

## A method for risk analysis across governance systems: a Great Barrier Reef case study

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2013 Environ. Res. Lett. 8 015037

(<http://iopscience.iop.org/1748-9326/8/1/015037>)

View [the table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 60.241.38.162

This content was downloaded on 05/04/2017 at 11:43

Please note that [terms and conditions apply](#).

You may also be interested in:

[Advances in monitoring the human dimension of natural resource systems: an example from the Great Barrier Reef](#)

N A Marshall, E Bohensky, M Curnock et al.

[Quantifying uncertainty and resilience on coral reefs using a Bayesian approach](#)

R van Woesik

[Assessing habitat risk from human activities to inform coastal and marine spatial planning: a demonstration in Belize](#)

Katie K Arkema, Gregory Verutes, Joanna R Bernhardt et al.

[Subjective risk assessment for planning conservation projects](#)

Edward T Game, James A Fitzsimons, Geoff Lipsett-Moore et al.

[Science–policy challenges for biodiversity, public health and urbanization: examples from Belgium](#)

H Keune, C Kretsch, G De Blust et al.

[A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions](#)

Alana Grech, Katie Chartrand-Miller, Paul Erftemeijer et al.

[Tropical seagrass meadows modify seawater carbon chemistry: implications for coral reefs impacted by ocean acidification](#)

Richard K F Unsworth, Catherine J Collier, Gideon M Henderson et al.

[Of mongooses and mitigation: ecological analogues to geoengineering](#)

H Damon Matthews and Sarah E Turner

# A method for risk analysis across governance systems: a Great Barrier Reef case study

Allan Dale<sup>1</sup>, Karen Vella<sup>2</sup>, Robert L Pressey<sup>3</sup>, Jon Brodie<sup>4</sup>,  
Hugh Yorkston<sup>5</sup> and Ruth Potts<sup>2</sup>

<sup>1</sup> The Cairns Institute, James Cook University, PO Box 6811, Cairns, Queensland, 4870, Australia

<sup>2</sup> Griffith School of Environment, Griffith University Gold Coast Campus, Parklands Drive Southport, Queensland, 4222, Australia

<sup>3</sup> Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland, 4811, Australia

<sup>4</sup> Australian Centre for Tropical Freshwater Research, James Cook University, Townsville, Queensland, 4811, Australia

<sup>5</sup> Great Barrier Reef Marine Park Authority, PO Box 1379, Townsville, Queensland, 4810, Australia

E-mail: [allan.dale@jcu.edu.au](mailto:allan.dale@jcu.edu.au)

Received 23 October 2012

Accepted for publication 4 March 2013

Published 21 March 2013

Online at [stacks.iop.org/ERL/8/015037](http://stacks.iop.org/ERL/8/015037)

## Abstract


Healthy governance systems are key to delivering sound environmental management outcomes from global to local scales. There are, however, surprisingly few risk assessment methods that can pinpoint those domains and sub-domains within governance systems that are most likely to influence good environmental outcomes at any particular scale, or those if absent or dysfunctional, most likely to prevent effective environmental management. This paper proposes a new risk assessment method for analysing governance systems. This method is then tested through its preliminary application to a significant real-world context: governance as it relates to the health of Australia's Great Barrier Reef (GBR). The GBR exists at a supra-regional scale along most of the north eastern coast of Australia. Brodie *et al* (2012 *Mar. Pollut. Bull.* **65** 81–100) have recently reviewed the state and trend of the health of the GBR, finding that overall trends remain of significant concern. At the same time, official international concern over the governance of the reef has recently been signalled globally by the International Union for the Conservation of Nature (IUCN). These environmental and political contexts make the GBR an ideal candidate for use in testing and reviewing the application of improved tools for governance risk assessment.

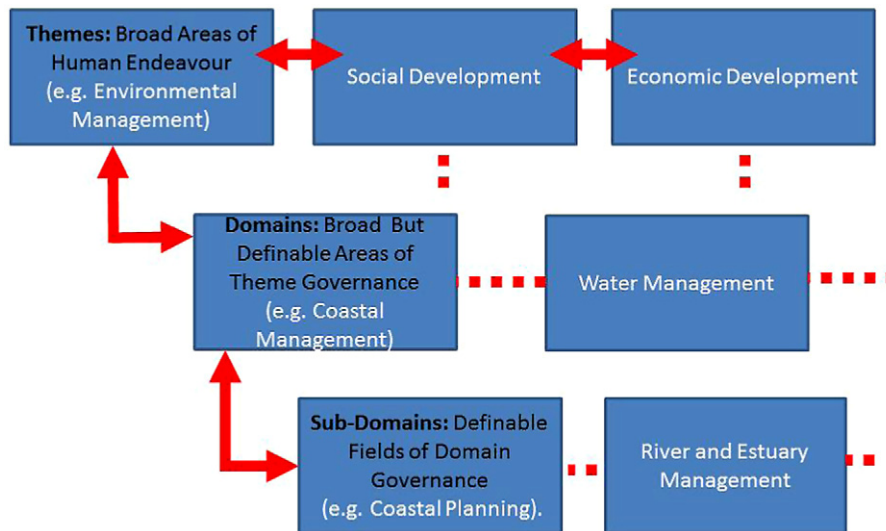
**Keywords:** coastal governance, risk assessment, Great Barrier Reef

## 1. Introduction

Public and academic attention to governance has increased in recent years (Weiss 2000, Graham *et al* 2003, Kemp and

Parto 2005). This will continue as civil society experiences new challenges to our environmental sustainability, economic wellbeing and social stability. Most commentators understand that contemporary global challenges will lead to increased scrutiny on the quality of governance from global to local scales (Young *et al* 2006). Further, in respect to the governance of the environment, it is now commonly accepted that society's economic, social, and cultural health depends on (finite) ecological systems. To this end, we now see

 Content from this work may be used under the terms of the [Creative Commons Attribution-NonCommercial-ShareAlike 3.0 licence](http://creativecommons.org/licenses/by-nc-sa/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.



**Figure 1.** Definitions and relationships between governance themes, domains and sub-domains, not showing integrated links across all three areas and scales.

much scientific attention on monitoring and reporting of the health of ecological systems at various scales. This enables policy makers and managers to predict and pinpoint specific biophysical risks that might disrupt societal prosperity. The governance systems that mediate the relationship between society’s needs and environmental outcomes, however, are rarely monitored in any cohesive or ongoing fashion. This means that, while the scientific community may be better armed to alert society of emerging environmental risks, there is little capacity to pre-emptively flag the need for targeted governance reform to avert these risks from emerging.

*1.1. Governance systems and risk assessment*

Parker and Braithwaite (2003 p 119) take a societal-wide view of governance as the ‘intentional shaping of the flow of events so as to realize desired public good’. This view suggests that governance is a systemic concept mediated by power relationships; various processes of bargaining and negotiation among differing interests in society leading to particular system outcomes (Dorcey 1986, Emerson *et al* 2011). Several authors (e.g. Folke *et al* 2005 and Paavola *et al* 2009) have attempted to describe the dynamics of governance systems, often considering that such dynamic systems are framed by a range of linked governance themes, scales, domains and sub-domains (figure 1). Within any theme (e.g. environment) or domain (e.g. coastal management) of governance, different sub-domains (e.g. coastal planning) tend to play out at various spatial and temporal scales. Hence governance consists of nested sub-systems within wider systems that, at any particular scale, are influenced by, and in turn influence, outcomes at other scales. This, however, is a polycentric (not hierarchical) concept and outcomes from past poor decisions may challenge more enlightened governance in the future (Ostrom 2008).

In such a systemic context, within a broad governance system (e.g. coastal management), failure of a particular sub-domain to deliver its intended outcomes (e.g. healthy

coastal ecosystems) needs to be understood in the context of the wider governance regime (Paavola *et al* 2009). There are, however, few analytical frameworks or empirical evaluations which consider the impact of governance on outcomes arising from complex multi-level, multi-stakeholder and multi-issue systems (Newig and Fritsch 2009, Kenward *et al* 2011). The consequence is that little has been done to develop standardized or rigorous methods for analysing and improving governance outcomes in systemic terms. The flow on effect is that the more systemic contribution of a wider range of governance themes, domains or sub-domains (and their strengths/weaknesses) is rarely attempted.

More systemic evaluative approaches imply that governance systems concerning social, economic and environmental themes in our society at any scale cannot be viewed in isolation (Plummer and Armitage 2007). Despite this, much analysis hones in on social, economic and environmental themes in isolation. Indeed, analytical thinking within such themes is often held hostage to related disciplines. The economic sciences (informing economic governance) often eschew the biophysical sciences (Cox 2002). Equally, the biophysical sciences often don’t integrate social and economic sciences (Dale *et al* 2002).

