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Indigenous Australians' knowledge of weather and climate

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Abstract Although the last 200 years of colonisation has brought radical changes in economic and governance structures for thousands of Aboriginal and Torres Strait Islanders living in remote areas of northern Australia, many of these Indigenous people still rely upon, and live closely connected to, their natural environment. Over millennia, living 'on country', many of these communities have developed a sophisticated appreciation of their local ecosystems and the climatic patterns associated with the changes in them. Some of this knowledge is recorded in their oral history passed down through generations, documented in seasonal weather calendars in local languages and, to a limited degree, transcribed and translated into English. This knowledge is still highly valued by these communities today, as it is used to direct hunting, fishing and planting as well as to inform many seasonally dependant cultural events. In recent years, local observations have been recognised by non-Indigenous scientists as a vital source of environmental data where few historic records exist. Similar to the way that phenological observations in the UK and US provide baseline information on past climates, this paper suggests that Indigenous observations of seasonal change have the potential to fill gaps in climate data for tropical northern Australia, and could also serve to inform culturally appropriate adaptation strategies. One method of recording recent direct and indirect climate and weather observations for the Torres Strait Islands is documented in this paper to demonstrate the currency of local observations of climate and its variability. The paper concludes that a comprehensive, participatory programme to record Aboriginal and Torres Strait

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Islander knowledge of past climate patterns, and recent observations of change, would be timely and valuable for the communities themselves, as well as contributing to a greater understanding of regional climate change that would be useful for the wider Australian population.

1 Introduction and background

> *Nganjinanga calendar yamba kari. Yamba nganjin Bamangka juku nyajil-nyajil. Yinya juku binalbajaku nganjin bama jarra yala*.—Peter Fischer, 1996
>
> We don't have a calendar. Bama story goes by the tree. The tree knows better than we do.—quoted and translated in (Hill 2004, 66).

Paleoenvironmental and thermoluminescence studies have shown that Aboriginal Australians have one of the longest living cultural traditions in the world, with recent archaeological records dating their culture back at least 50,000 years (Roberts et al. 1990). Unsurprisingly, Indigenous Australians have a long history of adaptation to gradually changing landscapes and climates. Ancestors of today's Aboriginal people lived in landscapes very different to what the current generation calls their 'country'. When continental icesheets melted about 15,000 years ago, sea levels rose, leading to greater inundation of northern Australia. River valleys were flooded and vast low lying wetland areas were created, which gradually filled with sediment to create the current mangrove swamp areas and salt mudflats that exist today (Chappell 1988; Reeves et al. 2008). Around 13,000 years ago, northern Australia was significantly drier than now, with an ecosystem in Arnhem Land and Kakadu more likely to look like the present drier southern compositions, rather than their current wetland ecosystems. Throughout the Holocene (10,000 BP to present), rising seas continued to profoundly reshape the continent as massive areas of habitable land in the north were inundated. Indirect impacts from changing rainfall and temperatures would have had significant impacts on the availability and diversity of flora and fauna used by Aborigines. In the far north-east of the country, the final submergence of the Torres Strait land bridge most likely occurred around 6,500 to 8,000 BP (Jennings 1971).

These ecosystems that provided food, shelter and cultural meaning in the past would likely be unrecognisable to the current generation of Indigenous people. However, records of these past environments remain in some of Australia's most significant Aboriginal rock art galleries. The major stylistic changes in the art have, in at least one area, been classified according to significant environmental changes, such as sea level fluctuations in the early Holocene, or predominant ecosystem type. For example, the presence of specific animals and human figures with boomerangs suggest the kind of landscape, open enough to use boomerangs, present at the time. The 'Estuarine period' (6,000–500 BP) included the mythical figure of the Lightning Man for the first time, possibly reflecting the 'new' experience of the violent storms associated with the wet season that evolved during that time. In effect, these art galleries could be seen as providing us with an informal historical documentation of regional changes in environment and climate. Similar features such as the change in intensity of land use, environmental conditions and fauna, are documented at sites in Cape York (Bruno and Lourandos 1998). Similarly (Luntz 2001), documents specific climate changes within Kimberley rock art in Western Australia dating back at least 20,000 years.

1.1 Aims

The main purpose of this paper is to document some of local observations of environmental change that might be relevant for developing a better understanding of climate impacts in the Torres Strait. It is suggested that through participatory programmes such as the one discussed in this paper which are guided by Indigenous methods of knowledge recording, local observations of seasonal cycles—and changes in those cycles—can be appropriately archived for the benefit of the community and cultural maintenance.

Documenting this knowledge is valuable to the community it because it allows elders to pass down knowledge to younger generations. In addition, databases that are collected as a result of these kinds of projects are held and owned by the community themselves. This process itself serves to build capacity within the community to manage their traditional knowledge and control who has access to it. Although cultural knowledge recording projects have been developing over the last few years in Aboriginal communities across Australia, the authors are not aware of any other project than the one discussed in this paper that specifically focuses on environmental change relating to climate impacts. Due to the significance of local observations of changing climate, the authors suggest that a more comprehensive programme that focuses on this issue be rolled out across the north (see also Green et al. 2010).

2 Present day Australian Indigenous knowledge of environmental change

There still is a great wealth of local environmental knowledge embedded in many Indigenous communities that are living on their country, much of which informs their cultural practice. However, the acknowledgement that there are untapped sources of Indigenous knowledge about past weather and climate changes in Australia by non-Indigenous scientists has only been discussed in the last few years (Hennessy et al. 2007). Interest has built in this area, with several traditional ecological knowledge recording projects including elements of weather and climate knowledge (Rose 1996; Smyth 1997; Lewis 2002). This limited engagement to date is unfortunate because there are multiple benefits of carrying out these activities. These benefits include: the importance of Indigenous knowledge as a process to promote participation, the potential to improve scientific knowledge through building the historic observation record, and the encouragement of the transmission of cultural knowledge from elders to younger generations.

