-logic framework that specifically and quantitatively tracks performance with respect to time-bound targets, and evaluates the validity of underlying assumptions, as well as adequacy of conservation effort and funding provided

Table 2. Attributes of a resilient Marine Protected Area (MPA) network design

Attribute	Design parameters
Size	"Bigger is better" —MPAs should be a minimum of 10-20 km in diameter to be large enough to protect the full range of marine habitat types and the ecological processes on which they depend (Palumbi *et al.* 1997; Palumbi 2004, 2009; Friedlander *et al.* 2003; Fernandes *et al.* 2005; Mora *et al.* 2006), and to accommodate self-seeding by short distance dispersers
Shape	Simple shapes are better, such as squares or rectangles, rather than elongated or convoluted ones to minimize edge effects while maximizing interior protected areas and associated biota (Carr *et al.* 2003; Friedlander *et al.* 2003).
Risk spreading • representation • replication, and • spread	*Representation*: protect at least 20–40% of each coastal marine habitat type (Bohnsack *et al.* 2003; Airame *et al.* 2003; Fernandes *et al.* 2005; Green *et al.* 2007) and substantial areas of the high seas (both benthic and pelagic) within no-take reserves, and higher levels of protection for rare or threatened ecosystems (AMSA 2008).
	Replication: protect at least three viable examples of each marine habitat type (Fernandes *et al.* 2005; Salm *et al.* 2006; Green *et al.* 2007).
	Spread: ensure that replicates are spread out to reduce the chances they will all be affected by the same disturbance event (Salm *et al.* 2006: Green *et al.* 2007).
	Select MPAs in a variety of temperature regimes using historical sea-surface temperatures and climate projections to ameliorate the risk of reefs in certain areas succumbing to thermal stress caused by climate change
Critical areas	Protect critical areas that are biologically or ecologically important, such as nursery grounds, spawning aggregations, and areas of high species diversity (Green *et al.* 2007)
	Protect critical areas that are most likely to survive the threat of climate change (e.g. areas that are naturally more resilient to coral bleaching (Roberts *et al.* 2003b; Salm *et al.* 2006; Green *et al.* 2007). These may include areas cooled by local upwelling, areas shaded by high, steep-sided islands or suspended sediments and organic material in the water column, reef flats where corals are adapted to stress, and areas with large herbivore populations that graze back algae and maintain suitable substrates on which coral larvae can settle.
Connectivity	Take account of biological patterns of connectivity to ensure MPA networks are mutually replenishing to facilitate recovery after disturbance (Roberts *et al.* 2003a; Green et el. 2007). MPAs should be spaced a maximum distance of 15-20 km apart to allow for replenishment via larval dispersal (Shanks *et al.* 2003; Mora *et al.* 2006).
	Accommodate adult movement of mobile species by including whole ecological units (e.g. offshore reef systems) and a buffer around the core area of interest. Where this is not possible, e.g. coastal fringing reefs, protect larger versus smaller areas (Fernandes *et al.* 2005; Green *et al.* 2007).
	Model future connectivity patterns to identify potential new coral reef substrates, so that measures can be taken to protect these areas now, and accommodate expansion of coral distribution to higher latitudes.
Ecosystem function and resilience	Maintain species interactions and feedbacks including intact trophic webs and healthy populations of key functional groups, particularly *herbivorous fishes* that feed on algae, facilitating coral recruitment and preventing coral-algal phase shifts following disturbances (Bellwood *et al.* 2004; Hughes *et al.* 2005). Also vital are foundation species such as seagrasses that reconfigure water flow, influence nutrient cycling, and provide critical habitat for a wide array of invertebrates, fish, turtles and dugong (Hughes *et al.* 2009)
Social Ecological Systems-based adaptive management, monitoring and reporting	Embed MPAs in broader scientifically based adaptive management frameworks, consistent with international law, that address other threats external to their boundaries (e.g. integrated coastal zone management with improved and adequate levels of protection and an 'ecosystems resilience' approach to fishing (Scheffer *et al.* 2005; Salm *et al.* 2006; Green *et al.* 2007) that recognises non-linearities that precede rapid, catastrophic and irreversible ecosystem collapse (Scheffer *et al.* 2005).
	Address sources of pollution (especially enrichment of water), which create conditions that favour algal growth and prevent coral larvae from settling.
	Monitor changes in precipitation caused by climate change that may increase runoff and smother reefs and seagrass beds with sediment; maintain adequate surveillance systems (Neville and Ward *in press*).
	Publish tri-annual audits within the program-logic framework that specifically and quantitatively tracks performance with respect to time-bound targets, and evaluates the validity of underlying assumptions, as well as adequacy of conservation effort and funding provided.