Further, within social, economic and environmental themes, major, specialist domains of governance can often be identified. In the environmental theme, for example, overlapping domains such as coastal, marine, water, forest, biodiversity and soil management are important. Within governance domains, there may again be several sub-domains of importance to overall system health. Sub-domains represent distinct activities such as policy, planning or delivery; drawing in particular expertise sets and stakeholders. Sub-domains can also operate over a defined period of space and time to achieve specific, often narrow, system outcomes. Consequently, institutions operating within particular sub-domains have a tendency to develop as cultural silos, leading to poor outcomes. Within an important environmental domain such as coastal management, for example, there

may be limited (but necessary) connections between major sub-domains such as coastal research, land use planning and river management (e.g. see Ross *et al* 2002).

### 1.2. Towards an integrated risk assessment of governance systems

In governance analysis, analysts must be aware that different governance themes, domains and sub-domains are interconnected, both between and within particular scales. This raises the possibility that one can regularly monitor the health of wider governance systems with the view to determining which domains and related sub-domains pose points of systemic risk. One can identify where governance failure may most contribute to poor societal outcomes, enabling adaptive managers to prioritize reform.

While the literature regarding systemic frameworks for governance analysis is emerging, few take a systemic approach to analysing those domains and sub-domains that present the most significant risks to the delivery of sound outcomes within the system. While Pahl-Wostl *et al* (2012), for example, link governance analysis to outcomes within the water management domain, they do not, however, expand on these concepts to add or apply a risk assessment layer to pinpoint those governance domains and sub-domains likely to pose the most risk to the system failing to deliver sound outcomes.

## 2. Why governance risk assessment in the GBR coastal zone?

Degradation of coastal and marine ecosystems due to terrestrially derived development and pollution and other causes is the subject of intense management activity (Doney *et al* 2009). Coral reefs around the world are threatened by human activities (Burke *et al* 2011) and many show signs of degradation (e.g. Pandolfi *et al* 2003). In many areas, reefs are exposed to a combination of stresses, including destructive fishing practices, overfishing or loss of herbivorous fish and other grazing organisms, modification and loss of coastal ecosystems, increased land discharge of sediment, nutrients and pesticides, outbreaks of coral predators linked to trophic changes, increased bleaching due climate change, and increased incidence and severity of coral diseases (Burke *et al* 2011, Maina *et al* 2011).

The GBR contains extensive areas of coral reef, seagrass meadows and estuarine ecosystems and is an important commercial and recreational fishery. Adjacent catchments discharge pollutants from agricultural, urban, mining and industrial activity. Pollutants include suspended sediment from erosion in cattle grazing, nitrate from crop fertilizers, and herbicides from various land uses. The fate and effects of these pollutants are relatively well understood, though new pollutants and ecosystem disturbances with poorly understood effects (e.g. hormones and commercial chemicals) may be emerging from urban areas and new industrial ports. Estuarine ecosystems of significance to Reef health are also under pressure from development, die-back and hydrological

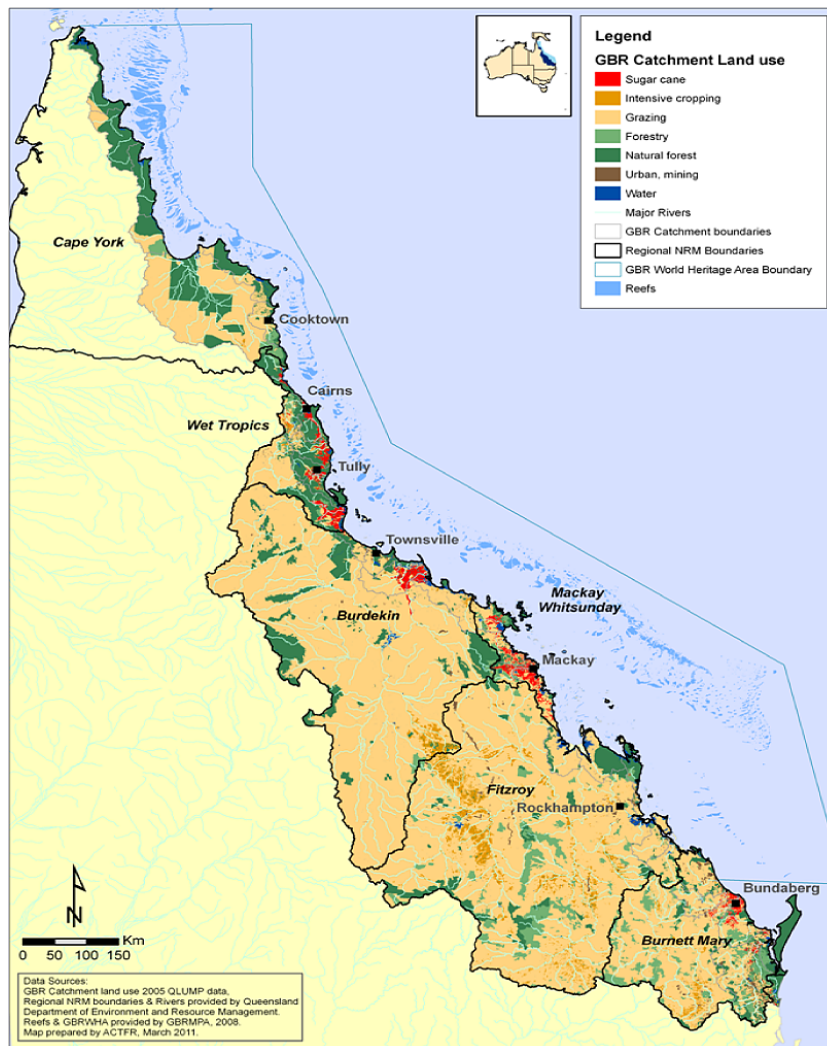
change and the Australian and Queensland Governments have consequently responded to concerns about the impact of poor coastal management.

The GBR is situated on the north-east coast of Australia (figure 2). It is a Marine Park under joint Australian (Federal) and Queensland (State) Government arrangements and declared a World Heritage Area in 1981. Despite this protected status, coral cover has sharply declined from levels near 28% in 1986 to less than 14% currently (Hughes *et al* 2011, Sweatman *et al* 2011, De'ath *et al* 2012). The causes of this decline are many and often reef-specific. In 2008 the current state of knowledge regarding the degradation of GBR ecosystems due to terrestrial pollution was reviewed and a 'Scientific Consensus Statement' prepared for the Queensland Government (Brodie *et al* 2008a, 2008b). The conclusions identify the key threats as including sediment and nutrients runoff of with the associated crown-of-thorns starfish outbreaks (Brodie *et al* 2005, 2008a, 2008b, 2011, De'ath and Fabricius 2010, DeVantier *et al* 2006, Fabricius 2005, Fabricius *et al* 2005, 2010), coral bleaching and mortality associated with climate change (Berkelmans *et al* 2004, Hoegh-Guldberg *et al* 2007, Hughes *et al* 2007), and coral diseases (Haapkyla *et al* 2011). Ocean acidification and its effects on coral calcification is an emerging threat (Cooper *et al* 2008, De'ath *et al* 2009). It is also recognized that these stressors do not act in isolation, with interactions likely but not well studied (Borges and Gypens 2010).

Other ecosystems such as coastal seagrass meadows are also believed to be under pressure due to declining water quality (McKenzie *et al* 2010) although, overall, seagrass in the GBR region is in reasonable condition (Waycott *et al* 2009). Mangrove forests are in good condition but subject to localized (and potentially increasing) losses from coastal development (Schaffelke *et al* 2005).

Brodie *et al* (2012) evaluated the appropriateness of current management responses and concluded that water quality associated with pollutant discharge from reef catchment is still a major issue. Recent research published since 2008 confirms these conclusions (Brodie *et al* 2010, Kroon *et al* 2012, Devlin *et al* 2012); that contaminants remain present in the GBR lagoon at concentrations likely to cause environmental harm (De'ath and Fabricius 2010, Lewis *et al* 2009, Schaffelke *et al* 2012, Kennedy *et al* 2012); evidence of the causal relationship between water quality and ecosystem health is more robust (Brodie *et al* 2011, Fabricius *et al* 2010, De'ath *et al* 2012); and that climate change will further confound the attribution of ecosystem degradation to single causes such as poor water quality (Borges and Gypens 2010, De'ath *et al* 2009, Hughes *et al* 2010).

