Earth Systems and Climate Change Hub

National Environmental Science Programme

Marine Biodiversity Hub

National Environmental Science Programme

Sources of resilience, vulnerabilities and uncertainties in Indigenous Peoples' adaptive capability to climate change

A synthesis from recent literature

Ilisapeci Lyons and Pia Harkness

June 2021

Earth Systems and Climate Change Hub Report No. 31

Australian Government

National Environmental Science Programme

The Earth Systems and Climate Change Hub is supported by funding through the Australian Government's National Environmental Science Program. The Hub is hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and is a partnership CSIRO, Bureau of Meteorology, Australian National University, Monash University, University of Melbourne, University of New South Wales and University of Tasmania. The role of the Hub is to ensure that Australia's policies and management decisions are effectively informed by Earth systems and climate change science, now and into the future. For more information visit www.nespclimate.com.au.

Copyright

© CSIRO 2021.

Sources of resilience, vulnerabilities and uncertainties in Indigenous Peoples' adaptative capability to climate change: A synthesis from recent literature is licensed by CSIRO for use under a Creative Commons Attribution 4.0 Australia licence. For licence conditions see https://creativecommons.org/licenses/by/4.0/

Citation

Lyons I and Harkness PL (2021) *Sources of resilience, vulnerabilities and uncertainties in Indigenous Peoples' adaptative capability to climate change: A synthesis from recent literature*. Earth Systems and Climate Change Hub Report No. 31. Earth Systems and Climate Change Hub, Australia.

Contact

Enquiries regarding this report should be addressed to:

Ilisapeci Lyons (Pethie)

CSIRO Land and Water

mailto:pethie.lyons@csiro.au

Published 06/2021

This report is available for download from the Earth Systems and Climate Change Hub website at www.nespclimate.com.au.

Important disclaimer

The National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, the NESP ESCC Hub (including its host organisation, employees, partners and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

The ESCC Hub is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document please contact info@nespclimate.com.au.

Contents

1 Introduction 4

1.1 The framework for this review 5

2 Sources of resilience - experience and knowledge of environments, rights and interests over traditional lands 7

2.1 Type of uncertainty – ignorance 7

2.2 Type of uncertainty – surprise 9

2.3 Type of uncertainty – volition of actors 9

2.4 Type of Uncertainty – volition of institutions 12

2.5 Summary 14

3 Sources of vulnerability – history of colonisation, contemporary context of socio-economic disadvantage, chronic poor health 15

3.1 Type of uncertainty – ignorance 16

3.2 Type of uncertainty – surprise 17

3.3 Type of uncertainty – volition of actors 18

3.4 Type of uncertainty – volition of institutions 20

3.5 Summary 23

4 Conclusion 24

References 26

Tables

Table 1 Analytic framework relating types of uncertainty for sources of resilience and vulnerability in building capability for climate adaptation planning (source Lyons et al. 2019).....5

Table 2 Analytic framework relating types of uncertainty for sources of vulnerability in building capability for climate adaptation planning (source Lyons et al. 2019).....7

Table 3. An exemplar of where future climate scenarios were utilised to develop Indigenous adaptation strategies and priorities.....8

Table 4 An exemplar of where the benefits of Indigenous fire knowledge and management under the effects of climate change are supported through a stewardship scheme. 9

Table 5 Case exemplars of the types of uncertainties that relate to the volition of actors 12

Table 6 Two exemplars of the types of uncertainties related to volition of institutions ...13

Table 7 Analytic framework relating types of uncertainty for sources of vulnerability in building capability for climate adaptation planning (source Lyons et al. 2019).....15

Table 8 An example of an uncertainty related to ignorance 16

Table 9 An example of an uncertainty related to ignorance 17

Table 10 A case exemplar of uncertainty that relates to the volition of actors from Arabana Country.....19

Table 11 Two case exemplars from the Arctic and New Zealand of uncertainty through volition of institutions in building adaptation planning capability.....22

REPORT SUMMARY

Sources of resilience, vulnerabilities and uncertainties in Indigenous Peoples' adaptative capability to climate change: A synthesis from recent literature

This synthesis of recent literature on Indigenous Peoples' planning for climate change identifies sources of resilience and vulnerabilities and the types of uncertainties in building adaptive capacity to climate change. Sources of resilience include experience and knowledge of the environment, rights and interests over traditional lands and waters; while history of colonisation and socio-economic disadvantage were key sources of vulnerability.

The synthesis draws on the Lyons et al. (2019) framework to explore the diversity of the types of uncertainties identified by Indigenous Peoples from Australia, New Zealand, Canada and the USA. The literature from these four nations illustrates the continued challenge and imperative of finding new ways to establish respectful understanding to work across institutional domains and knowledge systems on climate adaptation planning. Community understanding of trust, accountability, consultation, consent and protection of Indigenous knowledge are common concerns that limit the potential for knowledge co-production and innovative co-design initiatives to enable new types of climate adaptation partnerships. Indigenous Peoples from the nations included in this review seek to express their agency from and at multiple geographies beyond the boundaries of their traditional lands, through contemporary Indigenous decision-making processes and at scales at which the drivers of climate change are being enacted, at regional and national levels and with industry. These include dismantling the institutional barriers that are part of the legacy of colonisation that are expressed through the prioritisation of types of knowledge and relationships to the environment, and long-standing resource arrangements and systems that support familiar responses, such as engineering solutions.

Indigenous practitioners, leaders, researchers and their partners in government, non-government agencies, research, and industry are reshaping relationships that respond to the global challenge of climate change. Unlocking innovation with Indigenous partners will engage uncertainties in applying new technological, social, cultural and institutional practices, and highlight the importance of Indigenous-centred and co-designed approaches to manage sources of vulnerability and resilience through change. Opportunities for innovation include Indigenous-led scenario planning; government-resourced Indigenous ecosystem stewardship schemes; and monitoring programs focused on Indigenous priorities and decision-making systems to determine appropriate responses that together can reduce uncertainties for building adaptation planning capabilities for resilient Indigenous societies.

1 Introduction

Indigenous Peoples' involvement in looking after their traditional lands is central to sustaining customary practices and improving health, and is a defining pathway in climate adaptation (Nursey-Bray et al., 2020). Multiple factors (e.g. social, institutional and economic systems) interact to influence the types of vulnerabilities, opportunities and qualities of resilience Indigenous communities experience under the impacts of climate change (Hill et al., 2020a, Langton et al., 2012, Petheram et al., 2010, Parsons et al., 2019). We refer to Indigenous lands and waters broadly as traditional lands or Country. Indigenous risk perspectives, priorities and decisions about adaptation and mitigation responses vary across places, institutional settings, social and economic conditions and the biophysical context. Climate change actions reflect the worldviews, hopes and experiences of diverse Indigenous groups as well as their particular histories and the on-going effects of colonisation and negotiating the settler society (Howitt, 2020).

We provide a literature-based synthesis of issues and options to help re-situate and expand the dialogue and partnerships on climate related research, in line with Howitt (2020, p.1) on negotiating respectful modes of belonging together-in-place to reshape relationships that are responding to the global challenge of climate change. This review responds to three drivers:

1. Indigenous communities, individuals and households experience different levels and types of sources of vulnerabilities and resilience in response to climate change
2. Risk perspectives and uncertainties of building climate adaptation capability strongly shape climate adaptation priorities
3. The opportunities and role of western science to work with Indigenous Peoples to support their priorities for adaptation planning

This synthesis draws on the Lyons et al. (2019b) framework as a means to differentiate sources of resilience and vulnerabilities and types of uncertainties in building adaptive capacity. The framework is adapted from Maru et al. (2014) linked vulnerability-resilience model that describes a dynamic of the adaptive capacity of Indigenous Peoples' in remote Australia. It is based on two opposing cycles of positive reinforcement:

- Resilience arising from Indigenous experience and knowledge of environments associated with rights and interests over Country. Nation state governments around the world are increasingly recognising and acknowledging pre-settlement rights and interests (Brondizio and Le Tourneau, 2016, Artelle et al., 2019).
- Vulnerability arising from the legacies of colonisation and its policies that have produced contemporary context of socio-economic disadvantage, including poverty, and poor health (Maru et al., 2014, Richards et al., 2019).

This literature review is structured in two sections, the first presents the sources and nature of resilience and the second examines the sources and nature of vulnerability.

1.1 The framework for this review

The synthesis draws on emerging and new understandings of types of uncertainties, including risk, expressed by Indigenous Peoples. Table 1 below presents the analytical framework that situates Indigenous Peoples' contexts within sources of vulnerability and resilience and types of uncertainties that can co-exist in these contexts. The framework in Lyons et al. (2019b) broadens the engagement with climate adaptation that is often directed to risk-related uncertainty of probability of known events happening or potential scenario outcomes, to account for broader socio-cultural dimensions of uncertainty.