Table 3. Threat abatement strategies for Terrestrial Biodiversity off reserves

Threat Catetory	Mitigation strategies
Unsustainable population growth	• Stabilize or reduce populations in areas of high biodiversity and/or vulnerability through planning instruments and public education • Support local government policies and strategies that set a population cap within their shires
Lack of shared understanding	• Adopt a strategic approach (social ecological systems framework) to improving ecological literacy, commitment and engagement across all community sectors (Jordan *et al.* 2009)
Land-use practices resulting in loss, modification and fragmentation of habitats	• Ensure vegetation clearing controls at State and Local Government levels protect both remnant and regrowth vegetation in rural and urban areas • Wherever possible avoid further loss of biomass that fundamentally structures and underpins ecosystem processes • Adopt catchment- and landscape-wide strategies recognising, maintaining and restoring critical energy and materials fluxes, natural disturbance regimes, ecological processes and critical species interactions and other feedback interactions underpinning stability or resilience of biodiversity within natural bounds (Fahrig 2003)
Unsustainable resource use	• shift from single-species based maximum sustained yield to science-based ecosystem-resilience models that incorporate an understanding of resistance and resilience to disturbance (Worm and Duffy 2003; Duffy 2009; Gunderson *et al.* 2009; Hobbs and Suding 2009; Walker and Salt 2006). • Exclude extractive industries such as logging, mining and quarrying from relict, refugial ecosystems such as rainforests • Ensure policies and codes are ecologically credible rather than economically based • Effect transitions from native ecosystem-based resource extraction systems to agricultural, area-efficient systems, e.g. transition native forest logging to a well managed plantation-base; seed, flower, nectar, pollen or plant harvesting from natural ecosystems to *ex situ* cultivation • Stop illegal, unreported and unregulated resource extraction through stronger regulations, and enforcement, compliance and penalties • Address the causes of market failure that impact negatively on biodiversity
Alien species invasions	• Prevent, control or eradicate alien species that threaten ecosystems, habitats, or species through cross-scale, science- and ecosystems-based strategies that recognise synergistic effects (e.g. climate change exacerbates ASI) • Maintain or restore functional group diversity within ecosystems as a critical basis for invasion resistance (prevention) • Control or eradicate alien species by identifying (a) the *stage of invasion* i.e. initial dispersal, establishment, or secondary spread (Puth and Post 2005); (b) the *range dynamics* (size and spread rates) which depend on knowing residence time, habitat availability and propagule pressures (Wilson *et al.* 2007); and (c) *physiological traits* that determine competitive dominance and susceptibility to control measures • Strengthen institutional regulatory, monitoring and reporting processes to give higher priority to prevention and mitigation of early stages of invasion • Increase resourcing to both regulators and practitioners according to identified, quantified needs and achievable outcomes • Publish annual progress reports to facilitate adaptive management based on monitoring trends (McGeoch *et al.* 2007)
Pollution	• Reduce or eliminate ecological light pollution particularly affecting nocturnal and crepuscular species (Longcore and Rich 2004; Horvath *et al.* 2009) through planning schemes and community education. • Take a cross-scale, catchment and landscape approach to chemical pollution affecting terrestrial and aquatic systems
Inappropriate fire regimes	• Ensure fire management is ecologically and evidence-based at relevant fine scales (Parr and Andersen 2006; Whitehead *et al.* 2005) accounting for thresholds (Price *et al.* 2005) and responsive to the changing conditions associated with climate change. • Exclude fire from rainforest and wet sclerophyll forests (mesic environments) that are not adapted to fire or anthropogenic fire regimes (Haberle *et al.* 2006) • Exclude human settlements in mountainous and other sensitive regions that result in biased abatement strategies giving precedence to protection of property and lives over the protection of biodiversity. • Develop technologies and strategies based on early detection and response
Climate change	• Protect naturally occurring buffering mechanisms that provide resistance to climate change related warming (Laurance 2008) • Ensure connectivity between core conservation areas and off-reserve environmental gradients facilitating range expansion or habitat tracking • Take all measures necessary to reduce damaging greenhouse gas emissions

