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Modelling coastal planning in southwest Western Australia: complexity, collaboration and climate adaptation

Laura Stocker[a], Deborah Kennedy[b], Sarah Metcalf[c], Jeffrey M. Dambacher[d], Garry Middle[e] & David Wood[f]

[a]Curtin University Sustainability Policy Institute, [b]Curtin University Sustainability Policy Institute, [c]WA Department of Environment and Conservation, [d]Mathematics, Informatics and Statistics, CSIRO, [e]Department of Urban and Regional Planning, Curtin University, [f]Curtin University Sustainability Policy Institute

Email: L.Stocker@curtin.edu.au

Abstract: This action-research project investigates the extent to which current coastal planning arrangements can respond to climate change impacts such as coastal erosion and recession in the southwest of Western Australia. The complex social ecological system that comprises coastal planning in the region was modelled in a collaborative process. This took the form of a major action research workshop followed by further small workshops and interviews with key actors. The modelling process has implications for coastal planning as it shows that despite recent changes to coastal planning policy there are still significant areas of liability resulting from climate change that are not yet accounted for by governance. More generally, private and public coastal developments in WA are in a phase of rapid growth, with observable degradation of the coastal environment. Within the context of the model system, this implies that the positive feedback subsystems are strongly driving the system, and current levels of response to public liability and environmental advocacy are relatively weak and inadequate to achieve sustainable coastal management. For this system to be stable requires that negative system feedback be stronger than positive feedback. Future modelling efforts will investigate potential interventions and restructuring of governance system to achieve goals of sustainable development. Thus far, the main use of the model has been as a heuristic device to discuss the coastal planning system with key informants, and to identify constraints and opportunities to coastal adaptation through the planning system.

Keywords: *coastal governance, climate adaptation, qualitative modelling, social ecological systems, action research*

1. INTRODUCTION

Climate change is one of the most pressing yet difficult issues facing coastal planning in Australia. The 'coastal zone' - where the land and sea directly influence each other - is of enormous ecological, social and economic importance. Over 85 per cent of Australia's population is concentrated within 50 km of the coast, in capital cities or southern regional areas. Furthermore, growth in the coastal zone is consistently higher than the national average. The coastal zone contains much of the nation's infrastructure, manufacturing and fishing industries, and also many of the country's major tourism, heritage and ecological sites. Climate change thus poses a serious risk to many urban and regional coasts. Rising sea levels are a hazard that will put pressure on communities to retreat from the coast, accommodate sea level rise with flood-tolerant infrastructure, and defend their coasts with hard structures (Church et al. 2006, Pattiaratchi 2009). However, associated hazards such as storm surges, and consequent impacts such as shoreline erosion, groundwater salinisation and infrastructure destruction, will cause a retreat from the coast well before inundation from sea level rise occurs (Pilkey and Young 2009).

We are concerned with the governance structure and processes for the management of the south west of Western Australia's (SWWA) changing coast in the context of climate change and sea level rise. Our research aims to identify constraints to and opportunities for the governance of coastal adaptation to climate change (Stocker et al 2010; Wood & Stocker 2009). We focus on coastal planning. Our questions are: what is the current model of coastal governance in SWWA; and how effective is it likely to be for adapting to the impacts of climate change?

In answering our questions, we draw on complex systems thinking to analyse coastal governance. The application of complex systems ideas to governance of social-ecological systems has been discussed by a number of scholars (e.g. Folke et al. 2005, Duit and Galaz 2008, Norberg and Cumming 2008). Scholars recognise that studying system components separately leads only to partial understanding. Important feedbacks in these systems will be a function of cross-system interactions. Our research is framed by a view of social-ecological systems as linked systems that behave in highly complex, non-linear and dynamic ways in response to both positive and negative feedback loops over a range of spatial and temporal scales making them difficult to predict and control.