As outlined and adapted in Lyons et al. (2019b, p.1599) the framework draws on the indeterminacy of futures defined by Raskin et al. (2002):

> *[F]uture uncertainties that are part of complex socio-ecological systems involve distinct sources of uncertainties, ignorance, surprise, and volition*
>
> - *Ignorance is based on incomplete information about the dynamics of a system that generates multiple probabilities for possible future scenarios*
> - *Surprise is due to the inherent properties of complex systems which can exhibit emergent phenomena (related to feedbacks and dynamism) and structural shifts when thresholds are crossed*
> - *Volition refers to the unique roles of human actors, whose future choices have not yet been made*
> - *Volition refers to human institutions that create and reinforce their own trajectories, leading to unpredictable responses in climate change arenas.*

An understanding of the place-based contexts and the processes that drive uncertainty for building climate adaptation planning capability are central to responding to Indigenous climate adaptation priorities.

Table 1 Analytic framework relating types of uncertainty for sources of resilience and vulnerability in building capability for climate adaptation planning (source Lyons et al. 2019).

SOURCES OF RESILIENCE & VULNERABILITY	TYPES OF UNCERTAINTY FOR BUILDING CLIMATE ADAPTATION PLANNING CAPABILITY			
	IGNORANCE	**SURPRISE**	**VOLITION OF ACTORS**	**VOLITION OF INSTITUTIONS**
Source of Resilience Experience and knowledge of environments, rights and interests over country	Strategies and preparation based on ethical processes that address multiple scenarios of climate change	New resources becoming available with climate change.	Ability to draw on kin network Rights and access to manage country	Recognition of indigenous cultural resources, rights and interests that is part of wider societal adaptation planning.
Sources of Vulnerability History of colonialism, contemporary context of socio-economic disadvantage, chronic poor health	Engagement on the potential impacts of climate change on existing environmental, socio-economic and institutional vulnerabilities.	Type of and amount of loss of country from sea level rise Type of changes in distribution and availability of culturally important species.	Limited future opportunities to utilise IK with science to address climate change through indigenous driven processes.	Limited future multi-scale climate adaptation planning that continuously engage indigenous peoples as key groups with particular long-term relationships, interests and values over their traditional lands and seas.

We draw on field-based literature from Australia, New Zealand, USA and Canada to explore dimensions of uncertainty for climate adaptation planning capability for sources of resilience and vulnerability. At the forefront of such an analysis is an understanding that populations can have qualities of resilience and vulnerabilities at the same time (Ford et al., 2020, Lyons et al., 2019a). These qualities are related to Indigenous Peoples' attachments to traditional lands and their connections that can be expressed in diverse ways across spatial and temporal scales (Howitt, 2020, Whyte, 2018b, Nursey-Bray et al., 2020).

This literature review presents types of uncertainties for building climate adaptation planning capability, first for sources of resilience, then sources of vulnerability. Cases are presented under each section on vulnerability and resilience to highlight the interactions between them and the opportunities for engaging with Indigenous led and co-designed initiatives for climate adaptation. Case exemplars from the literature are summarised in tables in each sub-section on ignorance, surprise, volition of actors and volition of institutions, to show particular dimensions of vulnerability and resilience, and the different types and level of influence on Indigenous climate adaptation capability. The case exemplars are situated in unique social, economic, political, biophysical and cultural contexts.

2 Sources of resilience - experience and knowledge of environments, rights and interests over traditional lands

Resilience to changes in the environment are defined by Ford et al. (2020) as economic, cultural, demographic, historical and political factors that operate across different spatial and temporal scales (Ford et al., 2020). Knowledge collaborations and institutional arrangements are considered central to Indigenous groups and individuals seeking to build their adaptive capacities to respond to climate change and drive change at broader scales. Knowledge collaborations can enable the inclusion of multiple knowledge systems to build adaptive capacity of Indigenous Peoples and their organisations (Ford et al., 2020, Vogel and Bullock, 2020).

In this section we will focus on the sources of resilience, from Table 1, for building climate adaptation planning capability (Table 2). The types of uncertainties can include processes that address multiple scenarios of climate change, ability to draw on kin network and recognition of Indigenous rights and interests that are part of societal adaptation planning.

Table 2 Analytic framework relating types of uncertainty for sources of resilience in building capability for climate adaptation planning (source Lyons et al. 2019).

SOURCE OF RESILIENCE	TYPES OF UNCERTAINTY FOR BUILDING CLIMATE ADAPTATION PLANNING CAPABILITY			
	IGNORANCE	**SURPRISE**	**VOLITION OF ACTORS**	**VOLITION OF INSTITUTIONS**
Experience and knowledge of environments, rights and interests over country	Strategies and preparation based on ethical processes that address multiple scenarios of climate change	New resources becoming available with climate change.	Ability to draw on kin network Rights and access to manage country	Recognition of indigenous cultural resources, rights and interests that is part of wider societal adaptation planning.

We present case examples and main points from the literature for each of the types of uncertainties for building climate adaptation planning capability as identified in Lyons et al., (2019): ignorance, surprise, volition of actors and volition of institutions. Case exemplars are presented in tables in each sub-section to demonstrate the interaction of resilience and vulnerability that can both co-exist within a population.

2.1 Type of uncertainty – ignorance

Indigenous communities seek to engage western science in meaningful ways to understand the potential impacts of climate change and to develop responses at the institutional levels that are supported by government and other actors with common interests. There were few examples in the literature of sources of resilience under the uncertainty of ignorance. Ignorance relates to incomplete information on the state of a system and the drivers that determine its dynamics that lead to indeterminacy over possible futures (Raskin et al. 2002). This highlights the opportunity for participatory

scenario planning – scenario building, development and analysis (Flynn et al., 2018). The acquisition of new skills is a way to reduce ignorance (uncertainty) as this would pose the solution upfront. Reducing ignorance and uncertainty through acquisition of new skills for analysing risk to cultural heritage, such as recording important rock art sites, was found to build resilience in northern Australia (Carmichael et al., 2017). For example, climate change in the Arctic will continue to open shipping corridors through the region and this has implications for First Nation communities in the Arctic. Dawson et al. (2020) demonstrates how a knowledge collaboration (using scenario planning) between Inuit communities and government provided a significant opportunity to create a corridor framework that would serve government and Inuit values and interests, at local and regional scales. Several authors, Dawson et al. (2020), Richards et al. (2019), and Vogel and Bullock (2020) propose that early involvement of Inuit people in collaborative planning prepares governments, industry and communities to engage in dialogue on adaptation policy response strategies. Such strategies can address emerging socio-economic, health, and broader resource development risks related to increased shipping traffic through the Arctic.

The issues raised by Dawson et al. (2020) highlight broader questions of distributive justice and of recompense for communities that will potentially lose greater hunting grounds and subsistence food security, where industry and resource development projects can potentially gain from the effects of climate change. The uncertainties and emergent nature of the effects of significant changes in the environment, and their consequent opportunities for natural resource and transport industries that impact Indigenous systems, highlight the central role of iterative adaptive planning across institutions. Establishing inclusive scenario building and analysis processes for adaptation planning across knowledge systems brings local knowledge and priorities to coordinated governance and response strategies that consider indirect but related effects of climate change (Vogel and Bullock, 2020). There were few examples in the literature of collaborative scenario building. Table 3 below presents an exemplar of where future climate scenarios were utilized to develop Indigenous adaptation strategies and priorities.

Table 3. An exemplar of where future climate scenarios were utilised to develop Indigenous adaptation strategies and priorities

	IGNORANCE	AUTHOR(S)
Source of Resilience	Involvement of Inuit People in identifying alternative future shipping channels under changing environment and industry scenarios	Dawson et al. (2020) (Arctic)
Source of Vulnerability	Exclusion of Inuit People and Inuit values in the design of current shipping channels without clear policy and pathways for their decision-making inclusion into the future. Iterative planning capability yet to be developed across institutions.	

The literature highlights opportunities for collaborative and Indigenous-led scenario-based planning, building and analysis as a pathway to support cross-institutional planning and to build adaptation planning capacity.

