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## Environmental Research Letters



## LETTER

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

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N A Marshall<sup>1,2</sup>, E Bohensky<sup>1</sup>, M Curnock<sup>1</sup>, J Goldberg<sup>1,3</sup>, M Gooch<sup>4,5</sup>, B Nicotra<sup>2</sup>, P Pert<sup>6</sup>, L M Scherl<sup>2</sup>, S Stone-Jovicich<sup>1</sup> and R C Tobin<sup>2</sup><sup>1</sup> CSIRO, Land and Water Flagship, James Cook University, building #145, Townsville, Q4811, Australia<sup>2</sup> James Cook University, College of Marine and Environmental Sciences, Townsville, Q4811, Australia<sup>3</sup> James Cook University, College of Law, Business & Governance, Townsville, Q4811, Australia<sup>4</sup> Great Barrier Reef Marine Park Authority, Flinders Street, Townsville, Q4810, Australia<sup>5</sup> Cairns Institute, James Cook University, Australia<sup>6</sup> CSIRO, Land and Water Flagship, Cairns, Q4870, AustraliaE-mail: [nadine.Marshall@csiro.au](mailto:nadine.Marshall@csiro.au)**Keywords:** social system, ecosystem services, human and community well-being, resource dependency, natural resource management, drivers of change, social impact assessmentSupplementary material for this article is available [online](#)**Abstract**

The aim of this paper is to demonstrate the feasibility and potential utility of decision-centric social-economic monitoring using data collected from Great Barrier Reef (Reef) region. The social and economic long term monitoring program (SELTMP) for the Reef is a novel attempt to monitor the social and economic dimensions of social-ecological change in a globally and nationally important region. It represents the current status and condition of the major user groups of the Reef with the potential to simultaneously consider trends, interconnections, conflicts, dependencies and vulnerabilities. Our approach was to combine a well-established conceptual framework with a strong governance structure and partnership arrangement that enabled the co-production of knowledge. The framework is a modification of the Millennium Ecosystem Assessment and it was used to guide indicator choice. Indicators were categorised as; (i) resource use and dependency, (ii) ecosystem benefits and well-being, and (iii) drivers of change. Data were collected through secondary datasets where existing and new datasets were created where not, using standard survey techniques. Here we present an overview of baseline results of new survey data from commercial-fishers ( $n = 210$ ), marine-based tourism operators ( $n = 119$ ), tourists ( $n = 2877$ ), local residents ( $n = 3181$ ), and other Australians ( $n = 2002$ ). The indicators chosen describe both social and economic components of the Reef system and represent an unprecedented insight into the ways in which people currently use and depend on the Reef, the benefits that they derive, and how they perceive, value and relate to the Reef and each other. However, the success of a program such as the SELTMP can only occur with well-translated cutting-edge data and knowledge that are collaboratively produced, adaptive, and directly feeds into current management processes. We discuss how data from the SELTMP have already been incorporated into Reef management decision-making through substantial inclusion in three key policy documents.

**Introduction**

The need to incorporate social and economic data into environmental or natural resource management is well-established (Berkes and Folke 1998, Cinner *et al* 2009). More recently, a critical shift in policy

thinking has explicitly recognized the importance of nature to human development and economic sustainability (Guerry *et al* 2012). People are recognised as part of natural resource systems and regarded as beneficiaries of environmental planning rather than as impacts. This transition in policy thinking is expected

to enable environmental management that is adaptive and resilient where learnings and understanding of social, cultural, governance and economic aspects of natural systems are expected to better achieve management goals (Howden *et al* 2007, Stone-Jovicich 2015).

The human component of natural resource systems can be difficult to consider and even more so to incorporate into decision-making (Liu *et al* 2007, Reyers *et al* 2013). This may be because social data are often complex and the social, cultural, environmental and economic aspects of natural resource systems are often competing. Science salience, credibility and legitimacy are often also problematic with social data (Cash *et al* 2003). Processes and analytical tools that enable the efficient assimilation of robust and timely social and economic data into decision-making processes are very much needed, but are still only within their infancy.

Longitudinal, up-to-date and comparable social and economic datasets of key stakeholders can provide an opportunity to simultaneously consider trends, interconnections, conflicts, dependencies and vulnerabilities in advance of strategies and policies being proposed (Marshall *et al* 2013). Knowledge of each can lead to more effective, feasible and acceptable resource management strategies. However, whilst examples of single stakeholder group monitoring programs are plentiful (Bengston *et al* 1999, Boyd and Charles 2006, <https://lternet.edu/>), there are only few examples of broader long term social and economic information collection programs that balance biodiversity conservation with human development and wellbeing (Fox *et al* 2014), particularly in developed regions such as the Great Barrier Reef.

The aim of this paper is to demonstrate that, despite the unruly nature of social systems, decision-centric social-economic monitoring is feasible, and to do so we use an example from the Great Barrier Reef. The social and economic long term monitoring program (SELTMP) for the Great Barrier Reef represents the first large scale, multi-user-group, (potentially) long term social and economic monitoring program of its kind. We modify a framework from the Millennium Ecosystem Assessment (MA 2005) that endeavours to conceptualise the complexity of human systems through isolating those social system components most useful to environmental management and incorporating a range of stakeholder groups at a range of scales. A further aim was to increase the chance that the data would be considered in management processes. Our approach was to combine the conceptual framework with a strong governance structure and partnership arrangement (Stone-Jovicich 2015). Importantly, reef decision-makers were research partners and co-producers of knowledge (Cash *et al* 2003, Reyers *et al* 2015). The approach and lessons provide a model for the development of long term social and economic monitoring programs elsewhere. Whilst we are not able to report on trends or changes within the

social system at this early stage, the baseline data provide a unique insight into current social and economic conditions associated with the Great Barrier Reef. We have not attempted to interpret or analyse the data. Below we describe the SELTMP conceptual framework, design and initial baseline results.

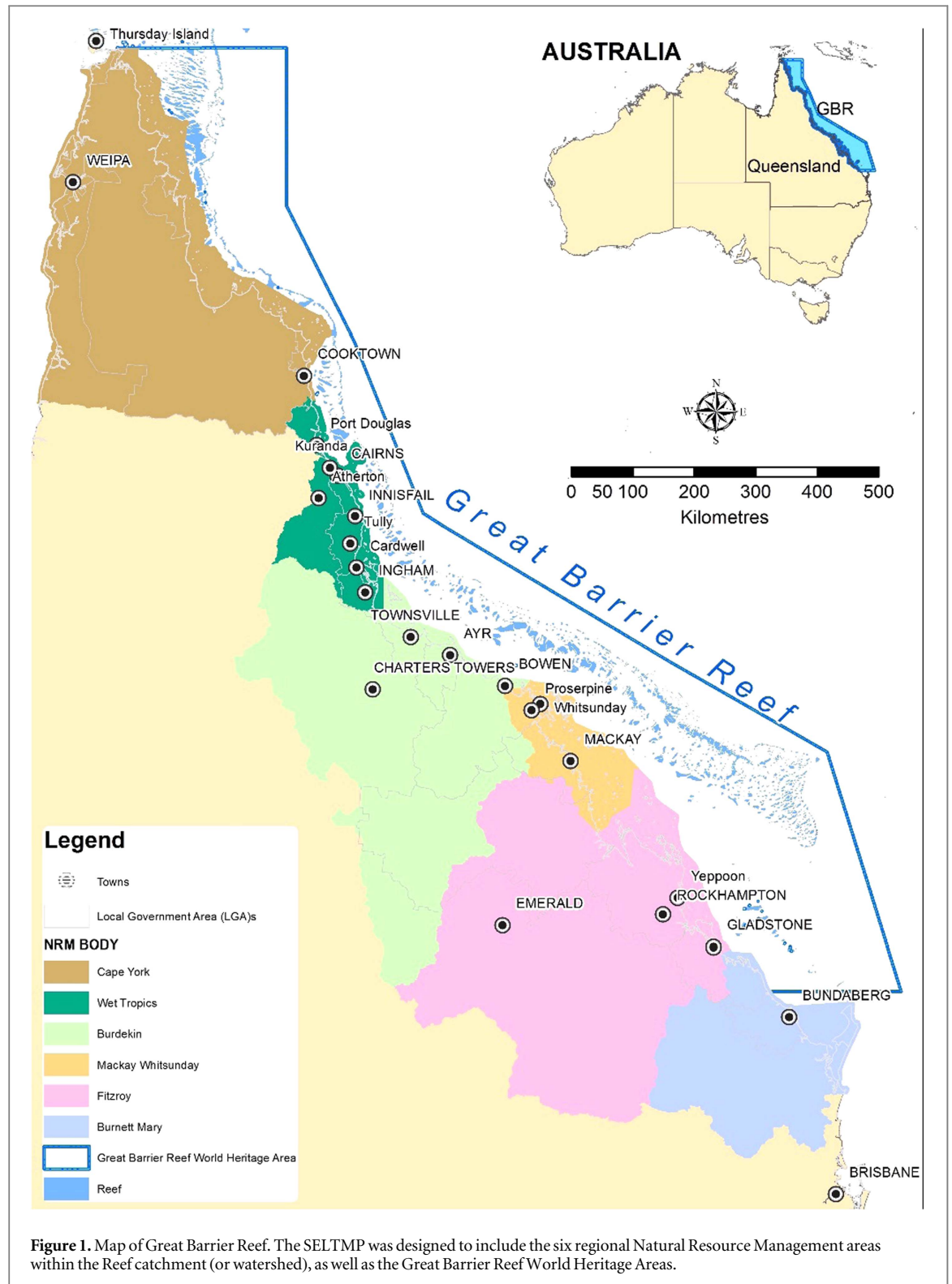
### Case study context: the Great Barrier Reef and its management

