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Exploring climate change adaptive capacity of surf life saving in Australia using Bayesian belief networks

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ABSTRACT

Surf Lifesaving (SLS) in Australia is an icon of local beach culture with more than 300 clubhouses distributed along the coastline. Their distribution at the interface of the terrestrial and marine environments means that assets and operations associated with SLS are particularly vulnerable to the effects of climate variability and climate change from both the land and the sea. For Australia, this is particularly pertinent given that the east coast is projected to experience SLR that is higher than global average. This study describes how a probabilistic modelling approach (Bayesian belief networks (BBNs)) and participatory modelling techniques were used to help elicit information on the key adaptive capacity determinants influencing the ability of Australian SLS to implement climate change adaptation options. 10 BBNs were developed across four stakeholder workshops at four locations within Australia. Results of this participatory modelling show that most determinants of adaptive capacity broadly related to funding, knowledge, equipment, communication and community support. For each workshop, the BBNs indicated broad consensus in the beliefs of the stakeholders for these broad and perhaps well-known determinants of effective adaptation. Conversely, there was less agreement between the stakeholders regarding the more specific determinants as evidenced by the results of the sensitivity analyses and in the levels of debate between the stakeholders. This highlights that as the determinants of adaptive capacity become more nuanced, there is more likely to be an imperfect, and less likely to be a shared, understanding of the system by the stakeholders. Overall, the approach used in this study has shown to be effective in exploring adaptive capacity at the community level and to improve community understanding and awareness of coastal hazards and climate change risks.

1. Introduction

Australia has a strong association with Surf Life Saving (SLS). Currently, approximately 166,600 trained volunteers associated with over 300 Surf Life Saving Clubs (SLSCs) are directly involved in delivering fundamental safety services to Australia's beach users (SLSA, 2014).

In order to provide water safety services and sports facilities for coastal communities, SLSCs are located in close proximity to the sea. Consequently, their infrastructure, assets and operations are at the interface between the terrestrial and marine environment and therefore are already exposed to a range of natural coastal hazards. This vulnerability is exemplified by Elrick et al. (2011) who found that 63% of Australia's SLSCs are currently located in areas at risk from coastal hazards and future climate change. The submergence and erosion of global coastal areas are cited as a key impact of sea level rise (SLR) (Wong et al., 2014). In the context of this study, which focuses on case study sites located on the east coast of Australia, the east coast of Australia is projected to experience SLR that is higher than global average (Church et al., 2013). These hazards are mainly beach and dune erosion and storm tide inundation, which can be exacerbated by sea level rise (SLR) and changes in the weather patterns (Nicholls and Leatherman, 1995; Nicholls et al., 2007).

Adaptation and adaptive capacity have been identified as central themes for increasing resilience and reducing vulnerability towards the impacts of climate change (IPCC, 2014). The IPCC (2014)

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provides formal definitions for both, with adaptation defined as:

> "*The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.*"

Critical for those decision makers involved in identifying adaptation options and enhancing adaptive capacity (i.e. the ability to adapt) are identifying the coastal hazards, the potential climate change adaptation options and the key determinants of adaptive capacity. The practical identification of adaptation options and determinants of adaptive capacity often require the use of techniques that rely on direct stakeholder engagement to provide the 'domain knowledge' critical to a better understanding the human dimension of climate change impacts and vulnerability (Nadkarni and Shenoy, 2004; Moser, 2005). However, the importance of evaluating this human dimension is offset by the high degree of uncertainty in 'how humans will respond to climate change?' (Moser, 2005). Participatory techniques that place the determination of the domain knowledge in the hands of the actors operating within the system of interest (in our case, Surf Lifesaving clubs in Australia) would appear to go some way in addressing this question as has been evidenced in recent studies using scenario planning (Tompkins et al., 2008), systems thinking (Sanò and Medina, 2012), cognitive mapping (Giordano et al., 2013) and Bayesian network modelling (Richards et al., 2013; Keys et al., 2014) techniques.

