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What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty

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ABSTRACT

Implementing climate-resilient pathways in conditions of uncertainty and change is a serious challenge. Approaches have been developed for this type of problem, one of which, Dynamic Adaptive Policy Pathways approach (DAPP), has been applied in practice in a limited number of circumstances, mainly for large infrastructure projects and at national scales. To better understand what it takes to catalyse uptake of DAPP to better address uncertainty and change than typical static planning approaches, we examined the role of a simulation game facilitated by a knowledge broker, in a real-life local decision setting on flood risk management in New Zealand. Four intervention phases over four years are described and their influence analysed: 1) creating interest through framing the science, 2) increasing awareness using the Game, 3) experimenting with DAPP, and 4) uptake of DAPP. We found that a knowledge broker introducing new framing of changing risk profiles, facilitating use of the Game and the DAPP approach in a real-life decision making setting, with contextual support from events and (inter)national reports, catalysed the uptake of adaptive pathways planning. We identified enabling requirements necessary for embedding adaptive planning into decision-making practice for addressing uncertainty and change.

1. Introduction

In response to uncertain environmental and socio-economic change, those managing flood risk are urged to develop adaptive plans to ensure communities' long-term sustainable economic development (Hallegatte et al., 2016). However, there are challenges in developing and implementing such plans to address changing climate impacts and socio-economic conditions, including; dealing with uncertainty and the need to do so; understanding and acknowledging different types of uncertainty; making robust and adaptive decisions that can cope with uncertainties about the future, and shifting planning practice from static to dynamic approaches.

A number of approaches that address uncertainty and change have been taken up in practice and science, allowing decision makers across many domains to address risk aversion in their choices (Webster, 2003). These include, real options analysis (Neufville, 2003), robust decision making (Lempert et al., 2003), iterative risk management (Haasnoot et al., 2011) and strategic planning approaches (Roggema, 2009). Another approach, Dynamic Adaptive Policy Pathways (DAPP) (Haasnoot et al., 2013), has been used increasingly for evaluating and implementing climate-resilient pathways for water management under uncertainty. Within the DAPP approach, a plan is conceptualized as a series of actions over time (pathways). The essence is the proactive planning for flexible adaptation over time, in response to how the future actually unfolds. The DAPP approach starts from the premise that policies/decisions have a design life and might fail as the operating conditions change (Kwadijk et al., 2010). Once actions fail, additional or other actions are needed to achieve objectives, and a series of pathways emerge; at pre-determined trigger points the course can change while still achieving the objectives. By exploring different pathways and considering path-dependency of actions, an adaptive plan can be designed, that includes short-term actions and long-term options. The plan is monitored for signals that indicate when the next step of a pathway should be implemented or whether reassessment of the plan is needed.

Adaptive pathways have been applied in real-world decision settings based on multiple scenarios and mainly for large, engineered infrastructure projects that manage floods, droughts and sea-level rise, such as for the Rhine delta, for the Thames

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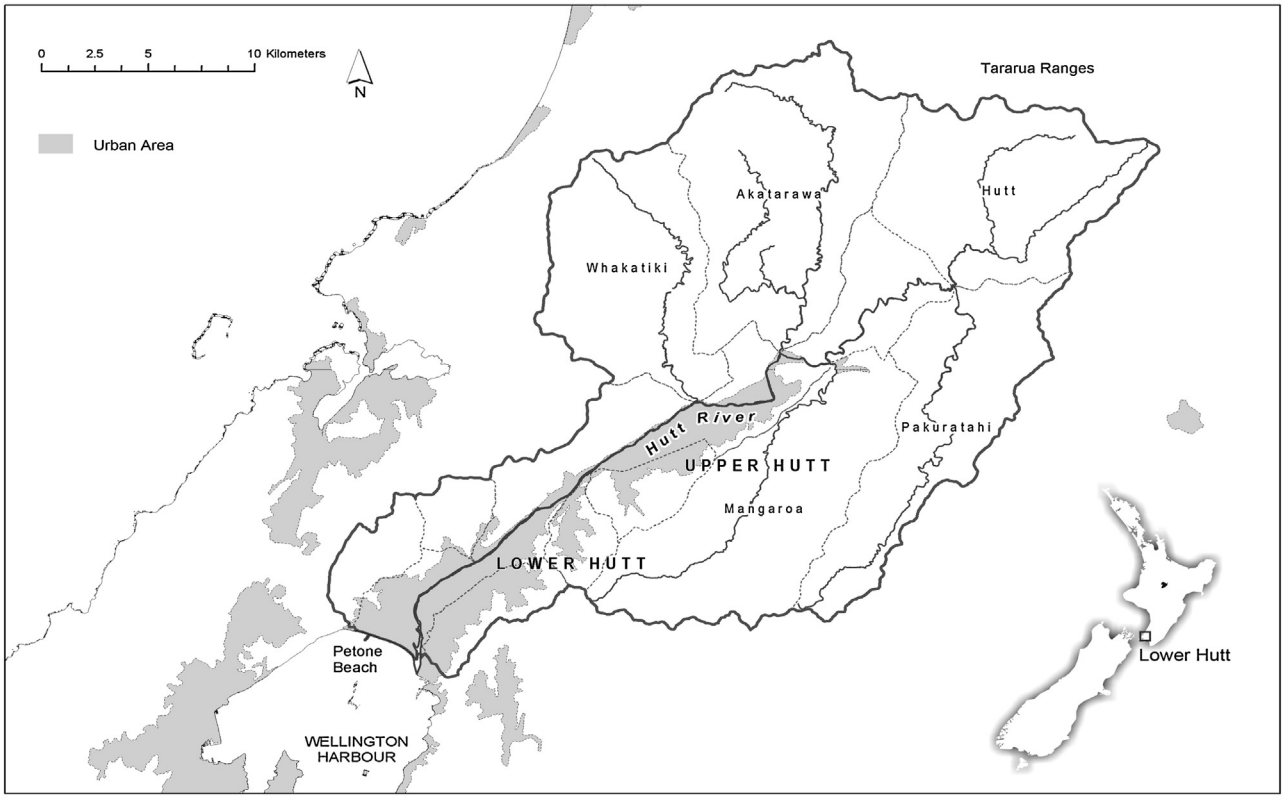

Fig. 1. Location of Hutt City in the Hutt catchment and New Zealand.

estuary and river catchment (Haasnoot et al., 2013; Ranger et al., 2013). These are at national scales with ready access to resources. Whether such pathways applications are applicable at other scales, institutional settings, cultures and resource scarce areas, is not yet fully tested. Where local government has no clear mandate for action and adaptation requires greater community consensus to implement adaptive approaches, such approaches hold promise, as shown by Barnett et al. (2014) in a coastal setting in south-eastern Australia where a locally focused and socially relevant adaptation pathway was developed. However, there are few examples of such pathways having been *implemented* within sub-national decision settings. Moreover, there exists no examination of what it takes to implement adaptation pathways in practice.

