Climate change adaptation: is there a role for intervention research?

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Abstract: While climate change will expose regions to similar impacts, the extent of those impacts and effective response at the local level will be determined not only by the location's sensitivity and vulnerability but also by local groups and individuals' capacity, including their institutional links, social networks and motivation to action. In parallel, scientific information and research plays a critical role in informing climate change adaptation by providing both an improved understanding of the actual climate risks and response alternatives.

The paper focuses on two local-scale intervention research projects undertaken in urbanised coastal areas in Brazil and in Australia focused on improving the dialogue between 'those who make science' and 'those who use science to make decisions' in order to make climate science more useful, and creating purposeful collective action respectively. A conceptual model is devised to investigate how intervention research could aid adaptive capacity by generating new knowledge and facilitating change towards climate change adaptation at the local level. Drawing on the findings, a framework is proposed to advance the role of intervention research in policy development for enhancing adaptive capacity.

Key words: risk; climate science; coastal communities; adaptive capacity; collective action

1. Introduction

There is strong evidence that climate change is already happening and that we will need to adapt to its impacts [1, 2]. However, to date, countries worldwide have placed low efforts into adaptation, particularly in urban areas [3]. While there are many barriers to adaptation ranging from social through individual [4], climate science continues to be identified as a major hurdle for decision-making involving adaptation [5, 6]. In particular, there are calls for climate science to be more useful to decision-making to foster adaptation [2].

Furthermore, climate change impacts are expected to be spatially non-uniform across the world, indicating that cities and regions will need to adapt to climate change in different ways [7]. Accordingly, there is no uniformity in the adaptive capacity of individuals, groups within society, organisations and governments or how they can respond to current and future climate change impacts [8]. Adger [9] argues that social capital is central to adaptive capacity as it enables civil societies to both interact with market and government institutions systematically and adapt to climate change impacts. Additionally, Adger highlights that collective action involves networks and flows of information between individuals and groups that are crucial to social capital and greatly improve decision-making.

The previous paragraphs introduce two critical factors that can influence adaptive capacity related to climate change: (i) the need for making climate science more useful to decision-making; and (ii) the role of collective action in enhancing adaptive capacity. In this paper, we explore how intervention research can play a critical role in dealing with both factors, thus enhancing adaptive capacity. In particular, intervention research has gained momentum over the last decades amongst sciences which deal with collective action processes [10]. Widely used in the fields of human health [11, 12] and management research [10], it comprises a type of research which allows collaboration/interaction between actors and researchers to generate the means for collective action [13].

Specifically, intervention research has been defined by Midgley [14] as ‘purposeful action to create change’. Based on this definition, we draw on insights from our intervention research projects that were individually conducted and focused on the two factors that can influence adaptive capacity to climate change identified above. The first was a sub-project of a four-year study of the social and ecological dimensions of climate change on the north coast of São Paulo, Brazil (the Climate Project) and the second was a collaborative planning process involving the Cardwell community in the North Queensland coast of Australia (the Cardwell Project). The Climate Project aimed to set groundwork research on the environmental consequences of climate change along the coast of São Paulo, including the investigation of how solutions may require better understanding of local and regional government stakeholders’ knowledge, concerns and actions related to climate change. The Cardwell Project comprised an ongoing partnership established in the aftermath of category five tropical cyclone Yasi between key community stakeholders and university researchers, and involved the conceptualization, development and subsequent steps towards implementation of a strategic action plan for the community’s future, particularly to strengthen their capacity in dealing with recurrent natural hazards.

To this end, the paper is structured in three parts following this brief introduction. In the first part, based on a literature review, we propose a conceptual model to guide our investigation on how intervention research can aid adaptive capacity. We then apply this conceptual model to evaluate our above-mentioned research projects, particularly in terms of knowledge generation and facilitation of change. We conclude the paper by outlining a framework that can advance the role of intervention research in policy development for enhancing adaptive capacity.

2. Intervention research for climate change adaptation

Climate change adaptation is understood here as the ‘actual adjustments, or changes in decision environments, which might ultimately enhance resilience or reduce vulnerability to observed or expected changes in climate’ [15] p. 720. In

the introduction of this paper we identified two critical factors that influence climate change adaptation: (i) the need for making climate science more useful to decision-making; and (ii) the role of collective action in enhancing adaptive capacity. In this context, there is a strong role for intervention research in aiding climate change adaptation as it entails a purposeful action to generate improved change [14] besides being conducive to dealing with complex problems such as climate change [16]. Further, this role of intervention research is in alignment with recent approaches to adaptive capacity in resilience studies which consider adaptive capacity to be a property that facilitates transition or transformations to a new system state [17]. Nonetheless, there are also problems related to intervention research that need to be managed and overcome to ensure the effectiveness of its process. In particular, these include difficulties in achieving broader stakeholder participation and representation [18], issues associated with theory building [19], knowledge generation and legitimisation [20], and increased need for negotiation between stakeholders to define desired goals and changes or adaptation alternatives and pathways (see Table 1 for a summary of the merits and problems associated with intervention research when involving climate change adaptation).