The Great Barrier Reef Marine Park is widely regarded as one of the most sophisticated and well-resourced natural resource management settings in the world (figure 1). The Great Barrier Reef supports a wealth of economic activity (\$5 billion per year) and is a vital contribution to the wellbeing of coastal communities (Larson *et al* 2013, Stoeckl *et al* 2011), Australians more generally (Goldberg *et al* 2016), and broader international community. The long term implications of climate change, poor water quality and coastal development have emerged as key sources of uncertainty and community expectations around each of these management challenges is high (Goldberg *et al* 2016).

Management of the Great Barrier Reef World Heritage Area includes a range of tools such as zoning plans, management plans, permits and licences (including environmental impact assessment and measures to avoid, mitigate and offset impacts), Traditional Owner agreements, compliance, fees and charges, policy, partnerships, stewardship, education, research, monitoring and reporting<sup>7</sup>.

Three key documents have recently been developed to guide management of the Great Barrier Reef; (i) The *Great Barrier Reef Region Strategic Assessment: Strategic Assessment Report*, (ii) the *Great Barrier Reef Outlook Report 2014*, and (iii) the *Reef2050 Long-Term Sustainability Plan* (LTSP). These are critical documents for the forward planning and management of the Great Barrier Reef Marine Park and World Heritage Area, and were the targeted policy recipients, in the short-term, of data collected from the SELTMP. For example, the LTSP focuses on the ecological, social and economic sustainability of Reef-dependent industries and activities that support the Australian economy. It has seven key themes, each with their own outcomes, objectives, targets, values and attributes (figure 2). Four of the themes presented in figure 2 describe the human dimensions of the system; (i) governance, (ii) community benefits, (iii) economic benefits, and (iv) heritage. Data from the SELTMP were expected to directly address community benefits and economic benefits. Community benefits were defined as: '... the vital role that a healthy vibrant Reef plays in community life. People visit the Reef for a wide range of reasons such as nature appreciation, opportunities

<sup>7</sup> COMMONWEALTH OF AUSTRALIA, 2015. *Reef2050 long-term sustainability plan*. Canberra: Department of the Environment and Great Barrier Reef Marine Park Authority.



for relaxation and enjoyment, cultural connections and for livelihoods.’ Economic benefits were defined as: ‘... financial benefits derived directly and indirectly from the Great Barrier Reef and its catchment.’

In 2011 the first comprehensive SELTMP for the Great Barrier Reef was initiated following repeated calls from reef managers of the World Heritage Great Barrier Reef for stronger and comprehensive social science data that could be used to assist managers in

their day-to-day duties. It was designed to collect information that would enable Reef managers and other decision-makers to detect changes in condition in the social system, measure social impacts associated with management interventions, monitor trends in public support for management and to provide data for analysing trade-offs associated with decision-making. The baseline phase focused on commercial fishing, marine tourism, coastal communities, national

