(Mal)adapting to tropical cyclone risk: the case of 'Tempestuous Tracy'

Geraldine Li explores human social adaptations to tropical cyclone risk in Darwin Australia leading up to Cyclone Tracy in 1974.

Abstract

This paper explores the process of human social adaptation in response to tropical cyclone risk in Darwin, Australia. Its particular focus is on the period leading up to Cyclone Tracy, which made landfall in Darwin on 24 December 1974, and the thirty years of learning, adapting and maladapting since. The paper focuses on social level responses to wind damage risk and storm surge risk, with particular emphasis on building codes and land use planning as adaptive responses to those risks. A separate paper from the same study tackles the problem of individual level perception and adaptation; see Li (2008). This paper concludes with a discussion of the implications of these findings for Darwin specifically and for the policy making process more generally.

Introduction

The city of Darwin in Australia's Top-End has had long history of destructive tropical cyclone impacts. The best known impacts include the Great Hurricane of 1897, the 1937 cyclone, and the Christmas Eve cyclone of 1974: 'Tempestuous[1] Tracy', that destroyed Darwin. In Cyclone Tracy more than sixty of its residents lost their lives, fifty to sixty percent of its houses and flats were damaged beyond repair, and the damage bill was of the order of hundreds of millions of dollars (DRC, 1975). While the previous cyclones provided the opportunity for social learning about tropical cyclone risk, and some learning and adaptation did occur, it was not until Tracy that radical learning took place. Residents, practitioners, such as engineers and architects, and policy makers alike responded to the tempest in ways unprecedented in Australian history. In particular, in the thirty years following Tracy, fundamental changes in the building code as a response to wind damage risk, and land use planning as a response to storm surge risk have occurred. It is possible that these changes have made Darwin one of the most cyclone resistant cities in the world (Walker et al., 1975; Walker, 2004).

The responses or practices, however, were not always adaptive. In some instances, the unintended consequences of policy making have resulted in maladaptation or the uptake of maladaptive practices that by no means reduce the risk to individuals or society as a whole. Social level responses to wind damage and storm surge risk include building code policy and practice, and land use planning policy and practice. The adaptive and maladaptive components of these responses can be investigated through applying an understanding of human adaptation or social learning and maladaptation to tropical cyclone risk. The theory of human adaptation and social learning combined with a systems thinking methodological approach and associated methods were employed to tackle this problem. These are discussed next.

Understanding human (mal)adaptation and social learning

Human adaptation refers to the human learning process, a feedback process that occurs when learning has taken place. It is evident in changed and improved mental models of reality and associated changes in individual behaviour or practice as well as in societal laws, policies, regulations and codes (Sterman, 2000); see sketch of this process in Figure 1a. For example, long term learning and memory of tsunamis in Simeulue provide islanders appropriate knowledge and required actions to respond to earthquakes, which worked to their advantage in the 2004 Boxing Day Indian Ocean

1. The term 'tempestuous' encompasses many of the adjectives used by the study's participants to describe and personify Cyclone Tracy. It is a term that portrays Tracy's turbulent violence felt by residents in Darwin at the time, and is used in this article as a reminder of the human side of the disaster.

Tsunami (UNESCO-IOC, 2005). Hence, effective adaptation takes into account direct or prior experience or history (Proust, 2004).

Human adaptation at the social level involves social learning. Social learning is 'a process of iterative reflection that occurs when we share our experiences, ideas and environments with others' (Keen et al., 2005). It involves a process of reflecting on what has been learnt, which then leads to new learning. If this argument is accepted then, in the context of social level policy making and practice, human adaptation and social learning of wind damage and storm surge risk would be a necessary process for those policies and practices to be effective.

Figure 1(a): Learning.
(Sterman, 2000, Figure 1-8)