[insert Table 1 near here]

One of the strengths of drawing on intervention research when addressing climate change is its potential to improving stakeholders' adaptive capacity, particularly because adaptive capacity is a practical issue that involves stakeholders' *ability to learn* and *ability to adapt* within their socio-ecological systems [27]. A conceptual model that illustrates how intervention research could improve adaptive capacity is shown on Figure 1.

[insert Figure 1 near here]

This conceptual model builds on the premise that intervention research is an approach that draws on elements of action research to address social problems [10, 21, 22]. While it is difficult to determine a typology of action research [11,

23], all forms of action research are based on the common ontological paradigm of participative reality, involve a bilateral relationship in which research and action inform each other, and contain a level of cyclic iteration [23]. As outlined in Table 1, these features of intervention research along with its potential for collaborative knowledge generation and application of knowledge are likely to have merit in aiding climate change adaptation because they could create opportunities for stakeholders to improve their *ability to learn* and *ability to adapt*.

However, these features of intervention research are not stand-alone; rather they comprise an interconnected process exemplary described by Avenier & Nourry [20]. First, the participative and interactive character of intervention research involves three main phases: negotiation, cross-fertilisation and mode of interaction [20]. The negotiation phase involves a fine-tuning of the two projects (i.e. the researchers' and the stakeholders' project) to align goals, cultures and contexts within which they exist. The cross-fertilisation phase enables the generation of a third project that is mutually beneficial to both researchers and stakeholders. The mode of interaction phase entails researchers to show commitment to stakeholders' project and sets a balance between 'observing to understand and act' and 'acting to observe and understand' *cf.* [20]. Hence, when applied to the climate change context, the participative and interactive character of intervention research could facilitate change in terms of shifting stakeholders' current state of adaptive capacity, which is determined by past and existing issues, trends and problems, towards a future state of adaptive capacity that ultimately leads to adaptation (see Figure 1).

Second, this shift is likely to be facilitated by the knowledge that is generated as part of the intervention research process. As outlined by Avenier & Nourry [20], three types of knowledge are likely to be produced as a result of the continuous interaction between researchers and stakeholders, including local knowledge, publishable knowledge and meta-knowledge. Local knowledge refers to answers (processes and results) required by stakeholders and their project. Publishable knowledge refers to knowledge produced by researchers in regards to their

research project. Meta-knowledge refers to overall knowledge about stakeholders or groups and organisations they represent. Our hypothesis is that it is through this knowledge generation process that stakeholders' could improve their *ability to adapt* and their *ability to learn* thus changing their current state of adaptive capacity (see Figure 1).

Following this hypothesis, we seek to answer three key questions based on the findings of our interventions. Firstly, Mastrandrea [2] argues that to enable the use of scientific information by decision-makers it is important to create mechanisms through which stakeholders and scientists work together from identifying the problem through proposing recommendations and strategies based on scientific information. Thus can the 'iterative' component [cf. 23] of intervention research assist in the generation of new knowledge and contribute to close a knowledge gap (improving the *ability to learn*) increasingly identified as a key barrier to adaptation given the ongoing evolution of climate science? Secondly, it is understood that there is no uniformity on how climate change will impact regions/places [7] or on the capacity of individuals, groups within society, organisations and governments to adjust to current and future impacts [8]. Consequently, can the production of local, publishable and meta-knowledge assist in improving our understanding of this diversity (improving the *ability to learn*)? Lastly, can those types of knowledge assist in identifying solutions that are tailored to the specificity of places and its communities and/or institutions (improving their *ability to adapt*)?

3. Research approach and context

Our research interventions were independently conducted from 2011 to early 2013 and involved stakeholders from urbanised coastal locations in Brazil and Australia (see Table 2 for key background information on both projects). Our projects adopted distinct qualitative mixed-methods approaches which are described below.