This intergenerational transmission of knowledge is crucial because for Aborigines and Torres Strait Islanders, this cultural knowledge is not written, but shared between generations through songs and stories. This lack of documentation has already led to the loss of some of this knowledge with the death of elders, and opened up calls for culturally appropriate knowledge recording to take place to prevent further loss.

Having its own intrinsic worth for cultural strength, Indigenous knowledge about managing the environment and its ecosystems is currently being explored by non-

Indigenous scientists for bush fire management in the tropical north and savannah country. Specifically, the traditional techniques of mosaic burning—that is, burning small patches of land to enable greater control of the fire front—have been acknowledged not only for their ability to maintain robust ecosystems by 'cleaning up the country' (Head 1994; Yibarbuk et al. 2001), but also for their potential to contribute to Australia's larger greenhouse gas mitigation effort (Dept of Climate Change 2008). In the most established burning project in Arnhem Land, in the Northern Territory, Aboriginal burning practices are being used to harness traditional fire management strategies to mitigate carbon dioxide emissions that would otherwise occur due to uncontrolled late season wildfires (Northern Territory Government 2008).

2.1 Global interest in the role of Indigenous ecological knowledge to understand climate impacts

Recognition of the value of Indigenous knowledge about environmental management in Australia has been fairly slow in comparison to other regions of the world, such as the Arctic communities. Globally, led by the Arctic and Small Island States, the role of Indigenous knowledge in sustainably managing ecosystems and natural resources has been internationally recognised for at least a decade (Calamia 1999; Krupnik and Jolly 2002; King and Skipper 2004; Laidler 2006).

For scientists, one of the values of Indigenous knowledge is that 'multiple observation methods', especially in areas with few scientific observations, can increase confidence in individual observations and broaden the scope of information available about environmental change (Huntington et al. 2004). A key reason for this interest in these 'new' data sources is the relatively recent recognition of the need to tailor environmental management strategies to specific locations. This concern is particularly salient for designing adaptive strategies for natural resource management of inhabited lands and, increasingly, for adaptation to climate change (Srinivasan 2004; Mercer et al. 2007).

The interest in alternative forms of climate data relates to the fact that in many geographic regions where there is a paucity of documented data, Indigenous knowledge can be a rich source of information about local level ecosystem changes over a temporal scale of several generations. Through enabling comparison of modelled climate changes and ecosystem effects with observation, specific Indigenous observations of local ecosystem changes may be used to validate model simulations to increase confidence in future climate projections, as well as providing information for historical climate reconstructions (L. Alexander pers. com. 2009). In this manner, Indigenous knowledge can serve to complement climate change science in a number of ways. In the Canadian Arctic for example, local, land-based expertise and community-based assessments undertaken by Indigenous communities have provided observations, predictions and explanations of climate change at scales and in contexts currently underrepresented in climate change research (Riedlinger 2001).

There are a few complicating factors to carrying out this process in Australia. The first relates to problems created by poor past relations between scientists and researchers working with Indigenous communities. The overwhelming response from communities is that they are over-researched, and not properly consulted about what specific information taken from them is being use for. A further complication experienced in many countries relates to the de-contextualisation of Indigenous knowledge by, for example, separating it from its original context, which can render it meaningless (see for example, Smith 1999, 35–36).

A final concern relates to differences in understanding how non-Indigenous scientists manage intellectual property. In many Australian Indigenous communities, knowledge is kept, or 'owned', by individuals, family or tribal units or whole communities. Frequently information is gender specific or accessible to only certain levels of initiates. These kinds of collective rights, or constraints on access to knowledge are typically not easily fitted into a non-Indigenous science model of intellectual property rights.

2.2 Alternative sources for knowledge of past weather and climate

Despite all these apparent difficulties, there are precedents for recognising the value of local knowledge of environmental change. Documentation of recurring natural phenomena, such as the dates of first occurrence of natural events in their annual cycle or daily records of the atmosphere data, have been recorded in diaries and journals in North America and Europe from the 1780s onwards (Kington 1980; Lawrence 2009). Some of these phenological records are so detailed that taken together, they can be analysed to find historical evidence of climate variability (Mock 1991). For example, Whitfield (2001) documents where these phenological observations have been used to compare a number of natural events that now occur earlier across much of the northern hemisphere—from opening of leaves to the return of migratory birds (Whitfield 2001). The value of phenological observations and historical data in climate reconstruction for the period prior to instrument records is also recognised in the IPCC reports. Specifically, sources of climatic reconstruction prior to instrumental records include a number of climate proxies including: blossoming and harvest dates, grain prices, ships' logs, newspapers, weather diaries, ancient manuscripts (Treut et al. 2007, 107). In principle, this data may be capable of providing estimates of climate at dates before instrumental records became available (Rosenzweig et al. 2007), although there are concerns relying solely on historical climatology records, specifically written material available prior to standardised instrumental records (Ingram et al. 1978).

Many Indigenous communities have accumulated records of ecological knowledge through their long history of managing their environments (Turner and Clifton 2009). Given the dearth of climate observation data sets for the southern hemisphere (Giambelluca and Henderson-Sellers 1996; Jansen et al. 2007), and in particular interest for this paper, in northern Australia, could a similar approach be taken? This paper suggests that the existing knowledge recorded in seasonal weather calendars, augmented by present day observations of shifting weather patterns and other phenological observations, could form valuable additional data if carefully collected and analysed. It is important to note however, that all Indigenous knowledge and local observations do not always sit easily within a western scientific paradigm. Povinelli (1995, 506) discusses this tension in the Aboriginal Australian context, where she points to the culture of 'disbelief that Dreamings can listen in anything but a metaphorical sense'.