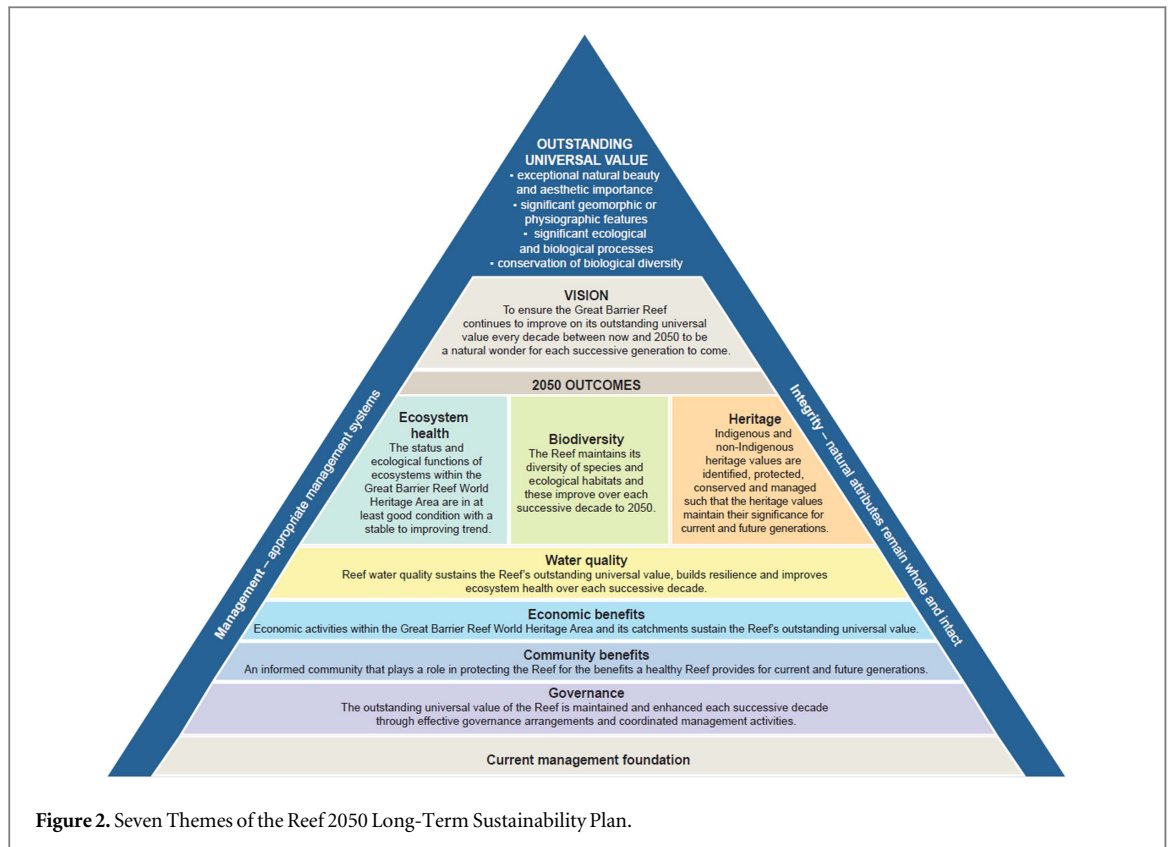


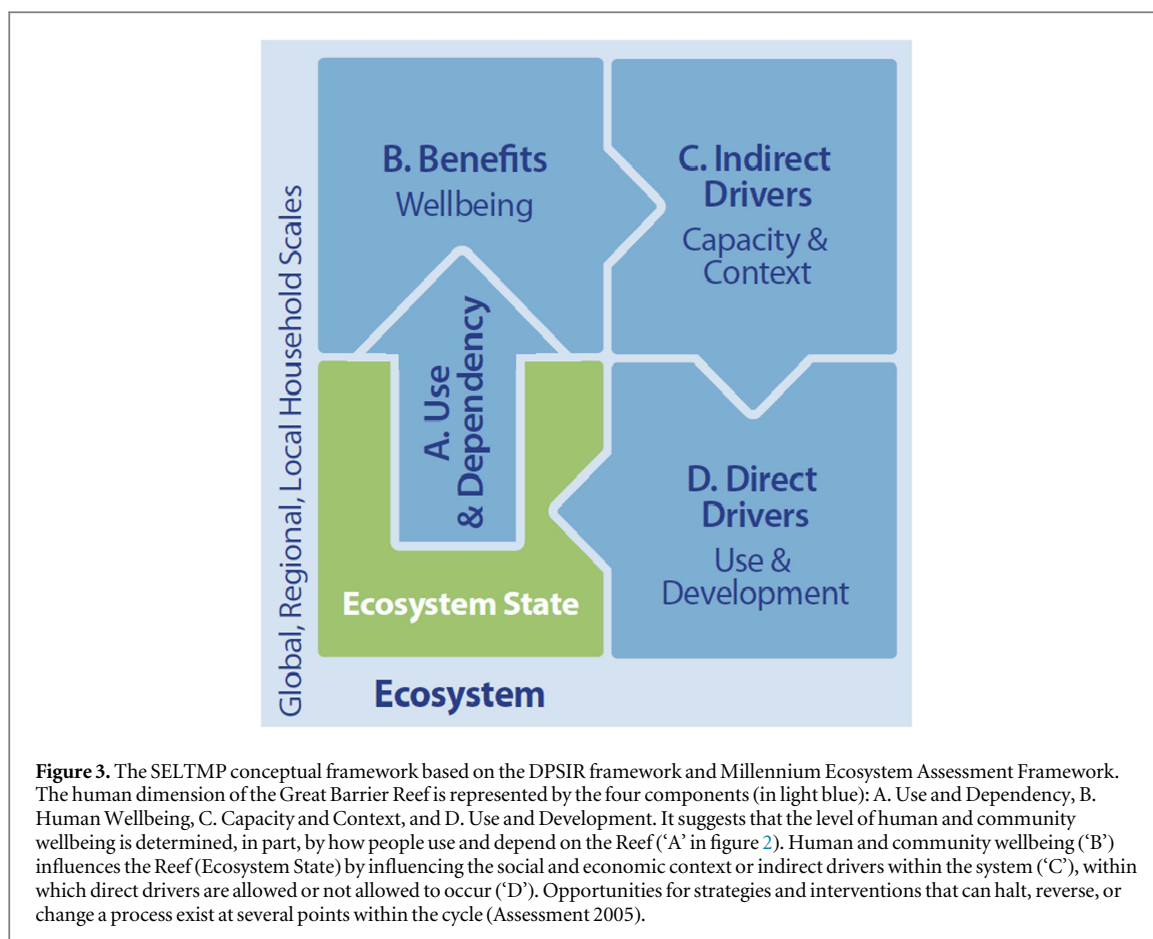
Figure 2. Seven Themes of the Reef 2050 Long-Term Sustainability Plan.

residents (Australians), and ports and shipping. Subsequent phases are planned to include Traditional Owners, agricultural industries and mining.

### The Great Barrier Reef monitoring program design

The SELTMP for the Great Barrier Reef was focused on process and structure so as to ensure both policy relevance and science credibility, salience and legitimacy (Cash *et al* 2003). A key design aim was to minimise redundancy, maximize end-user engagement and facilitate the co-production of knowledge. Our approach was to set up a series of advisory groups. We established a high level steering committee of only six members that ensured that the program was policy relevant and true to its contractual commitments yet sufficiently flexible to deliver on stakeholder needs. The group met twice a year and was chaired by a representative from the Great Barrier Reef Marine Park Authority, who was a key end user of the SELTMP data. We also established a Scientific and Stakeholder Advisory Panel (SSAP) comprised of 22 representative members across community, government, research and industry. Initially the SSAP met twice a year, but once established it only met annually. The purpose of the SSAP was to engage high level potential end-users of the research and maximise the relevance of the SELTMP to the broad range of stakeholders in the region. We also established technical working groups for each of the major sectors of commercial fishing, marine tourism, coastal communities, recreation, and ports and shipping as well as technical working groups to advise on cross-cutting issues of drivers of change

and wellbeing. The seven working groups comprised technical experts from community, government, research and industry. The groups met regularly and less frequently and less formally as the program continued, as agreed on by group members. Some groups comprised only a small number of members (e.g. four people in the Ports and Shipping working group), whilst others comprised larger numbers (e.g. 25 people in the Tourism working group). During the initial meetings, the groups were encouraged to highlight their own internal issues and priorities and discuss how the availability of social and economic data might be useful. Trust and effective relationships within each group were important to establish. Groups developed a 'wish list' of indicators over subsequent meetings. Some groups took longer than other groups to develop their 'wish list'. Group members understood that not all indicators on the 'wish list' would be monitored, and that whether they were chosen or not depended on their feasibility as well as whether there was scientific reason for them as dictated by the monitoring framework. The working groups were instrumental in selecting and prioritising the initial list of variables and indicators to be monitored. During the next phase of meetings, working group members were asked to assist SELTMP staff by identifying existing datasets where data describing chosen indicators could be accessed or made available. We then worked to access these datasets where possible. In the final stages of meetings, members of working groups were provided with project results and made aware of the compilation of data relevant to their working



group area. In this way, we worked to deliver data where needed.

Our approach to structure the SELTMP was to use the drivers–pressures–state–impact–response (DPSIR) framework from the Millennium Ecosystem Assessment (MA) (Stokstad 2005) as the underlying framework for the design of the program and to guide the process of indicator choice. The DPSIR framework, upon which the MA was based, was familiar to managers of the Great Barrier Reef Marine Park and later formed the basis of their *Reef2050 Long-Term Sustainability Plan* ([www.gbrmpa.gov.au](http://www.gbrmpa.gov.au)) (figure 3). We adapted the MA framework for the SELTMP to focus explicitly on the social and economic dimension of the Reef system and its relationship with the ecosystem (see figure 3). The adapted SELTMP monitoring framework focused on: (i) resource use and dependency, (ii) human and community wellbeing, and (iii) drivers of change (describing the context within which environmental decisions are made), each of which are described below. The adapted SELTMP framework enabled data needs and gaps to be identified, and guided the process to decide which indicators selected by the advisory panels (the 'wish list') would be most informative and feasible to monitor.

#### *Resource use and dependency indicators*

The character and extent of well-being can be determined by how people are financially, culturally,

spiritually and intellectually dependent on a natural resource (MA 2005). How people are dependent on a natural resource can provide foundational and fundamental information to Reef managers as it describes who uses the Reef, how many use the Reef, where they go, when, how, why and how much is used or harvested. Resource use and dependency provide a description of some of the community and economic benefits that each stakeholder group derive from the Great Barrier Reef, critical for reporting on the LTSP.

#### *Ecosystem benefits or Human and community wellbeing indicators*

Human and community wellbeing are related to a range of factors. Here we consider the well-being derived from an ecosystem as; (i) the opportunities that people associate with the Reef, (ii) the level of empowerment in reef processes and opportunities, (iii) the security or perceived levels of social stability, environmental sustainability and environmental quality both now and in the future ([www.worldbank.org/wellbeing](http://www.worldbank.org/wellbeing)). These indicators also provide additional descriptions of the community benefits that can be derived from the Reef, critical for reporting on the LTSP (Marshall *et al* 2007).

#### *Drivers of change*

This social-system component describes the social context within which management decisions are

made. Six categories of drivers were identified using the literature and a workshop within the 'Drivers of Change technical working group' as: (i) economic, (ii) social and cultural, (iii) demographic, (iv) political and management, (v) communication and media and (vi) science and technology (Bohensky *et al* 2011). Social-cultural aspects are presented in this manuscript as the particular driver requiring primary data collection (B). The drivers of change could be used in LTSP reporting.

### Methods and materials

In order to avoid redundancy and provide opportunities for partnerships, existing regional data sets (such as industry records, census data, government databases etc) were used wherever possible to provide indicators of key variables. Where existing data did not exist for priority indicators, we used standard social-science techniques to survey each of the major user-groups within the region (Bryman 2012). We report here on the primary (new) data collected through the SELTMP. National residents were surveyed via an online research panel and sample size was determined by budget ( $n = 2002$ ). Coastal residents ( $n = 3181$ ) and tourists (domestic and international,  $n = 2877$ ) were surveyed using face-to-face methods by a team of interviewers that were located across a range of public places in the main population centres along the Great Barrier Reef (the response rate was 53%). Our aim was to get as many surveys completed from coastal residents and tourists that we could within a four week period (July–September 2013 across all regions), and remain within budget. Marine tourism operators ( $n = 119$ ) and commercial fishers ( $n = 210$ ) were interviewed by telephone using our own contacts databases and publicly-available data. The samples represent 56% and 35% of each industry. For a detailed description on the survey approach, please see the supplementary material provided. The collective response rate for the marine-based industries was 76%.

