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Strategic adaptation pathway planning to manage sea-level rise and changing coastal flood risk

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ABSTRACT

Communities around the world are already committed to future sea-level rise. Long-term adaptation planning to manage associated coastal flood impacts is, however, challenged by uncertainty and contested stakeholder priorities. This study provides a proof of concept for a combined robust decision making (RDM) and dynamic adaptive policy pathways (DAPP) approach in coastal flood risk management. The concept uses model-based support and largely open source tools to help local government plan coastal adaptation pathways. Key steps in the method are illustrated using a hypothetical case study in Australia. The study shows how scenario discovery can provide multi-dimensional descriptions of adaptation tipping points which may inform the development of technical signpost indicators. Transient scenarios uncovered limitations in seemingly robust adaptation policies, where historical path dependencies may constrain the rate of adaptation and the extent to which future coastal flood impacts can be successfully managed. Lived values have the potential to offer insights about non-material social trade-offs that residents may need to accept for the benefit of reduced flood risk, and could form a basis for defining socially-oriented signpost indicators. However, the nuances and subjectivity of lived values means that ongoing engagement with residents is essential as part of a combined RDM and DAPP approach to preserve the communities' way of life. The learnings from this hypothetical case study suggest that testing in a real world participatory setting could be valuable in further developing a combined RDM and DAPP approach to plan adaptation pathways and manage future coastal flood risk.

1. Introduction

Sea levels are expected to continue rising for centuries regardless of whether greenhouse gas emissions are stabilised (Church et al., 2013). Globally, this will exacerbate coastal flood patterns, causing more frequent extreme sea-level events (Hunter, 2010), nuisance flooding (Ray and Foster, 2016) and permanent inundation of low-lying areas. However, projecting the effect of such environmental change and planning long-term adaptation options is fundamentally a 'wicked problem' that challenges clear definition (Rittel and Webber, 1973). In the context of climate change adaptation this is due to factors such as deep uncertainty (Lempert et al., 2003), natural climate variability (Hallegatte, 2009), contested stakeholder values (Bosomworth et al., 2017), short-term interests and social power inequalities (Few et al., 2007).

Local government are at the forefront of community decision-making. They have an important role in communicating climate change risk and supporting local adaptation planning. However, local government typically have unclear responsibilities, limited financial capacity and technical expertise, governance constraints and face liability concerns about adaptation policies (Productivity Commission, 2012). Notwithstanding these existing barriers, adaptation pathways are noted by users in Australian local government as being a useful planning tool (Lin et al., 2017) and experiences abroad suggests adaptation pathways have utility in supporting strategic decision-making (Bloemen et al., 2017).

Adaptation pathways represent sequences of promising options that provide alternate ways for decision-makers to achieve objectives through time. An adaptation tipping point is reached when a policy no longer achieves the decision-makers objectives, signifying that a new option needs to be implemented (Kwadijk et al., 2010). The year at which the adaptation tipping point is projected to occur is called the 'use-by year' (Haasnoot et al., 2015). Flexibility is a key attribute of