Qualitative models of complex systems are useful for synthesising the various aspects of systems in order to understand the complex interactions between the components and their effects (Costanza et al. 1993). Qualitative models focus on "the structural aspects and essential dynamics of the whole system" (Dambacher et al. 2007, 555). The main methodology used in this research is qualitative modelling of complex systems. We present a complex systems model of the current governance processes for addressing shoreline recession in SWWA. The model was produced from a number of facilitated and deliberative workshops of key stakeholders and its validity qualified and refined through one-on-one interviews with key stakeholders.

2. THEORETICAL AND METHODOLOGICAL FRAMEWORK

2.1 Complex social-ecological systems

Berkes and Folke (1998) began using the term "social-ecological" systems to stress that human systems are inseparable from ecological systems and that they evolve together across spatial and temporal scales. Important feedbacks in these systems will be a function of cross-system interactions. By conceptualising coastal governance as a complex social-ecological system we can begin to account for these feedbacks. Importantly, spatial differences in regional and local ecosystems and governance agents, institutions, and processes will "lead to varied social-ecological interactions in different locations and can have a large effect on such properties of a system as its ability to adapt to change" (Norberg and Cumming 2008, 289). Here we are concerned with the social-ecological phenomenon of the governance of climate change adaption on the coast.

2.2 Qualitative modelling of complex systems

Qualitative models use information gained from general observations rather than precisely specifying a systems variables and interaction strengths. A qualitative modelling approach recognises that complex systems can only ever be partially specified (Levins 1974). This is because human cognitive capacity to understand complex interactions is limited, making it impossible to include every complexity intrinsic to these systems into a reasonable analytical framework (Levins 1974, Anderies and Norberg 2008). Qualitative models "permit the inclusion of relevant but often immeasurable details in order to capture the structural aspects and essential dynamics of the whole system" (Dambacher et al. 2007, 555). Immeasurable variables include cultural, social, economic and other drivers of human actions (Dambacher et al. 2003a).

Qualitative modelling begins by defining the structure of a system, which is determined by system variables and the relationships that link them. The variables and their relationships are portrayed by sign-directed graphs, or signed digraphs (SDGs), where a link ending in an arrow (→) represents a positive direct effect (e.g., as in a birth rate supported by consumption of prey), and a link ending in a filled circle (—•) represents a negative direct effect (e.g., as in a death rate from predation). Once the structure of a system is defined, it is possible to analyse the system's feedback, which determines the qualitative conditions for system stability and perturbation response. These methods proceed via analysis of the signed digraph through graphical algorithms or through equivalent algebraic analyses of the system's community matrix (Dambacher et al. 2003b, 2007).

2.3 Methods

In the current research, a qualitative modelling approach of complex social-ecological systems is applied in order to determine the structure and processes of the governance system for the WA coast, especially as it relates to coastal recession. The modelling methodology used workshops and small group deliberation to generate key qualitative process variables relating to coastal governance and aspects of their interrelationships. The variables and relationships were first mapped out on a whiteboard in real time, with a focus on the relationships between the most salient variables described in terms of assets and threats. For example, climate change was described as a threat to an asset such as foreshore reserves through the process of coastal erosion; however, this relationship could be mediated by the remedial actions of local governments.

An integral part of the complex modelling of coastal governance presented here is the action-research approach in which stakeholders come together to generate information, knowledge and understanding about the system collaboratively and relationally. Through this approach the participants can at once be creators of collective knowledge and agents of potential future change to the system of which they are a part.

In June 2010 key stakeholders involved in SWWA governance were invited to a full-day seminar on Coastal Governance Futures in the context of climate change. Over 70 participants attended representing the state government (25% of participants), local government and regional councils (18%), universities and other research institutes (31%), private sector (10%), natural resource management groups (10%) and environmental non-government agencies (3%). Other participants included a member of State Parliament and an Indigenous elder. The broad aim of the workshop was to map and model the current coastal governance system for the SWWA (principally from Perth to Dunsborough) and to generate ideas for future approaches.