However, Brodie *et al* (2012) also note that their conclusion from the Consensus Statement that 'current management interventions are not effectively solving the problem' has now decisively changed since 2008 with the introduction of the Reef Rescue Program (Australian Government) and the Reef Protection Package (Queensland Government). Effective management action is being taken, although whether it is enough to achieve the Reef Plan targets or is the most appropriate form of management is



**Figure 2.** The Great Barrier Reef and associated coastal regions/catchments.

uncertain (Thorburn and Wilkinson 2013, Kroon 2012). This uncertainty needs to be constantly reviewed and re-assessed in light of an ever improving knowledge of reef health and the causes of ecosystem decline. Further, regular ebbs and flows in the health of the overall coastal governance system and its constituent domains and sub-domains also needs to be monitored. Within such a vast and complex governance system and within limited resources, however, a stronger framework or method for determining key governance risks (at theme, domain and sub-domain levels) is required.

### 3. A method for governance risk analysis in the GBR

As a prelude to ongoing risk analysis across the wider governance system delivering outcomes in the GBR, the following framework or method has been developed and trialled in a preliminary way. Before describing this method, however, it needs to be remembered that risk analysis is a key step in any risk management procedure. It seeks to determine the quantitative or qualitative value of risk related to a particular situation and a recognized threat. In any

risk analysis (particularly quantitative assessment), two key concepts need specific attention:

- *Likelihood.* While necessarily less quantitative than probability, likelihood captures the idea that something is likely to happen or to have happened. Governance failures with a very low likelihood of occurring effectively present a low risk to system managers; and
- *Consequence.* Consequence considers the importance of an effect, result or outcome of something (e.g. a governance activity) that has occurred earlier. A highly likely failure of some governance activities might actually have limited consequences (or impact) for the overall system, meaning they also should have a corresponding lower risk rating.

Together, analysis of risk likelihood and consequence, particularly in matrix form, provides a simple but powerful analytical structure, providing a framework for organizing and evaluating the evidence required for managers to make more informed choices about reform priorities. Further, more detailed analysis (e.g. impact assessment, cost–benefit analysis) of particular governance risks versus the consequence of taking no action is also important before

major reform decisions can be made about a particular system. These foundations guided our elucidation of some simple methodological steps to underpin risk analysis for the GBR governance system. These steps are now outlined in more detail below.

### 3.1. Step 1: determine the key domains and sub-domains of governance

A standardized step in more holistic analysis of a defined governance system (e.g. the wider system of governance influencing the health of the GBR) is scoping where the system fits within the broader global system of governance themes, domains, sub-domains and scales. Placing the system being analysed in this wider context enables analysts to more realistically explore domains and sub-domains that represent big risks to system outcomes. This step also enables the analyst to flag whether key sub-domains are indeed 'relics' that have been left floundering while the rest of the system has evolved. Many domains can have redundant sub-domains that no longer contribute to system outcomes. Such a contextualized approach also signals where transformational changes might be required.

This sort of scoping step can be undertaken and refined through a range of research techniques, including legislative and literature review, targeted discussions with policy makers and managers and consultation with relevant experts. Highly participative and adaptive approaches to this step deliver the best results, allowing continuous improvement and refinement in the scoping task over time.

### 3.2. Step 2: health analysis of key domains and sub-domains of governance

Once scoping has been completed, an assessment of the health of key domains and sub-domains can be undertaken; one particularly focused on exploring the strengths and weaknesses of key domains and sub-domains at various scales and the impact they are having on outcomes. In this regard, there is particular value in exploring both structural and functions characteristics of each relevant domain/sub-domain. Structural–functional schools of sociology provide an apposite conceptual framework for analysing the health of various governance systems as they view society as a complex system whose component parts work together to promote solidarity and stability (Macionis and Gerber 2011). While Dale and Lane (1993) outline the required structural characteristics of various governance systems, Dale and Bellamy (1998) characterize the primary functional characteristics of such systems. This step requires analysis of the structural and function health of each of the key domains and sub-domains within the system relative (in this case environmental) outcomes intended from the system.

As for Step 1, this analytical step can also be undertaken using a range of techniques from data-rich and participatory appraisal-based approaches to more rapid expert appraisal. While rapid expert appraisals can deliver insights, however, they are never a substitute for deeper and more participatory

forms of analysis that can lead to collective and durable agreement about, and implementation of, critical reforms within the system.

### 3.3. Step 3: likelihood and consequence analysis of key sub-domains of governance

Once a quality analysis of the health of key system domains and sub-domains is complete, using the precautionary principle as a guide, a simple likelihood and consequence matrix can be developed and applied to all relevant domains and sub-domains at all scales to pinpoint more risk-based priorities for reform. Three foundational analytic considerations need to be applied in this context:

- (1) *Standardized criteria for rating the likelihood of system failure at the domain/sub-domain level.* Such ratings can be developed/applied via a clear understanding of governance health data;
- (2) *Standardized criteria for rating the consequence of system failure at the domain/sub-domain level.* This also should be applied via a clear understanding of governance health data; and
- (3) *Recording the inherent logic applied to setting likelihood and consequence ratings.* This logic needs to be recorded to enable such ratings to be justified, explained and challenged where required. It also sets the foundation for reliable system benchmarking for the future.

Tables 1 and 2 suggest standardized criteria for rating risk and consequence that could be applied to such analysis. A standardized approach is important because it enables repeatability and benchmarking of the target governance system over time. In all cases, however, the quality of likelihood and consequence analysis will depend on the data under-pinning the assessment (based on Steps 1 and 2).

### 3.4. Step 4: assessment of inaction versus action in governance reform

While understanding the risk posed by the health of governance in various domains and sub-domains, it remains important that further analysis distinguishes between the costs or impacts of action versus inaction within and across the most high risk domains/sub-domains. With respect to the GBR, for example, the estimated cost of securing global action on climate change versus the projected economic, social and environmental costs on reef ecosystems is an important assessment as the costs of acting are significant to society as a whole. Faced with limited resources and little global influence, this reinforces the need for GBR policy makers and managers to prioritize action on reforming those governance domains that can increase the resilience of the reef in the short to medium term, while not abandoning, and indeed strengthening efforts to secure the global actions to reduce climate change. Thus, while reforms that can be delivered at low cost for significant benefit are most attractive to managers, emphasis is also needed on taking incremental steps and timing of reforms for big/complex issues.

**Table 1.** Rating scale for likelihood of system failure.

Risk rating	Decision rule
(1)	The governance system domain or sub-domain is in excellent overall health and will not fail to deliver its intended system outcomes
(2)	The governance system domain or sub-domain is in good overall health and is not likely to fail to deliver its intended system outcomes
(3)	The governance system domain or sub-domain is on a knife's edge and could fail to deliver its intended system outcomes
(4)	The governance system domain or sub-domain is in poor overall health and likely to fail to deliver its intended system outcomes
(5)	The governance system domain or sub-domain is dysfunctional and will fail to deliver its intended system outcomes

**Table 2.** Rating scale for consequence of system failure.

Consequence rating	Decision rule
(1)	Failure of the domain or sub-domain will have no consequence for overall system outcomes
(2)	Failure of the domain or sub-domain will have limited consequences for overall system outcomes
(3)	Failure of the domain or sub-domain will have consequences of concern for overall system outcomes
(4)	Failure of the domain or sub-domain will have significant consequences for overall system outcomes
(5)	Failure of the sub-domain will have catastrophic consequences for overall system outcomes

*3.5. Step 5: design, implement and adaptively monitor a progressive reform program*

Once detailed risk assessment has been completed and likelihood and consequence ratings have been developed, preliminary priorities for reform can be proposed. As Steps 1–4 are focused on the analysis of a wide range of themes, domains and sub-domains within a particular governance system, the overall risk assessment method sets the foundations for the effective design of strategic reform. Reform development and implementation, however, is best achieved within a collaborative framework. Hence, the more system participants are involved in Steps 1–5 of this risk assessment process, the better. If such analysis underpins adaptive management, then ongoing benchmarking of the health of the governance system and regular monitoring of risk profile change is desirable (Taylor *et al* 2006). Through both expert and participant discussion, however, the design of system improvements should always refer back to theory and past practice, thus ensuring past mistakes are avoided.

*3.6. A preliminary application of this risk assessment method in the GBR*

A long-term governance system risk analysis is currently being developed in considerable detail in the GBR by the research team. This longer term research aims to feed conclusions into regular Outlook Reporting (State of the Reef) and two current Strategic Assessments of management of the Reef (being conducted by the Great Barrier Reef Marine Park Authority) and the GBR coast (being conducted by the Queensland Government). These two Strategic Assessments were initiated by the Australian Government following a negative assessment of World Heritage Management by the IUCN.