The Brazilian intervention, the Climate Project, aimed to investigate perceptions of risks associated with climate change and adaptation strategies (their possibilities and limitations) at the local level to encourage purposeful collective action and improve the dialogue between ‘those who make science’ and ‘those who use science to make decisions’ in order to make climate science more useful. Empirical data was collected between August 2011 and June 2012 through focus group meetings [28], interviews and a one-day workshop. Focus group meetings involved four types of stakeholder groups: a) a science-based group involving researchers from the Climate Project representing four major themes: population studies, public policies, social conflicts and biodiversity; b) a practitioners group involving local technicians and policymakers dealing with risk assessment and management in the area; c) a neighbourhood leaders group involving people considered to be living in areas at risk by emergency management authorities; and d) a youth group involving 12 to 17 years old youngsters also considered to be living in areas at risk. In total, eight focus group meetings with an average of six participants were held, complemented by fifteen interviews with people who live in areas at risk, three interviews with heads of emergency managements agencies and with two scientists from two state-based research institutes who studied that particular coastal region, and a one-day workshop whereby researchers from the Climate Project, local technicians and policymakers had the opportunity to exchange information on climate science.

The Australian intervention, the Cardwell Project, aimed to explore how a bottom-up, community initiated and led, visioning and strategic planning initiative, could contribute to address sustainability and climate change adaptation challenges; and to identify what conditions would be required for successful collaborative community self improvement initiatives, particularly leading to sustainable and resilient communities, which are well adapted to natural hazards and a changing climate. This project adopted a scenario planning approach [29] and data was collected through stakeholder workshops, participant observation [30, 31] and semi-structured interviews [32]. In total, seven scenario planning [29] workshops involving community members were held between March 2011 and November

2012. With an average participation of 15 people, workshops involved the collaborative development of an action plan to improve the strategic recovery from disasters for the Cardwell community. Notes taken at each workshop were compiled through participant observation reports. Additionally, twenty-three interviews were held with community members between August 2011 and February 2013 to shed light on the attributes of sustainable and resilient communities that could aid adaptation to natural hazards and climate change.

Empirical data from both projects were independently coded using in-depth content analysis [33].

[insert Table 2 near here]

As discussed in the previous section, the potential for intervention research to aid climate change adaptation lies on its capacity to generate new knowledge and facilitate change, particularly through enhancing stakeholders' adaptive capacity. In this context, intervention research should assist in the improvement of stakeholders' *ability to learn* and *ability to adapt* therefore transitioning from a current state of adaptive capacity to a future one that is conducive to effective adaptation to climate change. Drawing on this understanding of the role of intervention research, we use the conceptual model illustrated by Figure 1 to guide our evaluation of the extent to which new knowledge was generated and change was facilitated in our research interventions. This evaluation is informed by the analysis of the empirical data collected by both projects and focuses on the interactive and participative character of intervention research (i.e. negotiation, cross-fertilisation and mode of interaction phases) and the knowledge generation process (i.e. local knowledge, meta-knowledge and publishable knowledge) as described by Avenier & Nourry [20]. Key results emerging from the empirical data analysis are presented next.

3.1 The Climate Project

The interactive and participative process

The *negotiation* phase between stakeholders and the research team started during the first field trips which involved technical visits to emergency management agencies and to some areas considered to be at risk. At that time, emergency management personnel highlighted their concerns about irregular settlements in areas at risk and the vulnerability of these settlements to extreme weather events. Consequently, they agreed that the research should focus on risk areas, risk perception and risk communication, and pointed out that they needed to have access to the latest scientific information. In parallel, the research team highlighted their research goals and sought support from emergency management agencies to identify and select potential participants to attend focus group meetings. Additionally, it was emphasised that the research process would create opportunities for stakeholders to speak to and to be listened by scientists involved in the Climate Project.

In terms of *cross-fertilisation* between the stakeholders' and researchers' projects, it was established that emergency management agencies would assist the research team in identifying participants and supporting the conduct of focus group meetings. Additionally, they would provide existing information on risk areas (including maps and risk assessment reports) to assist the research team in identifying gaps in knowledge specific to the area. On the other hand, the research team would seek to improve the dialogue between the Climate Project scientists and the practitioners in order to make climate science more useful and accessible. Based on these arrangements, a two-way communication process shaped the *mode of interaction* between stakeholders and the research team in which involved parties exchanged information about existing and needed knowledge associated with current and future adaptation.

Power relation dynamics were observed during the interactive and participative process led by the Climate Project. Power relations can be understood under the methodological theory of boundary critique inherent to intervention research as described by Midgley [14]. The author emphasises that when stakeholders (being individuals or groups) interact, their concerns can become sacred or profane on

each other's views. This is not a simplistic relationship as stakeholder's interests may be similar therefore accepting each other's concerns as sacred but co-operation is impeded by the lack of trust and/or by divergent envisioned strategies to address identified issues.