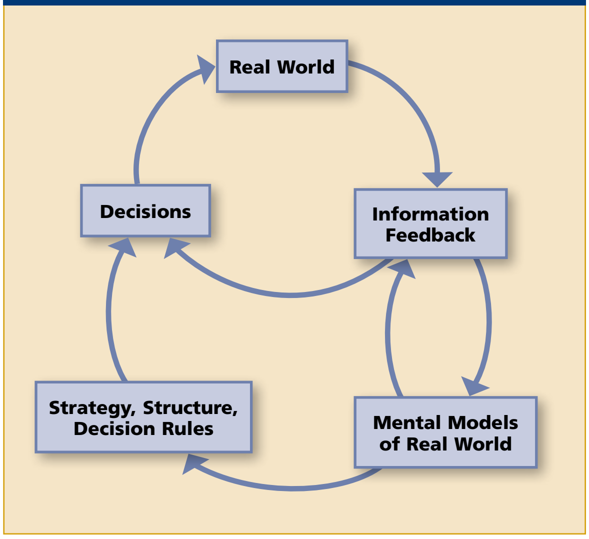
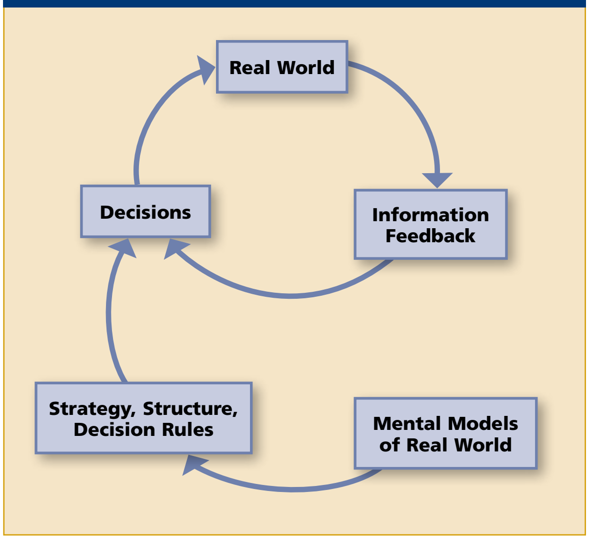


Figure 1(b): Not learning.
(Sterman, 2000, Figure 1-11)



Human maladaptation in contrast refers to those situations when belief in faulty mental models continues to the person's (group's or society's) detriment and the person (group or society) has failed to learn from experience. Maladaptation is commonly associated with two main learning barriers: societal blind spots and the counterintuitive nature of complex adaptive systems within which people are embedded (Forrester, 1971; Senge, 1990; Ison, 2005). For example, despite warnings and multiple prior impacts (opportunities for learning), New Orleans city officials and engineers continued to rely on levee and seawall protection to their detriment during Hurricane Katrina (Travis, 2005). This means that if prior learning has not been taken into account and/or society turns a blind eye to certain parts of a system, maladaptation is likely to ensue. This is depicted as 'not learning' in Figure 1b due to a missing link between information feedback and mental models of the real world.

These basic concepts of human adaptation and social learning, and maladaptation have been applied in this study to learning about and adapting or maladpating to tropical cyclone risk, in particular to wind damage risk and storm surge risk in the city of Darwin. Systems thinking methodology provides an avenue for presenting the results and demonstrating the interlinked and counterintuitive nature of complex adaptive systems.

Systems thinking and complex adaptive systems

Systems thinking is a methodological approach that provides theoretical and practical tools for understanding and analysing complex real world situations. It is a powerful approach because it enables the researcher to think about, describe and understand complex behaviour in simple yet rigorous terms. The human social and natural physical systems referred to in this study are considered complex and adaptive because they involve adaptive agents, such as humans who learn (Gell-Mann, 1994; Comfort, 1999). Numerous tools are available in a systems thinking approach to enable the researcher to better understand and model system processes and feedback dynamics. In this paper two main systems thinking tools are utilised: causal loop diagrams (CLDs) and reference modes (after Sterman, 2000).

Causal Loop Diagrams

CLDs (see e.g., Figure 1) are used to represent causal links and feedback in systems. With polarity signs, they are used to represent positive or negative feedback (e.g. see Figure 3). If feedback occurs in a complex adaptive system then 'the effect of any one decision, action or intervention is not proportional to the cause' (Sterman, 2000, p.22), which makes the system counterintuitive. Commonly feedback in social systems often goes unnoticed and so contributes to maladaptive responses and societal blind spots. The latter occurs when society becomes trapped into familiar ways of thinking and acting and complacency sets in (The Open University, 2005). This can manifest itself in the implementation of outdated policies or the formulation of new policies and processes that do not take into account new learning and the complex adaptive nature of systems.