## Results

The results presented below provide a large-scale overview of the relationship between people and the Great Barrier Reef. Detailed results from the 2014 baseline surveys can be downloaded from <http://seltmp.eatlas.org.au/seltmp>. We report here only on the 'big picture' data as they provide an unparalleled insight into current social and economic conditions within the region.

### Resource use

The Great Barrier Reef is a much used resource by all user groups (table 1). For example, 86% of local residents (total population = 909 422) had visited the Reef within the last twelve months (table 1),

representing 782 103 visitor days. Our results yield an estimated 66 568 effort days spent on the Reef by the 759 active commercial fishing operations; 132 008 days of operation on the Reef by the 569 advertised tourism operators and 52 129 700 total tourist days (assuming a tourist population of 74 471 000 and a 70% visitation rate to the Reef). In total, the Great Barrier Reef received an estimated 53.3 M days of use in 2013, with 98% of all days comprising tourism visitation. There were 8839 port visits from commercial ships. Resource use is typically measured as how people interact with the resource and to what extent, but overlaying cultural elements such as 'favourite places' (as opposed to 'frequented places') can be particularly useful to environmental managers who may want to know where the places that are important to people may be. A map of the favourite places of local residents is presented in figure 4 as an example of how resource use was captured (<http://seltmp.eatlas.org.au/seltmp>). This map might be useful to decide where extra resources might be allocated for heightened protection or recreational opportunities or to assess the level of threat that a potential change might be if near to a 'favourite place'.

### Resource dependency

People depend on the Reef for financial and cultural benefits. Financially, we found that 25% of local residents depended on the Reef directly for at least some of their household income. Culturally, the Reef was an important part of the lifestyle of local residents, providing recreational opportunities and fresh seafood. For example, 41% of local residents, 76% of tourism operators and 65% of fishers stated that they lived in the region because of the Reef. Similarly, 78% of coastal residents valued the Reef for the fresh seafood it provides (table 1).

All user groups indicated that the Reef was an important part of their identity (figure 4). In fact, the broader Australian community identified with the Reef more than local residents (table 1 and figure 5). Tourism operators most strongly identified with the Reef (mean 8.02 on a scale of 1–10), followed by Australian residents (mean 7.39), commercial fishers, (mean 6.95), local residents (mean 6.43), domestic tourists (5.45) and international tourists (3.53). In figure 5 we provide some examples of how different stakeholders are dependent on the Reef through their identities, perceptions of whether the Reef is the best place to enjoy recreational activities, perceptions around whether their job is a lifestyle, and whether they want to be in any other occupation. The level of attachment to identity, recreational opportunities or occupation provides resource managers with some insight into how people might perceive a proposed management change that may threaten their relationship with the Reef.

**Table 1.** Categories, components, indicators, example questions and results within the SELTMP for the Great Barrier Reef.

Categories and components	Broad indicators (key examples)	SELTMP example questions	Example results <sup>a</sup>
<b>Use and dependency</b>			
Resource use patterns	<ul style="list-style-type: none"> <li>• Activity type</li> <li>• Frequency of activities</li> <li>• Spatial patterns</li> <li>• Temporal patterns</li> </ul>	<p><b>COASTAL RESIDENTS:</b></p> <ul style="list-style-type: none"> <li>• In the previous 12 months, how many days did you visit the Reef for recreation?</li> <li>• Vessel ownership &amp; use details</li> </ul> <p><b>TOURISTS:</b></p> <ul style="list-style-type: none"> <li>• What were your main activities [on your visit]?</li> </ul> <p><b>TOURISM OPERATORS &amp; COMMERCIAL FISHERS:</b></p> <ul style="list-style-type: none"> <li>• Range of operations, type of operations.</li> </ul> <p><b>NATIONAL RESIDENTS:</b></p> <ul style="list-style-type: none"> <li>• Reef visitation in previous 12 months, lifetime.</li> </ul>	<ul style="list-style-type: none"> <li>• 86% of coastal residents in the region and 9% of Australians had visited the Reef in the previous 12 months.</li> <li>• 70% of tourists in the region had visited the Reef during their stay and 50% took part in a commercial Reef tour.</li> <li>• 30% of commercial fishers operate with 50 km of their home port; 46% roam further than 100 km from their home port.</li> <li>• 1073 active tourism permits in Reef in 2013 (many operators hold multiple permits).</li> <li>• Tourism operators spent a mean of 232 days on the Reef in the last 12 months</li> <li>• 44% of national residents surveyed had visited the Reef.</li> <li>• Tourists to the region stay in the region for a median of 10 days</li> <li>• Commercial fishers had spent 63 635 effort days in the Reef in the last six months, and harvest fishers had spent 2933 effort days</li> </ul>
Resource dependency	<ul style="list-style-type: none"> <li>• Cultural identity around Reef (occupational identity and life-style identity)</li> <li>• Place attachment to Reef</li> <li>• Family flexibility to move</li> <li>• Recreational and inspirational experiences</li> <li>• Formal and informal networks around the Reef</li> <li>• Economic benefits and investments</li> </ul>	<p><b>TOURISM OPERATORS &amp; COMMERCIAL FISHERS:</b></p> <ul style="list-style-type: none"> <li>• Annual business revenue &amp; number of employees.</li> <li>• There are not many other places that are better than the Reef for the tourism activities/commercial fishing that I do</li> <li>• I live in this region because of the Reef</li> <li>• I do not plan to be a resident of this region in the next 5 years</li> <li>• I am not likely to remain operating in this region if events such as cyclones and floods occur more frequently</li> <li>• I wouldn't want to be anything other than a commercial fisher</li> <li>• The fishing industry to me is not just a job—it is my lifestyle</li> </ul>	<ul style="list-style-type: none"> <li>• Mean of 22 employees for tourism businesses (range 1–400) see 2.2 additional employees for commercial fishing businesses (range 0–50).</li> <li>• 25% of Reef coastal residents rely of the Reef for at least part of their household income.</li> <li>• 41% of local residents, 76% of tourism operators and 65% of fishers stated that ‘I live in this region because of the Reef’</li> <li>• 66% of coastal residents agree that there are few places better than the Reef for the recreation activities they enjoy.</li> <li>• 78% of coastal residents value the Reef for the fresh seafood it provides.</li> <li>• 63% of residents indicated that the Great Barrier Reef is part of my identity</li> <li>• 84% of tourism operators said that the Reef was part of their identity</li> </ul>



Table 1. (Continued.)