To explore its potential applicability in a complex governance system like the GBR, a preliminary and rapid application of the above governance risk analysis method was undertaken and assessed. This preliminary approach was undertaken (in 2012) as an adaptive step in the design and further development of the method to facilitate its application in more detail in the GBR over time. As a preliminary approach, the primary emphasis was on the conduct of Steps 1–3, but cursory consideration was also given to the design of Steps 4 and 5. As a form of rapid appraisal, the primary research technique applied to the conduct of Steps 1 through 5 was through:

- (1) A delphi-style use of a team of experts with recognized and significant knowledge and experience in the governance of the GBR (the research team). This involved several iterative steps in crafting and the expert team reviewing the proposed approach and populating the required steps with real data and conclusions associated with the GBR government system context.
- (2) Two structured workshops with a range of key GBR stakeholders (an identifiable Project Steering Committee inclusive of Queensland and Australian Government agencies, local government, ports managers and representatives of various industry, conservation and indigenous organizations). In these workshops, stakeholders were asked to comment on the proposed approach and assist populating the required steps. Specifically, these workshops focused on stakeholders contributing their knowledge of GBR governance in Steps 1 through to 3.
- (3) Across all steps, a general and iterative review of relevant legislation and the published and grey literature was also applied, adding evidential and contextual detail.

The results emerging from the trial application of these steps were developed and again briefly presented in a workshop of the Project Steering Committee and Project Team for feedback. Together, these activities enabled both an active trial of the practical application of the posited methodological steps and preliminary feedback/evaluation of their potential for further development. Consequently, the results of this very early preliminary risk assessment for the GBR governance system are presented below before some concluding observations are provided concerning the applicability of the method.

**Table 3.** Coastal management domains and sub-domains of relevance to the Great Barrier Reef.

Environmental theme		Social theme		Economic theme <sup>a</sup>	
Coastal management domain	Biodiversity domain	Agricultural resources domain	Marine resources domain <sup>b</sup>	Water resources domain	Atmospheric resources domain <sup>c</sup>
<b>International coastal management sub-domains</b>					
Convention Concerning the Protection of the World's Cultural and Natural Heritage	Global Program of Action for the Protection of the Marine Environment from Land-based Activities (1995)	UN Convention on the Law of the Sea (1982)	Convention for the Protection of the Natural Resources and Environment of the South Pacific Region (1986)	Agenda 21—chapter 17: Rio Declaration on Environment and Development	
<b>National coastal management sub-domains (Australian)</b>					
Great Barrier Reef Marine Park Act	National Coastal Policy Framework	National Sea Change Taskforce (Local Government)	Environment Protection and Biodiversity Conservation Act		
<b>Provincial/state coastal management sub-domains (state of Queensland)</b>					
Coastal Management Act and State Coastal Plan	State Development and Public Works Act	Queensland Property Planning System	Reef Protection Act	State Development Act and Sustainable Planning Act	River Improvement Trust Act
<b>Regional coastal management sub-domains (Wet Tropics region)</b>					
Regional Land Use Planning System	Regional Traditional Owner Land and Sea Management System	Coastal Works Management System	River Improvement Planning and Delivery System	Regional Farm Planning and Management System	Coastal Reserves Management System
<b>Local coastal management sub-domains (Wet Tropics region)</b>					
Traditional Owner Country-Based Planning System	Local Planning Schemes and Development Approval System	Coastal Works Project Planning and Delivery System	Local Catchment and River Plans and Associated Works Delivery System	Property Plans and Management System	Coastal Reserve Plans and Delivery System

<sup>a</sup> The wider global economic theme and Australia's economic policy domain (based on continuous growth) continues to place increasing pressure on coastal ecosystems.

<sup>b</sup> The wider (natural resource) domain of marine resources influences reef ecosystem health, both through the planning and regulation of harvest quotas, fishing practices and mangrove protection.

<sup>c</sup> Wider global (natural resource) domains of climate change and energy management pose potentially catastrophic pressures directly on reef health and on coastal ecosystems.

#### 4. Results of a preliminary risk assessment of GBR governance systems

While a longer term and more detailed governance systems risk analysis is currently being undertaken for the GBR, we present the results of the preliminary appraisal to illustrate the possibilities and potential outputs of the risk analysis method being proposed in this paper.

##### 4.1. Key domains and sub-domains of coastal governance in the GBR

Emerging from Step 1, table 3 illustrates the results from the preliminary scoping of the wider context (themes, domains)

at various scales and different sub-domains with respect to the GBR. To illustrate a typical breakdown of domains and sub-domains at regional and local scale, an example for the Wet Tropics region is listed. For completeness, such context setting needs to be done for each unique geographic region as particular domains/sub-domains may be present or absent in different regions.

Based on table 3, consolidated domain and sub-domain categories were determined as the foundation for more detailed data collection and management for risk analysis for the whole GBR. Using the Major Project sub-domain, table 4 provides a sample of the sort of detailed data that has been and will continue to be collated as a foundation for



**Table 4.** A sample output of systemic governance risk assessment for a particular sub-domain.

Major coastal development project assessment sub-domain	Sub-domain descriptor: major coastal development projects have the potential for significant impact on coastal ecosystems that could adversely affect the Great Barrier Reef environment. These projects are assessed via Australian (Environment and Biodiversity Conservation Act) and Queensland Government (State Development Act) ministerial call-in powers for significant projects	
Governance health analysis	<p>Structural considerations</p> <ul style="list-style-type: none"> <li>• Vision for the sub-domain divided between environment protection (Australian Government) and economic development (Queensland Government)</li> <li>• No strong research/development framework or shared strategy development for continuous improvement in this sub-domain</li> <li>• No shared vision or clear framework for cumulative impact assessment</li> <li>• Often a strong negotiated vision between State and Local Government for assessment</li> <li>• Regular staffing turnover can cause problems with alignment of Australian and Queensland Government visions for project assessment</li> <li>• Major projects often have strong strategy development and implementation via private and/or government sector proponents</li> <li>• Both Queensland and Australian Government project assessment requirements are relatively clear, though negotiation frameworks for offsetting require greater clarity and consistency</li> <li>• Major project monitoring and compliance systems are quite weak, and often not well engaged with affected communities</li> <li>• Lack of shared framework for monitoring sub-domain success has led to IUCN concern, and two separate but linked strategic assessment processes under the Environment Protection and Biodiversity Conservation Act</li> </ul>	<p>Functional considerations</p> <ul style="list-style-type: none"> <li>• Current disharmony between major project assessment by the Australian and Queensland Governments which seek different outcomes</li> <li>• Expectations about major project assessments increasingly being clarified and negotiated</li> <li>• Social impacts can often be under-assessed in project development and assessment</li> <li>• Capacity of participating sectors often weak (e.g. rural sector, environment sector, etc)</li> <li>• Local government capacities to manage local impacts can often be weak</li> <li>• Research sector not engaged in a structured way with arrangements for major project monitoring and review</li> <li>• Can be poor alignment of assessment timelines set by the Australian and Queensland Governments, leading to reduced investor confidence</li> <li>• Understanding of impacts generally based on incomplete knowledge of environmental values and without contextual links to wider pressures or trends</li> </ul>
Considerations for likelihood of system failure	<ul style="list-style-type: none"> <li>• Currently extensive development of major projects on the Queensland coastline, affecting the coastal region while high commodity prices continue, although Queensland Government is looking to considerably rationalize governance processes in this domain</li> <li>• Currently much strategic tension between Australian and Queensland Government systems, and better alignment required between Australian and Queensland Government Strategic Assessments</li> <li>• Poor project monitoring frameworks and research relationships pose high risk</li> </ul>	
Likelihood rating	<b>4</b>	
Considerations for consequences of system failure	<ul style="list-style-type: none"> <li>• Failures in assessment of major projects could have significant regionalized consequences for estuarine and seagrass ecosystems</li> <li>• Major uncertainties in assessment frameworks for major projects could significantly discourage economic investment, with consequent economic and social impacts</li> </ul>	
Consequence rating	<b>4</b>	
Combined risk rating	<b>8</b>	
Priorities for reform	<ul style="list-style-type: none"> <li>• Explore potential of a combined framework for Strategic and project assessment in reef catchments and consider economic, social and environmental outcomes from a variety of development scenarios</li> <li>• Australian Government could consider greater regionalization of its assessment capacities for major projects and place more focus on securing successful devolution of the assessment process within agreed standards</li> <li>• Stronger framework for Cumulative Impact Assessment should be developed jointly by the Commonwealth/Queensland Governments in their Strategic Assessment processes</li> <li>• Standing and jointly agreed capacity should be developed for reef-wide approach to independent monitoring and engagement around major projects, with strong regionalized nodes</li> </ul>	

this preliminary and future risk analysis. The table 4 example illustrates the distinction between the structural and functional health of the sub-domain, as well as the connection between an understanding of sub-domain health (Step 2) and potential reforms.