The workshop was introduced by a specialist talk that presented the idea of complex systems and created a conceptual frame in which science, governance and the biophysical world could be understood as interacting within the same social ecological system. A mediated modelling process was then undertaken whereby inputs from participants around the table were translated into a model on a whiteboard in real time. The initial round of mediated modelling was very open, capturing the big picture of coastal governance in SWWA with a high level of detail. The modeller encouraged discussion and translation across the science-governance interface, entering both types of variables and processes into the model. These discussions also helped to frame the second round of mediated modelling, focusing on coastal planning and coastal recession in the SWWA. A facilitator helped to channel the numerous ideas from participants to the modeller in an orderly fashion.

Participants were given a draft model of the day and feedback was invited. The draft model produced was then used as a basis for additional more detailed, interviews and discussions with key respondents. Two small workshops were held to further refine the rough model into a functioning model. A series of one on one interviews occurred in which the relationships within the model and the governance context surrounding the model were discussed in detail. The model was refined again on the basis of these interviews. The results and discussion set out below are based largely on the views of interviewees, with some points clarified by reference to external specialists.

3. RESULTS AND DISCUSSION

3.1 Model description and interpretation

In this representation of the model (Figure 1), 'grey arrow' means that one variable promotes another; 'hatched arrow' means one variable suppresses another; 'double ended arrow' means that two variables promote each other. There are two main loci in the model. One locus is the process of coastal recession. The drivers of this are historical oceanographic forcing, climate-changed oceanographic forcing, and poorly designed development. Historical oceanographic forcing includes existing patterns of sediment transport and erosion. Climate-changed oceanographic forcing includes changes in existing patterns due to sea level rise, changes in storm high tide frequency and height and other impacts. Poorly designed development includes groynes and other infrastructure that interfere with coastal sediment transport and currents in such a way as to increase erosion. Coastal recession in turn decreases coastal ecosystem health (defined as a loss of dunal vegetation) and places established national assets, public property and private property at risk. It also places potential new property and redevelopment at risk. As a result of the increased public property and national assets at risk, impact on the public increases.

The second locus of the model is around the coastal development approval process, which is linked to the above locus via public impact and also via the construction of coastal residences. We suggest that the coastal development approval process is driven by a mutually reinforcing interaction of regional population, transport infrastructure and private sector development. That is, each of these factors promotes the other two. Private sector development applications drive both the local government development approvals process and the state government coastal development approvals process.