New approaches for adaptive planning are not just taken up by being made available to decision makers, additional measures are needed to catalyse the uptake of adaptive planning. Institutionalising adaptive planning requires well-tuned processes that address preferences and values of current, and those representing future generations (Haasnoot et al., 2011; Offermans et al., 2011). Also, complementary measures will be required to address societal change that has long lead times (Park et al., 2012). Campos et al. (2016) suggested that good communication of climate change risk is needed, to make climate change adaptation decisions. The following complementary measures for the adoption of adaptive pathways planning are suggested in the literature (Rosenzweig et al., 2011; Schenk and Susskind, 2015; Van der Brugge and Roosjen, 2015):

1. Public sector actors from multiple governance levels and the private sector
2. 'Buy-in from the top'
3. A coordinating agent
4. Regular interaction between scientists and stakeholders and
5. Uncertainty communication

Creating interactions between scientists and stakeholders, communicating uncertainty and coordinating within agencies to get 'buy-in from the top' for 'testing' adaptive planning approaches, suggested to us that 'serious games' had a part to play alongside knowledge broking. Serious games have been used to understand the interplay between human activities and water management decisions, for some time. More recently their use has focused on (social) learning about uncertainty, training water managers, increasing cooperative behaviour where there is high complexity, where actors are diverse and where values drive different perspectives on climate change (Harteveld, 2012; Hoekstra, 2012; Schenk and Susskind, 2015; Valkering et al., 2012; Van der Wal et al., 2016; Van Pelt et al., 2015). Games can also address the social and political conditions that create decision-making challenges in uncertain and changing conditions (Wise et al., 2014). We therefore turned to a potential priming tool, a simulation game, for gauging its effect on the adoption of DAPP and what is required to support the tool. The simulation game used is called 'Sustainable Delta Game' (adapted from Valkering et al. (2012) and described in the Appendix A) and a knowledge broker[1] (from the New Zealand Climate Change Research Institute (NZCCRI)) applied it in a local context in New Zealand.

In this paper we describe how simulation games, and knowledge broking, bridging science and practice, can, a) lead to changes in the practice of implementing adaptation at a local scale (Pelling, 2011), where facilitation, and otherwise unavailable new knowledge frames, can be introduced, and can, b) play a catalysing role in developing adaptive pathways, evaluating them and developing an adaptive plan, within current decision-making processes. We sought to 'test' whether by experiencing decision

[1] Knowledge broker is defined in this paper to mean people or organisations who move knowledge around and create connections between researchers and users of knowledge, creating new types of knowledge for particular audiences.

Table 1
Adaptive planning challenges: How the Game and knowledge broker address the challenges.

Challenges to adaptive planning	The Game	Knowledge broker
Decision making under uncertainty	Participants need to make decisions on water management while not knowing how the future will unfold. The game raises awareness about path-dependency of decisions- some actions close off later options as they become locked in e.g. city infrastructure in low-lying coastal areas exposed to sea level rise.	Framing of climate change risks to emphasise how uncertainty and consequences matters e.g. a moving mean increases the consequences at the tail of the distribution; increased frequency and magnitude of rainfall; use of scenarios across a range.
Understanding and acknowledging different types of uncertainty	Climate variability and climate change are included in the time-series (transient scenarios that underpin the Game). Newspapers address socio-economic developments. Multiple scenarios are discussed. Two or three teams with different values decide – after negotiation – on what actions to take. Some actions have high path-dependency. Actions can only be implemented in case of social support. Some actions are uncertain in their efficacy.	Communicating now future risks cannot be predicted where deep uncertainty exists. Communicating how socio-economic change will influence exposure to climate change risks. Introducing hitherto inaccessible new knowledge to participants.
Making robust and adaptive decisions that can cope with uncertainties about the future	During the course of the Game players receive simulated feedback on whether they are meeting objectives • 'Newspapers' on socio-economic development are circulated during the Game to simulate uncertainty and change • Change of values/social support from citizens is scripted based on what is happening in response to policy actions	Demonstrating, by being embedded in the DAPP assessment and decision process, how a range of options can be presented as adaptive pathways to influence the choices subsequently taken by the politicians.
Explaining the need/benefit for a more dynamic approach to decision making under conditions of uncertainty and change	The debrief after the Game reveals what was experienced during the Game and how participants can apply the experience and the thinking to assessing changing risk profiles in their real-life decisions that have uncertainty and change.	Facilitating discussion after the Games about the game experience and through demonstration in the DAPP assessment and decision process.
Shifting planning practice from static to dynamic approaches.	Experiential learning occurs during the Game. Debrief after the Game discusses how a shift from static to dynamic planning can be given effect.	The framing of the climate change risks
Implementation of an adaptive plan	Involvement of the elected politicians in Game sessions and briefings about the DAPP embedded adaptive thinking which influenced the pathways chosen	Uptake of the DAPP in an adaptive plan.
Contestation amongst affected interests	The Game can be used in community settings to create experiential learning about how uncertainty can be addressed and legitimate decisions made, in advance of damaging impacts, thus enabling different values to be addressed and greater understanding fostered	Advice on the communications strategy for the community consultation on options.

making under conditions of uncertainty in the 'safe' test environment of a simulation game supported by new knowledge and facilitated by a knowledge broker, adaptive pathways planning for climate change adaptation can be adopted in decision-making processes.

Using a timeline of interventions we show how the problem was framed to create interest in adaptive planning, how awareness was increased using the Game and DAPP in the 'test' environment of a real-life decision setting, and how adaptive planning was adopted. We discuss the role of the Game and a knowledge broker in catalysing the uptake of adaptive planning. Finally, we identify enabling requirements necessary for embedding adaptive planning into decision-making practice for addressing uncertainty and change.