#### 4.2. Likelihood and consequence analysis and priorities for reform

The broad and preliminary results for consequence and likelihood analysis (Step 3) are summarized in table 5 and presented in summary below. More detailed cost and impact analysis (Step 4) and priorities for system reform (Step 5) have not been fully undertaken and developed at this stage because this will require more robust data collection and participation to ensure stakeholder acceptance and eventual adoption. Such analytical and reform-focused additions are intended as the key outcomes in the further development and application of this risk analysis method to the coastal zone of the GBR.

Of most significance here is the need for international and national action with respect to avoiding or sequestering greenhouse gas emissions due to weaknesses within the international Greenhouse Gas Abatement sub-domain. While this is the case, this area of governance is routinely not an integrated part of governance specific to the GBR, despite the fact that the vast majority of reef-related governance in the coastal zone may in fact be addressing issues that could eventually be swamped by far bigger risks emerging from the failure of global and national governance in the Greenhouse Gas Abatement sub-domain. This suggests that, within limited available resources, Reef managers may in the interim need to focus their attention on governance actions that will increase the ability of the Reef to adapt to climate change, specifically improving water quality, creating adequate bio-refugia and managing water quality-linked outbreaks of pest species such as crown-of-thorns starfish. These actions, however, should not detract from the concurrent need for effective national leadership on reducing emissions.

Secondly, current weaknesses in the Major Projects sub-domain present a high risk to reef health and cause allied economic and social implications. Problems in this sub-domain arise from weaknesses in regional strategic and local land use planning which could better guide major project development and avoid cumulative impacts. The once strong Coastal Planning sub-domain has also now become redundant. The cost of reform in the Major Project sub-domain could be modest if focused on improving project assessment coordination, better engagement frameworks and impact monitoring. The spectre of the Australian Government devolving responsibility for major project assessment under the Environment Protection and Biodiversity Conservation Act to Queensland is significant and could resolve the current ideological gridlock between both Governments over the issue.

Another significant risk area that presents major opportunities is the potential emergence of a sound framework for delivery of ecosystem services across Reef catchments (the Ecosystem Services sub-domain). Current landscape-scale

investment in ecosystem service management is based on a welfare model which requires sustained government investment. Serious market-driven reforms could result from the emergence and convergence of international and national markets for carbon, biodiversity and water quality and refinements to Queensland's management of offsets for major project developments. This sub-domain is important as it represents a positive potential future change in the overall system rather than flaw in the existing system. It will rely, however, on continuous improvement in the Regional NRM, Property Planning and Management and Landscape Rehabilitation Delivery sub-domains.

A seemingly unrelated (social theme) governance domain assessed as important is the nation's school-based education system (School-Based Education sub-domain). The existing education system overall, while vocationally-oriented, has had two significant limitations. Firstly, Australia's education system is still not delivering students and a civic community with good understanding of the environmental and economic risks posed by poor natural resource management. This could retard the emergence of effective and acceptable societal-wide solutions to the major threats facing the Reef.

Beyond these most significant risks outlined above, the risk analysis shows a cluster of sub-domains finely balanced on the divide between significant risk of failure or potential success, and where the consequences of system failure are important but not catastrophic. These sub-domains represent new priorities for reform and include:

- *Reef Protection Legislation sub-domain.* The Reef Protection legislation has the potential to be effective but needs the new Queensland Government to radically reform intent and delivery;
- *Property Planning and Management sub-domain.* The State's property management planning system and associated property management services are highly fragmented and dysfunctional, but there is great opportunity for the new Government to shape positive reforms;
- *Indigenous Governance sub-domain.* The frameworks for strong indigenous governance of coastal resources, particularly iconic species such as turtle and dugong, have improved, and recent regional-scale coordinated efforts in Cape York, Torres Strait and other regions will enhance the stability of this sub-domain into the future.

The analysis shows another cluster of sub-domains of recent governance reforms that are just starting to stabilize and that are beginning to deliver positive outcomes for Reef health. The analysis, however, shows that they need more sustained effort. These core areas include:

- *The Reef Plan and Regional NRM sub-domains,* for the first time delivering strategic advocacy and alignment of effort alignment across regions; and
- *Water Quality Planning and Implementation sub-domain.* Having delivered the first water quality improvement plans over the last ten years, this sub-domain has resulted in beneficial changes in on-ground practices across the Reef's catchments.

**Table 5.** Outputs from a rapid risk analysis of the coastal governance system as it relates to the Great Barrier Reef.

Domain/sub-domain	Domain/sub-domain descriptor	L*	C*	R*	Preliminary justification of rating by expert panel
Key wider (non-coastal management) themes and domains of significance					
Australia's economic framework	Like most nations, Australia has a macro-economic policy based on continuous economic growth. This does not recognize limits to the productivity of natural systems	3	4	7	Even under continuous economic growth models, progressive threats to coastal and reef ecosystems will be slow to build. Policy system is to some degree self-regulated by natural economic cycles
Greenhouse gas emission management	Via the United National Framework Convention on Climate Change, slow progress is being made towards a global system for reducing greenhouse gases	4	5	9	The current international system is still far from cohesive international action. The consequence of failure could be catastrophic via increased coral bleaching, sea level rise, increased cyclonic intensity and ocean acidification
Commercial fisheries management	Commercial fisheries are managed both by Australian (export requirements using national sustainability guidelines) and Queensland Governments (input and output controls as part of a formal plan)	2	5	7	Governance in this sub-domain is quite mature though there would be major adverse consequences if governance deteriorated. More than 30% of the Marine Park is free from fishing and more than 60% is free from specific types of fishing (e.g. trawling)
Water planning and management	Environmental flows at catchment scale required to maintain catchment, reef and World Heritage values are determined through the National COAG Agreement on Water Reform and the Queensland Water Act	1	3	4	COAG Agreement has been a durable and stable policy framework delivering significant improvements in water governance. Queensland has been progressive in this field. Limited impact of consumptive use in high flows, however, consequences for the GBR are not as significant as other domains
National school-based education system	The Australian education system is funded by Australian and Queensland governments and monitored via COAG policy frameworks. Works to a national curriculum and focused on university/vocational development.	3	4	7	The Australian school-based educational system does not adequately provide the necessary skills in civics and critical analysis of major dilemmas facing society. Society-wide awareness and preparedness for action, however, is critical to long-term health of the coastal zone and reef
Pesticide regulation framework	The Australian Pest and Veterinary Medicine Authority (APVMA) manages the registration of pesticides for use and Australia is a signatory to international conventions	2	4	6	Sub-domain is quite mature and strongly regulated, though it would have major adverse consequences if it were not. GBRMPA has developed specific water quality guidelines for a number of pesticides being found in the GBR
Maritime safety framework	Shipping in the GBR is managed under the UN convention of the Laws of the Sea. GBR classified as one of the few particularly sensitive sea areas worldwide	2	3	5	The GBR shipping management system is efficient with continuous monitoring. However, most shipping incidents in the last two decades have been human error and the consequences can be locally catastrophic
Key coastal management sub-domains of significance					
Management of the GBR Marine Park	The GBR Marine Park Act underpins core planning and regulation of the World Heritage Area, delivering regulation of reef tourism, some fishing and other uses	2	3	6	Sub-domain has been stable and has made several progressive advances, including tourism regulation, green zones, and agreements with traditional owners. Overuse of reef resources is consequently not the risk it once posed
Reef Plan	The Australian and Queensland Governments have agreed to a strong bilateral approach to halt and reverse the decline of water quality in the reef lagoon	2	4	6	Reef Plan has a strong (but sometimes fragile) framework for intergovernmental and stakeholder partnerships. The consequence of serious decline in water quality would, however, have big impacts on resilience
Reef regulation	The Queensland Reef Protection Act, focused on sugar farming communities, is now shifting towards industry-based best-practice management	3	3	6	The regulation led to conflict between industry and conservation sectors failure of the legislation would be unlikely to have major consequences because of existing frameworks for improvement of industry practices

