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Engaging Australian Surf Lifesaving in coastal hazard and climate change adaptation with stakeholder driven modelling

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Abstract: Australia's beaches, an iconic playground and social hub for coastal communities, are threatened by coastal hazards and by the impacts of climate change. In particular, Surf Life Saving Australia (SLSA) has assets, facilities and personnel exposed to coastal hazards and climate change, including numerous surf life saving clubs (SLSCs), which can impact its capacity of providing beach and water safety for Australian beaches. This research employed a range of methods to identify climate change adaptation options and to identify mechanisms to enhance adaptive capacity, combining a range of system-oriented, stakeholder-based techniques, including system thinking conceptual modelling, structural analysis, system dynamics and Bayesian modelling. These techniques were employed in a series of workshops with local SLSCs and SLSA's head office and were designed to engage stakeholders and gather data for analysis. A range of adaptation options and adaptive capacity determinants were identified and tested. The final result is a set of actions to improve the adaptive capacity of the selected case studies, with implication for other SLSCs at the national level. The research shows how systemic, participatory approaches are effective in identifying critical issues and possible solutions to adapt to current coastal hazards and future climate change.

***Keywords**:* coastal hazards*,* climate change adaptation; systems thinking; system dynamics, Bayesian modelling, surf lifesaving

1 INTRODUCTION

Coastal living and lifestyle is central to the Australian culture. More than 80% of Australia's population is concentrated on the coast, mainly in coastal capital cities, suburbs and towns and many Australians use the beach all year round for leisure activities, such as swimming, surfing or fishing (DCCEE, 2009). Erosion and inundation are the main natural hazards threatening Australia's coastal settlements today. Erosion can gradually remove and reshape beaches and dunes and gradually expose and destroy ecosystems and settlements. Sea flooding is normally provoked by temporary elevation of the sea level associated with storm surges which can act as trigger for major erosion and water overflow onto low lying coastal areas. Along the east coast of Australia, these events are mainly driven by cyclones and other weather systems, such as East Coast Lows. The combination of these events in a short period of time (e.g. 6 months) can expose and damage coastal settlements with social, economic and environmental consequences. Examples of this are the sequence of storms of 1967 or the recent cluster of storms of 2013, both resulting in heavy damage to coastal settlements in the Gold Coast, in South East Queensland and in coastal towns of northern New South Wales. Climate change is currently posing an additional challenge to coastal settlements, with a recorded ~3mm of sea level rise per year (NTC-BOM, 2011) and a projected acceleration resulting in approximately 1 m sea level rise by the end of the century (CSIRO, 2011). Surf Life Saving Australia (SLSA) represents a movement currently made of more than 300 Surf Life Saving Clubs (SLSCs) and 150,000 volunteers. They provide beach and water safety and they are engaged in surf lifesaving training and competitions around the country. Clubhouses can be found in most coastal communities, with a higher concentration along the east coast of Australia, where the majority of the Australian population lives. The nature of their business requires SLSCs to be close to the water edge, with many of them historically built on hazard prone areas, which can be threatened by erosion and inundations. SLSA is the national body that provides coordination, information and support to State and regional branches and local SLSCs. SLSA has recently acknowledged the risks of climate change and has commissioned a first-pass vulnerability assessment, to identify clubs at risk, and the development of a roadmap for climate adaptation (Elrick et al. 2011). This study shows that more than 60% of SLSCs are located within zones of potential instability, and provided a set of actions for adaptation. Starting from these findings, our research seeks to provide a better understanding of coastal hazards and climate change risks at the SLSC scale and for SLSA at the national level.