Reference modes

Reference modes are illustrations of the pattern of behaviour 'unfolding over time…[that] shows how the problem arose and how it might evolve in the future' (Sterman, 2000, p.90). They can also be used as a tool to represent dynamic time series analysis of concrete and abstract concepts and to represent historical analyses of qualitative and quantitative data (e.g. see Figure 2). Historians use the terms diachronic and synchronic historical analysis for this. A diachronic study looks at the development of phenomena through time, while a synchronic study is concerned with events at a particular period. These historical analyses include searching for patterns of success and failure in the policy-making process; identifying sources of policy failures (according to the goal of a policy or broader societal goals); identifying and analysing key events in history; looking for causal links between key variables; and developing a dynamic hypothesis and/or assembling causal loop diagrams. This approach was adopted to analyse secondary and observation data.

Data

Two main data were collected in this study from 2004 to 2005: primary qualitative in-depth interview data and field observation and secondary data. Primary data comprised in-depth semi-structured interviews with 63 participants, including male and female, residing in Darwin and representing a broad range of risk profiles or mental models such as living in or out of the storm surge zone; having long term experience with cyclones in the region such as Cyclone Tracy; having recently arrived in the city with little experience with tropical cyclones; and working in, and having expert knowledge of, the field of tropical cyclone risk management. The sample of participants was not random as the recruitment of participants, using targeted and snow ball sampling approaches, was aimed at targeting a range of risk experiences so as to investigate a broad range of risk adaptation issues in-depth. While some of the findings presented in this paper utilise analyses of the primary data, the majority reported here arise from the analysis of secondary and observation data. Further details of the participant sample and interview themes can be found in Li (2007; 2008).

Secondary data was obtained from a number of sources that dealt with tropical cyclone risk. These include: newspapers and media reporting, government archives and current government reports and policy documents, oral histories and other historical documents, technical documents and reports, electronic media and various audio media, including television and radio reports of risk incidents. Observation data was collected over one year of living in the study region, and include memos of people's cyclone risk mitigation and preparedness activities, especially in the wet season; memos of cyclone risk attitudes in general; audio recordings from radio and television of cyclone risk warnings and educational material; and participation in cyclone risk commemorative events and celebrations. The experience gained by living in the field and accumulating passive observation data provided valuable insight into community behaviour associated with cyclone risk.

Findings

Through analysis of primary, secondary and observation data, and by applying an understanding of human adaptation and social learning together with systems thinking, the findings of this study can be presented in terms of key historical events that occurred at specific times in the past, and adaptive or maladaptive change over time (system dynamics). Both natural and social system aspects are relevant to the complex, adaptive real world problem that characterises this study. In particular actual tropical cyclone impacts on Darwin and elsewhere in Australia and overseas contributed to social learning about tropical cyclone risk. The nature of colonial and subsequent settlement periods also impacted on the level of learning and the policies implemented and the dynamics of the system. Dovers defines policies to be 'positions taken and communicated by government – "avowals of intent" that recognise a problem and in general terms state what will be done about it' (Dovers, 2005, p.12). The term social policy is used here more loosely to include any formal or informal government, private sector, group 'avowal of intent' to recognise a problem and state what will be done about it (i.e. an activity or a practice, which can be either adaptive or maladaptive). In particular, building codes that respond to wind damage risk and land use planning that responds to storm surge risk are investigated. The analysed data is presented as reference modes in Figures 2 and 4 and the feedback dynamics is presented in the causal loop diagrams in Figures 3 and 5. The raw data for this analysis can be found in Li (2007, Ch 9, Ch 10 and Appendix 16).

Policy responses to wind damage risk

Policy responses to wind damage risk had to reconcile the tension between a number of factors including liveability (making houses more comfortable for the tropical climate), wind damage safety in case of cyclones, and the cost of building. The tension was first met by colonists in the late 1800s when it was recommended that modifications to houses should be made to take into account the tropical climate and improve ventilation (Holland, 2000). During these early development years numerous severe cyclones had impacted Darwin damaging trees and buildings. Although regulators were concerned about housing standards no specific cyclone risk response was reported. For example, the Great Hurricane of 1897 did not result in any reported changes in building regimes in Darwin (Marsden, 2000), nor did the 1937 cyclone (IEA, 1974; BOM, 1977). Although Darwin was rebuilt after the 1937 cyclone, it wasn't until after WWII that wind speeds were considered in the construction of buildings. These two cyclones represent significant learning about wind damage risk, which is represented in Figure 2a, but not necessarily building codes to respond to such learning (Figure 2b).