Specifically, the Climate Project was testimony to power relations expressed in the form of a divide between the end-users and the producers of climate science, a divide that has been also observed by Hofmeester et al [39] in their study of coastal governance in Australia. Initially, end-user stakeholders involved in the focus group meetings perceived a relationship of expert (scientists) *versus* them (practitioners and community members). In particular, stakeholders presumed that experts would tell them how they should address the risks they faced and how they should adapt. This divide appeared to be partially attributed to existing stakeholder's consultation fatigue as it was articulated by a participant of the neighbourhood leaders focus group:

“... why does someone want to get information about an area at risk in Rio do Ouro [neighbourhood]? Why are people studying here? It is like we live in a glass bowl and people are watching us. More studies and information are better, but we need to know the reason and the focus of these surveys.” [Translated from Portuguese by the authors]

If not addressed, consultation fatigue or lack of trust in the process can certainly hamper stakeholder engagement in the research exercise. However, the *us versus them* perspective gradually subsided as stakeholders understood that their participation in the focus group meetings involved not only listening to but also being listened by researchers. In this case, the participative character of focus group meetings possibly enabled stakeholders to improve their understanding about each other's interests and concerns as well as develop trust in the intervention process. As a result, a neighbourhood community leader stated that:

“Our hope is that you [experts], with all information that you get from our meetings, will be able to give us an idea, a suggestion to help us not only about environmental behavior, health but also what is safe housing.” [Translated from Portuguese by the authors]

The knowledge generation process

Local knowledge was generated through an interactive one-day workshop whereby researchers from the Climate Project, local technicians and policymakers had the opportunity to exchange information on climate science, identify key issues affecting the area and key studies available for the region. This workshop enabled the identification of technical information needed for the area based on the exchange of point of views, interpretation of constraints and identification of targeted issues. *Local knowledge* was also collectively constructed by holding specific focus group meetings targeting the following themes: urban problems and risks due to climate and environmental change, relationships between science and politics, communication strategies, and relationships between community end-users and experts, scientists and policymakers.

In terms of *publishable knowledge*, the collected narratives highlighted that the social and economic context such as deficient economic and government support as well as the influence of religion were determinants in the way people responded to risk threats. For example, a neighbourhood community leader believed that:

“Today we are much protected by Ilhabela hill [offshore island] and by God.” [Translated from Portuguese by the authors]

Additionally, practitioners indicated that, despite efforts in improving communication channels in order to make climate science more useful, communication with scientists remained challenging. This was demonstrated by the frustration expressed by a local technician:

“I cannot count how many times I collaborated with academic studies. But rarely I got some results from these studies.” [Translated from Portuguese by the authors]

The research also confirmed the limitations local governments had to implement adaptation strategies due to limited resources and political interest. Problems associated with collective decision-making were also detected, as there had been limited public participation in formal consultation exercises as well as reduced public interest and social mobilization. As described by a neighbourhood community leader:

“People are not engaged... Recently we had a meeting in my neighbourhood to talk about the garbage problem. Only six, seven people came to that meeting. People are not involved... they are very dependent on politicians.” [Translated from Portuguese by the authors]

In terms of *meta-knowledge*, the research process enabled the generation of knowledge related to improving communication between scientists and end-users as well as the role of focus group as a qualitative and participatory research method. Climate Project scientists identified the value of two-way communication channels involving scientists and end-users, practitioners and community members, as they believed these opportunities were important for improving their understanding about how stakeholders perceived risks, as well as fostering bilateral cooperation for both the identification of knowledge gaps and the dissemination of available knowledge.

3.2 The Cardwell Project

The interactive and participative process

The *negotiation* between the stakeholders and the research team started during arrangements for the first workshop in the aftermath of tropical cyclone Yasi in February 2011. Led by the chamber of commerce, the stakeholders' project was strongly focused on keeping an economically viable township, particularly after

being stroked by natural hazards. On that occasion, stakeholders thought it was critical for the town to be a point of attraction to both new residents and visitors to keep local businesses viable and a strong community. On the other hand, the research team's project focused on improving the understanding of the attributes of self-empowered communities in terms of dealing with and being better prepared for natural hazards. Negotiations between stakeholders and the research team established the undertaking of a series of workshops focused on scenario planning to develop future options for Cardwell to be compiled in a 25-year action plan.