Ethnometeorologists provide insightful documentation of how different cultures observe climate and weather and what they perceive to be its causes and the place of weather in the life and belief system of their society (Sillitoe 1994). Programmes have begun to compile international ethnometeorological information to investigate this further (Pennesi 2007). Documented ethnometerological knowledge is limited in the Australian context, with the most detailed work undertaken incidentally by cultural anthropologists and linguists who, as subsets of larger work, have examined various climate related words and associations of winds, rain, thunder and lightning, and clouds (Simpson 1997).

There can be significant difficulties with cross-cultural differences and comprehension in the different paradigms of mainstream Australia and communities firmly grounded in their Indigenous culture. As discussed by Bradley (1999), many Indigenous languages are not easily translated (or reduced) into the 'language of objectivism', where object and subject, language and speech, place and people exist as separate and autonomous entities (Bradley 1999). Indeed, there are sometimes difficulties making a straight comparison between non-Indigenous conceptions of landscape, and Indigenous ones. One such example of this is Bradley's discussion of the translation of *'narnu-ruluruluwanka'* as 'a geographic land unit that consists tides or during cyclonic surges, it is proper saltwater country. It also has numerous small raised islets with sparse vegetation such as small melaleuca tress that provide good shade for resting and camping when moving through this country.'

Despite these difficulties in reconciling different perceptions of landscape and humans' place within it, during the last few years, two projects that document sources of Indigenous knowledge about weather and climate in Australia have been initiated.

The Bureau of Meterology's web-based Indigenous Weather Knowledge project has made three seasonal weather calendars for communities in the Northern Territory available online. Those shown include: the Jawoyn and Wardaman calendar from the Katherine Region, the Yanyuwa calendar from the Gulf of Carpenteria, and the Walabunnba from the central arid region north of Alice Springs (Bureau of Meteorology 2005).

The second project, the SharingKnowledge project, currently run out of the Climate Change Research Centre, UNSW, has recently begun to collaborate with the Traditional Knowledge Revival Pathways (TKRP) project to compile video documentation and databases of traditional knowledge of weather and climate for several Torres Strait Islands. The aim of this project is to identify previous adaptation strategies to extreme weather events such as storm surges and inundation that might be culturally appropriate to revisit in the context of climate change. The TKRP is an Indigenous led, multimedia process that works to redress previous concerns about 'doing' research in Indigenous communities. The TKRP method of knowledge recording was developed with the cultural protocols of managing and applying cultural knowledge and practices and direct involvement of the community's elders. In this way, the project seeks to respect and retain the integrity of the transfer of Traditional knowledge from elders to youth. Although the TKRP has not specifically documented climate change observations previously, it has worked in a number of communities across northern Australia and documented many Indigenous land management techniques and observations of environmental change.

Apart from the projects noted above, there are no centralised databases of seasonal weather calendars for Australia that the authors are aware of, although many have been independently documented for several Aboriginal communities by various researchers and community groups over the last few decades. Given that many of these calendars demonstrate a sophisticated local knowledge of seasonal change indicators and climate observations, the following section presents a sample of some of the currently published in English.

3 Australian Indigenous seasonal weather calendars

The Bardi of south-west Kimberley, Western Australia, break the year into six seasons, distinguished by 'the direction of prevailing wind, the intensity of rain, the times of flowering and fruit ripening and appearance, the fatness of animals and their abundance' (Smith and Kalotas 1985). The seasons are used to dictate when and where people move, return to look after country and forage on it. Season names are often directly related to these processes, for example, *Ngalandany*, which is the end of the wet season and translates to 'no fruit' (Smith and Kalotas 1985, 323). The seasonal weather calendar of the Yalanji of Cape York Peninsula, Queensland, is presented in (Hill 2004, 74). This detailed translated calendar shows the interactions of flora, fauna and seasonal change, fire times and weather events.

The Bininj and Mungguy, the local Aboriginal people in Kakadu National Park, recognise six seasons. Their seasonal calendar is accessible online at Kakadu National Park's web site. The nature of their interacting ecosystems is clearly seen in the seasonal (translated) descriptions, for example: *Gunumeleng* (October to December) is 'the pre-monsoon season of hot weather, which becomes increasingly humid. Along the creeks of Kakadu, the air is heavy with the scent of blossoming paperbark trees, which in the evenings attract colonies of feeding fruit bats. Thunderstorms build in the afternoons and scattered showers bring a tinge of green to the parched earth. As the streams begin to run, 'old water' washes into the permanent billabongs from stagnating pools, causing localised fish kills. Waterbirds disperse as surface water and new growth becomes more widespread. Barramundi move out of the waterholes, and downstream to the estuaries. It is the time people moved camp from the floodplain, to shelter from the violent storms of the wet season.'

The Wurdeja, Ji-malawa and Yilan Aboriginal communities of central north Arnhem Land, have developed an interactive educational tool based around their seasonal weather calendar, which also integrates language and cultural activities. The Burarra calendar shows the four seasons, *Lugurrma*, *Barra*, *Wilma* and *Jilicha*, which are related to the winds that blow at different times of the year. As indicated on the interactive tool, each season has its own patterns of winds and weather, plant growth and cycles of animal life and death. For these communities, understanding these patterns helps to know the right times for activities such as hunting and gathering, burning and ceremonial life. For example, 'when the leaves of the yam plant change colour it is time to burn the bush to clear the land for new growth and when the butterflies become active the monsoon rains will soon begin.' (Burarra Gathering n.d.)