**Table 5.** (Continued.)

Domain/sub-domain	Domain/sub-domain descriptor	L*	C*	R*	Preliminary justification of rating by expert panel
Major coastal project assessment	This domain represents and forms the Australian (Environment and Biodiversity Conservation Act) and State Government Ministerial call-in powers for significant infrastructure and development projects.	4	4	8	There is considerable tension between State and Commonwealth systems for approving major projects, with both based on significantly different visions. Improvements are being negotiated but failures within the major coastal projects domain could lead to cumulative coastal impacts
Coastal planning	The Coastal Management Act in Queensland was intended to reduce development pressure on the coast. Regional Coastal Plans have now been withdrawn and the coastal plan provisions codified at State level	4	4	8	Regional Coastal Management plans have generally had limited impact on either controlling the drivers or impacts of growth in the coastal zone. There is no clear framework for implementation of non-regulatory identified actions. Consequent risks could have broad-scale implications for land use
Regional land use planning	Regional land use planning in Queensland operates under the Queensland Sustainable Planning Act. Its primary focus is to set a broad regional vision and to deliver clear land use plans/ urban footprints	4	4	8	Regional land use plans are not in place across the Reef coast. While there is a strong focus on plan development, plans to date have not built strong mobilizing frameworks and Treasury support for agreed strategies. The new Queensland Government aims to revitalize regional statutory planning
Local government planning	Community Plans (Local Government Act) and Local Government Planning Schemes (Sustainable Planning Act) are important drivers of land use and management	3	4	7	Council land use planning systems are very stable in that they have a long heritage, but Community Plans are only in their infancy. The quality of planning depends strongly on the (variable) capacity and stability of Councils
Traditional Sea country management	Traditional lore governs use by indigenous communities of coastal resources of GBR significance (e.g. dugong and turtles). Traditional Use and Management Resource Agreements (TUMRAs) have been developed	3	3	6	Institutions related to land and Sea management by Traditional Owners can be limited in their capacity to effectively manage key resources such as turtle and dugong. Fragmentation in Government support limits management capacities with implications for some iconic reef species
Ecosystem service delivery (offsets)	An emerging but fragmented market for ecosystem services is evolving, initially via regulated offsets under several pieces of state and commonwealth legislation. A regulated carbon offsets market is emerging	4	5	9	A coherent market framework for ecosystem services could deliver substantive reconstruction of the World Heritage Area and coastal ecosystems and reduce pollutant runoff. The sub-domain has potential for major positive consequences if developed well and will be a serious lost opportunity if not
Property planning and management	Property-scale planning and property management programs, if driven by well supported property owners and managers, are one of the keys to delivering landscape outcomes based on agreed regional goals	4	4	8	There is no one clear framework for property management planning. There is no consistent approach that enables a strong link between on-ground action and regional landscape priorities. There are potentially significant consequences from failure as affected area the whole GBR catchment
Near-neighbour turtle/ dugong management	The six species of marine turtles in the GBR are all listed as threatened and are protected under Australian and Queensland legislation. A recovery plan and Biodiversity Conservation Strategy has been developed for the GBR	4	4	8	Globally significant breeding islands exist in the GBR for 4 species. Some species have shown signs of recovery in recent years, although a decline in seagrass health and recent extreme weather has seen unprecedented deaths. Lack of international action remains a serious concern
International whaling framework	Whaling is managed under two multinational instruments that address whaling in national and international waters. There is a moratorium in place on commercial whaling	1	4	5	Whaling has been banned in Australian waters since the 1960s and the humpback population has recovered to 50% of the estimated pre-whaling population. Interactions with humans, and especially entanglement in shark nets, are becoming more frequent. The governance system is stabilized

**Table 5.** (Continued.)

Domain/sub-domain	Domain/sub-domain descriptor	L*	C*	R*	Preliminary justification of rating by expert panel
Regional NRM planning and delivery	Queensland's Regional NRM planning framework results in the development of regional NRM plans in all major reef catchments, coordinated and reviewed by regional NRM bodies, with significant investment	3	4	7	Regional NRM planning has been embryonic, but has delivered some significant benefits, resulting in the development and coordinated implementation of the current \$200M Reef Rescue Program. Early progress is showing reasonable movement towards improved land management
River and drainage management	Two State Acts govern the management of floodplains across the coastal zone. Their primary objectives relate to economic development/public safety	4	4	8	There is no clear legislative and management vision for sustainable river and floodplain management of at the GBR scale. Capacities of local River Trusts are general limited and sub-domain failure contributes to reef pollution
Biosecurity (weed and pest) management	Biosecurity arrangements in the GBR cover both marine and terrestrial pests. Commonwealth programs and State regulations establish the foundation for pest planning and management	3	4	7	Australia's biosecurity system has long-standing and continuously improving institutional arrangements, but significant risks of new and serious incursions of marine and terrestrial pests remain. Failure consequences can be locally and regionally significant and potentially catastrophic (e.g. Crown of Thorns)
Voluntary community action	Voluntary community action operates from very local scales to whole catchments and the entire Reef. These groups receive investment through many sources	3	3	6	The voluntary action sector has continued to grow in size/breadth. Group burnout and effort fragmentation remain issues for governance. The sector, however, will remain an important and complementary sub-domain
Landscape rehabilitation delivery	Technical capacities for large-scale restoration of catchments, rivers and estuaries largely reside within the voluntary sector (Landcare groups), Councils (work crews) and, to a limited extent, the private sector	3	4	7	Lack of market-driven landscape restoration capacities have restricted development of this sub-domain. Training systems are also deficient and emerging delivery capacities often suffer from limited financial viability. This limits the opportunities for wide-scale system repair
Coastal infrastructure planning	The Coastal Plan provides mechanisms for the provision of maritime infrastructure. There are however, still many exclusions (e.g. ports). As a result, development of maritime facilities is ad hoc, though ports plans required	3	3	6	Coastal planning has sought to maintain nodal development along the coast but strip development continues to be the norm, fragmenting coastal habitats. Ports plans are generally undertaken in a structured way but fail to consider cumulative impacts
Coastal infrastructure management	Many local coastal infrastructure facilities (e.g. groynes, jetties, marinas, canals) are owned and managed by Councils and/or private operators. Approval and management is well regulated	2	2	4	This sub-domain is well regulated and monitored, generally at local scale. The consequences of system failure are localized and not significant. Issues arise with existing infrastructure. Many assets installed prior to modern legislation leave a legacy of impacts on the health and function of coastal ecosystems
Sewage treatment	Following significant State, Federal and Council investment over the last decade, most major sewage systems have been upgraded to tertiary level. Withdrawal of State subsidies is affecting upgrades	3	3	6	Upgrades of infrastructure and progressive asset management and innovation are continuously improving. System failure can have significant consequences for nutrient pollution locally or for particular regions within the GBR, especially when combined with rapid population growth
Support for farms and small businesses	There remains no clear framework for support for farms and small businesses as it relates to the health of the GBR coastal zone. A range of fragmented government, commercial, industry and not-for-profit services exist	3	3	6	A policy shift to market-based farm support and extension services some two decades ago has not been adequately replaced by commercial services. The consequences of system failure are important due to their implications for extensive pollution across the GBR

**Table 5.** (Continued.)

Domain/sub-domain	Domain/sub-domain descriptor	L*	C*	R*	Preliminary justification of rating by expert panel
Reef and coastal research and development	The GBR coast has a strong, well-funded framework for research on key issues (e.g. water quality) via universities and CSIRO. New institutions for research brokerage have emerged in recent years	2	3	5	This sub-domain has been well funded on key issues such as water quality. The resulting knowledge is well integrated with management decision making, including monitoring of reef health. The consequence of system failure would be important in managing the condition of GBR ecosystems

*L* = likelihood rating; *C* = consequence rating; *R* = combined rating.

There is another cluster of sub-domains in which significant progress has been made to the point where they now represent a low risk of governance failure. However, due to consequence ratings, these sub-domains need continuous improvement to ensure progressive benefits continue. These include:

- The *Commercial Fisheries Management and GBR Marine Park sub-domains*, where the management of reef-based fisheries on the east coast, having developed strong governance structures during the 1990s, are beginning to mature and stabilize;
- The *Water Resource Planning sub-domain*, with the processes having now secured the required environmental flows of water across most reef catchments;
- The *International Whaling, Pesticide Regulatory and Marine Safety sub-domains*; and
- The *Reef Research sub-domain* has developed cohesive and considerable depth and integration with policy, though there remains a strong dependency on Australian Government funding and there are shifting models for the governance of collaborative research.

Apart from analyses of specific domains and sub-domains, the governance systems risk analysis framework presented here also enables the analyst to make some broader cross-system observations on governance and priorities for governance reform to benefit the Reef. Examples include:

- (1) The importance of Australia continuing to play an active leadership role in developing and implementing strategic international conventions. In the case of climate change and international conventions such as whaling, for example, this analysis suggests self-interest should help motivate Australia's higher profile role in securing international action.
- (2) The multiple cross-jurisdiction and cross-legislative problems with efficiency and integration, leading to significant governance dysfunction. Indeed, some parts of the system have become redundant (e.g. coastal planning), while others remain weakly integrated (e.g. Regional NRM and Healthy Waterways Management Planning) and without a cohesive monitoring framework.