2 APPROACH

Our approach used a systematic exploration of stakeholders, climatic impacts and adaptive responses building on expert knowledge and community contributions, combining a range of systems-based techniques such as the analysis of social networks, stakeholder driven system conceptualisation, structural analysis of conceptual models, system dynamics and Bayesian belief network (BBN) modelling. Two rounds of workshops, in April/May 2012 and October/November 2012, were held at the case study locations including: Currumbin SLSC and North Kirra SLSC on the Gold Coast (Qld); Cudgen Headland SLSC, north east New South Wales (NSW); Ulverstone SLSC, northern Tasmania (Tas); and SLSA national office, Sydney. The project was carried out in 5 different stages: (i) stakeholder identification and engagement, stakeholder analysis, (ii) workshops on Adaptation options: problem scoping and systems thinking, (iii) analysis Adaptation Options: structural analysis and system dynamics modelling, (iv) Workshops on Adaptive capacity: BBN modelling, (v) analysis of Adaptive Capacity: sensitivity testing of BBN models. In this article we show results from Cudgen Headland Surf Life Saving Club. Other case studies results and additional synthesis can be found in Sanò et al. (2013).

2.1 Stakeholder identification and engagement, stakeholder analysis

Stakeholder analysis here builds on the snowballing sampling approach called Hydra (Sanò et al. 2010) where each stakeholder identified by the problem owner is asked to identify other potential stakeholders in an iterative process. In addition, we developed a survey to better understand the perception of stakeholders around climate change and adaptation issues for SLSCs. This process was replicated in each of the four case studies with the following steps: (i) identify on-board project champion, (ii), identify initial stakeholders, (iii), contact stakeholder nominations and invites to workshops; and (iv) conduct opinion survey on climate change, adaptation and social networks. Details of the stakeholder analysis are out of the scope of this paper and can be consulted in Sanò et al. (2013).

2.2 Workshops on Adaptation Options: Problem Scoping and Systems Thinking

The first round of workshops was held in April/May 2012 in the four case study locations. Each workshop involved 10 – 15 participants and commenced with the stakeholders being provided with contextual information regarding the research. This included project aims and an overview of issues related to climate change in their area or sector of concern. For example, information on extreme storms and erosion, coastline evolution and historical shoreline position, was presented drawing on the best available information. This briefing was supported by an overview of observed climate variability and climate change projections for the area of study. Simplified, non-technical language was used throughout the workshops. The process started by defining the object of the potential impacts i.e. issues or elements describing Assets, Operations and Community (AOC). Four questions were used to trigger the identification of these elements: (i) What assets are at stake? (ii) What operations are at stake? (iii) How do you engage with the community? (iv) Do you see any other issue/s related with climatic risks?. A second step was to identify climatic and non-climatic drivers, which may affect these issues/elements of the system. We provided an initial list, including sea level rise, cyclones and other extreme storms, changing rainfall, population growth. These issues/elements were then connected to other Drivers that may impact the AOC system, such as rip currents, erosion, inundations, water quality and other Drivers identified by the stakeholder group. With Drivers and Impacts on the AOC system, including connections, clearly identified, the next step was to identify adaptive Responses to these impacts. Drivers, Impacts and Responses were connected using a conceptual model which was then redesigned using a cross impact matrix multiplication software (MICMAC, 2014) (Figure 1).