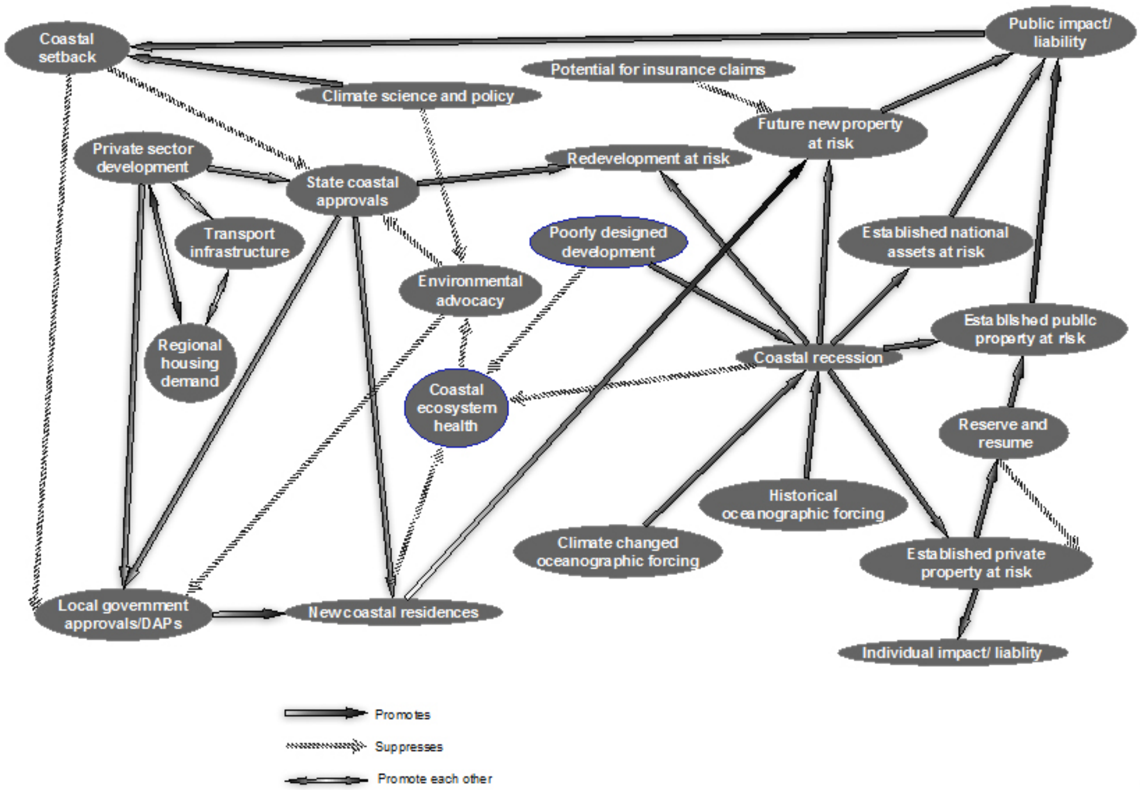

Figure 1. Qualitative model of coastal governance in south west Western Australia.

State plans for coastal areas are often strategic rather than statutory in nature and provide context for local governments to enable detailed town planning schemes. Local governments often promote Greenfield and intensive re-development in order to increase rates income and fund existing commitments to local infrastructure. Conversely, local governments sometimes refuse approvals but can be over-ridden by state government. This conjunction can drive ribbon development along the coast with few checks and balances. The increase in residences on the coast means that there is increased risk, because of both the increased hazard of coastal climate impacts, *and* the increased exposure in terms of the number of people potentially affected. Failure to take account of these factors through coastal planning and management will lead to increased vulnerability which will further increase overall risk.

One way in which the coastal planning system has responded to this risk in WA is to increase the coastal setback to 150m on sandy coasts[1]. This relates to new development, not to redevelopment or infill. The new setback was based on a revised calculation of sea level rise of 0.9 m by 2100 provided by the Department of Transport in consultation with a variety of coastal engineers and climate scientists (Bicknell 2010). The desired effect of the new setback and revised sea level rise formula is to reduce the public and individual impacts as described above. However, its main effect will be to reduce exposure in terms of new property at risk. It will not reduce vulnerability of established public or private property at risk or established national assets at risk. Nor will it affect the level of exposure due to redevelopment and infill.

Another factor that can potentially decrease the number of coastal developments is environmental advocacy, which can be through formal channels such as the Environmental Protection Authority or through the activities of lobby groups. Climate science and policy also has a weak impact on environmental advocacy.

One final factor that deserves a mention is the impact of insurance on property. Karl Sullivan, the General Manager for the Policy, Risk and Disaster Planning Directorate of the Insurance Council of Australia suggests that, from an insurer's perspective, the most significant factor driving the changing risk profile is the increased density of people and property in vulnerable areas; that is, there is more money at stake per square kilometre[2].

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[1] http://www.planning.wa.gov.au/Position_Statement_SPP2_6_Final_WAPC.pdf?id=2380

[2] http://www.seachangetaskforce.org.au/Publications/PlanningforClimateChange.pdf p. 22

Insurance premium trends will follow the trajectory of risk. Overall, it remains to be seen what the impact of insurance trends will be on the viability of coastal properties. Furthermore, our analysis/model suggests that current coastal planning processes are not yet adaptive.

3.2 Methodology – constraints and opportunities

In regard to the broader action research framework within which we located the modelling work, it is important to note that the model is framed by the participants themselves, by the leader of the initial workshop, by the subsequent interview process with respondents, and by the modellers as they filter participant inputs and conceptually build the model. The accuracy of the model is dependent upon the quality of inputs from participants and the modeller's interpretation of these inputs. A different group of participants and researchers could have generated a very different model. The present research began as a broader study of coastal governance but very quickly and consciously became framed more tightly around coastal planning and coastal recession as a way of narrowing the scope of the model which threatened to be unmanageable.