2.2 Type of uncertainty – surprise

Ecosystem service provision from Indigenous managed lands to regional and global societies is gaining increasing interest from non-Indigenous institutions. Sangha (2020) and Fuss et al. (2019) point to potential innovations for Indigenous ecosystem service schemes that can create work and development opportunities for Indigenous land managers, enabling new livelihood, well-being and resilience capabilities. In Australia, the literature shows how the re-introduction of Indigenous fire knowledge and practice can improve management of environmental systems under a changing climate (see Robinson et al., 2020 and, Williamson and Weir, 2020 for examples). Altman et al. (2020) illustrate the critical role of Indigenous centered fire management and the carbon abatement program in Northern Australia that delivers multiple benefits including protection of biodiversity, employment and management of wildfires. The authors also raise caution of the increasing costs of the program under changing climate and biophysical conditions. Bardsley et al. (2019) question the stark absence of Indigenous burning practices and knowledge in current environmental management intervention in the Mount Lofty Ranges in South Australia where there is, like other regions in Australia, increasing bush fire risk. Williamson and Weir (2020) further highlight the continuing trauma of dispossession on Aboriginal Peoples who have rights and interests on bushfire affected lands in urban and regional areas, but continue to be minimally engaged in post disaster recovery and adaptive planning. The absence of proper consideration of the inclusion of Indigenous knowledge negates improving environmental management and indigenous involvement and opportunities to explore social justice outcomes in established peri-urban landscapes (Bardsley et al., 2019, Williamson and Weir, 2020). While outside the geographical scope of this review, it is interesting to note that in Siberia it was reported that climate change could itself provide new livelihood opportunities, as warming may allow for the production of more southerly crop species (Callaghan et al., 2020). Table 4 below presents a case exemplar of where the benefits of Indigenous fire knowledge and management under the effects of climate change are supported through a stewardship scheme.

Table 4 An exemplar of where the benefits of Indigenous fire knowledge and management under the effects of climate change are supported through a stewardship scheme.

	SURPRISE	AUTHOR(S)
Resilience	Careful engagement with an emerging carbon trading market by an Aboriginal-owned not-for-profit to create opportunities for emissions reductions and income while improving environmental conditions.	Altman et al., (2020) (Australia)
Vulnerability	The market prices for carbon units and the emissions reduction fund scheme don't reflect the high cost of the remote work and the terrain of the activities.	

The literature highlights the limitations of western environmental management practices under a changing climate and the emerging adaption response opportunities of Indigenous-centred ecosystem stewardship schemes on Indigenous managed lands.

2.3 Type of uncertainty – volition of actors

Indigenous Peoples seek to engage in the climate change and adaptation dialogue holistically to incorporate community socio-economic, cultural and institutional interests. These broader goals require co-led adaptation planning to engage with multiple questions of: Indigenous expression of agency and assertion of collective rights; respectful engagement with Indigenous governance; cultural revival and sustenance; and self-determination (Mercer et al., 2020, Nursey-Bray et al., 2019, Nursey-Bray et al., 2020,

Artelle et al., 2019, Parsons et al., 2019). The literature suggests that adaptation planning must necessarily be couched within an enabling decision-making approach that:

- makes clear connections between place, economies and livelihoods and dynamic environmental changes
- engages beyond the geography of Country or traditional lands to the connections of groups and resource economies that have interests on traditional lands
- works with the fora of local forms of governance and decision-making systems
- creates opportunities for cross-generational healing, revival, wellbeing and re-dress legacy effects of wrongs from colonisation
- engages with and negotiates technological advancements that change the way activities are done on Country and walking in the two worlds scheduled by school and work commitments
- considers external socio-political pressures, governance and regulatory frameworks such as harvesting (wildlife) and competing land uses (mining interests) on traditional lands
- inclusion of Indigenous governance and knowledge in natural resource management policies and their translation into actions to transform management processes and decision-making.

Globally, Indigenous Peoples seek to define and articulate adaptation, the process of planning and the framing of risk and opportunities based on their worldviews and their Indigenous and historical knowledge (Nursey-Bray et al., 2020, Richards et al., 2019, Worden et al., 2020, Sawatzky et al., 2020). Responding to the effects of climate change is intrinsic to Indigenous obligations and responsibility to care for traditional lands (Altman et al., 2020, Worden et al., 2020, Zentner et al., 2019). In Canada and Alaska, the Inuvialuit and Gwich'in Peoples expressed the importance of connection and being on the land as integral to their way of adapting to climate change, continuing subsistence economies and traditions, and securing their lands and knowledge for future generations (Worden et al., 2020, Zentner et al., 2019). Efforts to foster intergenerational knowledge transfer helped next generations be aware of changes occurring and adapt to them (Richards et al., 2019, Galappaththi et al., 2019). Their agency to act is centred on their connection to their traditional lands and communities. For the Arabana People in Australia, adaptation was associated to a means of generating and reinforcing economic options and building adaptive capacity to enable their independence to return to live on their traditional lands (Nursey-Bray et al., 2020).

In Australia, New Zealand, Canada and USA, Indigenous knowledge and governance systems are the basis of Indigenous adaptation to changing environmental conditions (Nursey-Bray and Palmer, 2018, Worden et al., 2020, Altman et al., 2020, Sawatzky et al., 2020). Indigenous knowledge includes knowledge acquired through survival of colonisation as well as knowledge that has been shared over thousands of years, and is continually evolving (Herman-Mercer et al., 2019, Nursey-Bray et al., 2020, Parsons et al., 2016). This knowledge represents survival over thousands of years, and Aboriginal and Torres Strait Islander people draw resilience from knowing they have adapted to many environmental and climatic changes over millennia (Nursey-Bray et al., 2019). Indigenous knowledge and governance provide a framework for understanding what adaptation options may or may not be successful in the local context (Carmichael et al., 2017). For

example, Traditional Owners in Kakadu reported that sharing knowledge and educating the broader community about the vulnerability of cultural sites to the impacts of climate change was noted as being very important for protection of those sites – to foster support for proposed adaptation measures (Carmichael et al., 2017).

The co-production of knowledge for climate adaptation highlights the importance of learning with Indigenous Peoples and taking time to understand the nature of knowledge (Galappaththi et al. 2019). Knowledge co-production engages with questions about the ways that communication and understanding is established, and the responsibilities that are inherent with the process of setting aside the privilege and pre-conceptions of western science (Kalafatis et al., 2019, Galappaththi et al., 2019). These considerations include Indigenous Peoples setting the agendas, being paid for meaningful employment, being involved in culturally relevant research, and science plans that support mentoring (Dhillon, 2020). The literature has several examples of successful knowledge co-production. For example, Kalafatis et al. (2019), when observing knowledge collaborations between Native American tribe and climate science organisation affiliated individuals, highlighted that knowledge collaboration is as much about relationships of reciprocity based on agreed attitudes and practices as it is about creating new knowledge. Research with Gwich'in youth and next generations highlighted how sharing knowledge between generations improves understandings and enables them to be more perceptive to the changes that older generations are seeing (Proverbs et al., 2020). In this way, traditional knowledge is deemed important for protecting livelihoods and lifestyles under uncertainty into the future (Proverbs et al., 2020).

Globally, the inclusion of Indigenous knowledge in monitoring of the changing environment is a priority for Indigenous Peoples around the world (Sawatzky et al., 2020). The practice of monitoring, collection of data on traditional lands and community control of data fosters ownership over the use of information and asserts Indigenous collective rights (Wilson, 2019). Local observations and monitoring aids understanding of what climate adaptation options may be locally successful (Carmichael et al., 2017).

Community-based monitoring is often guided by principles of physical and spiritual connection to the land, reciprocity with land, observing, learning and sharing knowledge of land and self-determination in how knowledge is mobilised, disseminated and used to make decisions (Ansell et al., 2020, Sawatzky et al., 2020). For First Nations Peoples in Canada, monitoring outcomes include the responsibility to communicate this appropriately, and to anticipate the types of decisions that need to be made to sustain wellbeing (Wilson, 2019, Sawatzky et al., 2020).

Changes in technology are central in the portfolio of resources that can be utilised in adapting to a changing climate. For example, Indigenous Rangers in the Northern Territory, Australia, wanted to create 3D models of their most vulnerable rock art sites, so they could still be viewed in the event they were lost to climate change impacts (Carmichael et al., 2017). They also reported that digitisation of their cultural sites could generate data to support efforts to raise funds for their maintenance (Carmichael et al., 2017). Galappaththi et al. (2019) provides an example of young Inuit people in Canada using technology to co-learn through elders to build resilience in community fisheries using both learning by doing and formal education. In the Arctic, the use of technologies is changing some hunting practices, making some areas more accessible, reducing the time spent hunting (Herman-Mercer et al., 2019, Worden et al., 2020). The increased

accessibility of technologies including GPS and satellite imagery helped hunters to continue their practice under changing ice conditions in the Canadian Arctic (Proverbs et al., 2020). Galappaththi et al., (2019) further elaborate on how: satellite images and drones are used to assess ice conditions for travel; internet weather advice prevents travel at unsuitable times; GPS allows people to mark fishing spots and for navigation when travelling on ice; and VHF radios help people keep in touch with base when travelling. These changes are viewed differently by community members. Technology also was found to benefit climate change adaptation projects in Canadian First Nations Communities because Indigenous knowledge gave science based projects a local grounding (Proverbs et al., 2020). Combining scientific and local knowledge on the natural environment and society informs more nuanced understandings of climate change impacts (Proverbs et al., 2020); and can help to shape research and monitoring programs to address concerns across scales, from the local to the global (Sawatzky et al., 2020). Table 5 below presents two case exemplars of the types of uncertainties for building climate adaptation capability that relate to the volition of actors.