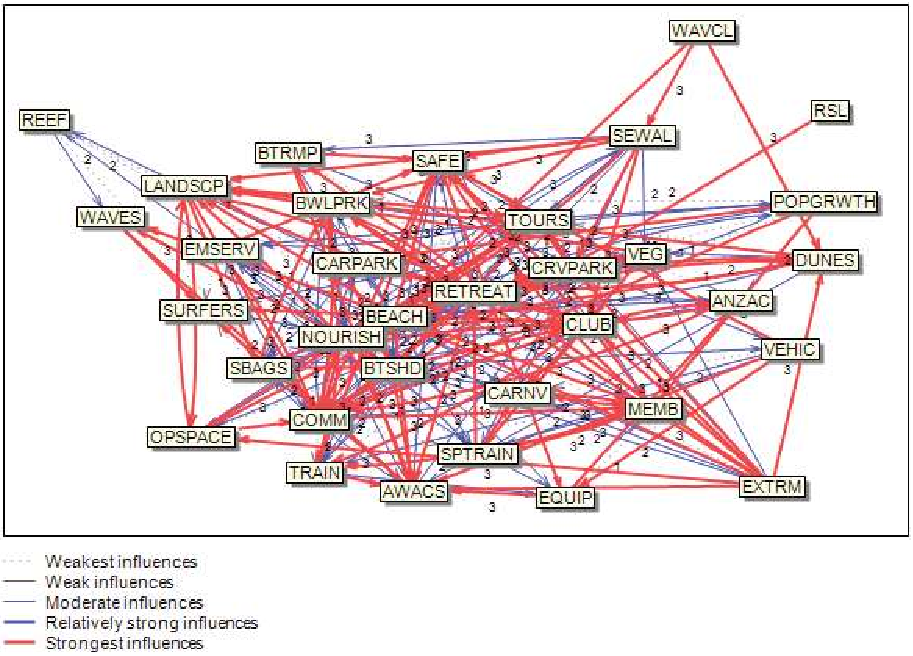

Figure 1: Direct influence model based on the outcome of the workshop and built with MICMAC, Case Study: Cudgen Headland SLSC

2.3 Analysis of Adaptation Options: Structural Analysis

The systems under study came in the form of a group of interrelated elements (variables/factors) derived from the first round of workshops. These conceptual models were translated by compiling variables and relationships identified by stakeholders into a matrix for further structural analysis using MICMAC,.. This process allows identifying the most influential variables of a network, using algorithms embedded in the software (ref). Table 2 shows the Adaptive Responses ranked by influence. Further modelling was done using System Dynamics simulations, to show stakeholders the possible impacts and effectiveness of Adaptive Responses (section 2.4). Relevant adaptive responses were then used to explore the adaptive capacity of clubs (section 2.5)

Table 2: Outcomes of the structural analysis of the above model with possible adaptive responses ordered from in order of influence over the system

N°	LONG LABEL	SHORT LABEL	INFLUENCE RANKING	RANKING
32	Beach nourishment	NOURISH	2	1
34	Planned retreat	RETREAT	3	2
12	Seawall	SEWAL	5	3
31	Sand bags	SBAGS	12	4
26	Training	TRAIN	19	5
30	All weather access	AWACS	24	6
33	Better equipment	EQUIP	26	7

2.4 Analysis of Adaptation Options: system dynamics modelling

Systems Dynamics (SD) simulations enabled an exploration of the dynamic implications of different adaptive responses over a period of time. These were carried out using VENSIM software. SD models enabled stakeholders to see how the system works over time. SD models were formulated by translating MICMAC conceptual models into systems dynamics models (Cole et al., 2007). The modeller determined specific equations and functions needed to explain relationships between variables (Fiddaman 1997). The results were examined to determine whether the model works effectively in simulating the system behaviour over time. A sensitivity testing allowed to explore how the models respond to small changes in input values, parameter values or other assumptions (Sahin et al. 2013).

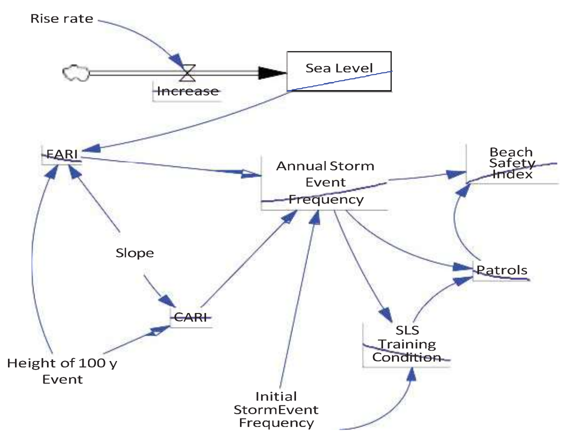

Figure 2: Climate change sub-model simulating sea level rise and resulting changes in a storm event frequencies

The outcomes of the modelling process (Figure 2) were presented to stakeholders during the second round of workshops, as a prelude to the exploration of adaptive capacity using Bayesian belief networks (BBNs).