The current model was analysed to identify subsystems associated with positive and negative feedback cycles:

Positive feedback subsystems

1. Transport infrastructure-regional housing demand.
2. Private sector development-transport infrastructure.
3. Regional housing demand-private sector development.
4. Transport infrastructure-regional housing demand-private sector development.

Negative feedback subsystems

1. Established private property at risk-reserve and resume.
2. *Environmental advocacy*-state coastal approvals-new coastal residences-coastal ecosystem health.
3. *Environmental advocacy*-local government approvals and DAPs-new coastal residences-coastal ecosystem health.
4. *Environmental advocacy*-state coastal approvals-local government approvals and DAPs-new coastal residences-coastal ecosystem health.
5. *Public impact and liability*-coastal setback-local government approvals and DAPs, new coastal residences-new property at risk.
6. *Public impact and liability*-coastal setback-state coastal approvals-new coastal residences-new property at risk.
7. *Public impact and liability*-coastal setback-state coastal approvals-local government approvals and DAPs-new coastal residences-new property at risk.

All positive, destabilizing, feedback in the system is associated with transport infrastructure, regional housing demand and private sector development. Each of these variables mutually reinforce each other, and an input to any one of them will lead to increases in the others that is bounded only by the degree to which these variables are inherently limited (e.g., regional housing demand is also regulated by human population, which is not explicitly represented; transport infrastructure is limited by the tax base of government investments). These positive feedback subsystems are linked to the larger system through state coastal approvals and local government approvals and DAPs. These variables are in turn associated with six of the seven negative feedback subsystems. An interesting feature of the negative feedback subsystems is that they all involve an element of environmental advocacy or public liability, which are italicised in above list of feedbacks.

For this system to be stable requires that negative system feedback be stronger than positive feedback (Dambacher et al. 2003b). Currently, private and public coastal developments in WA are in a phase of rapid growth, with observable degradation of the coastal environment. Within the context of the model system, this implies that the positive feedback subsystems are strongly driving the system, and current levels of response to public liability and environmental advocacy are relatively weak and inadequate to achieve sustainable coastal management.

Future modelling efforts will investigate potential interventions and restructuring of governance system to achieve goals of sustainable development. Thus far, the main use of the model has been as a heuristic device to discuss the coastal planning system with key informants, and to identify constraints and opportunities to coastal adaptation through the planning system. The initial version of the model constructed in the first workshop was more of a map depicting tangled relationships among a wide range of agencies and their responsibilities rather than processes. Later versions focussed on key variable and processes associated with coastal recession and coastal development approvals. The formal modelling methodology ideally retains only the critical processes and features of the system, with weak links being allowed to fall away. However, for heuristic purposes and for the sake of completion, participants wanted to see the processes relating to their own specialisation, and other processes about which they were concerned, clearly represented in the picture, even if these processes are not critical in the model. The final version presented here then shows what could be described as a core model. Use of the model as a visual heuristic device was more successful with some respondents than with others. It was especially useful for respondents who are familiar with complex systems. For one respondent whose professional experience is largely with simple linear systems, the model was very confronting. Overall as a heuristic device that helped deepen and broaden our shared understanding, it has been a useful process.

One constraint of the modelling methodology is that while it shows a complex system, it does not show a complex *adaptive* system, and thus the potential for learning and reflexivity cannot be represented within a single static model, but must be explored through an array of alternative models of possible futures. The model cannot tell us about the quality of relationships; relationships can only be either positive or negative. The quality of the relationships and the issues surrounding them, however, can be represented in the discussion of the model, as we have done in the present research. Moving beyond these limitations in order to model complex adaptive systems requires a more complicated model and this can "muddy the analytic waters" (Miller and Page 2007, 20). There is a trade-off between less exact analytics and greater potential for new insights (Miller and Page 2007).