- (3) The stark difference between the governance of the Reef proper and the catchments draining into it. Only in the past 10 years has a bilateral effort coordination emerged on land, while the Reef itself has had a single management authority (GBRMPA) for 30 years. Catchment governance is complex, requiring a focus on cross-institutional collaboration and coordination.
- (4) The need to consider spatial context due to the ecologically artificial boundaries of the World Heritage Area. There are considerable ecological links, for example, between the GBR proper and the Torres Strait to the north, the Coral Sea to the east, and the Burnett Mary marine waters to the south. There is, however, little cross-boundary effort alignment. One way to address this might be to see a stronger alliance between major allied planning processes (SEQ Waterways, Torres Strait Protected Zone, Coral Sea Marine Protected Zone, etc); and
- (5) The many international and Australian governance and legislative systems affecting the GBR that might seem unrelated, but in fact have the potential for significant impacts on its health (e.g. pesticide and shipping regulation).

**5. Conclusions: applying risk analysis of governance systems**

The Project Team and Steering Committee's feedback on the proposed risk assessment method suggest that rapid, expert panel-based applications of this proposed governance systems risk analysis method, even though only a preliminary step, can begin to powerfully identify the key governance themes, domains and sub-domains that present the most significant risks and those that require urgent reform in a complex governance system like that concerning the GBR. We conclude that such an approach can help government policy makers, reef managers and other important stakeholders to prioritize the next generation of governance reform as it affects the health of the GBR.

Specifically, preliminary analysis of the GBR governance system illustrated to us the importance of context setting of this nature proposed and a foundation in Step 2 of the method. In the Reef, many governance sub-domains are focused on

improving water quality to increase the ability of the reef to cope with the impacts of climate change. Under possible worst-case climate change scenarios, however, it could be that no amount of water quality effort will secure the Reef's ecological health. As system analysts, contextualizing the governance system in this way signalled to use that serious attention needs to be paid to influencing the wider governance system at entirely different scales (global versus regional) and in very different themes and domains (i.e. climate versus coastal management).

We consider, however, that such domain-based contextual analysis, does not suggest that more direct and localized governance domains become pointless. In fact, understanding this wider governance failure in a different domain (climate management) means actions in more obvious domains at regional and local scale (e.g. crown-of-thorns starfish management, refugia management, water quality, etc) may become more important as they represent action on cumulative stressors, in this case, improving the Reef's resilience to the consequences of poor global governance of greenhouse gas emissions (Ban *et al* 2012). This illustrates how up-front contextualization the broad framework of themes, domains and sub-domains of relevance to the governance system can enhance the practice of risk analysis.

We also conclude that risk analysis of governance systems, however, is applicable in many contexts and circumstances of equal complexity to socio-ecological systems such as the GBR. Indeed, we consider that the method can be applied flexibly as a means for keeping an integrated approach to analysis in systems that are influenced by a wide range governance themes, domains, or sub-domains across multiple scales. We also consider that this methodological approach has the flexibility needed to be adapted from use as a rapid risk appraisal technique, through to a comprehensive risk analysis framework. It can be used both as a dispassionate research tool or an engaging practice-based reform tool. It can also be easily adjusted to the budgetary and time constraints facing commissioning agencies; from government and research institutions to not-for-profits.

Government agencies may use this risk analysis approach in developing and assessing critical reforms in their decision-making systems. Alternatively, disempowered communities or institutions can use the framework to develop their campaigns for governance reform. Either way, fairer bargaining and negotiation within society, in the context of any theme, domain, sub-domain, or scale can only become stronger through its considered application. We also conclude, however, that some key factors, however, are worthy of note when in the design phase of the method's application:

- *Best effect in participatory rather than expert-assessment contexts.* Risk analysis of governance systems of this kind is best applied in participatory decision making;
- *Best applied within reform-oriented approaches.* One of the greatest strengths of risk analysis lies in providing the evidence for more participatory approaches to governance reform;

- *A foundation for benchmarking and monitoring governance systems.* Data outputs from risk analysis of governance systems create the ideal foundation for establishing long-standing benchmarks for governance systems and for monitoring progressive improvements;
- *Potential application in education/capacity building.* Risk analysis of governance systems of this kind provides a clear framework for the delivery of education about governance;
- *Determines areas of strategic governance research.* Governance systems risk analysis of this kind can identify strategic research priorities for reform; and
- *Leadership in continuous improvement in governance.* All governance systems need leadership to driving continuous system improvement. Ongoing processes of risk analysis need dedicated resourcing, and all system participants should have confidence in those leading analysis.

Sadly, risk-oriented and systemic analyses of governance are the exception rather than the rule. At a time where more effective governance analysis is needed to overcome society's more intractable problems, it is hoped this approach provides a practical risk assessment tool; a consistent approach to determining, benchmarking and monitoring the most significant risks within governance systems.

## Acknowledgments

Funding has been provided by the Australian Government National Environment Research Program Tropical Ecosystems Hub via the Reef and Rainforest Research Corporation. Many thanks also for the support of stakeholder input through the 'Conservation Planning for a Changing Coastal Zone' Project Reference Group. Thanks also to the Australian Centre for Ecological Analysis and Synthesis (ACEAS).

## References

- Ban N C, Pressey R L and Weeks S 2012 Conservation objectives and sea-surface temperature anomalies in the Great Barrier Reef *Conserv. Biol.* **26** 799–809
- Berkelmans R W C, De'ath A G, Kininmonth S J and Skirving W J 2004 A comparison of the 1998 and 2002 coral bleaching events on the Great Barrier Reef: spatial correlation patterns and predictions *Coral Reefs* **23** 74–83
- Borges A V and Gypens N 2010 Carbonate chemistry in the coastal zone responds more strongly to eutrophication than to ocean acidification *Limnol. Oceanogr.* **55** 346–53
- Brodie J, Bainbridge Z, Lewis S, Devlin M, Waterhouse J, Davis A, Bohnet I C, Kroon F, Schaffelke B and Wolanski E 2012 Terrestrial pollutant runoff to the Great Barrier Reef: issues, priorities and management response *Mar. Pollut. Bull.* **65** 81–100
- Brodie J E, Devlin M J, Haynes D and Waterhouse J 2011 Assessment of the eutrophication status of the Great Barrier Reef lagoon (Australia) *Biogeochemistry* **106** 281–302
- Brodie J, Fabricius K, De'ath G and Okaji K 2005 Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence *Mar. Pollut. Bull.* **51** 266–78
- Brodie J, Schroeder T, Rohde K, Faithful J, Masters B, Dekker A, Brando V and Maughan M 2010 Dispersal of suspended