2. Methodology

The study location started across three local governments, Greater Wellington Regional Council, Tasman and Nelson district councils, and the Ministry for the Environment at central government, as the Game and DAPP were being socialized and tested for their utility and then subsequently tailored for the New Zealand context. A local government flood risk management decision setting in New Zealand (see Fig. 1) was chosen as a learning 'experiment' for 'testing' DAPP in a real-life decision setting and understanding how its adoption was catalysed.

The research was undertaken over four years. We began by creating interest through framing presentations by the knowledge broker to GWRC and Hutt city advisors and elected decision makers on uncertainty and dynamic change and how climate change affects flood frequency. Discussions of the implications of the effects followed. Next, we further raised awareness using the Game by giving participants the experience of making decisions under conditions of uncertainty in a 'safe' simulated setting. Table 1 summarises some of the principle challenges for adaptive decision making and how the Game can address them. In the Game, a group of participants in several teams develop a sustainable water management plan for a stylised river (Haasnoot et al., 2012) by setting a vision, choosing policy actions and negotiating these actions with other teams. As the future unfolds over 100 years, participants experience what happens in the river and its catchment and adapt their plan, if needed, from simulated feedback on their decision choices, at four time points. A storyline of a possible future, including an adaptation pathway, develops. Reflection follows at the conclusion to the game, on the session storyline that developed, how the selected policy actions dealt with the challenges and uncertainties faced, and how these could have been improved; ending with a discussion of how the game experience and DAPP could inform real-life decisions.

The Game was used in four workshops in the greater Wellington region and the Tasman and Nelson districts with engineers, planners and elected politicians, to 'test' its utility for increasing understanding of changing climate risk. For the third and fourth game sessions, a tailored version of the Game for New Zealand settings was used. The 'debrief' sessions, were taped, transcribed and evaluated for; the effect of the Game on decision behaviour during the game, the net effect after the Game and its utility for use with DAPP for decision making in different domains. Participants

provided qualitative feedback on a set of questions (Appendix A) following reflection on the Game. Representative quotes from a range of participants in the game sessions are used to illustrate the effect of the Game on participants' understanding of the climate change problem and what enabled DAPP to be used in the first instance, further in a real-life decision settings, and subsequently adopted across the GWRC and more generally in New Zealand.

Inspired by the Game sessions and presentations, GWRC agreed to embed a knowledge broker in a decision process to develop with them an adaptive flood management plan for a reach of the Hutt River, using DAPP.

The motivation for this was that flood risk management and land use planning have generally adopted 'static' responses in the face of escalating risk and the realisation that the ability to adapt to changing risk will be compromised in the future because of lock-in of development at exposed locations created by past decisions. This legacy effect is difficult to shift towards adaptive practice (Lawrence et al., 2013b; Manning et al., 2015) because climate change risks are not well understood, the actors have different values, and electoral success drivers and entrenched professional practices, dominate (Lawrence et al., 2013b). Initiatives to implement adaptation mandates, have in a number of high profile cases met with contestation from private land owning interests to the identification of climate change risks and their codification in a land use plans (Allan and Fowler, 2014).

Options and pathways were identified and evaluated using the DAPP process, and real options analysis to test the different pathways for sensitivity to climate change scenario, discount rate, decision review dates and costs and losses. From this, an adaptation pathways map was drawn, and the relative costs and side effects of each pathway identified qualitatively. Two parallel tracks were used to develop the adaptation pathways; 1) technical sessions with the flood managers and project advisors; and 2) workshops with the politicians making decisions between options and pathways. Observations made at these meetings, newspaper clips from council publicity about the review of the flood scheme, and project reports were used for drawing conclusions about the uptake of the DAPP approach. A timeline of interventions (Fig. 2) illustrates the steps in the study process and contextual influences.

3. Findings: a timeline of interventions

Fig. 2 shows a timeline of interventions and the contextual influences. We identified four phases that are further described below: creating interest in the DAPP approach, increasing awareness of adaptive planning with the Game, experimenting with the DAPP, and the uptake of the DAPP approach.

3.1. Creating interest in adaptive policy pathways approach (2011–2013)

The primary mandate for climate change adaptation in New Zealand is through a 2004 amendment to the Resource Management Act 1991 (RMA) which requires those making decisions under the statute, "to have particular regard to the effects of climate change" (RMA s7(i)). This is supported by national guidance on flooding and coastal hazard risk management, and the New Zealand Coastal Policy Statement which makes specific mention of climate change effects. Catastrophic earthquakes in the Canterbury region in 2011 and 2012 sensitised all levels of government to address natural hazards more seriously, including floods and sea level rise. This was reflected in a legislation change in 2014 introducing 30 year infrastructure strategies and in 2015, a proposal for natural hazards to become a matter of national importance in the RMA.

In 2011, the NZCCRI developed risk-based framings of climate change impacts (Lawrence and Manning, 2012) which emphasized the significance for decision making of considering the effect of risk consequences and uncertainty on changing flood frequency with climate change. Research was undertaken on how changing risk can be accommodated through the use of dynamic adaptive planning approaches (this study). Examples of risk-based framings were presented and discussed with local government planners, engineers and asset managers in Wellington, Tasman and Nelson