Bayesian belief networks (BBNs) have been demonstrated as a well-suited framework for dealing competently with 'trans-disciplinary research' between researchers and stakeholders (Düspohl et al., 2012), for situations where there is scarcity and uncertainty in the data (Henriksen and Barlebo, 2008; Giordano et al., 2013) and where domain knowledge is crucial (Nadkarni and Shenoy, 2004). The 'front-end' of BBNs provides a graphical interface that is relatively straightforward for constructing models. This attribute of relative visible simplicity provides a mechanism for engaging directly with stakeholders and for eliciting their active participation in the model development process (Uusitalo, 2007; Kjærulff and Madsen, 2008; Richards et al., 2013). Such participatory modelling is known to increase the sense of ownership, place and trust in model outputs (McAllister et al., 2006; Hendricks et al., 2008; Jones et al., 2008) and help gain common understanding of a problem (Senge and Sterman, 1992). 'At the back-end', this user-friendly interface is complimented by the robust mathematics of Bayes theory that provides a formal approach to modifying prior beliefs in the presence of emerging evidence (Fenton and Neil, 2013).

In this paper, we describe (i) how BBNs were used to help elicit knowledge about climate change adaptation options from SLS stakeholders and (ii) how the outcomes of the BBN modelling process were used to identify the key adaptive capacity determinants influencing the ability of Australian SLS to implement these options.

2. Materials and methods

Ethical clearance was obtained through Griffith University to ensure the security and rights of the stakeholders during the participatory workshops. This was achieved through obtaining signed consent of all stakeholders, clearly communicating the right of the stakeholders to remove themselves from the workshop at any stage, maintaining anonymity of the stakeholders and secure data management.

2.1. Case studies

The selection of the case study sites (Fig. 1), in consultation with SLSA, weres guided by the findings of Elrick et al. (2011), which highlighted the vulnerabilities and pathways for SLSA decision-making under climate change.

Four case study sites (see the first four sites listed in Table 1) were initially selected for assessment. As is highlighted in the following section, these case study sites were to be involved in two rounds of participant workshops with the BBNs developed in the second round. However, due to reduced engagement in the second round (where the BBNs were developed) with the local stakeholders from the Currumbin SLSC, an additional case study (North Kirra SLSC) was used instead. Further details on the implications of this change are raised in the Methods and Discussion sections. Descriptions of the case study sites and their salient climate change-related main issues are detailed in Table 1 with further details provided in Sanò et al. (2013).

2.2. Methodological stages

The methodology used in the development of the BBNs incorporated the following five stages (Fig. 2):

Stage 1: Identifying suitable stakeholders for engagement in the project.
Stage 2: Conducting the first round of stakeholder workshops to develop system conceptualisations.
Stage 3: Post-workshop analyses on the system conceptualisations.
Stage 4: Undertaking the second round of stakeholder workshops where BBNs were developed.
Stage 5: Post-workshop analyses of the BBNs.

The following section provides a contextual description of the first three stages of data collection that preceded the BBN development and analysis (stages 4 and 5), which are subsequently described in detail.

2.3. Stakeholder engagement (stage 1)

In complex socio-environmental systems where multiple interests apply, bringing together the right people (the key stakeholders) is a way of building consensus, to avoid early-stage conflicts, to push the process forward against delays and to promote initiatives, which share decision-making responsibility (Hendricks et al., 2008; Jones et al., 2008). The chance of acceptance of change will generally be increased if stakeholders have been actively engaged during the project (Jones et al., 2008). For each of the case-study sites used in this study, the identification of suitable stakeholders was initiated through identifying and engaging with a local champion who would become the conduit between researchers and stakeholders. Local champions have been noted as a critical component of successful community engagement (Hendricks et al., 2008) and were used here to help identify additional stakeholders that had a direct association in the management of assets and operations within the case study SLSC (or SLSA).

2.4. System conceptualisation and post-workshop analyses (stages 2 and 3)

The first round of workshops (one workshop was held for each of the case study sites) was held between April and May 2012. The main purpose of these workshops was to use the expertise and beliefs of the stakeholders involved to develop a group-based