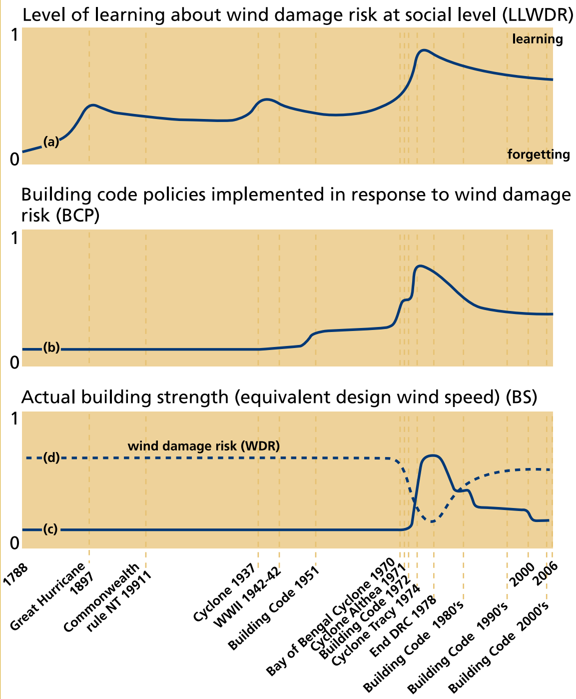
In the post-WWII to pre-Tracy period a number of building ordinances, regulations and manuals were produced by the Department of Housing and Construction (DHC, 1975b). In 1972 a new wind code was adopted, however, since application of the code was not required by law its use was not widespread. From July 1972 to December 1974 houses built in Darwin could be called 'houses with cyclone provisions' (DHC, 1975a). These aspects have been represented in Figure 2a as an increased level of learning about wind damage risk and Figure 2b as implementation of building codes with wind provisions.

The Government and engineers' response to wind damage caused by Cyclone Tracy was immediate. It included increasing the engineering wind load requirements in the building code applied to houses being built or renovated (Figure 2b). Initially the new code was accepted, but the issue of cost, especially as it related to the internal shelter and wind load requirements, soon became apparent (DRC, 1975; Walker, 1975). These were then abandoned, demonstrating the first phase of policy resistance by Darwin residents and the building industry. In Figure 2a this has been depicted by 'forgetting' or a decrease in learning as the engineered designs (wind loading) are decreased (Figure 2c and 2d) to compensate for this tension.

The system behaviour has acted to erode the original policy goals set up post Cyclone Tracy. From an engineering perspective this is perceived as maladaptive. In Figure 3 this is demonstrated in a fixes-that-fail systems archetype, which means that policies implemented to reduce risk in the long run actually fail due to policy resistant behaviour. In response to the pressure to reduce wind damage risk after a major cyclone (Cyclone Tracy) the Government adapted to the risk by implementing a strict building code. The 'fix' then is an increase in the number of houses thought to be built to the new building code regime (Figure 3).

This, however, resulted in a number of unintended consequences in the ensuing decades, including privatisation of the building inspection process, corrupt building practices, and problems with debris minimisation (Li, 2007). These unintended consequences resulted in decreasing the actual building wind strength, which in turn feeds back to increase the risk of wind damage; see Figure 3.

Figure 2: Policy history reference modes: wind damage risk.