Categories and components	Broad indicators (key examples)	SELTMP example questions	Example results <sup>a</sup>
	<ul style="list-style-type: none"> <li>• Employment figures</li> <li>• Business model/approach</li> <li>• Traditional and non-traditional cultural practices</li> </ul>	<ul style="list-style-type: none"> <li>• On a scale of 1–10, how much do you trust the information you receive about the Reef from the following groups?</li> </ul> <p><b>COASTAL RESIDENTS:</b></p> <ul style="list-style-type: none"> <li>• To what extent does the Reef contribute to your household income?</li> <li>• There are many other places that are better than the Reef for the recreation activities I enjoy</li> <li>• I value the Reef for the fresh seafood it provides</li> </ul>	<ul style="list-style-type: none"> <li>• 90% of fishers agreed the fishing industry was a lifestyle and not just a job</li> <li>• GVP for commercial fishing in the Great Barrier Reef was \$105 M (excluding harvest fisheries) (DAFF unpublished data, 2013, for 2012 calendar year).</li> <li>• Tourism operators most strongly identified with the Reef (mean 8.02) followed by Australian residents (mean 7.39), commercial fishers, (mean 6.95), local residents (mean 6.43), domestic tourists (5.45) and international tourists (3.53).</li> </ul>
<b>Wellbeing</b>			
Opportunities	<ul style="list-style-type: none"> <li>• Contribution to livelihoods</li> <li>• Recreation and spiritual opportunities</li> <li>• Industries' development &amp; maintenance</li> <li>• Skills and capacity building for sustainable use and management</li> </ul>	<p><b>COASTAL RESIDENTS, TOURISM OPERATORS &amp; COMM, FISHERS:</b></p> <ul style="list-style-type: none"> <li>• The Reef contributes to my quality of life and wellbeing</li> <li>• I am optimistic about the future of the Reef</li> <li>• I value the Reef because it supports a desirable and active way of life</li> <li>• The Reef is a valuable asset for the economy of this region</li> </ul> <p><b>TOURISTS:</b></p> <ul style="list-style-type: none"> <li>• How would you rate your overall satisfaction with this experience of the Reef?</li> </ul>	<ul style="list-style-type: none"> <li>• 80% of residents, 93% of tourism operators, and 88% of commercial fisheries stated that 'the Reef contributes to my quality of life and wellbeing'</li> <li>• 93% of coastal residents value the Reef for the lifestyle it provides, and 95% agree that the Reef is a valuable asset for the regional economy.</li> <li>• 88% of commercial fishers felt the Reef contributed to their quality of life, but only 46% felt optimistic about the future of their business.</li> <li>• The mean satisfaction rating for tourists' experience of the Reef was 8.5/10 (overall very high).</li> <li>• 92% of tourists stated that, it means a lot to me that I have been to the Reef</li> </ul>
Empowerment	<ul style="list-style-type: none"> <li>• People perceive that their needs around the Reef are acknowledged</li> <li>• Contribution to decision making</li> <li>• Collaborative and effective governance mechanisms including social institutions</li> </ul>	<p><b>ALL</b></p> <ul style="list-style-type: none"> <li>• I cannot make a personal difference in improving the health of the Reef</li> <li>• I have the knowledge and skills to reduce any impact I might have on the Reef</li> <li>• I regularly get involved in research and/or management activities for the Reef</li> <li>• I would like to do more to help protect the Reef</li> </ul>	<ul style="list-style-type: none"> <li>• 74% of coastal residents believe they can make a personal difference in improving the health of the Reef.</li> <li>• 41% of residents agreed that they cannot make a personal difference to the improve the health of the Reef</li> <li>• 46% of residents thought that they had the necessary knowledge and skills to reduce any impact that they might have on the Reef</li> </ul>

Table 1. (Continued.)

Categories and components	Broad indicators (key examples)	SELTMP example questions	Example results <sup>a</sup>
	<ul style="list-style-type: none"> <li>• Knowledge and stewardship</li> <li>• Cultural respect and rights (not yet monitored)</li> </ul>	<ul style="list-style-type: none"> <li>• I support the current rules and regulations that affect access and use of the Reef</li> </ul>	<ul style="list-style-type: none"> <li>• 78% of local residents, 69% of tourism operators, and 39% of commercial fishers stated that, 'I support the current rules and regulations that affect access and use of the Reef'</li> </ul>
	<ul style="list-style-type: none"> <li>• People perceive that their needs around the Reef are acknowledged</li> <li>• Contribution to decision making</li> <li>• Collaborative and effective governance mechanisms including social institutions</li> <li>• Knowledge and stewardship</li> <li>• Cultural respect and rights (not yet monitored)</li> </ul>	<p><b>COASTAL RESIDENTS, TOURISM OPERATORS &amp; COMM, FISHERS:</b></p> <ul style="list-style-type: none"> <li>• I cannot make a personal difference in improving the health of the Reef</li> <li>• I feel confident that the Reef is well managed</li> <li>• I have the knowledge and skills to reduce any impact I might have on the Reef</li> </ul> <p><b>TOURISM OPERATORS &amp; COMMERCIAL FISHERS:</b></p> <ul style="list-style-type: none"> <li>• I do not have fair access to the Reef compared to other user groups</li> <li>• I regularly get involved in research and/or management activities for the Reef</li> <li>• Industry rules and regulations create too great a burden on my time</li> </ul>	<ul style="list-style-type: none"> <li>• 74% of coastal residents believe they can make a personal difference in improving the health of the Reef.</li> <li>• 67% of tourism operators were confident the Reef is well managed, 68% supported current rules and regulations relating to Reef use, and 64% regularly get involved in research and/or management activities for the Reef.</li> <li>• 40% of commercial fishers felt they did not have fair access to the Reef compared to other user groups and 71% felt that industry rules and regulations created too great a burden on their time.</li> </ul>
Security	<ul style="list-style-type: none"> <li>• Perceptions of Reef quality and sustainability</li> <li>• Amenity and aesthetics</li> <li>• Feelings of pride and connectedness</li> <li>• Confidence in Reef management</li> </ul>	<p><b>ALL:</b></p> <ul style="list-style-type: none"> <li>• I would not be personally affected if the health of the Reef declined</li> </ul> <p>The aesthetic beauty of the Reef is outstanding</p> <p><b>COASTAL RESIDENTS, TOURISM OPERATORS &amp; COMM, FISHERS:</b></p> <ul style="list-style-type: none"> <li>• I feel proud that the Reef is a World Heritage Area</li> </ul> <p><b>TOURISM OPERATORS &amp; COMMERCIAL FISHERS:</b></p> <ul style="list-style-type: none"> <li>• I am uncertain how to plan for changes in the Reef that may affect me, such as floods, cyclones or financial crises</li> </ul>	<ul style="list-style-type: none"> <li>• 59% of national survey respondents indicated that they would be personally affected if the health of the Reef declined.</li> <li>• 96% of tourists agreed that the aesthetic beauty of the Reef is outstanding, however 31% indicated that the place they visited most recently was not in great condition.</li> <li>• 68% of commercial fishers felt proud that the Reef is World Heritage.</li> <li>• 61% of tourism operators are confident they can plan for changes in the Reef, such as floods, cyclones of financial crises.</li> </ul>
<b>Indirect drivers: Socio-cultural context</b>			
Values	<ul style="list-style-type: none"> <li>• Economic</li> <li>• Intrinsic (e.g. biodiversity)</li> </ul>		<ul style="list-style-type: none"> <li>• 70% of national survey respondents rated the Great Barrier Reef as the most, second most or third most inspiring place in Australia (highest ranked).</li> </ul>

**Table 1.** (Continued.)

Categories and components	Broad indicators (key examples)	SELTMP example questions	Example results <sup>a</sup>
	<ul style="list-style-type: none"> <li>• Aesthetic</li> <li>• Lifestyle</li> <li>• Scientific and educational</li> <li>• Personal and experiential</li> </ul>	<p><b>ALL:</b></p> <ul style="list-style-type: none"> <li>• I value the Reef because it supports a variety of life, such as fish and corals</li> <li>• I value the Reef because we can learn about the environment through scientific discoveries</li> </ul> <p><b>NATIONAL RESIDENTS:</b></p> <ul style="list-style-type: none"> <li>• How inspiring is the Reef? (Comparison to other national landmarks)</li> </ul>	<ul style="list-style-type: none"> <li>• The highest ratings for values of the Reef by coastal residents were: aesthetic values (9.10/10), biodiversity (9.07), economic (8.86), scientific and educational (8.48), lifestyle values (8.45) and international appeal (8.04).</li> <li>• The highest ratings for values of the Reef by tourism operators were: aesthetic values (9.2/10), biodiversity (9.5), economic (9.4), scientific and educational (8.7), lifestyle values (8.7) and international appeal (9.0).</li> <li>• The highest ratings for values of the Reef by commercial fishers were: aesthetic values (9.0/10), biodiversity (9.0), economic (9.0), scientific and educational (7.3), lifestyle values (8.7) and international appeal (6.8).</li> </ul>
Perceptions of Reef condition and threats	<ul style="list-style-type: none"> <li>• Ecosystem state/health</li> <li>• Pressures and threats</li> </ul>	<p><b>ALL:</b></p> <ul style="list-style-type: none"> <li>• What are the first words that come to mind when you think of the Reef?</li> <li>• What do you think are the three most serious threats to the Reef?</li> </ul>	<ul style="list-style-type: none"> <li>• The different stakeholder groups perceived threats to the Reef differently. For example, for coastal residents the most frequently identified threats were shipping, overfishing and pollution; whereas for tourists the most serious threats were tourism, climate change and pollution (Curnock <i>et al</i> in review <i>hopefully</i>).</li> </ul>
Level of connectedness with the Reef	<ul style="list-style-type: none"> <li>• Place attachment</li> <li>• Identity around Reef</li> <li>• Relationship with the Reef</li> </ul>	<p><b>COASTAL RESIDENTS, TOURISM OPERATORS &amp; COMM. FISHERS:</b></p> <ul style="list-style-type: none"> <li>• The Reef is part of my identity</li> <li>• I live here because of the Reef</li> </ul> <p><b>TOURISM OPERATORS &amp; COMMERCIAL FISHERS:</b></p> <ul style="list-style-type: none"> <li>• I wouldn't want to be anything other than a tourism operator/commercial fisher</li> </ul>	<ul style="list-style-type: none"> <li>• 80% of national survey respondents agreed the Reef is part of their national identity.</li> <li>• 40% of coastal residents agreed that they live in the region because of the Reef.</li> <li>• 60% of tourism operators and 66% of commercial fishers did not want to be in any other occupation.</li> </ul>
Networks, information and trust	<ul style="list-style-type: none"> <li>• Societal norms</li> <li>• Information sources</li> <li>• Media and social media coverage</li> <li>• Trust in institutions</li> </ul>	<p><b>ALL:</b></p> <ul style="list-style-type: none"> <li>• Rating scores for level of trust in the information about the Reef from different sources, including Reef management agencies, research institutions, media and social media. <i>MEDIA ANALYSIS (reported elsewhere)</i></li> </ul>	<ul style="list-style-type: none"> <li>• The media and social media were the least trusted sources of information about the Reef among all groups (lowest mean ratings).</li> <li>• Commercial fishers rated their trust in the management agency as low (mean = 3.9/10), while tourism operators gave a much higher rating (mean = 7.1/10).</li> </ul>