The Yolngu from north-east Arnhem Land recognise six seasons, each of which is clearly identified by distinct changes in plant and animal behaviour and climatic conditions (Davis 1989). The record of daily activities of the Yolngu is one of the most comprehensive documented recordings of daily interaction with the seasonal changes in their environment by any Indigenous Australian group that has been translated into English. The Crocodile Islands seasonal calendar, showing the links between traditional foods, seasonal availability, winds, observations of the ocean and clouds, is documented in Halling (1999). The detail about the seasons includes indictors relating to climate such as: *Rarrandharr* which is the main dry season. At this time, 'the warm south east wind blows as the pandanus fruit begins to fall to the ground. As soon as the Stringybark tree flowers, snakes lay their eggs and all types of honey can be found' (Halling 1999).

Although these calendars do not reflect the nuances of natural climate variability directly, the capacity for years (or seasons) to take longer or shorter than the 'usual' calendar year is accommodated through the notion of 'long' or 'short' years. It is not clear how any future increase in extreme weather events (such as an increase in hot spells, increasing intensity of cyclones or more intense storm surges) would affect the understanding and confidence in seasonal weather calendars.

3.1 Language specific references to understanding weather and climate

Linguists have translated and documented a number of weather and climate phrases in a several Aboriginal languages. For example, the Yarralin from the north west of the Northern Territory have several types of rain identified in their language as noted in Rose (1997). Various rain terms include: for cold weather rain, hot weather rain, the first rain after the really hot time of the year, the smell of the first rains (Webb 1997). The Gidjingarli of Arnhem Land seasons are defined by the dominant winds within them (Webb 1997). There is very little information documented about similar knowledge in any of the Torres Strait Islander languages.

Despite a lack of transcribed information on Torres Strait Islander weather and climate, the significance of the weather on daily life is clear in the number of references to clouds, weather, storms and tides in Torres Strait songs (Edwards 2001). Other indications of seasonal change used by Boigu Islanders related to turtle-mating time (October and November) when the ground would become softer from the *dagui ari* (spear rain), which was followed by *maymel*, which was heavier and made the ground very soft.

The interaction of the seasons with the tides and the availability of various food sources for Mer Islanders, such as fish, is also documented in Sharp (1993). The significance of Meriam identities being intimately connected to natural events is further illustrated in the naming of their main clan groups, which include names associated with wind directions, as well as specific songs associated with these directional winds (Sharp 1993).

4 Research findings

The research work carried out in the Torres Strait and discussed in this paper was initiated as a result of an invitation by Torres Strait Islanders to investigate the problems they were facing from storm surges and erosion from king tides. In February 2006, especially strong winds in combination with the expected king tides caused significant damage on several Islands. A presentation of photos of these events and first hand observations were discussed at the SharingKnowledge workshop (SharingKnowledge 2006). This workshop was held to bring together

Indigenous community leaders and research scientists to discuss the impacts of climate change.

Funding to carry out research work in the Torres Strait was obtained in late 2007. Several research trips to several of the islands resulted over the 2 years. Specifically, on island workshops about climate impacts were held on six islands in 2008, and Traditional Knowledge recording projects were carried out in collaboration with the TKRP on Saibai, Boigu, Poruma, Warraber and Mer Islands during 2008–2009. The co-authors of this paper who are sharing some of their traditional knowledge are from Poruma (Billy) and Mer (Tapim). The interviewees were then contacted to confirm that they were comfortable having these observations documented in this paper. As acknowledgement of their ownership of this knowledge and their intellectual contribution to this paper, these elders are listed as co-authors.

More recent interviews with elders on Mer, Saibai and Boigu, carried out in collaboration with TKRP project, were also reviewed for observations and knowledge about climate variability and change.

Other Indigenous knowledge and observations for this paper have been compiled from existing published information and interviews performed by Green with Indigenous elders on several of the Torres Strait Islands. Green has been working in the Torres Strait since 2006 and has presented some of these findings in collaboration with Islander leaders (Green 2007) and in Green (2006).

4.1 Meriam Mer seasonal knowledge

> My world is my family, the land, and the sea, the things that I do. The sea, the sky, the wind—that's my environment. The wind tells me, the cloud gives me messages. We've got names for these clouds. This cloud is *apgegur*, this other one is a *lid lid*, this rain cloud is *kub* and they have special meaning for my life. I get messages, we talk in a way.—Alo Tapim, Mer Islander Elder, 2008

As indicated by the interview with Alo Tapim, one of the traditional owners of Mer Island, seasonal knowledge is still used to direct hunting, fishing and gardening as well as many cultural practices.

> In January to February the turtle eggs hatch and they crawl out and go down to the water. Round that time the turtles are really fat, it's a good time to get them. In late February to March, the turtles start to get lean the fat starts to get watery. People still hunt them for meat. The change in weather around April to May is called '*ilait*'. That's the transition period from *koki* to *sager*. In May and June there is rain but it's a different rain [to the monsoonal rain]. In the monsoon time, there's a blanket of cloud and it rains and rains. Whereas in *sager,* the rain is a passing shower. We call that rain '*uaur kus*'–*uaur* is another name for *sager*, but mainly used in the western islands, *kus* means little... In *uaur kus* there's no lightning or thunder. You only get lightning and thunder in *koki,* in the heavy rain monsoon time.
>
> In June through to August, green turtles start to mate. In October and November they come up on the beach to lay eggs. In August there are white caps everywhere [on the water] from the south-east winds. They sometimes blows right through to September. Then it's getting near to changing season: enter the summer, the hot weather. September is really hot and dry. This time

from September is called *nur*. Some of the indicators are the leaves on the plants, the leaves become yellow. It's harvest time for things like yam.