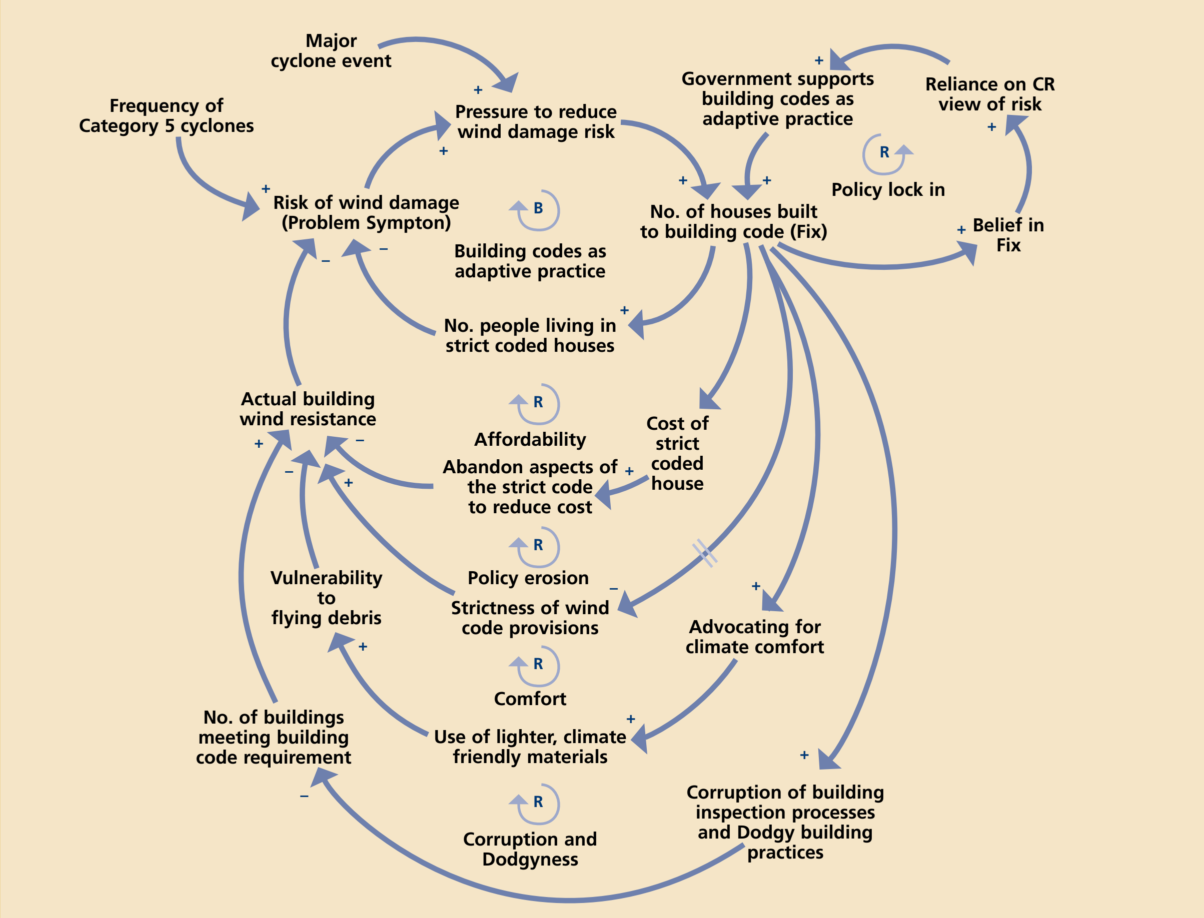


Policy responses to storm surge risk

Policy responses to storm surge risk had to take into account experience and learning from interstate and overseas (Cyclone Althea in Townsville, Bay of Bengal cyclone and storm surge) and reconcile residential planning practices and residents' desire to live near the sea.

As demonstrated in Figure 4e the level of social learning about storm surge risk really only began to rise in the late 1960s and early 1970s. In 1967 the Commonwealth Bureau of Meteorology (BOM) conducted a study of storm surge and wave action in Darwin. The specific reason was to study the 'meteorological influence on the sea in the vicinity of Darwin for the purpose of planning in the environs of the city' (BOM, 1967, p.1). The report noted that phenomena such as storm surge 'may be severe, in which case unplanned development may prove disastrous' (BOM, 1967, p.1). Although the report made no specific recommendation for planning options in Darwin it was clear that the possibility of

Figure 3: Wind damage Risk Building Code Policy: A fixes-that-fail systems archetype.

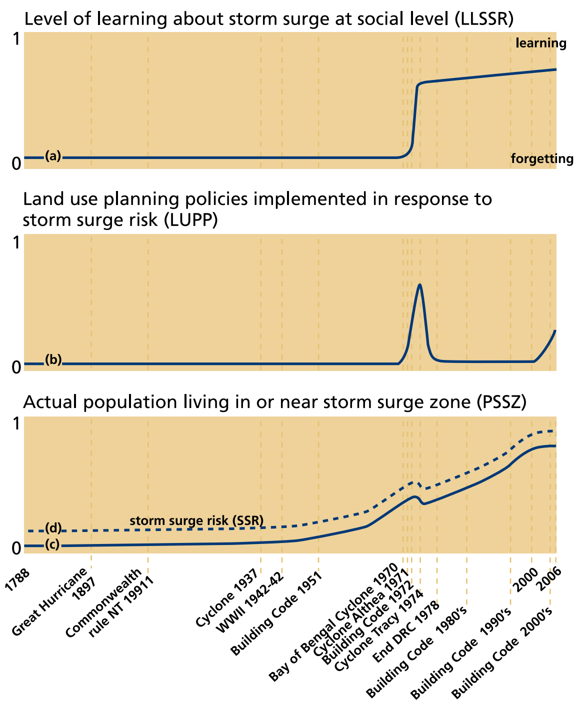


extreme events was cause for concern. The catastrophic Bay of Bengal cyclone (1970) and cyclone Althea (1971) provided an opportunity for further learning about storm surge risk in Darwin. Actual policy change, however, was not considered in the context of planning in Darwin until after Cyclone Tracy.