Table 5 Case exemplar of the types of uncertainties that relate to the volition of actors

	VOLITION OF ACTORS	AUTHOR(S)
Resilience Vulnerability	Monitoring environmental conditions is strongly related to attachments and an expression of stewardship of traditional lands bringing localised perspectives of wellbeing priorities to adaptation strategies. Inuit communities can be more heavily involved in monitoring and reporting than in developing and operationalising strategies to adapt to rapid transformative environmental change.	Sawatzky et al. (2020) (Circumpolar North)

The themes highlighted in the literature demonstrate that adaptation is an expression of Indigenous collective agency centred on connections and relationships to traditional lands. Connection to traditional lands can be expressed through monitoring of environmental change and is one means of asserting collective rights and strengthens Indigenous Peoples' agency in the use of information through Indigenous decision processes.

2.4 Type of uncertainty – volition of institutions

Indigenous decision-making processes, knowledge, culture and ways of being connected to traditional lands are a strong foundation for beginning dialogue for climate adaptation (Carmichael et al., 2017, Nursey-Bray and Palmer, 2018, Zentner et al., 2019, Parsons et al., 2019). Indigenous decision-making processes and authorities can lie across geographies, and express Indigenous responsibilities, relationships, and knowledges in different ways (Whyte, 2018a). These represent contemporary configurations of people and place, where strong connections can be sustained through knowledge sharing and education, despite people living away from place. For the Arabana People in Australia, respectful and productive climate adaptation planning necessarily engages with Arabana history, the situatedness of their knowledge, and acknowledges that knowledge connections exist in many places (Nursey-Bray et al., 2020). Nursey-Bray et al. (2020) points to the possibility of adaptation occurring through contemporary decision-making fora within and across Indigenous groups, situated across geographies with multiple connections, capabilities and forms of authority that relate back to place. These dimensions together generate unique capacities and dialogue for adaptation planning and action. Zentner et al. (2019) highlight the Arctic Gwich'in communities' unity in seeking to

conserve and manage an area of wildlife refuge, revered for its cultural and traditional significance, from the impacts of climate change that is intersecting with the energy development interests that lie elsewhere, including government and industry on their traditional lands. Adaptation planning should occur within a broader political and economic context where Indigenous Peoples seek to be engaged to respond to the effects and the industry and government drivers accelerating climate change.

In Australia, using locally embedded approaches has been found to build resilience, whether supported by government or non-government organisations (Ansell et al., 2020, Carmichael et al., 2018). Locally controlled planning helps to foster interventions which are locally valued and sustainable (Carmichael et al., 2017). By supporting Indigenous People as agents of change and acting through traditional institutions where possible, tailored and place-based climate change adaptation programs can be developed and implemented (Nursey-Bray et al., 2019). The Arnhem Land Fire Abatement (Northern Territory) Limited, a non-profit Aboriginal owned company, continues to foster a specific form of participatory governance across landowner groups to manage their engagement with the savannah burning carbon credit program that is sold on markets (Ansell et al., 2020).

Formal government-led frameworks that enable and resource Indigenous priorities on climate adaptation can transform the landscape of science and policy to broaden the benefits of collaborative science and governance to meet the multiple interests of Indigenous Peoples in adaptation planning (Dawson et al., 2020, Saunders et al., 2020). For example, the Government of Canada's Arctic Policy Framework includes the priority of continued collaboration with Arctic communities to ensure their priorities are at the fore of decisions impacting the Canadian Arctic and the government's role in the region (Dawson et al., 2020). Dawson's (2020) analysis of co-management arrangements in Arctic Canada cautions that legal protection often doesn't involve Indigenous Peoples as decision-makers, only beneficiaries, challenging the priorities and risks that become included in adaptation planning. Table 6 below presents two exemplars of uncertainties of volition of institutions from Australia demonstrating the innovations of Indigenous institutions across geographies.

Table 6 Two exemplars of the types of uncertainties related to volition of institutions

	VOLITION OF INSTITUTIONS	AUTHOR(S)
Resilience	Indigenous decision authorities and knowledge connections to place draw from and lie across multiple geographies and expressed in a variety of ways.	Nursey-Bray et al., (2020) (Australia)
Vulnerability	Adaptation planning that continues to narrow Indigenous knowledge to old and 'Traditional Knowledge' that is based only in one geography	
Resilience	Traditional Owners in Arnhem Land are continuing to practice fire management and care of their Country, through participatory governance of an Aboriginal owned not-for-profit company, to meet their income and environmental goals in carbon credit projects under increasing seasonal weather extremes.	Ansell et al., 2020) (Australia)
Vulnerability	Culturally important plants yet to be formally included in regional prioritisation processes for adaptation planning. Iterative planning capability yet to be developed across institutions.	

A key theme from the literature is that Indigenous innovation in adaptation capability is based on Indigenous-led decision processes and authorities that are connected to traditional lands and lie across geographies.

2.5 Summary

In this section we presented general themes of the types of uncertainties for sources of resilience from the literature using the Lyons et al. (2018) framework. These include emerging opportunities and the increasing importance for ecosystem stewardship schemes on Indigenous lands, engaging with community based monitoring more broadly as a process that supports Indigenous governance and decision-making for their traditional lands, and adjusting adaptation planning processes to engage with Indigenous governance that is situated across geographies. The literature shows the inter-connectedness of resilience and vulnerability and that their sources can emanate from diverse processes, historical institutional and political systems of disadvantage while also highlighting the strength and multiple paths of expressions of Indigenous resilience much of which remains largely absent in the framing and engagement with climate adaptation planning. In the next section we present themes from the literature on the types of uncertainty for adaptation planning capability for sources of vulnerability.

3 Sources of vulnerability – history of colonisation, contemporary context of socio-economic disadvantage, chronic poor health

Indigenous Peoples' relationship and connection to traditional lands, to place, is the foundation on which environmental change is made sense of, understood and acted on. These relationships are a source of resilience that are also made vulnerable through the legacies of colonial dispossession, post-colonial policies that weaken indigenous institutions and customary practices that are not enabled in the collective action needed to respond to the fast pace of environmental change.

In this section we will focus on the sources of vulnerability from Table 1 (see Table 7 below). Vulnerability is socially, politically and culturally situated (Howitt, 2020, Ford et al. 2020, Nursey-Bray et al. 2019, Parsons et al. 2019). The types of uncertainties for building climate adaptation planning capability include type of and amount of loss of Country from sea level rise, and future opportunities to utilise Indigenous knowledge with science to address climate change through Indigenous-led processes. Case exemplars are presented in tables under each sub-section to illustrate the inter-connectedness of vulnerability and resilience, that these can co-exist within a population though not necessarily with the same influencing effect.

Table 7 Analytic framework relating types of uncertainty for sources of vulnerability in building capability for climate adaptation planning (source Lyons et al. 2019).

SOURCES OF VULNERABILITY	TYPES OF UNCERTAINTY FOR BUILDING CLIMATE ADAPTATION PLANNING CAPABILITY			
	IGNORANCE	**SURPRISE**	**VOLITION OF ACTORS**	**VOLITION OF INSTITUTIONS**
History of colonialism, contemporary context of socio-economic disadvantage, chronic poor health	Engagement on the potential impacts of climate change on existing environmental, socio-economic and institutional vulnerabilities.	Type of and amount of loss of country from sea level rise Type of changes in distribution and availability of culturally important species.	Limited future opportunities to utilise IK with science to address climate change through indigenous driven processes.	Limited future multi-scale climate adaptation planning that continuously engage indigenous peoples as key groups with particular long-term relationships, interests and values over their traditional lands and seas.

The types of uncertainties presented in this section demonstrate the types of mechanisms that can increase the sources of vulnerability for Indigenous Peoples and communities in building climate adaptation planning capability. The first of these types of uncertainties is ignorance.

3.1 Type of uncertainty – ignorance

The uncertainties of the effects of climate change on transportation systems and infrastructure and the consequential costs to remote communities is a concern that is often not considered in technical and scenario assessments of a changing environment. Dawson et al. (2020), Hill et al. (2020b), Khalafzai et al. (2019), Hall and Crosby (2020), and Richards et al. (2019) show how Indigenous Peoples living in remote communities are concerned about the heightened risks from increasingly dangerous transport networks, on roads and ice, under more severe weather events. These concerns include risks to human life, costs to personal transport systems, access to health facilities and consequential effects on costs of goods and services.