The doldrums season is October–November—it's very hot, very dry and calm. Not a breath of air. And at night you get that heavy dew. At night when you sit watching the stars you sit with a blanket or else you'll get wet [from the dew]. There's no dew in the earlier *ilait* [earlier in the year]. So this is the transition from the hot to the rainy season. Then *koki* sets in again. The rain that comes before *koki* sets in, that's *kipagogob*. It comes just before *koki.* It's heavy rain and immediately after that the young plants will shoot up. The place will start to look green. But then the hot sun sets in and wipes out that green and kills it off. The dew goes on. As the young trees and plants die off, then the *koki* comes in.

Clouds are general indicators. At night, you get '*uaini perper*', which is a particular type of lightning or '*perper*'. *Uaini perper* is when you see a flash on lightning on the horizon—it is distant lightning that lights up the sky. But you don't see the bolts of lightning, just the distant lighting up of the night sky. This heralds the coming of *koki*. And [it's also a sign that] you must finish planting if you're going to have a successful year. *Uaini perper*—that gives you about 3–4 weeks warning before the onset of *koki. Koki* sets in in early December.

4.2 Seasonal weather calendar for the Torres Strait region (generalised) for an 'average' or 'before time' year (reproduced from unpublished report, n.d.)

Month	Weather	Plant behaviour	Animal behaviour
January	Kuki/Koki–North westerly Monsoon and sea calm	– Sorbi/ouzoo fruit ripens – Waroop waroop ready to eat – Korad fruit ripens – Time to plant corn, pumpkin watermelon and kumara (sweet potato)	– Barramundi found in creeks and swamps – Biddai/gole (squid) are plentiful – Frigate birds are plentiful – Tukmul (File Stingray) can be found near the beach
February	Kuki/Koki–North Westerly Monsoon and strong north westerly winds	– Mekai/Miker (almond) trees start to flower – Gargarber/ero (bell fruit) ripens for second time round – Ubar/enau (wongai) trees start to flower	– Zaber/Zab (garfish) are plentiful – Kaiar/learer (crayfish) come back to the reef – Graz/sai (fish traps) are repaired – Frigate birds are plentiful
March	Kuki/Koki–North Westerly Monsoon with strong winds and rough seas	– Custard apple ripe and ready to eat	– Zaber/Zab (garfish) are plentiful – Aubu/Daber (mackerel) are plentiful – Dangal/Deger (Dugong) start to produce young – Kadal (crocodile) found in swamps – Frigate birds are plentiful

Month	Weather	Plant behaviour	Animal behaviour
April	Kuki/Koki–North Westerly Monsoon with strong winds and seas rough	– Custard apples ripe and ready to eat – Kaper trees are in flower	– Wapi/lar (fish) are plentiful
May	Kuki/Koki–North Westerly Monsoon with strong winds and seas rough	– Crops are ready and blessed – Fire corner fruit trees flower – Plant Kumara (sweet potato) in the swamps – Mekai/Milker (almond) fruit are ripe	– Biru Biru/Biro Biro (rainbow bird) appears
June	Kuki/Koki–North Westerly Monsoon with strong winds and seas rough	– Fire corner fruit trees flower – Weri/waiwi (mango) trees start to flower – Planting of Mangolo (Cassava) – Mekai/Milker (almond) fruit are ripe	– Barramundi in swamps – Kaiar/Kaier (Crayfish) get new skin – Digidigo/Inporoporo (Ducks) return to swamps
July	Sageer/ZoGob–South easterly winds and seas rough	– Ubar/Ehau (Wongai) are ripe and ready to eat – Gabau/Lewerkar (Yam) and Kumala (Sweet Potato) are harvested	– Stone fish come to the edge of the beach – Buiai/Gole (Cuttlefish)
August	Sageer/ZoGob–strong south easterly winds and seas rough	– Ubar/Ehau (Wongai) are ripe and ready to eat – Gabau/Lewerkar (Yam) and Kumala (Sweet Potato) are harvested – Urab/u (coconut) leaves dry out	– Kaiar/learer (crayfish) leave the reefs – Kadal (Crocodile) start to lay eggs – Torres Strait pigeon fly to the Australian mainland from PNG (biru biru)
September	Sageer/ZoGob–strong south easterly winds and seas rough	– Wei wei/waiui (Mango) ripens – Mekai/Miker (almond) trees lose their leaves	– Waru/Nam (Turtle) mating season – Prawns found in swamps – Biru Biru/Biro Biro (rainbow birds) in great numbers – All seabirds are resting and eggs are plentiful
October	Sageer/ZoGob–strong south easterly winds and seas rough	– Gergerber/Ero (bell fruit trees) start to flower – Time to plant Kutam/Kuba (bananas) – Time to plant Gaban/lerkas (Yam) – Cashew nut fruit is plentiful	– Waru/Nam (Turtle) mating season – small school
November	Nagai/Naiger– tropical storms or sea dead calm	– Gergerber/Ero (bell fruit trees) start to ripen – Cashew nut fruit is plentiful	– Waru/Nam (Turtle) eggs are plentiful – Dangal/Deger (Dugong) produces young – Biddai/gole (squid) are plentiful

Month	Weather	Plant behaviour	Animal behaviour
			– Tukmul (File Stingray) can be found near the beach – BiruBiru/BiroBiro (rainbow birds) flies North
December	Nagai/Naiger–tropical storms or sea dead calm	– New Mekai/Miker (almond) leaves and flowers	– Waru/Nam (Turtle) eggs are plentiful – Biddai/gole (squid) are plentiful – Tukmul (File Stingray) can be found near the beach – Tup (Sardines) are hatched

4.3 Recent unexplained changes

Several recent changes in some environmental indicators and unusual weather were observed by Jack Billy, one of the traditional owners of Poruma Island, in April 2008. These comments are in reference to the last 3 years when the weather (and associated plant and animal behaviour) was considered to be unusual in comparison to what was understood to happen in the usual 'before time' cycles that are recorded in their seasonal calendar.