In terms of *cross-fertilisation* between the two projects, it was expected that stakeholders would be able to put together an action plan under the facilitation of the research team to strengthen the town's viability in the face of current and future natural hazards, whereas the research team would be able to undertake research activities (interviews and participant observation at workshops) with key stakeholders involved in this process. While this comprised the first negotiation episode, ongoing negotiation was necessary throughout the whole process of preparing the action plan which took 18 months. Such ongoing negotiation became a key feature of the *mode of interaction* between the researchers and stakeholders. For example, one of the key negotiations focused on the need to broaden the representation of participants in the workshops beyond the members of the chamber of commerce and sympathizers to ensure the action plan better reflected the aspirations of the broader community. While the initial group of stakeholders was concerned that broadening the participation in workshops could potentially generate conflicts due to differences in values and based on past events, stakeholders understood that the broader community would only embrace the action plan if greater participation were achieved. The need to broaden participation in the process was summarized by this workshop participant:

“The re-group at the end of the day session of the workshop showed that people were enthusiastic about what they wanted. The big

picture was out of sight but they focused on specific actions. It was good to know that they left comfortable to be included as the community needs to be included.”

Similar to the Climate Project, power relations were also observed in the Cardwell Project. In this case, the interactive component of the project, which lasted several months, helped participants to ease those power relations as they began to understand that they sought the same improvements for their community. However, it is important to stress that the power relations described here were eased at that point in time and for it to continue to prevail, ongoing opportunities for dialogue and potentially a neutral facilitator were required. In particular, it was established that proper protocols needed to be put in place to deal with future conflict of interests that could emerge during the subsequent implementation of the action plan. In this case, workshop participants possibly improved their *ability to learn* as they interacted with each other and dealt with conflict of interests during the intervention process. However, to improve their *ability to adapt* a great deal of negotiations within the community would still be required during the implementation of the action plan given the need to rehabilitate fractured relationships caused by past disputes. An interviewee highlighted this need for ongoing negotiations as well as the impossibility of achieving full participation in the implementation of the action plan:

“There is absolutely no way in the world that we could have got a document [action plan] like that without that process. Even with the process, we have people who still either don’t understand or... but it's a bell curve. There is always going to be those people outside the third standard deviation that you are just never going to bring on board. We all know that.”

The knowledge generation process

Local knowledge was collectively constructed throughout the series of seven workshops and culminated in the production of the action plan. The action plan

was guided by a proposed future vision for the community generated during the first two workshops to identify the town's strengths, weaknesses, opportunities and threats related to its ability to deal with recurrent natural hazards as well as through the identification of stakeholders' priorities to achieve such vision. The core content of the action plan referred to a series of future options for the community constructed through an iterative process in which community members were given the opportunity to submit a selection of options to be assessed by the whole group in the fourth workshop. Initially, a total of 25 preliminary future options were proposed to be included in the action plan. Future options were then reviewed by the research team and re-confirmed by workshop participants before being reassessed during workshops five, six and seven. From the initial economically focused project, throughout the iterative process the stakeholders broadened their project scope to include other major areas that required attention to ensure its viability beyond economic stability. These included ownership and management of community affairs, disaster risk management, conservation and natural resources management, social and community well-being, and supporting its Indigenous community.

In parallel, *publishable knowledge* emerging from the research project related to the identification of key attributes of community resilience associated with the recovery from disasters. Drawing on workshop outputs, two characteristics were identified amongst stakeholders that are understood in the literature to be important elements that assist the community recovery process after disasters [40, 41]. These include place attachment and strong social networks. These two characteristics became evident during workshop two, when participants were able to indirectly reflect on the actual impact of cyclone Yasi upon their community and identify key characteristics of their community that enabled them to overcome/deal with such impact. Specifically, a strong sense of belonging and identity was identified to be one of the key strengths of their community, including the responsibility for taking care of the place and its people as outlined by the interviewee below:

“...being involved in a community it gives you a lot of satisfaction and a lot of personal satisfaction knowing that you're contributing. Being a founding family you might say I have a bit of a feeling that I have a custodianship of the region. If something's going on I should involve myself with it so I can find out the details, how it will affect the residents of the town, how it will affect the town progressing forward, or whether or not it's going to be detrimental.”