Hill et al. (2020b) highlight concerns of the Ltyentye Apurte community on housing availability and design for the local environment, and uncertainties of heating and cooling costs under more extreme seasonal temperatures. The authors demonstrate that collaborative adaptive actions within the Ltyentye Apurte community's influence were possible, such as planting trees for cooling and small-scale erosion control, but these were short term actions for a community locked into an externally driven mal-adaptive pathway.

In Alaska, Tran (2020) shows how the effects and opportunity for action on slow acting processes such as erosion, can create crisis once a threshold of damage is reached. Greater understanding of the effects of climate change on slow moving environmental processes, such as erosion on lands and waters, are important as these can have devastating impacts on livelihoods and culture. Table 8 below presents a case exemplar from Central Australia of the Ltyentye Apurte community that faces future uncertainties of severe weather conditions, including extreme temperatures, and a source of resilience through a ranger program that is acting now to plant trees for their future cooling effects.

Table 8 A case exemplar of uncertainty related to ignorance showing the interaction of vulnerability and resilience from Central Australia

	IGNORANCE	AUTHOR(S)
Vulnerability	Uncertainties about the effects of severe weather on living conditions with existing housing and strategies for cooling homes, as well as access to the community and health facilities, costs of goods and services.	Hill et al., (2020) (Australia)
Resilience	On-ground ranger program that sourced and planted trees for shade around living spaces.	

Indigenous Peoples are expressing increasing interest to engage with climate projections that can aid discussions about pathways of change under a changing climate and sensitive environmental conditions (Flynn et al., 2018). They seek to engage in appropriate locally acceptable scenario building and analysis processes to understand the potential effects of future climate change scenarios to determine their response and adaptation pathways options (Dawson et al., 2020, Flynn et al., 2018, Khalafzai et al., 2019, Lyons et al., 2020, Parsons et al., 2019). Progress is limited by western technical expertise to interpret climate models, and the global climate drivers that affect local conditions and investment in resources that enable participatory scenario planning (Flynn 2020). Indigenous Peoples have also reported feeling disadvantaged due to a lack of opportunity for planning and access to western science and scientists (Pecl et al., 2019); and lack of knowledge about climate change among younger generations due to poor education standards in Indigenous communities (Carmichael et al., 2017). Until climate change is recognised and addressed as a significant issue to human social and natural systems that requires inclusive processes to manage and adapt to change, routine practices that privilege particular knowledges and practices will continue to operate as stop gap measures to managing risk and uncertainties.

A key theme from the literature are the presence of wider social and economic uncertainties in building climate adaptation planning capabilities that are related to access to resources and the costs of goods and services.

3.2 Type of uncertainty – surprise

Indigenous Peoples are increasingly expressing uncertainty about seasonal changes and their effects and greater certitude of extreme events. In Central Australia, the Ltyentye Apurte community have observed more severe and frequent storms, changes in temperatures and precipitation (Hill et al., 2020b). There have also been reports of changing availability of important plant resources in many parts of Australia (see Hill et al., 2020b, Lyons et al., 2020 for examples). In the Arctic and Alaska, Indigenous Peoples are reporting warmer and shorter winters (Khalafzai et al., 2019, Worden et al., 2020). In Alaska, Tran et al. (2020) refers to the decline of fur seal populations and seabird species. Albert et al. (2018) and Herman-Mercer et al. (2019) report changed subsistence food gathering activities from altered snow and sea ice conditions in Alaska. Dawson (2020) also reports changing food security for Inuit hunters whose ability to hunt has been severely curtailed by reduced sea ice conditions. Table 9 below presents a case exemplar from Alaska illustrating the inter-connectedness of vulnerability and resilience for remote Chevak and Kotlik communities who are experiencing disproportionate effects of climate change. These communities began to incorporate moose in their portfolio of resources as these became available to them through the effects of climate change.

Table 9 A case exemplar of uncertainty related to surprise illustrating the interaction of vulnerability and resilience

	SURPRISE	AUTHOR(S)
Vulnerability	Coastal communities are experiencing severe storms after the reduction of autum ice that previously provided a buffer. Storm driven tides have impacted freshwater availability, plant communities and wildlife movement across the landscape.	Herman-Mercer et al., (2019) (Alaska)
Resilience	A diverse resource base and flexible subsistence system that enables species substitutions within the communities. These are underpinned by subsistence insitutions that have adapted to socio political and environmental change.	

Internationally, concerns are being expressed about the loss of knowledge associated with customary subsistence activities and the sharing of knowledge related to changes in hunting and foraging activities across generations (Tran 2020, Khalafzai 2019, Albert 2017, Wodon 2020). The loss of local knowledge is identified as a key source of vulnerability. In some cases the impacts of knowledge loss were direct, for example some young Inuit have poor knowledge of important survival skills on ice, as well as handling dog teams and sewing seal skin (Galappaththi et al., 2019). Richards et al. (2019) similarly reported increased safety concerns on the land and instances of hunted animals being wasted due to the legacy of colonial discouragement of use of Indigenous knowledge. Along with concerns of loss of Indigenous knowledge, many communities reported feeling disadvantaged due to low formal education rates, with impacts for locally grounded adaptation planning (Galappaththi et al., 2019).

The types of uncertainties stated here are important considerations in exploring the role of technology and mixed approaches to co-learning within Indigenous Peoples and in knowledge sharing that can happen beyond place. As stated above, observing and monitoring these changes in ways that strengthen Indigenous decision-making processes and governance is central to building adaptation planning capability (see Wilson, 2019).

A key theme from the literature is that Indigenous Peoples are continuing to observe and experience unpredictable seasonal weather patterns. Indigenous institutions play a central role in adaptation to socio-political and environmental changes but can also be challenged by the pace of change.

3.3 Type of uncertainty – volition of actors

There is strong support for knowledge collaborations across the research community, however knowledge collaborations can be harmful when national and federal regulations are not regularly reviewed and adapted regionally with context relevant outcomes for Indigenous communities (Kalafatis et al., 2019). Knowledge co-production projects that aim for collective decision-making to manage and respond to the effects of climate change can weaken respectful participation when power is not genuinely acknowledged and actively countered through Indigenous methodologies (Parsons et al., 2019). Such challenges can be particularly stark, as remarked in Nursey-Bray et al. (2020) of pre-conceptions of traditional knowledge as expressions of sacredness and stories. Requests to be involved in collaborative projects require practical forms of compensation to individuals and groups and recognition that highly sought-after participants are often juggling multiple commitments and priorities and respect for Indigenous expertise (Hill et al., 2020b, Kalafatis et al., 2019).

Knowledge collaboration procedures can harm or strengthen trust building and reinforce injustices between settler societies and Indigenous Peoples (Kalafatis et al., 2019). Dhillon (2020) points to the patterns of exclusion of women and youth as central actors (in leadership roles) in a social network analysis of a Canadian climate science collaboration. Exclusion of diverse Indigenous voices, the improper use of traditional knowledge and the exclusion of Indigenous People, or the right people, from dialogue affects the accountability of decision-making, quality of knowledge creation and its application and type of engagement (Kalafatis et al., 2019, Dhillon, 2020). Approaches which embrace multi-generations and diversity enable the inclusion of different kinds of knowledge held by different people in Indigenous communities (Dhillon, 2020). The complexity and multiplicity of issues to be addressed with Indigenous Peoples on climate change require long-term engagement (Kalafatis 2019). Table 10 presents a case exemplar of uncertainty from Arabana Country, that relates to the volition of actors in building climate adaptation capability. Government pre-conceptions of Arabana adaptation as being based on 'traditional' knowledge can generate vulnerabilities in the types of collaborations sought, the type of knowledge partnership, and the scoping of pathways for adaptation planning.

Table 10 A case exemplar of uncertainty that relates to the volition of actors from Arabana Country

	VOLITION OF ACTORS	AUTHOR(S)
Vulnerability	Government policy actors hold pre-conceived ideas of Arabana adaptation to be based on climate knowledge that is 'traditional' or 'old'.	Nursey-Bray et al., (2020) (Australia)
Resilience	Arabana People and knowledge holders express their knowledge in multiple ways at regional and local scales. Arabana knowledge includes historical knowledge of colonisation, their Country and is continually in a process of becoming.	

Indigenous communities are negotiating and managing fast and unpredictable environmental changes that act on existing stressors and weaken sources of resilience. Technological advancements are also changing the ways Indigenous knowledge is recorded, stored, shared and circulated, with opportunities for hybrid innovations. Digital transformation introduces new challenges of data control and benefit sharing arrangements that strengthen self-determination and sovereignty in building climate adaptation planning capability across knowledge systems (Wilson, 2019). Woden (2020) and Tran et al. (2020) demonstrate the multiple layers of uncertainties that Inuit communities are negotiating under the effects of climate change, including:

- increasingly hazardous harvesting conditions and the effects on inter-generational knowledge sharing;
- the combined effects of loss of elders and youth wage employment and formal education on knowledge sharing; and
- western and technological influences that are changing the way types of knowledge sharing happens.