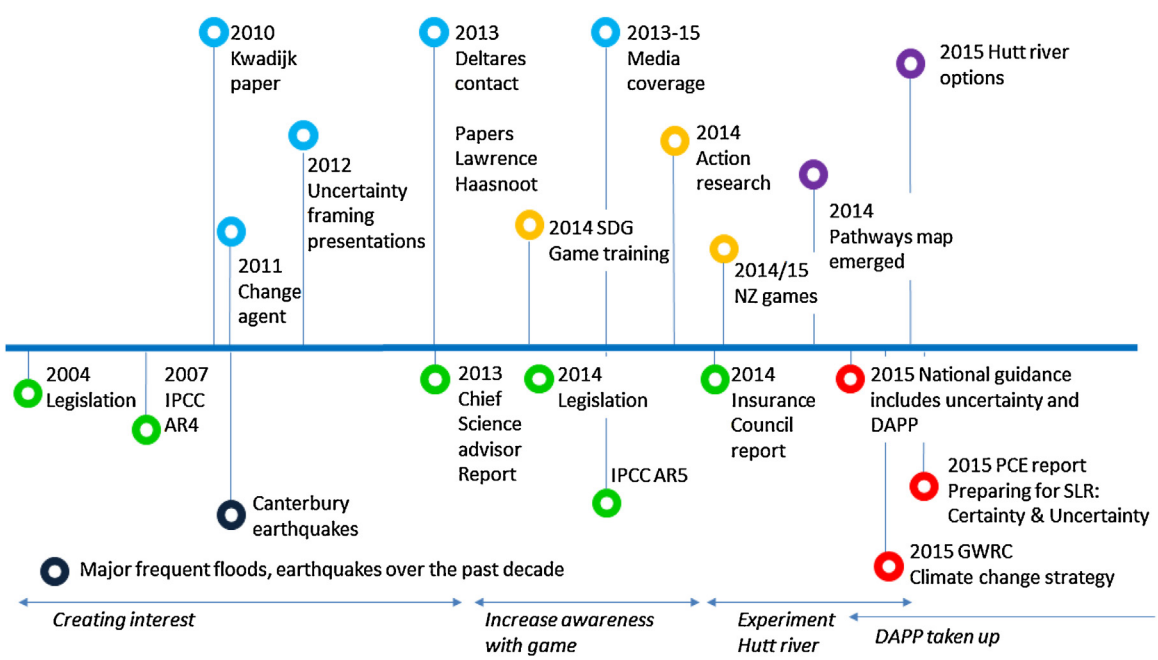

Fig. 2. Timeline of interventions. Blue = Creating interest, Yellow = Increasing awareness, Purple = Experiment Hutt river, Red = DAPP uptake, Dark Blue = Major hazards, Green = context.

Fig. 3. Photos of game sessions.

regions (bottom of the north and top of the south islands of New Zealand). The learning from applications of adaptive planning approaches in the Netherlands (Haasnoot et al., 2012, 2013) and the Thames catchment (Ranger et al., 2013; Reeder and Ranger, 2010), and from IPCC reports (IPCC, 2014; Reisinger et al., 2014), were used in briefings and presentations.

During 2012 and 2013 practitioners and politicians were interviewed on the barriers and enablers for making robust and flexible decisions under conditions of uncertainty and change (Lawrence and Manning, 2012). This body of work (Lawrence et al., 2013a, 2013b) was made available to the GWRC as part of a developing interest in using the Game and the DAPP approach in its decision making.

Reports by the Prime Minister's Chief Scientist (Gluckman, 2013) and the Insurance Council (Insurance Council of New Zealand, 2014) reinforced climate change risk management approaches in conditions of uncertainty, providing a more supportive context for the application of DAPP.

3.2. Increasing awareness with the Game (2014–2015)

In the second phase, the Game was used as a learning opportunity to raise awareness and understanding of decision making under uncertain conditions (Fig. 3). Several 'training' sessions, with the flood, coastal and strategic planners, were held with the Dutch developers of the Game. This increased understanding of the Game and how it could be used with the DAPP. Interest was such that councils wanted the Game tailored for New Zealand decision settings, which were used subsequently, with a unitary council (Tasman District Council which has both regional and district functions), a district council (Wellington City Council), and a central government agency (Ministry for the Environment). This enabled different governance levels and functions to participate, thus increasing awareness of the value of the Game and the DAPP approach.

Participants became aware that their short-term decisions were based on a perceptions that adaptation actions (typically protective structures), are too costly. "*We make short term decisions [the Game] started like real life. Actions were perceived as too expensive and uncertain.*" [Hydrologist] Initially, low cost actions, like evacuation training, were taken within the bounds of the status quo. Feedback from the simulation about 'actual' cost of flood damages and casualties, how the climate conditions varied and affected the outcome of the response options, led the players to change their decision focus. "*We took low cost options to see what would happen. It took feedback to hone the choices from reactive to proactive.*" [Elected councillor] Participants became more proactive and considered the long-term effect of their decisions by anticipating and adjusting the response options. "*This game showed we can make long-term decisions by anticipating and adjusting.*"[Planner]

Negotiations with the other teams enabled a pathway to be charted that had fewer side-effects. "*Working in a team demonstrated that experts from different fields with their experience and knowledge could find solutions for different situations in a very short period of time. We got better results through negotiation with the other groups. Wrong assumptions could be identified.*" [Elected councillor]

Experiencing uncertainty and the need to change through time, brought understanding that a change of course could result with less disruption and at lower cost. "*We experienced uncertainty and could chart a pathway. First decision is very important. It gets costly to change direction, but it is possible. Post negotiation we found ourselves having to undo some of the work/cost already completed at great expense.*" [Flood risk manager]

3.3. Experiment with adaptive approach in Hutt River (2014–2015)

The next phase was an experiment with the DAPP approach. Using the Game with the GWRC heightened the understanding of the Hutt River City Centre Upgrade (flood protection) project team, of how an adaptive response to uncertainty in a river catchment could be managed over 100 years as flood frequency changed. The knowledge broker worked with GWRC staff to identify options, evaluate them and develop an adaptive pathways map using the DAPP approach. The aim was to upgrade the existing flood defence system to 1:440 years and maintain that level ('level of service' (LoS)) over at least 100 years (the objective). The discharge related to the 440 year standard increasing over time as a result of climate change, with a greater change in the higher emission scenarios. As a result, if the existing system was upgraded only to the current 440 year standard of 2300 cumecs, it would fail to provide the required LoS over 100 years and further actions would be required. The efficacy of five options were evaluated for their ability to maintain the protection level over 100 years, using three climate change scenarios, for meeting development/transport/recreation objectives, the effect of land use planning measures, and comparative costs of staged implementation of options. Each option consisted of a portfolio of measures, and for each portfolio the 'adaptation tipping point' conditions were assessed in terms of the discharge it could accommodate. Three options were taken forward for further evaluation using the DAPP. Fig. 4 shows the pathways map. Similar to a metro map, the Adaptation Pathways map shows alternative routes to get to a desired point in the future. All routes presented satisfy the minimum performance level in terms of the 1:440 protection level. For example, it is possible to first implement a 70 m river channel with a lower level of protection and delay property purchase (Option 4). This option reaches a tipping point if the 1:440 discharge is 2300 m3/s. Depending on the scenario this can occur in 2040–2050. After this tipping point, the river channel can be extended to 90 m possibly with a 25 m berm (option 2c; pathway 5 in the scorecard), or with a