Although storm surge damage was minimal during Cyclone Tracy, the destruction of Darwin sparked a controversial policy reaction to planning and storm surge risk that was met with severe policy resistance by Darwin's residents. In particular it began with a radical proposal to replan the city, which included propositions from planners and others to 'the complete re-siting of the settlement, the abandonment of the northern suburbs for settlement in the short term and the concentration of the population in the southern half of the city, and the relocation of the airport' (D'Rozario, 1978, p.5). The re-siting of Darwin was abandoned immediately when the Commonwealth Government 'categorically assured the citizens of Darwin that Darwin would be rebuilt on its present site' (D'Rozario, 1978, p.5). This dynamic is depicted as a spike centred around 1974 in Figure 4f. The spike represents an attempt to implement land use planning policies that reduce storm surge risk by restricting development in the storm surges zone, followed almost immediately by the abandonment of such policy. These dynamics are also illustrated in the CLD in Figure 5. In this instance the social maladaptation was on the part of the community at large rather than the engineering community or the government.

In the ensuing years to present numerous studies about storm surge risk in Darwin have been conducted and the storm surge zone (SSZ) has been calculated and recalculated on a number of occasions (Li, 2007, Chapter 10). During this time the level of learning about storm surge risk has gradually increased. Unlike building code responses to wind damage risk, land use planning responses to storm surge risk seem to have reached a renewed adaptive policy response over the past few years (Figure 4f). The Planning Scheme Amendment 2006, which is the land planning instrument under the NT Planning Amendment Act 2005, clearly identifies land use planning as an adaptive approach to mitigate and manage storm surge risk (see DPI, 2006, p.97). It did, however, permit some residential uses in specific developments such as the Darwin City Waterfront to go ahead in high storm surge risk areas, albeit with consideration of storm surge levels; see (DPI, 2006, p.140).

Figure 4. Policy history reference modes: storm surge risk.
The reference modes in this figure are interpretive illustrations of the system dynamics gained through analyses of both qualitative and quantitative sources of storm surge risk information.