The types and degrees of challenges vary across and within Indigenous communities, but Indigenous institutions remain the cornerstone of long-term capacity development that will secure the multiple interests of Indigenous Peoples in climate adaptation planning.

The literature highlights several themes, first that pre-conceptions of Indigenous knowledge can undermine knowledge co-production for adaptation planning. Second, that short-term engagement can undermine trust and the type of relationships required to build appropriate adaptation planning capability. Third, fast and unpredictable environmental changes and technological advancements act on existing social and economic stressors of Indigenous societies.

3.4 Type of uncertainty – volition of institutions

The legacies of colonisation continue to be present in Indigenous settlements that have been forcibly moved to live in areas that have limited adaptive options, and where indigenous knowledge and the breadth of responsibilities have been undermined by multiple drivers of change, including infrastructure, land dispossession, pollution, urban development and industry (Hill et al., 2020b, Khalafzai et al., 2019, Williamson and Weir, 2020, Whyte, 2018a). Hill et al. (2020b) present an example from Central Australia of Government designed homes that do not incorporate cultural values and are ill-equipped to protect households of Ltyenty Apurte community under extreme temperatures. Fayazi et al. (2020) show how the lack of recognition of land rights for a Mohawk by the Canadian Government has left its members vulnerable, with limited relocation options from the flood zone. Externally driven institutional processes create uncertainties and risks to Indigenous Peoples lives where their priorities and governance are not properly considered and included in climate adaptation planning.

Resources for Indigenous land management programs in Australia, including lack of resources or sustained funding, and issues around biases in how funds and programs are distributed, were highlighted as a source of uncertainty and instability limiting long-term planning and capability development (Altman et al., 2020, Nursey-Bray et al., 2019). Some of the factors highlighted were targeting of remote areas over regional or urban areas (where most Indigenous People live); and an ongoing issue around low continuity of funding for programs (Nursey-Bray et al., 2019, Carmichael et al., 2017). In the Northern Territory, Indigenous rangers found that lack of funding prevented investment in important partnerships for protecting Indigenous heritage (Carmichael et al., 2017).

Vulnerability created through the privileging of western knowledge and institutional arrangements occurs across governments and industry. Industry represents on-going pollution generating activities that contribute to the complex mix of climate, social, economic and environment related change that are of interest to Indigenous Peoples. The absence of Indigenous knowledge in service delivery planning and development, and in the understanding of the breadth of dimensions of risk, by default increase exposure of Indigenous Peoples to the continuing effects of climate change and industry (Dawson et al., 2020, Fuss et al., 2019). Dawson et al. (2020) highlights the lack of local perspectives and priorities in existing sea corridors in the Arctic and by default the types of values that are protected, in contradiction to the formal rights ascribed to Indigenous Peoples in the land claim agreements established under the Canadian reconciliation agenda.

Greater harm can be inflicted on Indigenous Peoples when climate adaptation planning decisions are disconnected from those made for and by industry, who themselves represent existing types of accepted planning processes with communities (Herman-Mercer et al., 2019). Fuss et al. (2019) points to the lack of Indigenous Peoples' involvement in land planning and the narrowed consent processes acknowledged by the Canadian government. The narrowed terms of Indigenous decision-making enable development decisions without full understanding and consent of potential environmental harm. Hunsberger and Awasis (2019) highlights the epistemic limits that governments and industry can operate from, when they define Indigenous knowledge to particular practices and land use systems, they undermine the Indigenous law and decision-making frameworks that govern use and sustenance of value systems that are connected to particular lands and waters. Hunsberger and Awasis (2019) points out that government, industry, and the First Nations people had different understandings of procedural fairness and transparency and the types of benefits that would be delivered to First Nations communities in an oil sands pipeline development. Indigenous adaptative resilience can be undermined by the effects of industry, through positive reinforcement of environmental degradation, and disruption of the relationship of people to the environment at a pace that compromises self-determination of those societies (Whyte, 2018a).

Resource development planning does not sufficiently incorporate the current and future threats to culture and livelihoods posed by climate change to Indigenous communities (Hunsberger and Awasis, 2019, Zentner et al., 2019). Responsibilities for the social welfare of Indigenous communities can be overlooked in the drive to develop resources (Zentner et al., 2019). Indigenous Peoples who live and own resource rich lands and waters can be disempowered when the debate of climate change is disconnected from natural resource development. Zentner et al. (2019) highlights the anticipated effects of continued development on habitat displacement and predation on the Porcupine Caribou Herds that is important to the Gwich'in communities. Hunsberger and Awasis (2019) points to the exclusion of the contributions of fossil fuel development on already encroached Indigenous lands to dialogue about climate change and the circular effects on Indigenous communities. Environmental pollution of Indigenous lands potentially affects culture, harming Indigenous relationships of responsibilities to traditional lands and future generations. Table 11 below presents two case exemplars of uncertainty through volition of institutions. One is of the Gwich'in peoples in the Arctic who had not been consulted on future oil and gas resource development in the Arctic National Wildlife Refuge (ANWR). The Gwich'in people have established a unified steering committee to uphold their rights to be included in development decision-making. The second exemplar is from New Zealand, of the legacy and continuing Pakeha government policies that exclude Maori knowledge and social values from decision-making of river systems. Resilience is being exercised and generated from the reassertion of Maori values, law and rights through legal mechanisms and institutional arrangements to establish relational ethics to manage rivers.

Table 11 Two case exemplars from the Arctic and New Zealand of uncertainty through volition of institutions in building adaptation planning capability

	VOLITION OF INSTITUTIONS	AUTHOR(S)
Vulnerability	Development of oil and gas resources in the Arctic National Wildlife Refuge (ANWR) will intensify the livelihood challenges already being experienced by Gwich'in people under the cumulative threats of climate change. Threats to Gwich'in people had not been consulted on development plan.	Zenter, E. (2019) (Arctic)
Resilience	Gwich'in people's inter-generational relationship to their traditional lands and advocacy by Gwich'in unified steering committee upholding their rights to be included in development decision-making (in line with fulfilment of international treaty obligations under the Alaska National Interest Lands Conservation Act)	
Vulnerability	Legacy of and the continuing Pakeha government policies and actions exclude Maori knowledge and social values from management and decisions-making of river systems in the Rangitaiki Plains in NZ have generated path dependency.	Parsons, M. et al., (2019) (New Zealand)
Resilience	Maori values, law and rights that are being reasserted through legal mechanisms and new institutional arrangements. Connections with other collaborative institutional arrangements that establishing relational ethics in policy discussions to manage rivers.	

Khalafzai et al. (2019) and Parsons et al. (2019) draw our attention to government designed policies, planning and infrastructure, of managing rivers and flood events have established mal-adaptive path dependencies in New Zealand and Canada. Parsons et al. (2019) demonstrate how various historical mechanisms including institutional arrangements (layers of governance and divisions of responsibilities) for flood management, investment in fixed costs of infrastructure, legislation and learning processes that operate within particular types of prioritised knowledge and data self-stabilise and reinforce pathway dependencies that continue to privilege the colonial worldview in flood risk management and river management in the Rangitāiki Plains in New Zealand. Khalafzai et al. (2019) relays how flood mitigation infrastructure in the James Bay region of Northern Ontario increased the unpredictability of severe flooding events and work to constrain the future growth of Kaschewan First Nation communities. The authors call for greater inclusion of Indigenous decision-making, of the people directly experiencing and being affected by the effects of climate change (increased summer flooding) and annually exposed to the increased unpredictability created through fixed investment in infrastructure, and have now become reliant on the government institutional arrangements that manage the community dyke flood management system.

Similarly, Albert et al., (2018) and Herman-Mercer et al. (2019) demonstrate how colonial policies of community relocation have, over time, severely minimised the adaptive capacities of communities. For the Inupiat village, in Alaska, the government continued to invest in shoreline protection structures while deliberating on community requests to re-locate to a preferred site. In a remote Inuit community in Labrador, Canada, called Black Tickle, the church's resettlement program placed the community on a water-poor island where the community members continue to suffer the effects of water insecurity under a decentralised water governance system. In contrast, the lack of understanding of western institutional arrangements was a source of vulnerability to flood damage for a Mohawk community on the border of USA and Canada, as they tried to warn authorities about impending danger, but were unaware of the appropriate channels to work through (Fayazi et al., 2020). The sources of vulnerability for these Indigenous communities continue to be reinforced through the legacies of colonial decision-making systems and settler government institutional arrangements.