- sediments and nutrients in the Great Barrier Reef lagoon during river-discharge events: conclusions from satellite remote sensing and concurrent flood-plume sampling *Mar. Freshw. Res.* **61** 651–64
- Brodie J and Waterhouse J 2012 A critical review of environmental management of the 'not so Great' Barrier Reef *Estuar. Coast. Shelf Sci.* **104/105** 1–22
- Brodie J et al 2008a *Scientific Consensus Statement on Water Quality in the Great Barrier Reef* (Brisbane: The State of Queensland (Department of Premier and Cabinet))
- Brodie J et al 2008b *Synthesis of Evidence to Support the Scientific Consensus Statement on Water Quality in the Great Barrier Reef* (Brisbane: The State of Queensland (Department of Premier and Cabinet))
- Burke L, Reynter K, Spalding M and Perry A 2011 *Reefs at Risk Revisited* (Washington, DC: World Resources Institute) p 114 (available at [www.wri.org](http://www.wri.org))
- Cooper T F, De'ath G, Fabricius K E and Lough J M 2008 Declining coral calcification in massive Porites in two nearshore regions of the northern Great Barrier Reef *Glob. Change Biol.* **14** 529–38
- Cox D 2002 *Why Economists Should Study Biology* (Library of Economics and Liberty) ([www.econlib.org/library/Columns/Coxbiology.html](http://www.econlib.org/library/Columns/Coxbiology.html))
- Dale A and Bellamy J 1998 Regional resource use planning: an Australian review *LWRRDC Occasional Paper 9/98* (Canberra: LWRRDC)
- Dale A P and Lane M B 1993 Strategic perspective analysis: a procedure for participatory and political social impact assessment *Soc. Nat. Resour.* **7** 253–67
- Dale A P, Taylor N and Lane M 2002 *Social Assessment in Natural Resource Management Institutions* (Melbourne: CSIRO Publishing)
- De'ath G and Fabricius K 2010 Water quality as a regional driver of coral biodiversity and macroalgae on the Great Barrier Reef *Ecol. Appl.* **20** 840–50
- De'ath G, Fabricius K, Sweatman H and Puotinen M 2012 The 27-year decline of coral cover on the Great Barrier Reef and its causes *Proc. Natl Acad. Sci.* **109** 17995–9
- De'ath G, Lough J M and Fabricius K E 2009 Declining coral calcification on the Great Barrier Reef *Science* **323** 116–9
- DeVantier L M, De'ath G, Turak E, Done T J and Fabricius K E 2006 Species richness and community structure of reef-building corals on the nearshore Great Barrier Reef *Coral Reefs* **25** 329–40
- Devlin M J, Harkness P, McKinna L, Abbott B and Brodie J 2012 Mapping the pollutants in surface riverine flood plume waters in the Great Barrier Reef, Australia *Mar. Pollut. Bull.* **81** 224–48
- Doney S C, Fabry V J, Feely R A and Kleypas J A 2009 Ocean acidification: the other CO<sub>2</sub> problem *Ann. Rev. Mar. Sci.* **1** 169–92
- Dorsey A 1986 *Bargaining in the Governance of Pacific Coastal Resources: Research and Reform* (Vancouver: Westwater Research Centre, University of British Columbia)
- Emerson K, Nabatchi T and Balogh S 2011 An integrative framework for collaborative governance *J. Public Adm. Res. Theory* **22** 1–29
- Fabricius K E 2005 Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis *Mar. Pollut. Bull.* **50** 125–46
- Fabricius K, De'ath G, McCook L, Turak E and Williams D 2005 Changes in algal, coral and fish assemblages along water quality gradients on the inshore Great Barrier Reef *Mar. Pollut. Bull.* **51** 384–98
- Fabricius K, Okaji K and De'ath G 2010 Three lines of evidence to link outbreaks of the crown-of-thorns seastar *Acanthaster planci* to the release of larval food limitation *Coral Reefs* **29** 593–605
- Folke C, Hahn T, Olsson P and Norberg J 2005 Adaptive governance for social-ecological systems *Annu. Rev. Environ. Resour.* **30** 441–73
- Graham J, Amos B and Plumptre T 2003 Principles of good governance in the 21st century *Policy Brief No. 15* (Ontario: Institute of Good Governance)
- Haapkyla J, Unsworth R K F, Flavell M, Bourne D G, Schaffelke B and Willis B L 2011 Seasonal rainfall and runoff promote coral disease on an inshore reef *PLoS One* **6** e16893
- Hoegh-Guldberg O et al 2007 Coral reefs under rapid climate change and ocean acidification *Science* **318** 1737–42
- Hughes T P, Bellwood D R, Baird A H, Brodie J, Bruno J F and Pandolfi J M 2011 Shifting base-lines, declining coral cover, and the erosion of reef resilience: comment on Sweatman et al. (2011) *Coral Reefs* **30** 653–60
- Hughes T P, Graham N A J, Jackson J B C, Mumby P J and Steneck R S 2010 Rising to the challenge of sustaining coral reef resilience *Trends Ecol. Evol.* **25** 633–42
- Hughes T P, Rodrigues M J, Bellwood D R, Ceccerelli D, Hoegh-Guldberg O, McCook L, Moltchanivskyj N, Pratchett M S, Steneck R S and Willis B L 2007 Regime-shifts, herbivory and the resilience of coral reefs to climate change *Curr. Biol.* **17** 360–5
- Kemp R and Parto S 2005 Governance for sustainable development: moving from theory to practice *Int. J. Sustain. Dev.* **8** 12–30
- Kennedy K et al 2012 Photosystem-II herbicides on the Great Barrier Reef: results from up to five years of monitoring and a preliminary comparison with remote sensing derived water quality parameters *Mar. Pollut. Bull.* **81** 292–305
- Kenward R et al 2011 Identifying governance strategies that effectively support ecosystem services, resource sustainability and biodiversity *Proc. Natl Acad. Sci. USA* **108** 5308–12
- Kroon F J 2012 Towards ecologically relevant targets for river pollutant loads to the Great Barrier Reef *Mar. Pollut. Bull.* **81** 261–6
- Kroon F J, Kuhnert K M, Henderson B L, Wilkinson S N, Kinsey-Henderson A, Brodie J E and Turner R D R 2012 River loads of suspended solids, nitrogen, phosphorus and herbicides delivered to the Great Barrier Reef lagoon *Mar. Pollut. Bull.* **81** 167–81
- Lewis S E, Brodie J E, Bainbridge Z T, Rohde K W, Davis A M, Masters B L, Maughan M, Devlin M J, Mueller J F and Schaffelke B 2009 Herbicides: a new threat to the Great Barrier Reef *Environ. Pollut.* **157** 2470–84
- Leys A and Vanclay J 2011 Social learning: a knowledge and capacity building approach for adaptive co-management of contested landscapes *Land Use Policy* **28** 574–84
- Macionis J J and Gerber L M 2011 *Sociology* 7th edn (Toronto: Pearson)
- Maina J, McClanahan T R, Venus V, Ateweberhan M and Madin J 2011 Global gradients of coral exposure to environmental stresses and implications for local management *PLoS One* **6** e23064
- McKenzie L J, Unsworth R K F and Waycott M 2010 *Reef Rescue Marine Monitoring Program: Intertidal Seagrass—Annual Report for the Sampling Period 1st September 2009–31st May 2010* (Cairns: Fisheries Queensland) p 136 ([www.gbrmpa.gov.au/\\_data/assets/pdf\\_file/0009/7677/RRMMP\\_Seagrass\\_annual\\_report\\_2009\\_10.pdf](http://www.gbrmpa.gov.au/_data/assets/pdf_file/0009/7677/RRMMP_Seagrass_annual_report_2009_10.pdf))
- Newig J and Fritsch O 2009 Environmental governance: participatory, multi-level- and effective? *Environ. Policy Govern.* **19** 197–214
- Norström A V, Nyström M, Lokrantz J and Folke C 2009 Alternative states on coral reefs: beyond coral-macroalgal phase shifts *Mar. Ecol. Prog. Ser.* **376** 295–306
- Ostrom E 2008 *Polycentric Systems as One Approach for Solving Collective-Action Problems* (New York: Social Science Research Network) ([http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1304697](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1304697))
- Paavola J, Gouldson A and Kluvánková-Oravská T 2009 Interplay of actors, scales, frameworks and regimes in the governance of biodiversity *Environ. Policy Govern.* **19** 148–58



- Pahl-Wostl C, Lebel L, Knieper C and Nikitina E 2012 From applying panaceas to mastering complexity: towards adaptive water governance in river basins *Environ. Sci. Policy* **23** 24–34
- Pandolfi J M *et al* 2003 Global trajectories of the long-term decline of coral reef ecosystems *Science* **301** 955–8
- Parker C and Braithwaite J 2003 Regulation *The Oxford Handbook of Legal Studies* ed P Cane and M Tushnet (Oxford: OUP)
- Plummer R and Armitage D 2007 Ecological economics: a resilience-based framework for evaluating co-management *Ecol. Econ.* **61** 62–74
- Ross H, Bellamy J, Ewing S and Meppem T 2002 *Integrated Catchment Management: Learning from the Australian Experience for the Murray Darling Basin: Overview Report* (Canberra: CSIRO Sustainable Ecosystems)
- Schaffelke B, Carleton J, Skuza M, Zagorskis I and Furnas M J 2012 Water quality in the inshore Great Barrier Reef lagoon: implications for long-term monitoring and management *Mar. Pollut. Bull.* **81** 249–60
- Schaffelke B, Mellors J and Duke N C 2005 Water quality in the Great Barrier Reef region: responses of mangrove, seagrass and macroalgal communities *Mar. Pollut. Bull.* **51** 279–96
- Sweatman H, Delean S and Syms C 2011 Assessing loss of coral cover on Australia's Great Barrier Reef over two decades, with implications for longer term-trends *Coral Reefs* **30** 521–31
- Taylor B, McDonald G and Heyenga S 2006 *Evaluation of Regional Planning Arrangements for Natural Resource Management 2005–2006: Benchmark Report II* (Brisbane: Healthy Savanna Planning Systems Project, Tropical Savannas Management, CSIRO)
- Thorburn P J and Wilkinson S N 2013 A pragmatic approach to evaluating water quality benefits of agricultural management practices *Agric. Ecosyst. Environ.* at press (doi:10.1016/j.agee.2011.12.021)
- Waycott M *et al* 2009 Accelerating loss of seagrasses across the globe threatens coastal ecosystems *Proc. Natl Acad. Sci. USA* **106** 12377–81
- Weiss T 2000 Governance, good governance and global governance: conceptual and actual challenges *Third World Q.* **21** 795–814
- Young O *et al* 2006 The globalization of socio-ecological systems: an agenda for scientific research *Glob. Environ. Change* **16** 304–16