The weather observations include:

> Everything is back way. Last year and year before too—last three years—the weather has changed.
>
> The rain is starting later. This time [this past year] *kuki* is late and the rain is late.

Observations of animals that are behaving unusually:

> 2001 was late on turtle mating and hunting.
>
> ...For example on Murray all the turtles don't come. And the turtles we see are not really fat. Turtles should be healthy in August–November, mating at *nagai* time. We catch them and they are fat. Now we don't see them any more but they still lay their eggs.
>
> Now the turtle and fishing is late, the fruit is late, so we're still in *muturo*
>
> When we cut the mackerel yesterday there were eggs there. The eggs are now ready to go out to baby, so it's really mature. Normally we eat the wongai with the mackerel.
>
> The boys go out for crayfish now, they said not much big one. They're still small, so still *nagai* time. So the big ones are going to lose their skin, change their skin from *kuki*.
>
> But as soon as they carry the fish in the mouth we can tell the birds have hatched, *nagai* and *muturo* are close now. Then people go and pick them eggs on the sand cay. Two weeks ago, we saw birds with fish, that should be in [August]. So I tell them boys to go and get eggs.

> This lunchtime, I went diving and got six blackfish. They were really fat, which is opposite for this side of the year—they should be fat in [August–November].
>
> We don't find them blackfish near the beach, but you find them on the reef. They go on the wrong time. When we spear blackfish the other day, one or two were really strong, but their skin, they still weren't mature.
>
> Observations of plants and trees that are behaving unusually:
>
> The wongai tree near the Anglican church [on Poruma Island]: it [its fruits] should be ready to eat in October/November. But the fruit is ready to eat now, in April. Three years now we've noticed that. The wongai is six months late.
>
> The coconut: that fruit belongs in August, it shouldn't have a small fruit now, it should be big.
>
> Sweet potato: you should dig it up in November month. You plant them in winter to make them grow, in Sept–Oct *kuki* it's a little bit cold and you get dew. Different kinds of kumera: purple and white and red [are grown]. Last year they were very small. But now Mum tell me the ground is cracked, she can tell they're big [this year].
>
> *Gassi*—that's fruit, wild potato. He green now, like flower on top. When the flower die, it's a good time to dig—use that to make flour. Mum cooks *gassi* with blackfish, but the potato isn't ready to make the flour to cook it in.

However, further east on Mer Island, Uncle Alo Tapim commented that he had not seen events that were outside the usual patterns of long and short years. For him, the unusual events of that year related to a lack of turtle sightings in October and concern over ongoing beach and rock erosion problems at various points around the Island.

> Because of the climatic change now, the order and the periods are still the same but everything has moved around. Eg—[pointing to what normally happens in Jan–Feb–March on a seasonal weather calendar] all this information has moved around. But it always switches backwards and forwards, we've always had that. So for example sometimes it's a short year urut: *teupai urut*. Sometimes it's *piripiri*: long year. This process (circling his hand around the seasonal calendar on the table) is still in place, the timing maybe has some variations. I haven't seen very much change in the land. Only the turtle [lack of tracks on Mer this year] and, of course, the erosion.

This comment seems to indicate a familiarity with natural variability in the climate system and associated ecosystem change rather than indication of observed climate changes as suggested by the informant over a longer period of time.

Beach or shoreline erosion is at the forefront of concern for many Torres Strait Islanders on the central coral cay and top western Islands and eastern Islands. The task of identifying natural erosion and enhanced erosion caused by rising seas is extremely challenging. Shoreline erosion has been observed on several of the islands for at least two generations. Records of needing to build a sea wall on Boigu to protect infrastructure begin in 1960. On Saibai, as the mangrove area in the front of the island gradually reduced, the main coast track along the front of the village area has been washed away and rebuilt at least twice (J. Warusam pers. com. 2007).

5 Other forms of climate knowledge: Indigenous Astronomy

The correlation between the movements and patterns of stars and changes in the weather was of critical importance to Aborigines when their survival depended on a thorough knowledge of environmental changes (Haynes n.d.). Several Aboriginal groups used the appearance of specific constellations as indicators of changes to seasonal supplies of food. The Pitjantjatara used the appearance of the Pleiades in the dawn sky as an indicator of the dingo breeding season. Arnhem Land traditional owners used the appearance of Arcturus in the eastern sky at sunrise as an indicator that the spike-rush, a reed used to make fish traps and food carrying baskets, was ready for harvesting (Halling 1999).

Interviews with Torres Strait Islanders suggest that knowledge relating to activities guided by the appearance of particular stars and planets is still current. An informant on Mer notes, '*Beizam,* the shark, it also tells us about rain. Rain is coming through the shark's gills. The way its head goes into the water, if it goes into the gills, that's rain time, *koki* time. We see that in about October to November. And when it swings the tail, it's going to get windy, we'll get the white caps [on the waves].'

Other documented knowledge about the use of stars and planets for seasonal indicators occurs in Sharp (1993). These include the appearance of *Usiam*, the Pleiades, in the *naiger/naigai* season which is read as a sign of fair weather and time for sailing. Gardening activities were also guided by the stars. Specifically, for Mer Island, when the left hand of *Tagai*, the southern Cross appears, it is use as a sign to plant *ketai* (wild yam) and *kakigaba* (a shallow-rooted yam) with the appearance of *Kek*, Venus being the sign to dig for yams (Sharp 1993).

Similarly, the stars were for guiding gardening activities and sea travel on Boigu. Documented by Boigu elders, the appearance of the shark constellation in September indicates the right time to dig the soil. When its mouth was pointing down over the New Guinea mainland, Torres Strait Islanders would know it was the right time to burn the grass, and dig the ash into the ground (Boigu Island community council 1991). The Milky Way, *Kygas,* (the shovel-nosed shark) would be used to travel by sea. When its head looked to the east, then they would know that the currents would be running to the west. When the head was in the south and the tail in the north, then the current would be running to the east (Boigu Island community council 1991).