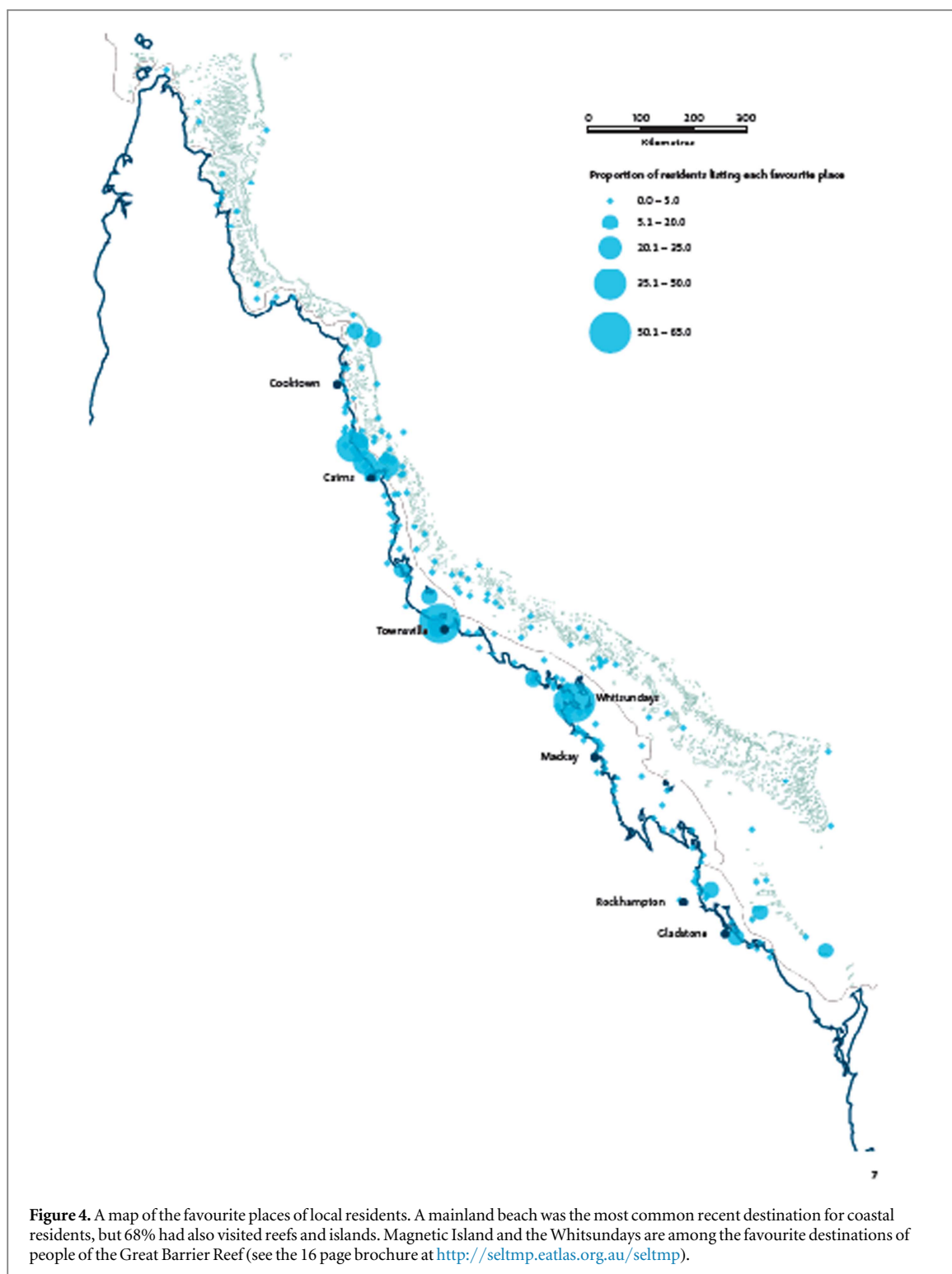
**Table 1.** (Continued.)

Categories and components	Broad indicators (key examples)	SELTMP example questions	Example results <sup>a</sup>
Adaptive capacity and resilience to change	<ul style="list-style-type: none"> <li>Capacity to manage uncertainty around Reef</li> <li>Level of strategic skills</li> <li>Buffers to change</li> <li>Level of interest in the future of the Reef</li> </ul>	<p><b>ALL;</b></p> <ul style="list-style-type: none"> <li>I am confident things will turn out well for me regardless of future events such as floods, cyclones or management change</li> <li>I am uncertain how to plan for changes in the Reef that may affect me such as floods, cyclones, or management change</li> <li>I am good at developing scenarios of the future of my business and planning for them</li> <li>I discuss new ways of solving problems associated with my business with others</li> <li>I am more likely to adapt to changes as a result of floods or cyclones compared to other [coastal residents] I know.</li> <li>I have planned for my financial security in the event of a crisis</li> <li>Interest in adapting to change</li> <li>I am interested in learning how to better prepare my business for significant events, such as the global financial crisis, cyclones and floods.</li> </ul>	<ul style="list-style-type: none"> <li>46% of commercial fishers were confident things would turn out for them regardless of events.</li> <li>37% of commercial fishers were certain of how to plan for changes in the Reef that could affect them</li> <li>68% of fishers felt that they were good developing scenarios for the future and planning for them.</li> <li>78% of fishers felt that they were more likely to adapt to changes compared to others they knew</li> <li>69% of commercial fishers had planned for their financial security</li> </ul>
Perceptions of Governance	<ul style="list-style-type: none"> <li>Confidence in management</li> </ul>	<p><b>ALL</b></p> <ul style="list-style-type: none"> <li>I feel confident that the Reef is well managed</li> <li>I support the current rules and regulations that affect access and use of the Reef</li> <li>I do not have fair access to the Reef compared to other user groups</li> <li>Industry rules and regulations create too great a burden on my time</li> </ul>	<ul style="list-style-type: none"> <li>67% of tourism operators were confident the Reef is well managed and 68% supported current rules and regulations relating to Reef use, and 64% regularly get involved in research and/or management activities for the Reef.</li> <li>40% of commercial fishers felt they did not have fair access to the Reef compared to other user groups and 71% felt that industry rules and regulations created too great a burden on their time. 21% of residents thought that they did not have fair access to the Reef compared to other groups.</li> </ul>
Reef Stewardship	<ul style="list-style-type: none"> <li>Support for regulations</li> <li>Personal responsibility to protect the Reef</li> <li>Personal empowerment</li> </ul>	<p><b>COASTAL RESIDENTS, TOURISM OPERATORS &amp; COMM. FISHERS:</b></p> <ul style="list-style-type: none"> <li>I support the current rules and regulations that affect my access and use of the Reef</li> </ul> <p><b>COASTAL RESIDENTS, TOURISTS, TOURISM OPERATORS &amp; COMM. FISHERS:</b></p> <ul style="list-style-type: none"> <li>It is not my responsibility to protect the Reef</li> </ul>	<ul style="list-style-type: none"> <li>95% of coastal residents, 91% of tourists, 86% of tourism operators and 86% of commercial fishers felt that it was the responsibility of all Australians to protect the Reef</li> <li>87% of coastal residents, 79% of tourists, 98% of tourism operators and 90% of commercial fishers felt it was their responsibility to protect the Reef.</li> </ul>