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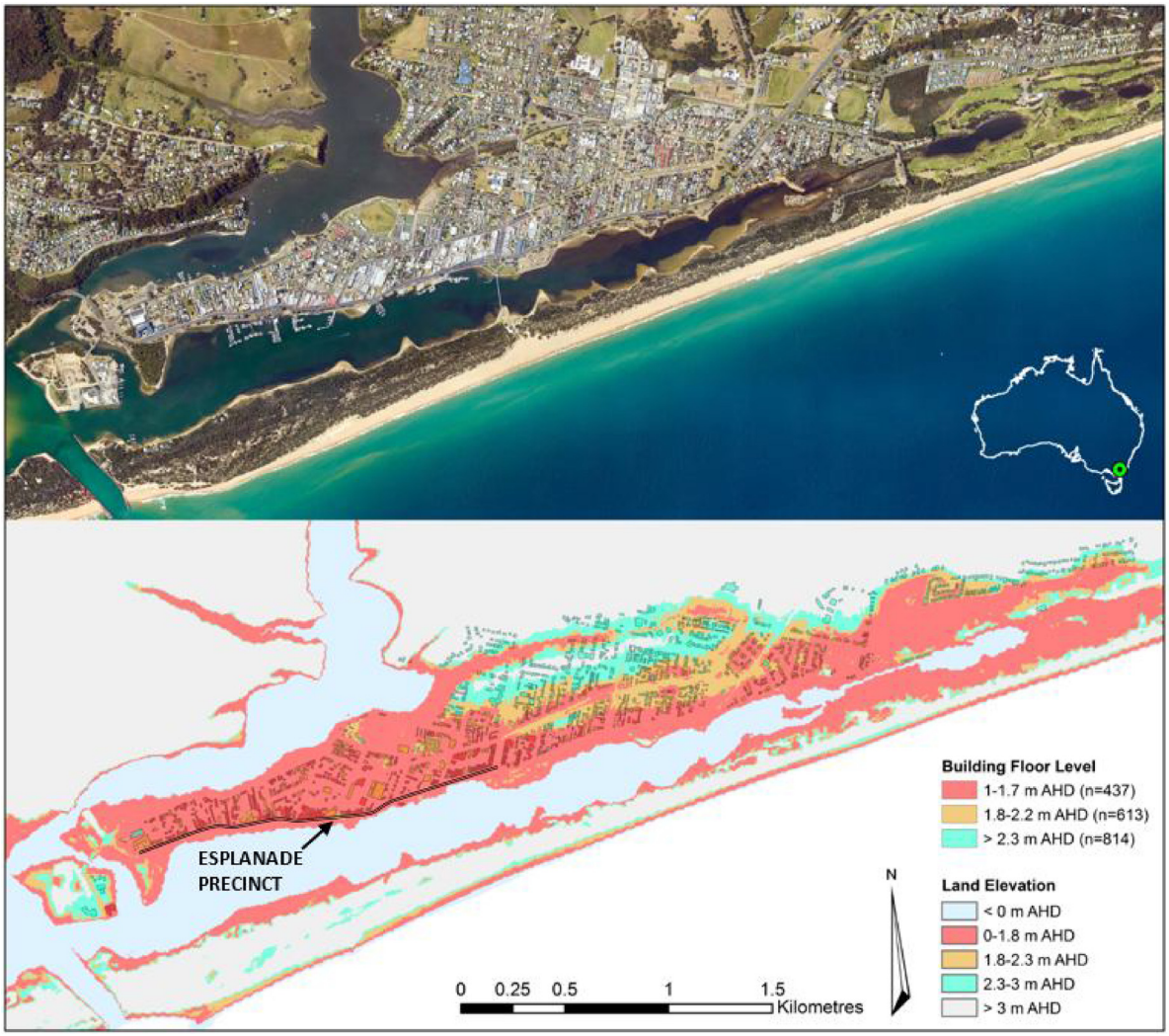

Fig. 1. Aerial image of Lakes Entrance (top panel) and the GIS model (bottom panel) showing digitised properties (n = 1864) and vertical land elevation relative to the Australian Height Datum (AHD). Please refer to the web version of this article for a colour version of this figure.

adaptation pathways as multiple options are kept open to decision-makers in the future. Notably adaptation pathways have utility in coastal flood risk management where change in stressors that influence flood impacts, such as sea-level rise, are characterised by slow moving trends (Bloemen et al., 2017).

Faced with an uncertain future, exploratory modelling can help decision-makers reason with system behaviour and the interaction amongst models and variables. Exploratory modelling performs a series of computational experiments to analyse the implications of future assumptions on policies (Bankes, 1993). It does this by using models and simulations to systematically explore a large set of future scenarios (Kwakkel, 2017), providing insights to decision-makers about potential shortcomings in the policy (Walker et al., 2013). The use of exploratory modelling across many scenarios enables a wide set of futures to be considered (Gong et al., 2017), helping to overcome limitations in human cognition (Lempert, 2013) and biases that individuals tend to exhibit when forming judgements about an uncertain future (Tversky and Kahneman, 1974). Two prominent decision support methods that utilise exploratory modelling concepts to support decision-making under conditions of uncertainty are robust decision making (RDM) (Lempert et al., 2003) and dynamic adaptive policy pathways (DAPP) (Haasnoot et al., 2013). Although each method has its own strengths, both are complementary in nature (Kwakkel et al., 2016). A combined RDM and DAPP approach was demonstrated by Ramm et al (2018) using scenario discovery to describe adaptation tipping points, which can be used to begin planning adaptation pathways. Scenario discovery provides visibility around what key uncertainties cause policies to no longer manage flood impacts successfully (i.e. an adaptation tipping point reached), adding value to traditional pathway methods. The use of exploratory modelling and analysis techniques in coastal flood risk management is becoming increasingly accessible to resource constrained authorities through open source spatial data, programming languages, tools (e.g. Kwakkel, 2017) and GIS software.

Exploratory modelling is appropriate for assessing the implications of adaptation policy in measurable terms, however, evaluating the implications of adaptation policy on non-material social values is not straightforward as values are shaped by ethics, risk, priorities, culture, knowledge and power structures (Adger et al., 2009). They also change over time and space (Meze-Hausken, 2008). Values-based approaches to climate change adaptation contribute knowledge about *what* people value in their everyday lives, *where* values are assigned to natural or manmade areas and *whom* increasing coastal flooding is likely to cause the greatest disruption (Ramm et al., 2017). Considering values-based research acknowledges that “something greater than money is at stake” (O’Brien and Wolf, 2010: 233) and that individuals may face difficult trade-offs decisions between what values are worth preserving and what climate change impacts are acceptable (Tschakert et al., 2017). Examples of values-based approaches include social and cultural values

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