The key themes highlighted in this section are the legacies of colonisation that continue to be expressed through loss of quality of trust, consent and accountability across Indigenous and non-Indigenous institutions. The legacy of colonisation includes procedural vulnerability, a condition of settler society that occurs through government and industry centred planning and recognition that assumes an understanding of consultation, consent and trust. Environmental risk management based on fixed investments in infrastructure and institutional arrangements that service that system increase the unpredictability of adaptation for Indigenous Peoples.

3.5 Summary

In this section we presented themes of the types of uncertainties for sources of vulnerability from the literature using the Lyons et al. (2018) framework. These include uncertainties over future pathway options that can be generated through co-designed and Indigenous-led scenarios, uncertainties in building climate adaptation capacity to respond to changing access to resources, and the costs of goods and services that are integral to Indigenous livelihood. Indigenous Peoples are continuing to observe and experience unpredictable changes to the environment that are exacerbating existing stressors. Indigenous institutions are central to building community adaptation planning capacities, but they also face the challenge of adapting to fast-paced socio-political and environmental changes.

Colonisation and the legacies of colonial policies continue to be a source of vulnerability for Indigenous Peoples in their preconceptions of Indigenous knowledge and the privileging of western knowledge in resource and environmental risk management. Preconceptions of Indigenous knowledge undermine knowledge co-production partnerships for climate adaptation planning and transformative change. The loss of quality of trust and accountability in climate adaptation planning collaborations across Indigenous and non-Indigenous institutions reflect the on-going effect of colonisation.

4 Conclusion

This report presents a synthesis of contemporary literature regarding the types of uncertainties for building climate adaptation capacities as expressed by Indigenous Peoples from Australia, New Zealand, Canada and USA. This review of the literature through the lens of the framework presented by Lyons et al. (2019) has enabled a methodical approach to understanding the uncertainties that relate to both sources of resilience (experience and knowledge of the environment, rights and interests over traditional lands and waters) and vulnerability (history of colonisation, context of socio-economic disadvantage). The review illustrates that sources of uncertainties for building adaptation planning capabilities for resilience and vulnerability can co-exist at any one time and have different degrees of influence within Indigenous groups.

Indigenous Peoples continue to connect and have relationships with their traditional lands and Country in multiple ways across diverse Indigenous social, political, economic, and ecological systems that demonstrate continued survival and resilience through colonisation and its legacies, and environmental change. Adaptation planning and the conceptualisation of vulnerability and resilience span geographical, political, and temporal scales. An understanding of the sources of resilience and vulnerabilities, as conceptualised by Indigenous Peoples, and the nature of the uncertainties in building capacity for climate adaptation planning, can transform adaptation planning to meet the broader goals of self-determination, cultural revival, and inter-generational care. Offering an approach that builds trust and humility for two-way learning that is strongly based on continued affirmation of consent, and trust and accountability at multiple levels of government, industry and research will challenge the institutional systems that continue to facilitate power differentials. Governments and research agencies would also need to be prepared to resource genuinely collaborative and Indigenous-led decision-making. This synthesis highlights the continued challenge and need to enact new ways of working together on climate adaptation planning that is advocated around the world by Indigenous practitioners, leaders, researchers and their partners in government, non-government agencies, research, and industry.

This this review has identified several opportunities for research collaboration to support Indigenous-led initiatives to build climate adaptation planning capabilities. These include:

- Indigenous-driven and co-designed scenario planning, that includes scenario building and analysis, climate adaptation projects
- Indigenous environmental monitoring programs is an important pathway to support Indigenous Peoples' agency through Indigenous decision processes
- Working with contemporary Indigenous governance on climate adaptation planning that are connected to Country and situated across geographies
- Creating and enabling markets for Indigenous ecosystem stewardship programs that create multiple benefits for the environment and Indigenous goals

Enabling pathways to connect Indigenous Peoples to regional and national policy mechanisms and industry on resource development dialogues that shape the drivers of climate change.

References

Albert, S., Bronen, R., Tooler, N., Leon, J., Yee, D., Ash, J., Boseto, D. & Grinham, A. 2018. Heading for the hills: climate-driven community relocations in the Solomon Islands and Alaska provide insight for a 1.5 degrees C future. *Regional Environmental Change,* 18**,** 2261-2272.

Altman, J., Ansell, J. & Yibarbuk, D. 2020. No ordinary company: Arnhem Land Fire Abatement (Northern Territory) Limited. *Postcolonial Studies,* 23**,** 552-574.

Ansell, J., Evans, J., Rangers, A., Rangers, A. S., Rangers, D., Rangers, J., Rangers, M., Rangers, N. N., Rangers, W., Rangers, Y. & Rangers, Y. M. 2020. Contemporary Aboriginal savanna burning projects in Arnhem Land: a regional description and analysis of the fire management aspirations of Traditional Owners. *International Journal of Wildland Fire,* 29**,** 371-385.

Artelle, K. A., Zurba, M., Bhattacharyya, J., Chan, D. E., Brown, K., Housty, J. & Moola, F. 2019. Supporting resurgent Indigenous-led governance: A nascent mechanism for just and effective conservation. *Biological Conservation,* 240**,** 108284.

Bardsley, D. K., Prowse, T. a. A. & Siegfriedt, C. 2019. Seeking knowledge of traditional Indigenous burning practices to inform regional bushfire management. *Local Environment,* 24**,** 727-745.

Brondizio, E., S. & Le Tourneau, F., -Michel 2016. Environmental governance for all. *Science,* 352**,** 1272-1273.

Callaghan, T. V., Kulikova, O., Rakhmanova, L., Topp-Jorgensen, E., Labba, N., Kuhmanen, L. A., Kirpotin, S., Shaduyko, O., Burgess, H., Rautio, A., Hindshaw, R. S., Golubyatnikov, L. L., Marshall, G. J., Lobanov, A., Soromotin, A., Sokolov, A., Sokolova, N., Filant, P. & Johansson, M. 2020. Improving dialogue among researchers, local and indigenous peoples and decision-makers to address issues of climate change in the North. *Ambio,* 49**,** 1161-1178.

Carmichael, B., Wilson, G., Namarnyilk, I., Nadji, S., Brockwell, S., Webb, B., Hunter, F. & Bird, D. 2017. Local and Indigenous management of climate change risks to archaeological sites. *Mitigation and Adaptation Strategies for Global Change,* 23**,** 231-255.

Carmichael, B., Wilson, G., Namarnyilk, I., Nadji, S., Brockwell, S., Webb, B., Hunter, F. & Bird, D. 2018. Local and Indigenous management of climate change risks to archaeological sites. *Mitigation and Adaptation Strategies for Global Change,* 23**,** 231-255.

Dawson, J., Carter, N., Van Luijk, N., Parker, C., Weber, M., Cook, A., Grey, K. & Provencher, J. 2020. Infusing Inuit and local knowledge into the Low Impact Shipping Corridors: An adaptation to increased shipping activity and climate change in Arctic Canada. *Environmental Science & Policy,* 105**,** 19-36.

Dhillon, C. M. 2020. Indigenous Feminisms: Disturbing Colonialism in Environmental Science Partnerships. *Journal of Physics D-Applied Physics,* 53.

Fayazi, M., Bisson, I.-A. & Nicholas, E. 2020. Barriers to climate change adaptation in indigenous communities: A case study on the mohawk community of Kanesatake, Canada. *International Journal of Disaster Risk Reduction,* 49.

Flynn, M., Ford, J. D., Pearce, T., Harper, S. L. & Team, I. R. 2018. Participatory scenario planning and climate change impacts, adaptation and vulnerability research in the Arctic. *Environmental Science & Policy,* 79**,** 45-53.

Ford, J. D., King, N., Galappaththi, E. K., Pearce, T., Mcdowell, G. & Harper, S. L. 2020. The Resilience of Indigenous Peoples to Environmental Change. *One Earth,* 2**,** 532-543.

Fuss, G. E., Steenberg, J. W. N., Weber, M. L., Smith, M. A. & Creed, I. F. 2019. Governance as a driver of change in the Canadian boreal zone. *Environmental Reviews,* 27**,** 318-332.

Galappaththi, E. K., Ford, J. D., Bennett, E. M. & Berkes, F. 2019. Climate change and community fisheries in the arctic: A case study from Pangnirtung, Canada. *Journal of Environmental Management,* 250**,** 109534.

Hall, N. L. & Crosby, L. 2020. Climate Change Impacts on Health in Remote Indigenous Communities in Australia. *International Journal of Environmental Health Research*.