**Table 1.** (Continued.)

Categories and components	Broad indicators (key examples)	SELTMP example questions	Example results <sup>a</sup>
		<ul style="list-style-type: none"> <li>• I would like to do more to protect the Reef</li> <li>• It is the responsibility of all Australians to protect the Reef</li> <li>• I cannot make a personal difference in improving the health of the Reef</li> </ul>	<ul style="list-style-type: none"> <li>• 54% of tourists, but only 37% of coastal residents, 10% of tourism operators and 15% of commercial fishers felt they did not have the knowledge and skills necessary to reduce any impact they might have on the Reef.</li> </ul>
<b>Direct drivers: human use, development and impacts</b> <i>(reported elsewhere)</i>			

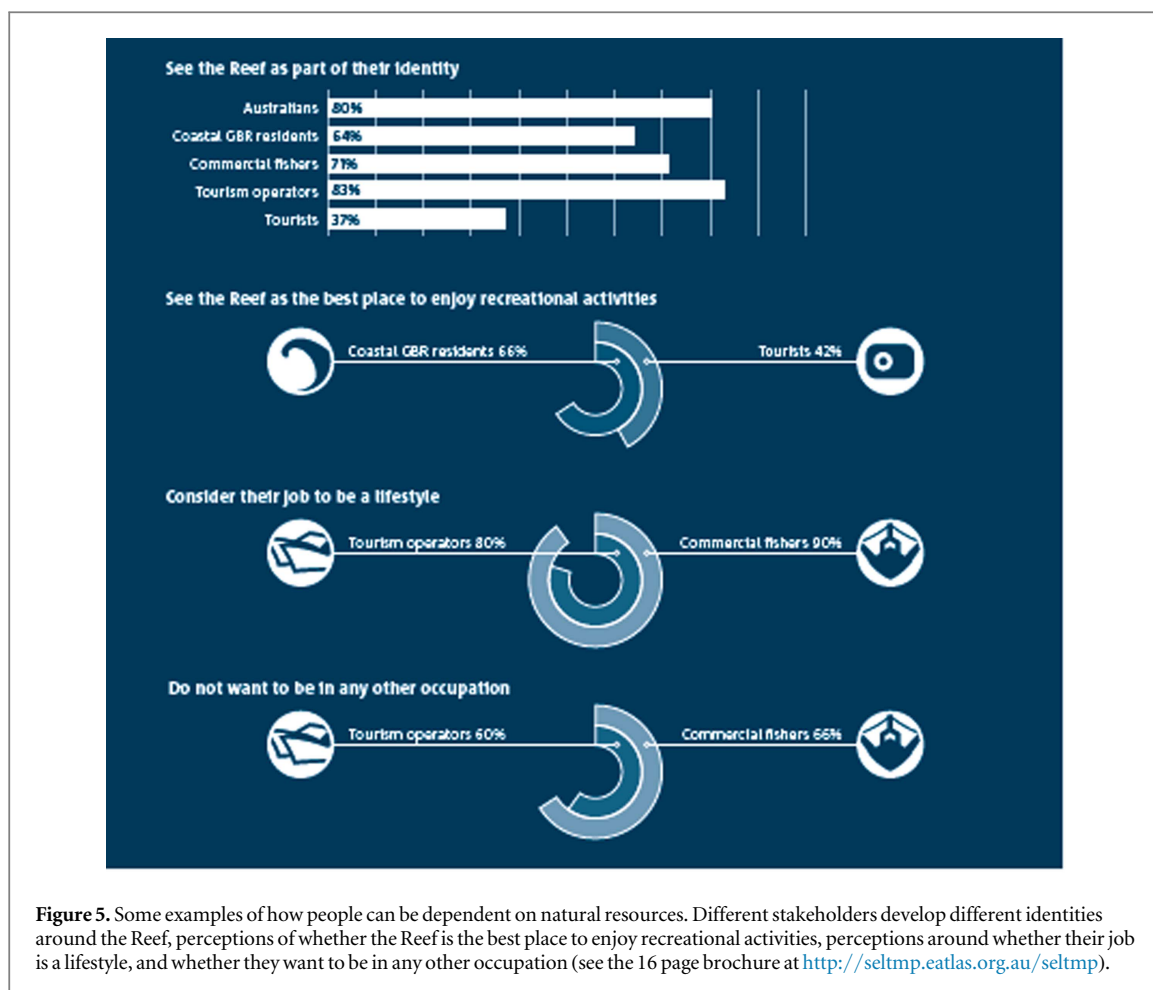
<sup>a</sup> for full results see [www.seltmp.eatlas.org.au](http://www.seltmp.eatlas.org.au)



### Well-being

All stakeholders derived well-being from the Great Barrier Reef (table 1). For example, this was evident from the high proportion of respondents affirming that ‘the Reef contributes to my quality of life and wellbeing’ (80% of residents, 93% of tourism operators, and 88% of commercial fisheries). Some 92% of tourists stated that, ‘it means a lot to me that I have been to the Reef’. However, fishers felt less secure and less empowered than other groups; many were not

optimistic about the future of their business (46%). Only 39% of commercial fishers supported the current rules and regulations affecting access and use of the Reef, compared with 78% of local residents and 69% of tourism operators. Other measures of the well-being that people feel around the Great Barrier Reef are presented in figure 6. Specifically, figure 6 presents results around the security that people feel towards its beauty, condition, future, and threats. If people continue to report on the outstanding aesthetic



qualities of the Reef, for example, it is likely that their well-being around the Reef is being maintained, and that management actions are achieving their goals.

### Social-cultural drivers of change

Example data reflecting the perceptions, attitudes, beliefs, values, behaviours and perceptions of norms of all user groups are presented in table 1 so as to describe the context within which management decisions are made, and how particular political decisions or management strategies might be driven as a consequence of this context. Many commonalities and conflicting priorities were observed within and between user-groups. For example, commercial fishers valued aesthetic values more highly (9.0/10), than biodiversity (9.0), economic (9.0), scientific and educational (7.3), lifestyle values (8.7) and international appeal (6.8). These results were comparable to all other stakeholder groups suggesting that the Reef was most valued for its aesthetic qualities regardless of the economic benefits that some user groups may derive. Conflicts were recognised in how people perceived threats to the Reef. For example, coastal residents identified threats as shipping and overfishing (Curnock *et al* in review).

### Discussion

We have developed a baseline dataset that empirically characterises the current social and economic conditions within the Great Barrier Reef. The data across all stakeholder groups empowers reef managers, industries and communities to gain an unprecedented insight into how people use the Reef (where they go, how often, when, how), and why (financial, cultural, spiritual and intellectual reasons), as well as recording stakeholder perceptions, attitudes, experiences, behaviours and perceptions of norms around the Reef resource. In sum, these measures describe the current social-cultural context within which behaviours are observed and decisions are made.

As a (un-analysed) baseline record, the data presented provides opportunities for specific input into policy processes and day-to-day management decisions (Turner *et al* 2016). For example, in the development of the current Whitsunday Plan of Management (a key tourism area within the Reef), Reef managers can relatively accurately gauge the number of residents and recreational fishers, tourism operators and domestic and international tourists, and commercial fishers. From here, Reef managers can consider inter-connections between stakeholder groups overlapping



in space, identify hotspots for conflict, and protect places in which stakeholder groups are particularly dependent. The richness of data will mature with time as longitudinal trends and relationships emerge, as additional users and industries are incorporated and as comparisons are made with other resource systems (Rothlisberger *et al* 2010). Whilst a non-response bias may have occurred, the results reinforce the notion that people have a complex and rich relationship with the Great Barrier Reef, and that it is feasible to establish a social and economic monitoring within a complex and large social-ecological system.

Although the Great Barrier Reef is a capacity and resource-rich setting, we see that our framework and general approach can be applied in other contexts and within other countries that have lower resources and capacities. Commitment to long-term monitoring is critical for adaptive and resilient resource management. Long-term monitoring offers the best research approach available for refining theory and methods for conceptualizing and assessing how people are prepared for change and adapt. Long-term monitoring

also offers the best opportunity to assess the future of each industry and community in the face of various change events including climate change, environmental degradation, regulatory change, cultural change and other non-defined short-term impacts through analyses of 'before' and 'after' data. Through accessing publically available and longitudinal datasets, such as the SELTMP, local and global social scientists can provide new insights through re-interpreting the data in novel ways. For example, Turner *et al* (2016) have reinterpreted the data to assess how trust, confidence and equity affect legitimacy. Goldberg *et al* (2016) similarly reviewed the data to more fully describe the response of Australians to climate change.