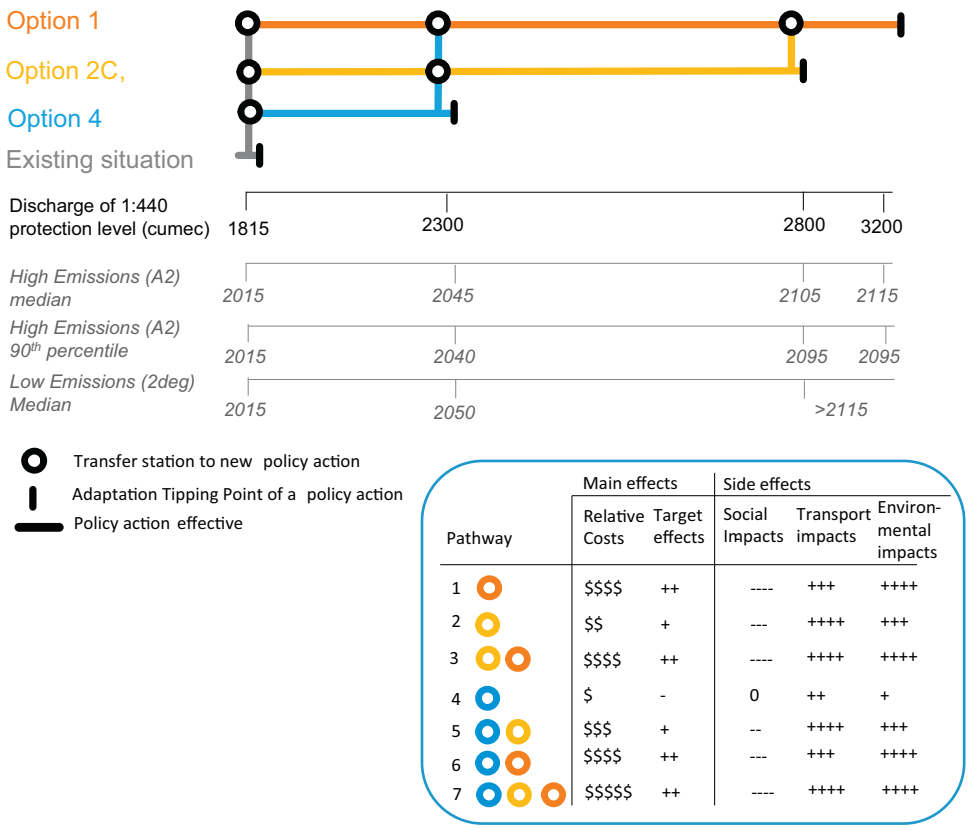

Fig. 4. Hutt River City Centre Upgrade Project: adaptation pathways map showing options, scenarios, decision moments, relative costs of options and potential side effects requiring consideration. Relative impacts are indicated with – and ++; – is negative impact and + positive impact. All pathways except pathway 5 have negative social impacts as land has to be purchased. The map is generated by the Pathways Generator (http://pathways.deltares.nl/) based on (Greater Wellington Regional Council, 2015).

Table 2
Pathway options and their costs.

Option	Description	Cost	Total discounted costs + loss figures[2]
Option 1	A 90 m river channel and 50 m berm; right and left stopbanks meets the standard over 100 years in all scenarios	$267m	$270
Option 2C	A 90 m river channel 25 m berm; properties to be purchased	$143m	$154
Option 4	70 m river channel; 30 years of flood protection; lower level of protection (2300 cumecs); properties purchased after 20 years	$114 m until 2035	$202
Staged Option 4 to 2C		Additional $68 m = $182m	$185

50 m berm (option 1, pathway 6). The Fig. 4 qualitative scorecard shows that Pathways 1, 3, 6, and 7 exhibit the best target effect. Option 4 starts to perform unacceptably (not reaching the 1:440 year objective) after 40–50 years and thus requires a staged decision to move to Option 2C; Option 2C by itself reaches the target by 2095–2105, and only Option 1 will enable the target to be met going beyond 100 years. A description of the options and their costs is shown in Table 2.

During 2015, GWRC also undertook an economic analysis of the pathways developed, based on real options analysis. The value was examined of pursuing flood protection options that are flexible, rather than adopting a single solution that cannot be adapted to deal with changing and unpredictable external conditions, like the effect of climate change on peak river flows (Greater Wellington Regional Council, 2015). The results showed that a flexible investment strategy that enables a change of course in the future was more likely to deliver a lower cost outcome, than pursuing a single option, unless the probability of a climate change-induced increase in flood frequency and its associated economic loss is almost certain.

Two IPCC assessment reports published during the course of the research also highlighted the value of adaptive pathways planning for addressing uncertainty and changing risk profiles (IPCC, 2014). These provided legitimacy for adaptive planning and thus

[2] The total discounted costs plus loss figures takes into account the statistically expected loss from a flood event that breaches the stopbanks. While the pathway 4-2C looks costlier than proceeding with 2C directly, there is a chance that Option 2C does not have to be pursued. In fact, the cut-off probability is 48%. Ie, if the probability of a Scenario A2-50% climate change flood is perceived to be greater than 48%, Option 2C should be pursued straight away. Without the option of delay, the cut-of probability is only 16%. Thus the flexibility of delay results in a more conservative investment strategy.

Box 1. Greater Wellington Regional Council Climate Change Strategy and Implementation Plan 2015

"GWRC commits to an approach that enables us to make decisions in the face of uncertainty."

Adaptation policy includes;
"Consider the effects of climate change as an integral part of planning and decision-making.

Increase long-term adaptive capacity through the use of adaptive planning tools and techniques."
Implementation plan includes;
"Use adaptive planning concepts to understand and evaluate the potential long-term consequences of different policy actions using Sustainable Delta Game workshops which are underway."

reinforced the council's desire to change how it assessed and made decisions about flood risk management.

3.4. The uptake of the DAPP approach (2015-)

In this phase, the interest in DAPP developed, became ongoing, and was taken up in policy and practice. For example, in addition to its use in options appraisal for the Hutt river project, it was included in the GWRC Climate Change Strategy and Implementation Plan (October 2015) (see Box 1); an adaptive pathways planning approach was included in the revised Ministry for the Environment Coastal Hazards and Climate Change Guidelines for local government; and DAPP was suggested by an expert advisor (Bell, 2015) as an approach for inclusion in the Auckland Unitary Plan for assessing options that can address changing risk profiles from sea level rise. The need for more adaptive approaches for managing uncertainty in sea level rise risks over time, was highlighted Parliamentary Commissioner for the Environment (2015).