Table 4. Threat abatement strategies for off-reserve marine biodiversity

Threat Catetory	Mitigation measures
Lack of shared understanding	• Adopt a strategic approach to improving ecological literacy, commitment and engagement across all sectors of the community (Jordan *et al.* 2009)
Inappropriate marine practices that fragment and/or trap marine biota	• Review the practice of shark netting and similar "zoning" practices leading to precipitous declines in vulnerable marine species (sharks, whales, turtles, stingrays etc.) • Base protection of human lives on evidence-based, scientifically sound mitigation and communication strategies
Overfishing	• Apply an ecosystem based approach and the precautionary principle to NRM (*not* single-stock maximum sustainable yield) (Walker and Salt 2006; Olsson *et al.* 2008) • Phase out destructive fishing practices (such as bottom trawling over vulnerable habitats, gill-netting and prawn trawling with very high by-catch levels, and the use of explosives) by 2012 (a United Nations deadline) • Stop illegal, unreported and unregulated resource extraction through appropriate regulations, compliance and penalty measures
Alien species invasions	• Reduce impacts of alien species invasions of marine ecosystems introduced by international shipping and aquaculture through interception or removal of pathways (Molner *et al.* 2008). This recognises that once alien species become established, it can be nearly impossible to eliminate them (Thresher and Kuris 2004). • Adopt an analytical framework that prioritises species-specific threats and identifies pathways for entry and spread of invasive species (Molner *et al.* 2008).
Pollution	• Develop pollutant-specific strategies to eliminate impacts on marine biodiversity. Pollutants include oil, sewage, suspended sediments, marine debris, chemicals, radioactive waste, eutrophication and thermal pollution which originate from land- and marine-based activities (shipping, oil and gas exploration, stormwater runoff and poor land management practices) • Ensure cross-scale (space and time) and cross-agency management strategies to maintain water quality • Encourage and fund research to fill gaps in knowledge with respect to short- and long-term impacts
Climate change	• Control resource use in areas that are more likely to survive the threat of climate change (e.g. areas that are naturally more resilient to coral bleaching (Roberts *et al.* 2003; Salm *et al.* 2006; Green *et al.* 2007). These may include areas cooled by local upwelling, areas shaded by high, steep-sided islands or suspended sediments and organic material in the water column, reef flats where corals are adapted to stress, and areas with large herbivore populations that graze back algae and maintain suitable substrates on which coral larvae can settle. • Control resource use in a variety of temperature regimes using historical sea-surface temperatures and climate projections to ameliorate the risk of reefs in certain areas succumbing to thermal stress caused by climate change

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[i] The National Biodiversity Strategy (1996) and the *World Charter of Nature 1982)* state that:

i. *"There is in the community a view that the conservation of biological diversity has an ethical basis. We share the Earth with many other life forms that warrant our respect, whether or not they are of benefit to us. Earth belongs to the future as well as the present; no single species or generation can claim it as its own"*; and

ii. *"Every form of life is unique, warranting respect regardless of its worth to man, and, to accord other organisms such recognition, man must be guided by a moral code of action"* (World Charter of Nature 1982)