The success of a program such as the SELTMP can only occur with well-translated cutting-edge social and economic science data and knowledge that directly feeds into current management processes. The science must be excellent, collaborative and must itself adapt as learnings from the monitoring datasets are developed. Within the Great Barrier Reef context, policy documents have clearly articulated targets and



outcomes. Data from the SELTMP have already been incorporated into Reef management policy processes through the development of the *Great Barrier Reef Region Strategic Assessment: Strategic Assessment Report*, the *Great Barrier Reef Outlook Report 2014*, and the *Reef 2050 Long-Term Sustainability Plan (LTSP)*. Each document used SELTMP data to describe the drivers of change affecting the Reef, and to assess the impacts of human activities undertaken within the Reef region. Each document describes attributes of human well-being that are linked to the Great Barrier Reef. The Strategic Assessment and Outlook Report also recorded the current conditions and values that describe the community benefits derived from the Reef. Currently, SELTMP data is being used to populate several 'report cards' within the region (Pascoe *et al* 2016). Report cards are increasingly used to measure and record changes in ecosystem health over time and provide ongoing snapshots of progress towards specific ecosystem health goals (Pascoe *et al* 2016). While most report cards focus on the biophysical components of the system, there is a growing interest in including the social and economic implications of ecosystem management to provide a greater social-ecological system understanding.

Partnerships between social scientists, ecological scientists and environmental managers are key to successful environmental management. Through co-producing knowledge and building trust, as well as sharing knowledge and acknowledging disciplinary differences in science approaches, more resilient and sustainable decision-making may be possible (Cvitavovic *et al* 2015). Approaching environmental issues through a systems understanding is critical to address complex dynamic relationships. Working across disciplines helps expose knowledge blind-spots, questions assumptions, exposes trade-offs and synergies and leads to better solutions (Arkema *et al* 2015, Marshall *et al* in review). A significant next challenge is to integrate social conditions and trends data with data from ecological monitoring programs to provide decision makers with a holistic understanding of the Reef system (Pooley *et al* 2014).

Further innovations in social and economic monitoring are needed if the complex and competing human aspects of resource systems are to be more effectively integrated into decision-making processes. The frequency that data should be collected is one such improvement. For example, while some social indicators are known to be relatively robust through time (such as education, income, population), and fluctuate only minimally, there is only little information available to determine the frequency with which others should be monitored to detect change (such as wellbeing, values, trust, etc) (Stidham *et al* 2014). Other innovations will need to focus on reducing the costs associated with monitoring, such as considering citizen science approaches that cut the costs of data collection (Wood *et al* 2013, Martin *et al* 2016).

Innovations in data collection and presentation through social media mechanisms also need attention. Innovations in increasing the useability of data are particularly needed, and these are likely to be influenced by better choice of indicators, the extent of end-user involvement, the accessibility of monitoring data, the suitability and timeliness of interpretation, the frequency of new data collections, non-response improvements and the frequency of review, learning and assessment.

We hope that this is the beginning of a new era in natural resource management where social and economic information of social-ecological systems are collected and used as a routine part of natural resource management decision-making processes. Such developments are the foundations required for effective resource management in the face of increasing demands and accumulating threats that will inevitably accompany a rapidly changing world.

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## References

- Arkema K K *et al* 2015 Embedding ecosystem services in coastal planning leads to better outcomes for people and nature *Proc. Natl Acad. Sci. USA* **112** 7390–5
- Berkes F and Folke C (ed) 1998 Linking social and ecological systems for resilience and sustainability *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience* (Cambridge: Cambridge University Press)
- Bengston D N, Fan D P and Celarier D N 1999 A new approach to monitoring the social environment for natural resource management and policy: the case of us national forest benefits and values *J. Environ. Manage.* **56** 181–93
- Bohensky E *et al* 2011 Future makers or future takers? A scenario analysis of climate change and the great barrier reef *Glob. Environ. Change* **21** 876–93
- Boyd H and Charles A 2006 Creating community-based indicators to monitor sustainability of local fisheries *Ocean Coastal Manage.* **49** 237–58
- Bryman A 2012 *Social Research Methods* (Oxford: Oxford University Press)
- Cash D W, Clark W C, Alcock F, Dickson N M, Eckley N, Guston D H, Jager J and Mitchell R B 2003 Knowledge

- systems for sustainable development *Proc. Natl Acad. Sci. USA* **100** 8086–91
- Cinner J E *et al* 2009 Linking social and ecological systems to sustain coral reef fisheries *Curr. Biol.* **19** 206–12
- Cvitanovic C, Hobday A, van Kerkhoff L, Wilson S K, Dobbs K and Marshall N A 2015 Improving knowledge exchange among scientists and decision-makers to facilitate the adaptive governance of marine resources: a review of knowledge and research needs *Ocean Coast Manage.* **112** 25–35
- Fox H E *et al* 2014 How are our MPAs doing? challenges in assessing global patterns in marine protected area performance *Coastal Manage.* **42** 207–26
- Goldberg J *et al* 2016 Climate change, the Great Barrier Reef, and the response of Australians *Palgrave Commun.* **2** 15046
- Guerry A D *et al* 2012 Modeling benefits from nature: using ecosystem services to inform coastal and marine spatial planning *Int. J. Biodiversity Sci. Ecosyst. Serv. Manage.* **8** 107–21
- Howden S M *et al* 2007 Adapting agriculture to climate change *Proc. Natl Acad. Sci.* **104** 19691–6
- Jabareen Y 2004 A knowledge map for describing variegated and conflict domains of sustainable development *J. Environ. Plan. Manage.* **47** 623–42
- Larson S, De Freitas D M and Hicks C C 2013 Sense of place as a determinant of people's attitudes towards the environment: implications for natural resources management and planning in the Great Barrier Reef, Australia *J. Environ. Manage.* **117** 226–34
- Liu J G *et al* 2007 Complexity of coupled human and natural systems *Science* **317** 1513–6
- MA 2005 Ecosystems and human well-being: synthesis *Ecosystems and Human well-being: Synthesis* (Washington, DC: Island Press)
- Marshall N A *et al* 2007 How resource dependency can influence social resilience within a primary resource industry *Rural Sociol.* **72** 359–90
- Marshall N *et al* 2013 Social vulnerability of marine resource users to extreme weather events *Ecosystems* **16** 797–809
- Martin V Y, Christidis L, Lloyd D J and Pecl G T 2016 Public interest in marine citizen science: is there potential for growth? *Bioscience* **66** 683–92
- Pascoe S, Tobin R C, Windle J and Marshall N A 2016 Developing a social, cultural and economic report card for a regional industrial harbour *Plos One* **11** e0148271
- Pooley S P, Mendelsohn J A and Milner-Gulland E J 2014 Hunting down the chimera of multiple disciplinarity in conservation science *Conservation Biol.* **28** 22–32
- Reyers B *et al* 2013 Getting the measure of ecosystem services: a social-ecological approach *Frontiers Ecol. Environ.* **11** 268–73
- Reyers B, Nel J L, O'Farrell P J, Sitas N and Nel D C 2015 Navigating complexity through knowledge coproduction: mainstreaming ecosystem services into disaster risk reduction *Proc. Natl Acad. Sci. USA* **112** 7362–8
- Rothlisberger J D *et al* 2010 Future declines of the binational laurentian great lakes fisheries: the importance of environmental and cultural change *Frontiers Ecol. Environ.* **8** 239–44
- Stoeckl N *et al* 2011 The economic value of ecosystem services in the great barrier reef: our state of knowledge *Ann. NY Acad. Sci.* **1219** 113–33
- Stidham M *et al* 2014 Longitudinal social science research in natural resource communities: lessons and considerations *Soc. Nat. Resour.* **27** 1104–8
- Stone-Jovicich S 2015 Probing the interfaces between the social sciences and social-ecological resilience: insights from integrative and hybrid perspectives in the social sciences *Ecol. Soc.* **20** 25
- Stokstad E 2005 Ecology—taking the pulse of earth's life-support systems *Science* **308** 41–3
- Turner R A *et al* 2016 Leveraging trust for effective natural resource governance *Ecol. Soc.* **21** 18
- Wood S A, Guerry A D, Silver J M and Lacayo M 2013 Using social media to quantify nature-based tourism and recreation *Sci. Rep.* **3** 2976