In terms of *meta-knowledge*, the process enabled the generation of knowledge related to two major areas: collaborative planning and scenario planning. As part of the collaborative planning process, it became clear that stakeholders were able to identify and deliberate on focal issues perceived to affect their community but lacked communication channels to convey their messages to authorities. For example, during the second workshop, a participant highlighted that:

“...there was no completely opposite view about where we should go. Group priorities showed that convergence. There was some arguing about a few diverging points but the workshop changed the perception in the community that [group x] wants high-rise on the foreshore, instead they want to achieve the same objective: political exercise of being a united town to front up the government. We need to work on that and the process has started.”

In terms of the scenario planning approach, it was ascertained that this approach was conducive to not only deal with uncertainties involved in climate change but also to overcome differences in values and potential conflict between stakeholders. Scenarios were developed during workshops three and four in which participants realised that their aspirations, despite differences in values, were similar when considering a future for the area. In particular, it was recognised the need to maintain their social and ecological assets at a high standard, therefore workshop participants decided to have this need clearly stated as one of the axis in the scenario matrix.

4. Advancing the ability to learn and adapt through intervention research

The first key insight to emerge from our interventions is that there were variations and possibly limitations in the extent and in-depth of knowledge generated by the projects. For example, while in the case of the Climate Project the intervention helped to shed light on the type of scientific knowledge needed by stakeholders to promote climate change adaptation, it also revealed that knowledge communication was still challenging. A major outcome of this intervention was the improvement of scientists' ability to learn about the personal dimension involved in people's decisions, even when at risk, that surpasses the pragmatic rational approach which is often defended by decision-makers and scientists in general (see Figure 2). Although scientists of the Climate Project might have been aware of this issue, the actual interaction with people living in areas at risk expanded their learning of how complex those decisions are. Hence the intervention clarified that producing climate science for its own sake was not sufficient to improve people's ability to adapt; rather there was a need for improving the understanding of people's adaptive capacity to define areas that required better support and improvements through the policy process. However, it appears that the intervention favoured the researchers' ability to learn more than the stakeholders' posing the question as to whether it facilitated a unilateral instead of a bilateral change. This is a crucial hurdle that needs to be addressed in order to also advance stakeholders' ability to learn thereby fostering adaptation.

[insert Figure 2 near here]

The Climate Project was essentially research-driven and focused on improving the understanding of stakeholder's needs in terms of technical information required to assist the decision-making process in order to make climate science more useful. As discussed by Dilling & Lemos [42], there are differences between what scientists think is useful and what is actually usable from a stakeholder/practice perspective often determined by a 'pull-push' process. Typically the push

end of the process is represented by the research agenda set by scientists while the pull end is characterised by the priorities raised by stakeholders. The authors [42] suggest that to strike a balance in the 'pull-push' process, knowledge needs to be co-produced through continuous iteration between the two groups. Thus one of the critical roles for intervention research to advancing the ability to learn and adapt lies in assisting the achievement of this balance. However, as observed in the Climate Project, the creation of conditions for the iterativity to occur is not sufficient and, as argued by Dilling & Lemos [42], science producers and users need to also own the problem and set common goals together as well as create innovative ways of interaction to co-produce knowledge.

The second key insight to emerge from our interventions is that out of the three types of knowledge generated, local and meta-knowledge appears to be the most critical in advancing stakeholders' ability to adapt, albeit the three types of knowledge are interlinked [20]. For example, in the case of the Climate Project, while emergency managers stressed that it was critical to improve the communication of knowledge (scientific knowledge) to people living in areas at risk, neighbourhood leaders highlighted a series of barriers impeding their ability to adapt, including inherent cultural beliefs through economic constraints and reduced public participation in common affairs (see Figure 2). Thus the availability and communication of scientific knowledge on their own were not sufficient to improve stakeholders' ability to adapt as other impediments also needed be overcome. Comparatively, in the context of the Cardwell Project, which was problem solving-driven, generated local and meta-knowledge revealed that a great deal of effort was to be employed in conflict resolution to settle people's priorities, thereby enabling strategic planning to be defined and implemented through their action planning process (see Figure 3). Despite the quality of the action plan, without settling these critical hurdles, it is unlikely that the plan will be successfully implemented therefore compromising stakeholder's ability to adapt. Further, the intervention research process ceased as the action plan started to be implemented highlighting the need for consideration of the best timing and duration of interventions. The timing and duration of interventions thus

comprise a third insight provided by our research and, ideally, when focused on climate adaptation planning, interventions should be carried out also during the implementation phase of their outputs (e.g. action plan, knowledge communication etc.) to enable in-depth evaluation of its role in improving stakeholder's ability to adapt or the actual change sought to be achieved.