The GWRC has subsequently 'played' the Game in other flood risk management settings in a different part of its region, with advisors, politicians and community members, and helped disseminate the Game and DAPP approach through professional discipline groups. The value of the Game, as a primer for decision makers to learn how to address uncertainty and dynamic climate change, is starting to become embedded in practice. Further opportunities for its uptake nationally will follow implementation of the revised Coastal Hazard and Climate Change guidance, and further development of the DAPP is beginning through the Resilience National Science Challenge[3] is beginning. To date, the Game has provided critical leverage for shifting entrenched static risk assessment and analysis practice amongst professional groups and consultants, and opening up the use of DAPP in real-life decision settings.[4]

Furthermore, uptake by other agencies has been observed. For example, during 2014 and 2015 the Wellington City Council and GWRC set up a network of council staff, to share learning about climate change adaptation, including DAPP applications, extending to other city councils, the Local Government Association of New Zealand, university and other research organisations. The Game, the DAPP and a pathways generator[5] have received publicity across policy and practice domains for their value as catalysts for learning to make adaptive decisions.

4. Discussion: what it took to catalyse uptake of dynamic adaptive pathways planning

We discuss the role of the game and the knowledge broker in catalysing the use of DAPP. This discussion of the findings is based on observations at Game sessions, participant feedback at debrief sessions and interviews of participants.

4.1. Role of the Game

The Game enabled learning that created a space for changed practice. The game sessions resulted in the three types of learning described by Baird et al. (2014).

a) Acquiring new knowledge or restructuring existing knowledge (cognitive learning).

Use of the game in combination with the uncertainty framings, triggered a change in how future risk was perceived by flood managers; from static to dynamic representation of risk. A regional council manager explained the shift this way;

"The depiction of changed probability and damage using a risk based approach- hadn't thought about it that way before. A good way of describing the impacts. And can use this [DAPP] to identify range and timing and lead time and stages for action." [Flood risk manager]

This created the setting for adoption of the DAPP in the Hutt 'experiment', and subsequently in other projects. By reframing the 'problem', we also observed a shift towards a wider range of options being considered, including adaptive land use planning measures and land use controls to accommodate and/or avoid flood risk, the timeframe and timing of the different response decisions, the need for continuous consideration of changing climate risk and what might trigger the reset button. Such considerations were seen by participants as potentially useful for managing community expectations of continued protection and their perceptions of 'safety'. Furthermore, participants began to question their predominant reliance on flood warning, emergency management and static structural protection. As a result, both the short- and long-term consequences of decision choices were considered, as participants received the simulated feedback after each time slice in the Game.

These findings are consistent with Pahl-Wostl et al. (2010) who suggest that learning through experimentation can help move decision making from prediction and control, to adaptive processes that are better suited to addressing uncertainty and change. For example, by experimenting with new approaches to flood management, flood managers learned that the regulatory

[3] See http://www.mbie.govt.nz/info-services/science-innovation/national-science-challenges/key-documents.

[4] Currently the Resilience National Science Strategy Edge project is integrating the use of the DAPP into the Hawkes Bay Regional Councils' development of a Coastal Hazard Strategy 2120 with the community, to enable the effects of changing climate risk to be adequately represented. See http://www.hbcoast.co.nz/.

[5] The generator is software that enables pathways to be drawn using different scenarios. It can be accessed at http://pathways.deltares.nl/.

environment within which they operate can create barriers to adaptive planning (Lawrence et al., 2013b).

b) Changing practice norms leading to convergence of group approaches to decision making (normative learning).

Understanding what it takes to make decisions in uncertain conditions converged in the interactions within the Game teams and between teams in negotiations. The negotiations conducted in the Game stretched participants 'experience' over a longer timeframe with 'real' feedback. It was observed that they could come to an agreed decision through negotiation. This was reported as building confidence to make decisions in uncertain conditions, and for communicating that adaptive decisions can be made ahead of climate change impacts occurring. In the debrief sessions, participants were able to reflect on how the Game experience could influence their real-life decision experience and be used with the community for exploring and implementing water management options.

The Game stimulated discussion amongst the participants about using the game to experiment with options based on different planning time horizons across different council functional domains and the impact of a portfolio of options on future outcomes. One of the participants said: *"Incredibly useful for having those conversations about where to invest and what to do about it once it's here. The Game gives an experience of thinking in this long term way."* [District council asset manager] Another reflected:

> *"Climate change is something that's deeply uncertain that we all recognize, but there are also a lot of other things that we find convenient to consider as certainties rather than uncertainties, like economic growth, population growth, transport, biodiversity that are dynamically changing, that could actually be fed into an adaptive planning approach*". [Regional council strategic planner]

After the Game, the GWRC flood managers championed the DAPP for use in other projects (See Box 1), and for capability building.

These findings are supported by research in behavioural psychology, which suggests that the closer the actual experience of a risk or process to the participants reality or timeframe (Weber, 2006, 2010), makes it more likely that the risk will be addressed (Evans et al., 2014).

c) Improving understanding of the views of others and greater cooperation (relational learning). Participants reported that they learned to listen to different viewpoints based on different visions for the future in a Game setting and could see how the Game could be used for encouraging greater cooperation at a political level.

> *"The diversity of views and bottom-lines discussed in the negotiations could be drawn out in negotiations using the Game to reduce the dysfunctional relationships between councils. Using the Game like this with the politicians would be a useful exercise for them". [River engineer]*

Where consistent leadership was observed in the negotiations, this built legitimacy with the other teams and led to stronger learning outcomes observed and reported by the participants. One respondent reflected:

> *"My feeling is that none of them* [individual teams] *would do as well as the negotiation by the team captains. I thought that was really effective and a really critical part of the whole thing. I don't think we would have had anywhere near as good a result without the inter-team negotiations."* [Regional council engineer]

These findings are consistent with those of Runmore et al. (2016) with respect to enhancing collaborative capacity, fostering social learning and developing adaptation literacy amongst the participants studied. The Game was not used with the community due to the constraints of the particular decision setting.