Herman-Mercer, N. M., Laituri, M., Massey, M., Matkin, E., Toohey, R. C., Elder, K., Schuster, P. F. & Mutter, E. 2019. Vulnerability of Subsistence Systems Due to Social and Environmental Change: A Case Study in the Yukon-Kuskokwim Delta, Alaska. *Arctic,* 72**,** 258-272.

Hill, R., Adem, Ç., Alangui, W. V., Molnár, Z., Aumeeruddy-Thomas, Y., Bridgewater, P., Tengö, M., Thaman, R., Adou Yao, C. Y., Berkes, F., Carino, J., Carneiro Da Cunha, M., Diaw, M. C., Díaz, S., Figueroa, V. E., Fisher, J., Hardison, P., Ichikawa, K., Kariuki, P., Karki, M., Lyver, P. O. B., Malmer, P., Masardule, O., Oteng Yeboah, A. A., Pacheco, D., Pataridze, T., Perez, E., Roué, M.-M., Roba, H., Rubis, J., Saito, O. & Xue, D. 2020a. Working with indigenous, local and scientific knowledge in assessments of nature and nature's linkages with people. *Current Opinion in Environmental Sustainability,* 43**,** 8-20.

Hill, R., Walsh, F. J., Davies, J., Sparrow, A., Mooney, M., Council, C. L., Wiser, R. M. & Tengo, M. 2020b. Knowledge co-production for Indigenous adaptation pathways: Transform post-colonial articulation complexes to empower local decision-making. *Global Environmental Change-Human and Policy Dimensions,* 65.

Howitt, R. 2020. Unsettling the taken (for granted). *Progress in Human Geography,* 44**,** 193-215.

Hunsberger, C. & Awasis, S. 2019. Energy Justice and Canada's National Energy Board: A Critical Analysis of the Line 9 Pipeline Decision. *Sustainability,* 11.

Kalafatis, S. E., Whyte, K. P., Libarkin, J. C. & Caldwell, C. 2019. Ensuring climate services serve society: examining tribes' collaborations with climate scientists using a capability approach. *Climatic Change,* 157**,** 115-131.

Khalafzai, M. a. K., Mcgee, T. K. & Parlee, B. 2019. Flooding in the James Bay region of Northern Ontario, Canada: Learning from traditional knowledge of Kashechewan First Nation. *International Journal of Disaster Risk Reduction,* 36.

Langton, M., Parsons, M., Leonard, S., Auty, K., Bell, D., Burgess, P., Edwards, S., Howitt, R., Jackson, S., Mcgrath, V. & Morrison, J. 2012. *National Climate Change Adaptation Research Plan For Indigenous Communities*.

Lyons, I., Hill, R., Deshong, S., Mooney, G. & Turpin, G. 2019a. Putting uncertainty under the cultural lens of Traditional Owners from the Great Barrier Reef Catchments. *Regional Environmental Change,* 9**,** 1597-1610.

Lyons, I., Hill, R., Deshong, S., Mooney, G. & Turpin, G. 2019b. Putting uncertainty under the cultural lens of Traditional Owners from the Great Barrier Reef Catchments. *Regional Environmental Change,* 19**,** 1597-1610.

Lyons, I., Hill, R., Deshong, S., Mooney, G. & Turpin, G. 2020. Protecting what is left after colonisation: embedding climate adaptation planning in traditional owner narratives. *Geographical Research,* 58.

Maru, Y. T., Stafford Smith, M., Sparrow, A., Pinho, P. F. & Dube, O. P. 2014. A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Global Environmental Change,* 28**,** 337-350.

Mercer, N., Hudson, A., Martin, D. & Parker, P. 2020. "That's Our Traditional Way as Indigenous Peoples": Towards a Conceptual Framework for Understanding Community Support of Sustainable Energies in NunatuKavut, Labrador. *Sustainability,* 12.

Nursey-Bray, M. & Palmer, R. 2018. Country, climate change adaptation and colonisation: insights from an Indigenous adaptation planning process, Australia. *Heliyon,* 4.

Nursey-Bray, M., Palmer, R., Smith, T. F. & Rist, P. 2019. Old ways for new days: Australian Indigenous peoples and climate change. *Local Environment,* 24**,** 473-486.

Nursey-Bray, M., Palmer, R., Stuart, A., Arbon, V. & Rigney, L. I. 2020. Scale, colonisation and adapting to climate change: Insights from the Arabana people, South Australia. *Geoforum,* 114**,** 138-150.

Parsons, M., Fisher, K. & Nalau, J. 2016. Alternative approaches to co-design: insights from indigenous/academic research collaborations. *Current Opinion in Environmental Sustainability,* 20**,** 99-105.

Parsons, M., Nalau, J., Fisher, K. & Brown, C. 2019. Disrupting path dependency: Making room for Indigenous knowledge in river management. *Global Environmental Change,* 56**,** 95-113.

Pecl, G. T., Ogier, E., Jennings, S., Van Putten, I., Crawford, C., Fogarty, H., Frusher, S., Hobday, A. J., Keane, J., Lee, E., Macleod, C., Mundy, C., Stuart-Smith, J. & Tracey, S. 2019. Autonomous adaptation to climate-driven change in marine biodiversity in a global marine hotspot. *Ambio,* 48**,** 1498-1515.

Petheram, L., Zander, K. K., Campbell, B. M., High, C. & Stacey, N. 2010. 'Strange changes': Indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia). *Global Environmental Change,* 20**,** 681-692.

Proverbs, T. A., Stewart, A. R., Vittrekwa, A., Vittrekwa, E., Hovel, R. A. & Hodgson, E. E. 2020. Disrupted ecosystem and human phenology at the climate frontline in Gwich'in First Nation territory. *Conserv Biol*.

Richards, G., Frehs, J., Myers, E. & Van Bibber, M. 2019. The Climate Change and Health Adaptation Program: Indigenous climate leaders' championing adaptation efforts. *Health Promotion and Chronic Disease Prevention in Canada-Research Policy and Practice,* 39**,** 127-130.

Robinson, C., Maclean, K., Costello, O. & Pert, P. 2020. Empowering Indigenous leadership in cultural buring and natural disaster recovery and resilience measures. *Climate and disaster resilience disaster report.* Australia: CSIRO.

Sangha, K. K. 2020. Global Importance of Indigenous and Local Communities' Managed Lands: Building a Case for Stewardship Schemes. *Sustainability,* 12.

Saunders, W. S. A., Kelly, S., Paisley, S. & Clarke, L. B. 2020. Progress Toward Implementing the Sendai Framework, the Paris Agreement, and the Sustainable Development Goals: Policy from Aotearoa New Zealand. *International Journal of Disaster Risk Science,* 11**,** 190-205.

Sawatzky, A., Cunsolo, A., Jones-Bitton, A., Gillis, D., Wood, M., Flowers, C., Shiwak, I. & Harper, S. L. 2020. "The best scientists are the people that's out there": Inuit-led integrated environment and health monitoring to respond to climate change in the Circumpolar North. *Climatic Change,* 160**,** 45-66.

Tran, J., Divine, L. M. & Heffner, L. R. 2020. "What are you going to do, Protest the Wind?": Community Perceptions of Emergent and Worsening Coastal Erosion from the Remote Bering Sea Community of St. Paul, Alaska. *Environmental Management*.

Vogel, B. & Bullock, R. C. L. 2020. Institutions, indigenous peoples, and climate change adaptation in the Canadian Arctic. *Geojournal*.

Whyte, K. 2018a. Settler Colonialism, Ecology, and Environmental Injustice. *Environment and Society-Advances in Research,* 9**,** 125-144.
Whyte, K. 2018b. What do indigenous knowledges do for indigenous peoples? *In:* Neslson, M. K. & Shilling, D. (eds.) *Traditional Ecological Knowledge: Learning from Indigenous Practices for Sustainability.* Cambridge, UK: Cambridge University Press.
Williamson, M. & Weir, J. 2020. Aboriginal peoples and the response to the 2019-2020 bushfires, Working paper No. 134/2020. *Working paper No. 134/2020.* Canberra.
Wilson, N. J. 2019. "Seeing Water Like a State?": Indigenous water governance through Yukon First Nation Self-Government Agreements. *Geoforum,* 104**,** 101-113.
Worden, E., Pearce, T., Gruben, M., Ross, D., Kowana, C. & Loseto, L. 2020. Social-ecological changes and implications for understanding the declining beluga whale (Delphinapterus leucas) harvest in Aklavik, Northwest Territories. *Arctic Science,* 6**,** 229-246.
Zentner, E., Kecinski, M., Letourneau, A. & Davidson, D. 2019. Ignoring Indigenous peoples-climate change, oil development, and Indigenous rights clash in the Arctic National Wildlife Refuge. *Climatic Change,* 155**,** 533-544.

Earth Systems and Climate Change Hub

National Environmental Science Programme

www.nespclimate.com.au