2.1 Workshops on Adaptive capacity: BBN modelling

The outcomes of the previous analysis (Section 2.3 and 2.4) were useful to provide a better understanding of the possible adaptive responses to the risk of climate change. Based on the data collected and the analysis carried out in the previous phases, a set of five general options applicable to the clubs were identified for the second round of workshops when stakeholders were then asked to select a subset (typically three) to use as the focal point of the BBN development process. For the three SLSC case studies the adaptation options were focused on assets and operations at the club level (Table 3).

Table 3: Adaptation options to be tested at the club level (all clubs)

ADAPTATION OPTION	DESCRIPTION
Defend	Stay at current location of the asset and protect with external works (e.g. seawalls, dunes)
Retreat	Relocate the assets and place them at a location that is away from the impacts (of climate change)
Accommodate	Improve the assets' design standards to cope with extremes and future sea level rise.
Training	Incorporate coastal hazards and extreme events in the training curricula of surf life saving
Equipment	Identify potential equipment needs for the future

During the second round of workshops, BBNs were constructed around adaptive responses to identify a set of adaptive capacity determinants. The development of the models was undertaken using NETICA software (www.norsys.com/netica.html). The process was undertaken in 4 stages:

1. <u>Pre-development information</u>: The stakeholders were given an overview of the framework that will be used to develop the BBNs, including formal definitions of common BBN terms ('variables',

'states', 'causality', 'linkages') and specification of the key methodological requirements for developing the model structure and discretization of variable states (Richards et al., 2013).

2. BBN structure development: The stakeholders were asked to identify up to three variables (adaptive capacity determinants) that influence the adaptation response variable (critical element). This represents the first level of the BBN structure. Further hierarchical layers were added using the same process until a network of variables was created. Depending on the time availability during the workshop, these Bayesian networks were developed to 3-4 hierarchical levels. The participants then discretised all variables within the BBN using qualitative descriptors. (refer to Richards et al. 2013 for further details).

3. Conditional Probability Tables (CPTs): The developed BBN structure was then parameterized by the stakeholders by populating the associated CPTs, which quantify the strength of causality between 'parent' and 'child' nodes. These CPTs were populated through a combination of one-on-one meetings during the workshop based on individual stakeholder beliefs (refer Richards et al. 2013 for further details).

4. Narrative capture: Discussions between participants throughout the workshops and comments by individuals during the CPT populating process were recorded to give additional context to the modelling process.

2.2 Analysis of Adaptive Capacity: Sensitivity testing of BBN models

A final sensitivity analysis was undertaken on each of about 10 BBNs created during the workshop using NETICA. BBNs were produced for each adaptation option tested, such as defence, retreat, accommodate or improved training. This helped identify the inputs that most affect the output and is an important process in model testing, to understand the influential pathways through the developed BBNs and, in the context of this study, identifying important determinants of adaptive capacity. Figure 3 shows the results for one case study area and one adaptation option. Darker colours in this figure are associated with determinants with higher influence in determining the adaptive capacity of implementing a specific adaptive response, in this case "Defending/Accommodating".