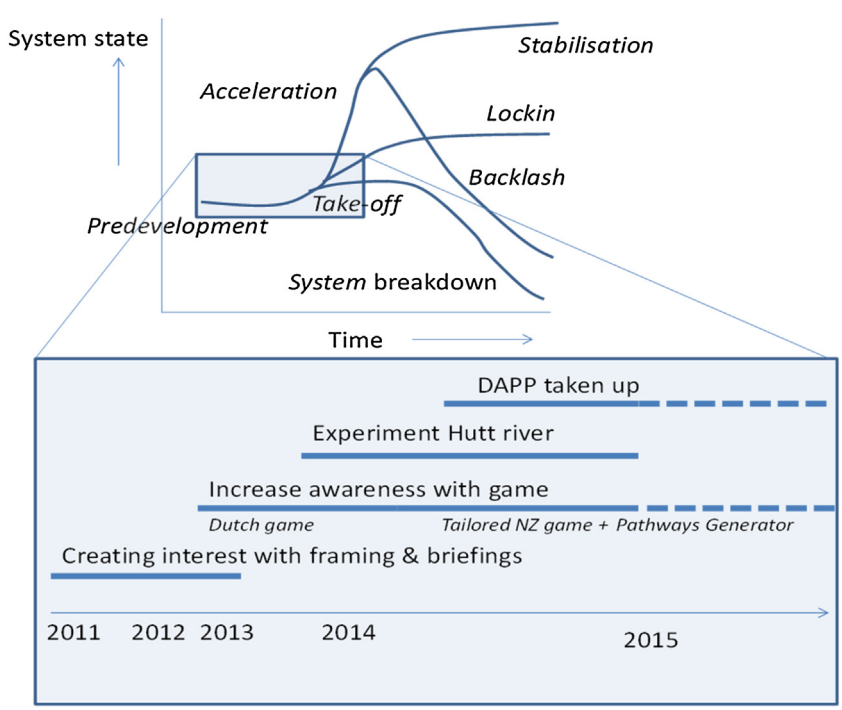

Fig. 5. Possible pathways towards a desired situation (upper part; Adapted from (Van der Brugge and Rotmans, 2007), in relation to the 4 different phases of adoption of dynamic adaptive pathways planning observed in the New Zealand case, which appears to be on in the Take-off phase towards Stabilisation, but could also end up in Backlash or Lock-in pathways.

4.2. The role of a knowledge broker

The knowledge broker played several roles, starting with translating knowledge from a range of sources (Fig. 2) into framings that conveyed the uncertainties and changing characteristics of the risks and their consequences, facilitating learning at the Game sessions and introducing the DAPP approach into a decision process—a catalytic and continuity role 'joining the dots' inside and outside the council. Participants reflected on the role of the knowledge broker. "*A knowledge broker can 'signal' changes in knowledge that can shape the perceptions of the science.*" [Local government river engineer]. The initial framing of the science was pivotal in exciting interest in addressing climate change uncertainty in flood risk management decisions. Subsequently, an entry point was created for the use of the Game and DAPP in a decision setting, when the GWRC managers were seeking a capability shift by staff, in the knowledge that climate change potentially impacted their design parameters for flood risk management.

By being able to present the DAPP approach to a GWRC joint council committee prior to the consideration of options for the flood scheme project, the knowledge broker was able to increase the understanding of the politicians about the effects of climate change on flood frequency. This led to a range of options and their consequences being considered over a 100 year timeframe (Greater Wellington Regional Council, 2015). The Game session 'experience' of the politicians, prior to the actual decisions on options being made, provided further learning, to which they referred during the committee debate on the options. Meanwhile, the 'virtual training' with the developers of the Game (Fig. 2), helped familiarize council staff with the Game and with the DAPP approach, prior to its use in the real-life decision context. The economic analysis of a number of 'pathways' also arose from the interest and understanding that developed, and facilitated council committee decision making on the options on which it wished to consult. These outcomes were observed by the knowledge broker during the course of the research.

The effect of an external knowledge broker, working within a council decision process, catalysed capability building and interest by senior managers in the GWRC. This gave tacit mandate for use of the DAPP approach and opportunities for staff to work across council functions, facilitating Game sessions and capability-building in the flood management and other domains within the council (see Box 1). The sub-committee Chair, played a leadership role with councillors by supporting the process. This combination of external and internal 'change' agents and leadership, facilitated new knowledge being embedded within the advice to council.

4.3. Adoption of adaptive practice

The degree to which new knowledge can be taken up and sustained in real-life decision settings will depend on reinforcement by further relational learning, and on codification of practice to provide a clear mandate for adopting the DAPP approach in current decision-making processes. This was manifest in the observed reliance by participants on legitimate sources of knowledge (e.g. IPCC) and through its inclusion in National Guidance for their exercise of statutory planning functions and powers (Lawrence, 2015).

Van der Brugge et al. (2005), in a technology context, suggest that several elements need to be in place for uptake of new knowledge; be able to leverage change from short to long time horizons, from fragmented to an integrated approach at multi-scales, with multiple actors and domains, and from linear knowledge-building to 'learning-by-doing and doing-by-learning'. In this study these elements were observed. In this research, uptake of new knowledge occurred, shifting the decision-making focus from the short term to decisions that were robust and flexible over at least 100 years. A more integrated approach across governance scales developed between the GWRC and the Hutt City Council and the DAPP was integrated into the regional climate change strategy. A shift from linear knowledge building to a learning style based on doing adaptive planning using the DAPP and sharing the learning across agencies was achieved. These shifts represent a transition which, based on the findings of this research, appears to be on Fig. 5 Take-off phase, accelerating towards Stabilisation, but could also end up in Backlash or Lock-in pathways (not accelerating) which could destabilise uptake. This was confirmed by participants in the research.

5. Conclusions

The use of the Game and DAPP is shown in the timeline of interventions (Fig. 2) and by illustrative quotes from participants. The shift to using a dynamic adaptive pathways planning approach was primed by the use of the Game, supported by the role of the knowledge broker, reinforced by regular interaction between scientists and participants, and through the use of uncertainty communication. The game stimulated the process of social learning as described by Baird et al. (2014) and Van der Wal et al. (2016) and catalysed the uptake of DAPP. The contextual matters shown in Fig. 2 provided a backdrop that helped enable the adoption of a new approach for planning where there is uncertainty and changing climate risk profiles.