6 Discussion

> Narrative recollections and memories about history, tradition, and life experience represent distinct and powerful bodies of local knowledge that have to be appreciated in their totality, rather than fragmented into data, if we are to learn anything from them. (Cruikshank 2005, 259).

This paper has identified that the interaction of flora, fauna and climate with Indigenous cultural activities is recorded in oral histories and in traditional knowledge associated with seasonal weather patterns and climate. Further, it is clear that many communities still understand the changing season through their local weather calendars, demonstrating a sophisticated knowledge of a number of indicators of seasonal change.

Across northern Australia, there still exists a comprehensive store of living Indigenous knowledge related to weather and climate that is tied to specific locations. It is clear that the use of environmental indicators to forecast changes in weather and climate were used and are still used on several of the Torres Strait Islands. As indicated by the most recent observations, there is not yet consensus on whether the changes witnessed on some of the islands over the last few years are out of the ordinary pattern of ‘long’ and ‘short’ years (i.e. natural variability) or not. It is perhaps important to keep in mind that for Torres Strait Islanders, the cause of change is of less immediate importance than the outcome. For example, it is not surprising that Islanders respond with a great deal more concern to tsunami alerts, and tend not to strongly differentiate between the potential impacts of these natural hazards in comparison to those of king tides aggravated by slow onset sea level rise or storm surges. This issue highlights a more general problem: the difficulty of differentiation between natural variability, natural hazards and extreme weather caused by climate change.

The documenting of Aboriginal knowledge is further advanced than that of Torres Strait Islander knowledge of weather and climate. However, we have shown that there currently exists a large body of knowledge of environmental indicators and weather observations in the memories of many Island elders that have not yet adequately been recorded. Given the potential value of these observations for forecasting the impacts of climate change and planning anticipatory adaptation activities for the Islands, we propose that further knowledge recording activities are advanced so that this knowledge is not lost.

What is problematic for all of these communities is the need to adapt to relatively rapid change, such as that brought about by climate change, with a lowered social and economic resilience. For the majority of northern Australian communities, the impacts of climate change will exacerbate already stressed social and economic situations.

Indigenous knowledge may well be one of the keys in understanding how best to engage in culturally appropriate climate change adaptation strategies for these communities. Given that many of these communities have survived in gradually changing environmental for thousands of years, adapting to change is not a new phenomenon for them. Backcasting to gain a greater understanding of what people did in the past in response to environmental changes—for example, what plants could be eaten in emergencies, where wells could be found, or which dune ridges remain above flood water when the surrounding countryside was inundated—may well prove to be valuable knowledge to guide future adaptation strategies.

Despite the inherent complexities involved in not just considering Indigenous knowledge as ’data’ but rather, in the spirit of Cruikshank’s quote above, taken in totality as a knowledge system, it does seem that there is value in working with communities to understand how Indigenous knowledge of past change and observations can inform climate impact assessments. This paper has identified one project that has used Indigenous research methods to record and store this knowledge that embodies respect for cultural protocols to build partnerships between researchers and Indigenous communities.

One suggestion resulting from this paper is that a national programme to record this Indigenous knowledge of weather and climate knowledge is developed. Such a participatory programme to record Aboriginal and Torres Strait Islander knowledge of past climate patterns and recent observations of change would be timely and valuable for the communities themselves, as well as contributing to a better understanding of regional change that would be informative for the wider population.

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References

Boigu Island Community Council (1991) Boigu: our history and culture. Aboriginal Studies, Canberra

Bradley J (1999) Wirriyarra Awara: Yanyuwa land and seascapes. South Atl Q 98(4):801–816

Bruno D, Lourandos H (1998) Rock art and socio-demography in north-eastern Australian prehistory. World Archaeol 30(2):193–219

Burarra Gathering (n.d.) Burarra gathering. Available at: http://burarra.questacon.edu.au/home.html [Accessed 21 January, 2009]

Bureau of Meteorology (2005) Indigenous weather knowledge. Available at: http://www.bom.gov.au/iwk/ [Last accessed 20 Oct 2009]

Byg A, Salick J (2009) Local perspectives on a global phenomenon—climate change in Eastern Tibetan villages. Glob Environ Change 19:156–166

Calamia M (1999) A methodology for incorporating traditional ecological knowledge with geographic information systems for marine resource management in the Pacific. Tradit Mar Resour Knowl Information Bulletin 2(10):12

Chappell J (1988) Geomorphic dynamics and evolution of tidal river and floodplain systems in northern Australia. In: Wade-Marshall D, Loveday P (ed) Northern Australia: progress and prospects. ANU, Darwin

Cruikshank J (2005) Do Glaciers listen? UBC, Canada

Davis S (1989) A man for all seasons. Angus & Robertson, Sydney

Dept of Climate Change (2008) Carbon Pollution Reduction Scheme. Available at: http://www.climatechange.gov.au/emissionstrading/index.html [Accessed January 18, 2009]

Edwards R (2001) Some songs from the Torres Strait. Rams Skull, Qld

Giambelluca T, Henderson-Sellers A (1996) Climate change: developing southern hemisphere perspectives. Wiley, USA

Green D (2006) How might climate change affect island culture in the in the Torres Strait? CSIRO working paper #11. CSIRO, Melbourne

Green D (2007) Sharing Knowledge. Presentations from 2006 workshop. Available at: sharingknowledge.net.au [Accessed October 20, 2009]

Green D, Jackson S, Morrison J (2010) Risks from climate change to Indigenous communities in the tropical north of Australia. A scoping study. Commonwealth Department of Climate Change, Canberra

Halling H (1999) From ochres to eel traps: aboriginal science and technology resource guide for teachers. Science Educators Association, Canberra