[insert Figure 3 near here]

Generating a better understanding of the community's aspirations and capacities as well as issues that need to be addressed is critical to assist the decision-making process. These aspects not only comprise first hand elements of the overall adaptive capacity of systems but also inform community-based adaptation when resources and official adaptation efforts are deficient [43, 44]. In this context, if intervention research is able to provide this type of information it can certainly contribute to generating specifically tailored solutions to places and its communities and/or institutions. However, considering that intervention research is concerned with facilitating change for improvement [14], what is the acceptable level of change that it should achieve? Moser and Ekstrom [45] highlight that change may entail how individuals within an organisation change their perceptions of or thinking about the issues, how they use available information, how they make decisions, and how they interact with other organisations. However, this level of change is somewhat confined to the ability of learn dimension of the adaptive capacity process and, as highlighted by our interventions, change also needs to occur in favour of improving stakeholder's effective ability to adapt. Nevertheless, Moser and Ekstrom [45] stress that those changes at the individual level are conditional to changes in the broader governance context in which they act; thereby adaptation needs to be enabled through changes that need to occur at the institutional and governance levels. These may include changes in the legal and political system, decision-making and operational processes. Thus to advance stakeholder's ability to learn and adapt we suggest that the intervention process should also encompass the assessment or evaluation of desired changes as outlined in Figure 4.

[insert Figure 4 near here]

This assessment is not restricted to intrinsic characteristics of the outcomes of the joint project; rather, as show on Figure 4, it also involves the identification of other systemic changes at the institutional and governance levels which are mostly like to emerge during the implementation phase of desired changes. This type of information is critical to directly inform how existing policies need to be revisited and possibly changed. Information in this case is likely to be principally conveyed through publishable knowledge as a critical mean to support the need for changes across current policies. Drawing on findings of our interventions, we believe that for intervention research to accomplish its full potential in achieving purposeful action to generate improved change [14] its timing and duration need to include the implementation end of sought changes. Our interventions suggest that it is only under this broader understanding of impediments to improved changes that the current state of adaptive capacity can in fact be transformed *cf.* [17] thereby leading to effective climate change adaptation.

5. Conclusion

It is increasingly recognised worldwide that adaptation to unavoidable climate change impacts is critical, however there is great variability in how places and their populations will be able to adapt. Thus it is important to increase our understanding not only of the determinants of adaptive capacity but also of how it can be enabled. This paper explored the role of intervention research in aiding climate change adaptation through improving stakeholder's ability to learn and ability to adapt. The paper focused on two interventions: the Climate and the Cardwell projects independently conducted in Brazil and in Australia, respectively.

Specifically, we sought to explore how intervention research could aid climate change adaptation through its interactive and participative process as well as the types of knowledge it enables to be generated. Our findings that emerged from our interventions point to three key insights that need be highlighted to advance

the role of this type of research when focusing on climate change adaptation. First, it is important that all parties included in the interventions (stakeholders and researchers) equally benefit from the knowledge generation process. This is likely to be achieved by a thorough negotiation, cross-fertilisation and mode of operation phases which enable the establishment of a common goal/ vision for the joint project as well as define how knowledge is to be co-produced. However, for future interventions aiming to improve the relevance and usability of climate science, only the provision of opportunities for stakeholder interaction and participation to occur is not sufficient. In fact, special attention needs to be given in both the research design and conduct to enable the joint project to be finely adjusted in relation to the 'pull and push' process *cf.* [42] involved in knowledge generation.

Second, out of the three types of knowledge capable of being generated through interventions, local and meta-knowledge have a critical role in improving stakeholder's ability to learn and to adapt. These types of knowledge provide important information related to the diversity and types of needs stakeholders have. In particular, they allow for the self-assessment of the system in which stakeholders are involved therefore identifying its strengths, weaknesses and also fine-tuning stakeholder's aspirations toward a common collective goal. Conversely, publishable knowledge can play a greater part in informing policies targeting the improvement of policies to advance adaptive capacity particularly in terms of outlining required institutional and governance changes that may hinder adaptation. Additionally, publishable knowledge that draws on collaborative research experiences is likely to have stronger inside knowledge of the system in which stakeholders are involved thereby providing information that is both empirically grounded and legitimised by end users.

Last, the timing and duration of interventions are crucial to enable their findings to inform policies specifically focused on improving the adaptive capacity process. While some level of change may be achieved through interventions, when dealing with climate change adaptation, it is important to critically examine

the acceptable level of change to be the result of the process. In particular, intervention research needs to also involve the implementation end of desired changes to fully document the opportunities for and constraints to how the current state of adaptive capacity can be in fact transformed.