The learning process enabled the politicians to integrate DAPP into a real-life decision setting and use it elsewhere in the region and in other domains. This in turn, triggered DAPP applications across multiple levels of government, including applications in other river catchments and coastal areas and inclusion in national guidance to local government and garnered support for further development of tailored games for New Zealand and their application elsewhere. While this research has started a transition to adoption of DAPP there still exist factors that could destabilise on-going adoption e.g. ability to sustain capability building in the use of DAPP and the enablers critical to the adoption of DAPP reported by Rosenzweig et al. (2011), Schenk and Susskind (2015), Van der Brugge and Roosjen (2015). The role of the Game was enabled by the availability of usable research and appropriate tools for the problem and recent events showing uncertainty in our knowledge and the vulnerability of the system to climate. The role of the knowledge broker was enabled by champions and coordinating agents within the decision-making organisations, use of networks across practitioner and political spheres of experience and influence. Context factors affecting the ability of DAPP to 'take off', include the adequacy of the institutional frameworks, planning and protection measures, and socio-political pressures. These will require further testing under different decision settings and institutional traditions and through comparative studies.

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Appendix A. Game process

The *Sustainable Delta Game* (http://deltagame.deltares.nl) developed in the Netherlands simulates a decision setting in a river catchment that helps participants to learn about preparing water management for an uncertain future. It has been played by water managers, scientists, students and diplomats in several developed and developing countries. In the game, a group of participants in several teams develop a sustainable water management plan for a river by setting a vision, choosing policy actions, negotiating these policy actions with other teams and having them simulated at several time points over 100 years. As the future unfolds, the participants experience what happens in the river and its catchment. Was there a flood or a drought event? What is the opinion of community? How do socio-economic conditions change? What happens upstream? Do the water policies need to be adapted? With simulations based on environmental models (Haasnoot et al., 2011) and transient scenarios (Haasnoot et al., 2015), participants get direct feedback on their policy actions. In addition, negative impacts of floods and droughts, support of inhabitants, economic growth and impacts on nature need to be taken into account when deciding on responses for inclusion in the adaptive water management plan. Several scripts for game sessions are available. Each script includes a climate change scenario, context, relevant newspapers, and citizen perspective for different situations. Fig. A1 displays an example of such a script: the river inflows, newspapers and the different time periods that are played in each round.

The simulation model (for details, see Haasnoot et al. (2012) is implemented in PCRaster (Van Deursen, 1995) and describes the cause-effect relations within the water system based on results of more complex hydrological and impact models previously applied on the Rhine delta. The model was checked for internal consistency and plausibility of the outcomes by expert judgment. The effects of different transient climate change scenarios (Haasnoot et al., 2015) are considered through changes in river discharge that cover typically flood and drought situations. For the New Zealand version of the game, the river inflows were scaled because rivers are much smaller compared to the Rhine River. The model then calculates the effects on river water levels, probability of levee failure, flood damage, agriculture and nature diversity. This model was adapted for New Zealand by removing the navigability modules and adding impacts and actions for agriculture.

After the Game, the participants and facilitator reflect on what happened during the simulation as the storyline developed and the adaptation pathway emerged. They discuss what triggered this pathway, how it can be improved, and what it could mean in practice using the following questions:

- Did you behave in a more reactive or proactive way?
- At what point in the Game did you experience a change in strategy?
- What arguments did you use to change?
- What was the role of negotiation?
- What did you learn from the game session?
- Other comments?

In this context, different possible futures are considered and the path-dependency, robustness and adaptivity of actions are discussed. The game primarily has learning objectives, but it can

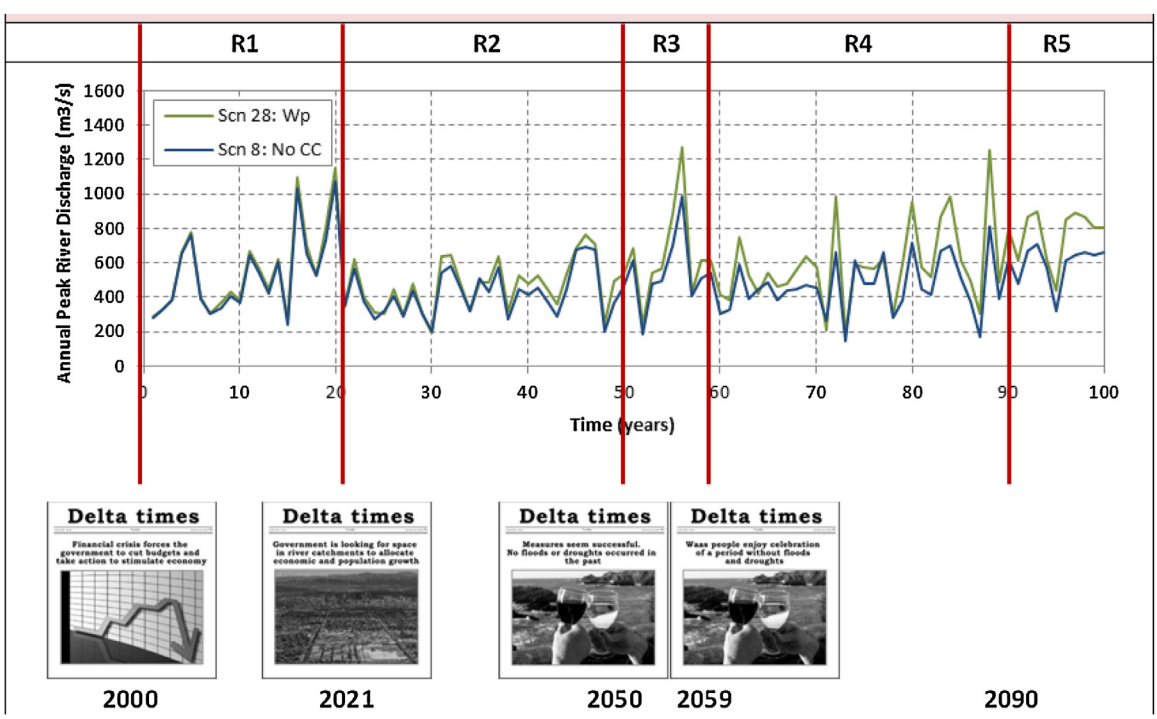

Fig. A1. Part of a script for a game session, showing the river inflow, the different rounds and newspapers.

change behaviour, which then influences how adaptive pathways are subsequently developed.

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