Head L (1994) Landscapes socialised by fire: post-contact changes in Aboriginal fire use in northern Australia, and implications for prehistory. Archaeol Oceania 29:172–181

Hennessy K et al (2007) Australia and New Zealand. Climate change 2007: impacts, adaptation and vulnerability. In: Parry M et al (eds) Contribution of working group II to the fourth assessment: report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Hill R (2004) Yalanji Warranga Kaban: Yalanji people of the rainforest fire management book. Little Ramsay, Qld

Huntington H, Callaghan T, Fox S, Krupnik I (2004) Matching traditional and scientific observations to detect environmental change: a discussion on Arctic terrestrial ecosystems. Ambio 13: 18–23

Ingram M, Underhill D, Wigley T (1978) Historical climatology. Nature 276(5686):329–334

Jansen E et al (2007) Palaeoclimate. In: Solomon S et al (eds) Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, UK

Jennings J (1971) Sea level changes and land links. In: Mulvaney D, Golson J (eds) Aboriginal man and environment in Australia. ANU, Canberra

King D, Skipper A (2004) Climate forecasting with traditional Maori knowledge. IWA Science Climate Update 64

Kington J (1980) Daily weather mapping from 1781. Climatic Change 3:7–36

Krupnik I, Jolly D (2002) The Earth is faster now: indigenous observation of Arctic environmental change. ARCUS, Alaska

Laidler G (2006) Inuit and scientific perspectives on the relationship between sea ice and climate change: the ideal complement? Clim Change 78:407–444

Lawrence A (2009) The first cuckoo in winter: phenology, recoding, credibility and meaning in Britain. Glob Environ Change 19:173–179

Lewis D (2002) Slower than the eye can see: environmental change in northern Australia's cattle lands, a case study from the Victoria River District, Northern Territory. Tropical Savannas CRC, Darwin

Luntz S (2001) Aboriginal art depicts climate change. Australas Sci 22(4):28–29

Mercer J, Dominey-Howes D, Kelman I, Lloyd K (2007) The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. Environ Hazards 7(4):245–256

Mock C (1991) Historical evidence of a cold, dry summer during 1849 in the north-eastern Great Basin and adjacent Rocky Mountains. Clim Change 18:37–66

Northern Territory Government (2008) Discussion Paper on NT Climate Change issues. NT government. Available at: http://www.nt.gov.au/dcm/legislation/climatechange/docs/cc_discussion_paper.pdf

Pennesi K (2007) Improving forecast communication: linguistic and cultural considerations. Bull Amer Meteor Soc 88:1033–1044

Povinelli E (1995) Do rocks listen? The cultural politics of apprehending Australian Aboriginal Labor. Am Anthropol 97(3):505–518

Reeves J, Chivas A, García A, Holt S, Couapel M, Jones B, Cendón D, Fink D (2008) The sedimentary record of palaeo-environments and sea-level change in the Gulf of Carpentaria, Australia through the last glacial cycle. Quat Int 183(1):3–22

Riedlinger D (2001) Community-based assessments of change, contributions of Inuvialuit knowledge to understanding climate change in the Canadian Arctic. Masters thesis available at: http://mspace.lib.umanitoba.ca/handle/1993/1940

Roberts R, Jones R, Smith M (1990) Thermoluminescence dating of a 50,000-year-old human occupation site in northern Australia. Nature 345(6271):153–156

Rose D (1996) Nourishing terrains: Australian Aboriginal views of landscape and wilderness. Australian Heritage Commission, Canberra

Rose D (1997) When the Rainbow walks. In: Webb (ed) Windows on meteorology: Australian perspective. CSIRO, Melbourne

Rosenzweig C et al (2007) Assessment of observed changes and responses in natural and managed systems. In: Parry M et al (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, UK

SharingKnowledge (2006) Sharing knowledge: a workshop on climate change impacts and adaptation strategies for Northern Australian Indigenous Communities, Darwin, Northern Territory, Australia, 29–31 March 2006

Sharp N (1993) Stars of Tagai: the Torres Strait Islanders. Aboriginal Studies, Canberra

Sillitoe P (1994) Whether rain or shine: weather regimes from a New Guinea perspective. Oceania 64(3):246–270

Simpson J (1997) Perceptions of meteorology in some Aboriginal languages. In: Webb (ed) Windows on meteorology: Australian perspective. CSIRO, Melbourne

Smith L (1999) Decolonizing methodologies. Research and indigenous peoples. Zed Books, London

Smith M, Kalotas A (1985) Bardi plants: an annoted list of plants and their use by the Bardi Aborigines of Dampierland, in north-western Australia. Rec West Aust Mus 12(3):317–359
Smyth D (1997) Recognition of Aboriginal maritime culture in the Great Barrier Reef Marine Park: an evaluation. Available at: http://www.nt.gov.au/transport/safety/marine/tides/ntports.shtml
Srinivasan A (2004) Local knowledge for facilitating adaptation to climate change in Asia and the Pacific: policy implications. IGES-CP Working Series Paper
Treut L et al (2007) Historical overview of climate change. In: Solomon S et al (eds) Climate Change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, UK
Turner N, Clifton H (2009) It's so different today: climate change and indigenous lifeways in British Columbia, Canada. Glob Environ Change 19:180–190
Webb E (1997) Windows on meteorology: Australian perspective. CSIRO, Melbourne
Whitfield J (2001) The budding amateurs. Nature 414(6864):578–579
Yibarbuk D, Whitehead P, Russell-Smith J, Jackson D, Godjuwa C, Fisher A, Cooke P, Choquenot D, Bowman D (2001) Fire ecology and Aboriginal land management in central Arnhem Land, northern Australia: a tradition of ecosystem management. J Biogeogr 28(3):325–343