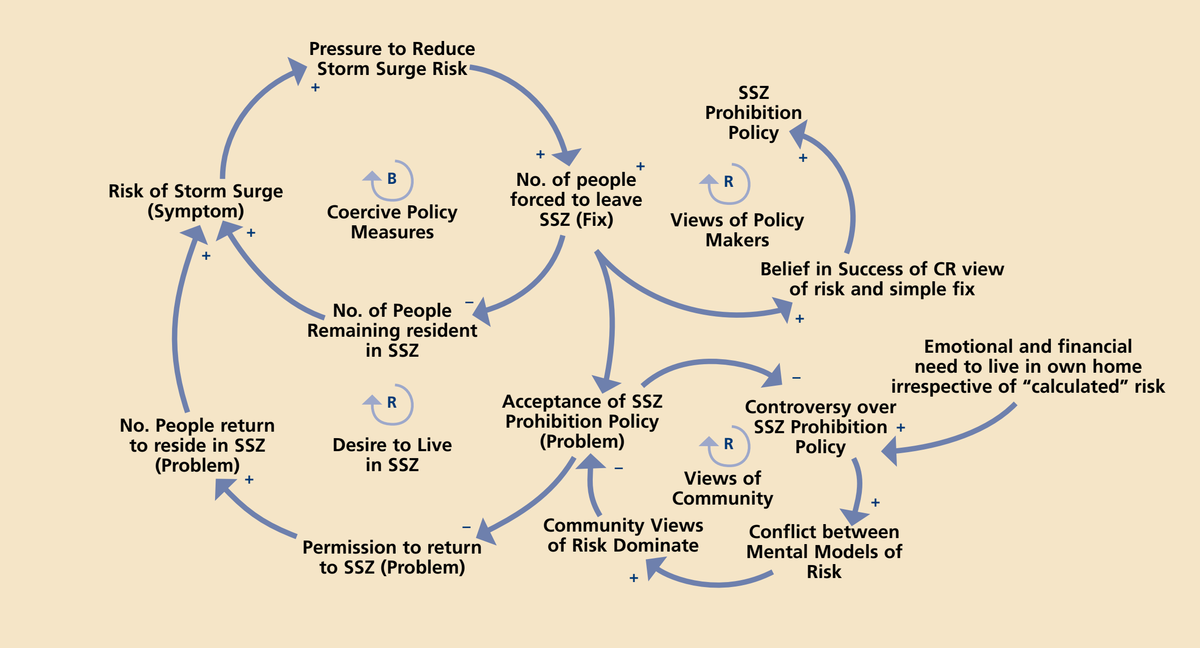


Discussion

The Government has yet to tackle the proposition that the wind code provisions might have been eroded since the post-Tracy building code and that the use of lighter, climate friendly, more comfortable material may have increased the risk of damage from flying debris. None of the consequences of policy making discussed above have yet been 'tested' by the impact of a major cyclone, nor have the consequences of a potential increase in the frequency of Category 5 cyclones as the globe warms[1], been included in the policy making process. Prior to Cyclone Tracy no Category 5 cyclone had been recorded in the NT nor included in the BOM's database of historical cyclone events (see BOM, 2006). In their early stages Cyclone Thelma (1998), Ingrid (2005) and Monica (2006), which passed within 200 kilometres of Darwin, may have been a threat to Darwin. If these events had impacted Darwin the policy responses and social-level adaptive processes may have been quite different.

Although the social policy that addresses storm surge risk has changed recently, the number of people living and assets and developments located in the storm surge zone has increased considerably in the years since cyclone Tracy.

Figure 5. Mal(adapting) to storm surge risk: a fixes-that-fail system archetype.
B refers to a balancing (negative) feedback loop, and R refers to a runaway (positive) feedback loop. CR refers to calculable risk; see detailed explanation in Li (submitted). SSZ refers to storm surge zone.



1. For more information on Climate Change in Australia see CSIRO and BOM (2007).

The exact exposed population is difficult to determine but a Northern Territory Emergency Services (NTES) estimate of the total population in the storm surge zone in 2007 was 9,914 for the NTES 1999 storm surge zone (Pers. Comm. Peter Davies, NTES, 20/11/2007). Although it may have reached a plateau in the last few years, this number is likely to increase due to some ongoing residential development in the SSZ, such as the Darwin City Waterfront. This increase in population since cyclone Tracy has been illustrated in Figure 4g and an associated increase in risk in Figure 4h.

The first attempt to learn about storm surge risk in the period immediately after Cyclone Tracy, and use land use planning as an adaptive practice, lasted less than a year. This was followed by a thirty-year period of maladaptation, with continued development in the SSZ, typical of a path dependent system. Despite recent social policy adaptations, the current and future population at risk of the effects of storm surge is likely to continue to pose an adaptive challenge for Darwin emergency services and planners well into the future.

Conclusion

This paper has discussed the processes of social learning and (mal)adaptation to wind damage risk and storm surge risk in the city of Darwin in the period leading up to, and the thirty years since, 'Tempestuous Tracy'. Using an understanding of the theory of social learning and adaptation together with systems thinking approaches and tools, this paper has demonstrated that social level responses to risk are not always adaptive. Societal blind spots in the form of policy resistance to the effective implementation of both land use planning polices to adapt to storm surge risk as well as building code policies to adapt to wind damage risk have clearly dominated the dynamics of the complex adaptive system under investigation.

Maladaptation in terms of structural safety in the case of wind damage risk, and in terms of exposed populations in the case of storm surge risk, ensues. To adapt better, we need to consider the long time frames for human adaptation, and the potential for maladapation as well as for changing future risk. In the policy making process, a proactive approach to social learning, such as through participatory community learning programs and adaptive governance, that allows for these dynamic and adaptive systems responses may be a way to achieve this.

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Geraldine Li's current research interests and activities include developing integrated systems approaches to risk, risk assessment, management and human adaptation. This involves introducing the dynamical systems thinking or 'integrative' paradigm into complex, interlinked human social and environmental problems, such as climate change vulnerability and adaptation. She is currently a research fellow at the Fenner School of Environment and Society, Australian National University, Canberra.