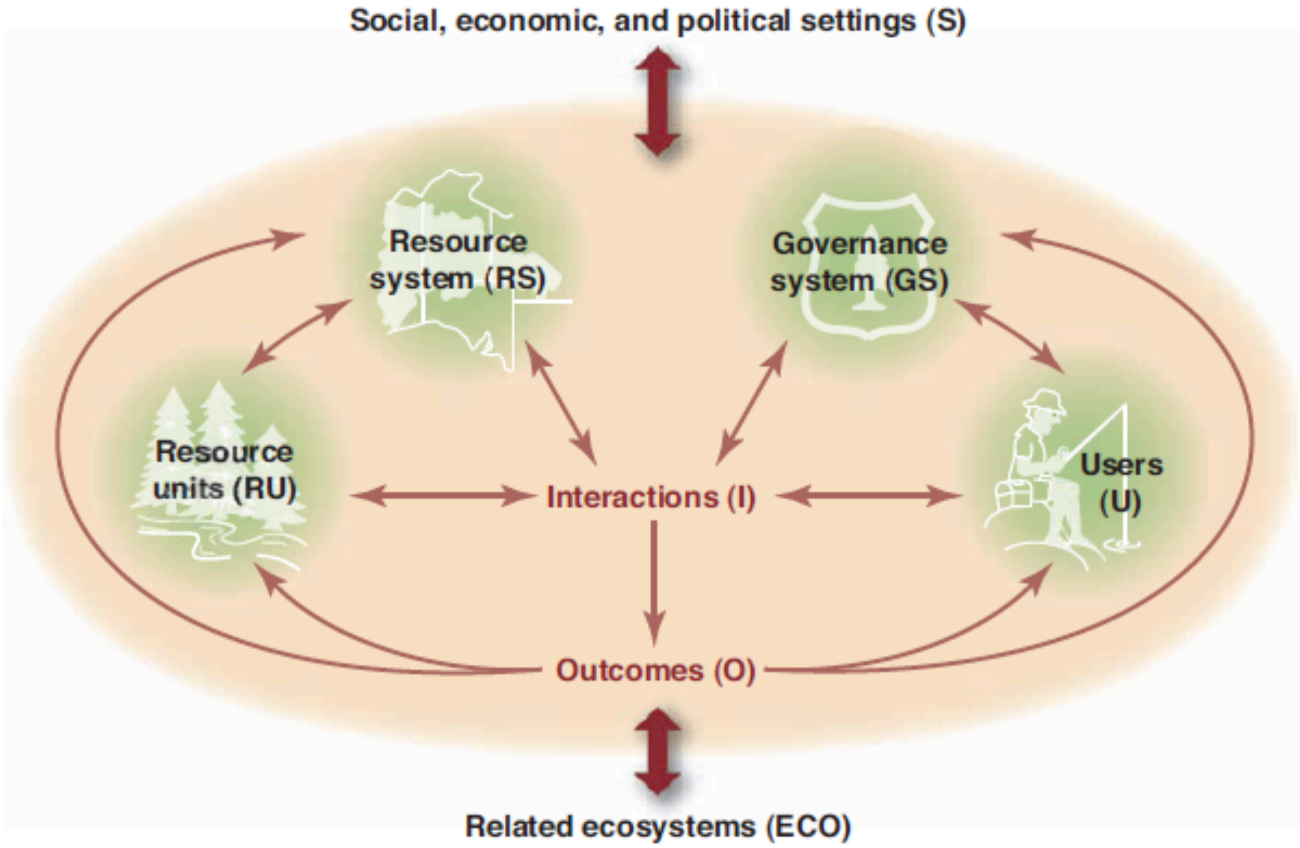

Fig. 1. The core subsystems in a framework for analyzing social-ecological systems.

From Ostrom (2007, 2009)

Related Ecosystems • Climate patterns • Disturbance regimes • Pollution patterns • Flows in and out of focal SES	**Social, Economic & political Setting** • Economic development • Demographic trends • Media organization • Market incentives • Political stability • Government resource policies
Resource systems • Sector • Size & location of resource system • Productivity of system • Equilibrium vs non-linear self-organising properties; • Predictability of system dynamics (**resilience**, thresholds)	**Governance Systems ***** • Government organisations • Non-government organisations • Property-rights systems • network structure • constitutional rules • operational rules • collective choice rules • sanctioning processes • monitoring processes
Resource units • Resource unit mobility • Growth/replacement rate • Number of and Interaction among resource units • Economic value • Spatial/ temporal distribution	**Users** • Number & location of users • Socioeconomics of users • History of use • Leadership & knowledge of SES • Technology used • Social capital • Importance of resource
Interactions • Harvesting levels of diverse users • Information sharing among users • Conflicts among users • investment activities • lobbying/networking • deliberation processes	**Outcomes** • Social performance measures — efficiency, equity, accountability, sustainability • Ecological performance measures — overharvesting, resilience, biodiversity, sustainability • Externalities to other Social Ecological Systems (SES)