3.3 Planning implications

Most governments are moving to divest themselves of legal liability around impacts of climate change. It seems likely that governments will only be found legally liable for climate change impacts if they cannot show that they have taken reasonable steps to manage climate change impacts using the best available science. In WA the planning system is central to governance related to coastal impacts from climate change, in particular sea level rise and will likely be the focus of any litigation. The key question here is 'has the planning system taken those reasonable steps to manage climate change impacts using the best available science?'

Steps should include creating policies that adequately address climate change and ensuring subsequent plans and schemes are consistent with these policies. The key planning policy relevant here is SPP 2.6, and its most recent amendments applies a 150m set back to allow for climate change related coastal recession. This is consistent with the science and new greenfield site developments would normally need to comply with this setback requirement. Arguably, any new greenfields development that is given an exemption to this could, unless special conditions are applied, set up a potential successful future legal action. New developments could be allowed within 150m in cases where adaptive measures are applied in acknowledgement of the future risk: for example, the development has a sunset clause where the allowed setback is consistent with the timeframe of the development. Structure and infrastructure would need to be adaptable to this timeframe as well and have the ability to be removed as required. The key here is that the sunset approval conditions are based on the science and the expectation that the approval does not imply on-going development rights.

Local governments have decision making powers for individual development within an approved scheme and subdivision and could also potentially be legally liable if they do not apply state policy properly. They may also be liable even if they do apply state policy in not allowing a coastal development within 150m and then the state government overturns their refusal. That is they could theoretically be liable for a ruling made by the state government.

Our discussion has focused on new greenfield sites that will be approved under the revised SPP. However, the SPP revisions are not retrospective. Thus many existing coastal areas in Perth have inadequate setbacks, taking into account climate change; and existing planning schemes reflect the old policy position. Planners will be faced with dilemmas of how to deal with new applications for development on land that will be subject to coastal recession but is already zoned for urban purposes. Applying the provisions of the existing planning scheme would allow development within this at-risk area, but the science is telling the planners not to approve development. A refusal based on science would head off future litigation but would likely trigger current litigation action. This planning policy area needs urgent attention.

Adaptive measures are often cited as being necessary in dealing with issues like climate change where levels of uncertainty exist, but planning has not, to-date, readily shown itself to have the capacity to be adaptive. Adaptive planning offers some potential in dealing with the above planning dilemma and is worthy of further exploration by both academics and planning decision makers.

4. CONCLUSIONS

In this paper we present a complex model of the current coastal governance arrangements in the SWWA, focusing strongly on coastal planning. The research examines the likelihood of the effectiveness of this model for adapting to the impacts of climate change.

The initial mediated modelling process brought together for the first time a wide range of knowledge makers, decision makers and other stakeholders with an interest in coastal governance and climate change. The model is a useful heuristic tool that brought together knowledge and governance processes into a single frame. Nonetheless, understandings drawn from the model are limited by methodological constraints and, in the first instance, by the large number of people in the room.

The model also serves the purpose of a visual map of processes and variables and has proved a useful basis for ongoing discussion with actors. The model represents a reasonable compromise of full complexity and oversimplification of a system. The model presented in this paper appears to be strongly driven by positive feedbacks associated with private property development, transport infrastructure and regional housing demand, among other factors. These positive feedbacks are reflected in relatively weak limitation of coastal development approvals and consequently, the runaway ribbon development on our coast. In future work we will analyse what changes would need to be made to the model system to support sustainable coastal development.

The coastal governance landscape has been quite dynamic since the first workshop such as revision of SPP 2.6 now recorded in the current version of the model. The problems caused by lack of regulation of coastal development in SWWA under current conditions will increase as sea levels rise and coastal erosion take effect. The partial solution provided by the revised SPP 2.6 will be tested by the extent to which it is implemented and the extent to which it can be further adapted and enhanced to account for new information. Existing infrastructure and coastal residences remain an unaddressed problem because of the lack of linkage in our coastal governance system between coastal planning and coastal management.

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