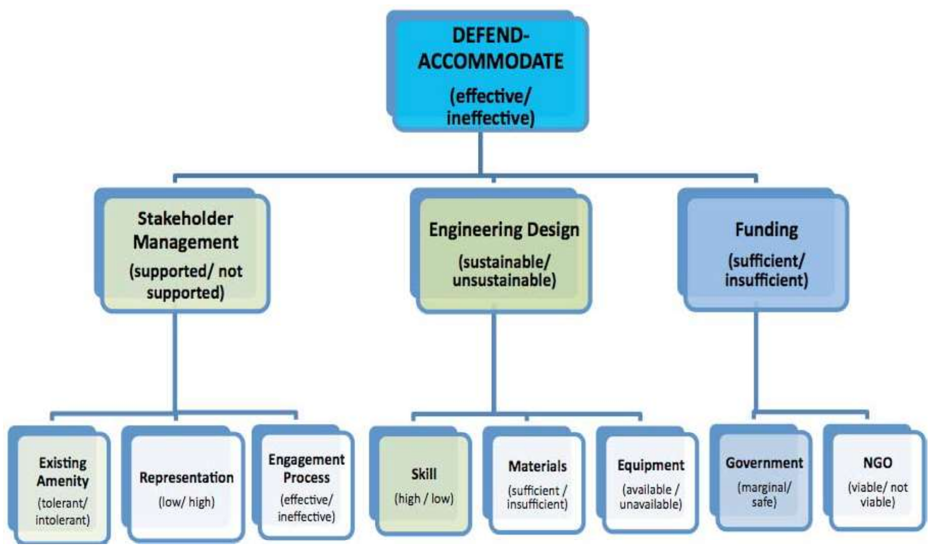

Figure 3. Bayesian Belief Network showing the determinants (and their respective states) of the capacity to implement the adaptive response "Defend-Accommodate" for Cudgen Headland SLSC.

3 DISCUSSION AND CONCLUSIONS

The Systems Thinking and modelling approaches employed in this study demonstrated to be effective in engaging stakeholders and researchers in identifying adaptation options and adaptive capacity determinants for selected SLSCs and SLSA. These techniques were the base to:

1. Collect data and information by involving relevant stakeholders in the modelling processes.

2. Carry out further analysis to understand the collected data and provide stakeholders with specific feedback and adaptation options to discuss.
3. Explore adaptation options and the adaptive capacity determinants to implement them.

The combination of these techniques can be used to create alternative options or pathways. However, the decision over specific actions or works will require more detailed studies for the design of infrastructure and facilities or the relocation to safer areas. These limitations are implicit to the method, which does not aim to find the exact alternative solution to a problem but rather focus on possible adaptation pathways and the adaptive capacity limitations. Table 4 reports a synthesis of adaptation options, adaptive capacity determinants and possible actions to improve adaptive capacity for all case studies.

Table 4: List of most influential determinants of effective implementation of the adaptation option for the three SLSCs and the SLSA, and identified measures to enhance adaptive capacity

CASE STUDY	ADAPTATION OPTION	ADAPTIVE CAPACITY DETERMINANTS OR CONSTRAINTS	POSSIBLE ACTIONS TO ENHANCE ADAPTIVE CAPACITY
Cudgen Headland	Retreat	Funding	Create mechanisms to access funding sources
		Beach safety	Provide access to alternative equipment to keep a presence at the beach, e.g. removable buildings
	Defend and Accommodate	Funding	Create mechanisms to access funding sources
		Engineering design	Inform clubs about possible adaptation options
	Operations	Training programs	Integrate coastal hazards and climate change in surf life saving training programs
		Funding	Improve fundraising mechanisms
Ulverstone	Retreat	Community will	Provide information to the community about existing options
		Funding	Create mechanisms to access funding sources
	Defend	Knowledge and expertise	Provide technical information to clubs
	Operation	Quality of trained staff	Integrate coastal hazards and climate change in surf life saving training programs
North Kirra	Operation	Quantity of trained staff	Promote training programs within the community
		Effective equipment	Identify possible innovations in equipment
SLSA	Mainstreaming climate change	Mainstream climate change	Mainstreaming climate adaptation into operations
	Club capacity building	Partnerships	Improve communication with clubs
	Partnership	Relationships/connection s (sufficient funding, effective personnel and effective organisation)	Build relationships with national organisations (insurance companies, federal and state bodies, etc.)

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