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Table 1. Merits and problems related to intervention research applied to climate change adaptation

Features of Intervention Research*	Merits	Problems
Based on action research to address social problems [10, 21, 22]	Using climate science to inform adaptation	Uncertainty related to climate science can undermine communication of risks and associated adaptation options
Common ontological paradigm of participative reality [11]	Guiding research outputs to address stakeholders' needs towards adaptation	Great deal of negotiation between stakeholders and researchers required
Bilateral relationship between research and action, cyclic iteration [23]		Difficulty in defining roles of participants in the research process [24]
Interactive process between researchers and targeted stakeholders [20]		Difficulty in achieving broader stakeholder participation in the research process [18]
Generation of practical knowledge that is useful to people [19]	Applicability of research outputs to address stakeholders' needs towards adaptation	Limited potential to build theory [19], prove, define and legitimise knowledge generation that can inform adaptation elsewhere [20]
Potential for improving general well-being and setting sustainable relationships with the environment [19]	Contribution to solving environmental problems thus leading to adaptation [24]	Difficulty in achieving adaptation at broader temporal and spatial scales
Embodied foresight [25]	Useful to address long-term adaptation issues	Difficulty in grasping long-term adaptation benefits based on current actions; urgency in adapting to critical issues

Purposeful action to generate change [21]	Applicability of research outputs to address stakeholders' needs towards adaptation	<p>Difficulty in generating consensus amongst participants towards sought change/ adaptation alternatives</p> <p>Disparity of interests and goals amongst participants towards sought change/ adaptation alternatives</p>
Boundary critique [13, 21, 26]	Definition of issues and actors to be included in the adaptation research	<p>Great deal of negotiation between stakeholders and researchers required to define stakeholder engagement and adaptation issues</p> <p>Difficult to be achieved at broader temporal and spatial scales</p>
Theoretical and methodological pluralism [14, 21, 26]	Ability to deal with complexity associated with climate change adaptation	Limited potential to build theory [19], prove, define and legitimise knowledge generation that can inform adaptation elsewhere [20]
Action for improvement [14, 21, 26]	Potential for temporal and spatial improvement and shaping adaptation decision-making	<p>Localised context only</p> <p>Disparity of interests and goals amongst participants towards sought improvement/ adaptation alternatives</p>

* Features extracted from literature, sources indicated after each feature.

Table 2. Outline of the intervention research projects

	Climate Project - Brazil	Cardwell Project - Australia
General description	A sub-project of a four-year (2009-2013) large-scale research project focused on the relationship between urban growth, vulnerability and adaptation on the São Paulo Coast.	A partnership between the Cardwell community and researchers established to conceptualise and develop a long-term action plan for the community's future. Partnership initiated by the Cardwell Chamber of Commerce in the aftermath of cyclone Yasi in March 2011.
Project location	Three municipalities from the north coast of São Paulo: Ubatuba, São Sebastião and Caraguatatuba; approximate population 253,000.	Cardwell in Far North Queensland; approximate population 1,200 [34]
Key issues facing the area	<p>Informal settlements on slopes and riverbanks and reservoirs, scarcity of drinking water and sanitation, and poor distribution of public services [35].</p> <p>Climate change likely to exacerbate the current vulnerability of the area due to increase in the frequency and intensity of extreme weather events [35, 36]</p> <p>The area is under increased pressures of tourism, industrialization and oil extraction further challenging its social and ecological integrity [37].</p>	<p>Vulnerability to extreme weather events such as cyclones which often cause widespread floods and wind destruction [38].</p> <p>Nestled between two World Heritage areas, the Wet Tropics and the Great Barrier Reef with significant high value environmental assets likely to be affected by climate change.</p>
Project outputs	Identification of determinant factors in how people respond to risk threats (social and economic context, deficient economic and government support, the influence of religion); identification of problems associated with collective decision-making; generation of knowledge related to improving communication between scientists and	Development and confirmation of a vision for the future of the community; identification of a series of future options for the community which were tested against two scenarios; and development of a 25-year action plan which contains a series of prioritised actions to be implemented over the life of the action plan in order to achieve its

Climate Project - Brazil	Cardwell Project - Australia
<p>end-users as well as the role of focus group as a qualitative and participatory research method.</p>	<p>vision and strategic intents.</p>

Fig. 1. Conceptual model illustrating relationship between intervention research and the adaptive capacity process

Figure 2. Climate Project key insights

Figure 3. Cardwell Project key insights

Figure 4. Framework linking intervention research and the development of policies to enhance adaptive capacity