Pariwilpa Mokarina Warai[1]: Ancient and recent Australian desert hunter-gatherer responses to climatic variability

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[1] Trans: 'The Heavens have turned to bone'. Dieri reference to severe drought times (Kimber 2001).

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INTRODUCTION

The interaction between climate change and human population processes, morphological and socio-cultural change are topics of on-going investigation important to understanding the trajectory of human adaption and change (see Dennell *et al.* 2011; Hewitt 2000; Hiscock and Wallis 2005; Hublin and Roebroeks 2009; Joordens 2011; Scholz *et al.* 2007; Smith and Ross 2008; Stewart and Stringer 2012). While it is widely accepted that changing climatic conditions have exerted a profound influence on human bio-cultural adaptions, there are a range of positions regarding the timing and nature of these interconnected processes (see Eller *et al.* 2004; Eriksson *et al.* 2012; Hawks *et al.* 2000; Premo and Hublin 2009; Stewart and Stringer 2012).

The low genetic diversity of humans indicates that hominin populations experienced regular extinctions and population contractions during periods of global cooling and subsequent expansion and recolonisation following climatic amelioration by groups migrating from glacial/arid refugia (Bennett and Proven 2008; Cordova *et al.* 2013; Jorde *et al.* 1998; Stewart *et al.* 2010). Such cycles of expansion and contraction also appear to have played a significant role in Late Pleistocene and Holocene human population dynamics and socio-cultural adaptions (see d'Errico and Sanchez-Goni 2003, 769; Hiscock and Wallis 2005; Pavlov *et al.* 2004; Smith 1989, 100; Stewart and Stringer 2012; Thorley 1998, 35). It has been convincingly argued that the development of complex social networks and increased critical population size provided buffers against climate change unavailable to earlier hominins (see Bailey *et al.* 2009; Bar-Yosef 2002, 376; Finlayson 2005, 462; Ghirlanda and Enquist 2007; Hiscock *et al.* 2011, 657; Holliday 1997; Krings *et al.* 2000, 145; Powell *et al.* 2009; McBrearty and Brooks 2000; Richerson and Boyd 2000; Sterelny 2011, 816; Stiner 2001).

During periods of severe climate change it is likely that Pleistocene populations occupying marginal environments were forced to either abandon territory and migrate to more resource-rich regions, or adapt in-situ to changing environmental conditions. However migration to areas with more favourable ecological settings may have been constrained in circumstances where resources were limited and competition was high, where neighbouring groups were also experiencing resource decline, or in areas of inter-group conflict.

Archaeological evidence from Australian arid-zone sites indicates that socio-cultural and technological adaptions in response to climatic fluctuations facilitated occupation throughout the Holocene. As I will discuss in Chapter 2 archaeological signatures of occupation presence and absence at key sites across the arid-zone are characterised by spatial and temporal variability and raise questions regarding whether the Last Glacial Maximum (LGM) resulted in abandonment of the desert, as sites such as Kulpi Mara and Serpent's Glen rock shelters suggest; or contraction to aridity refugia such as the MacDonnell Ranges as indicated by the light and intermittent site use at Puritjarra throughout the LGM.

Another question concerns whether apparent mid-Holocene changes in archaeological deposits reflect an intensification in technology, population density and economy. Increased site use at this time is indicated from archaeological sequences across the region as well as more intensive use of grass seed suggested by an increase in the frequency of grindstones. These economic and technological changes have been attributed by some researcher to increased population densities and altered land use patterns linked to climatic change (Smith and Ross 2008; Williams *et al.* 2010). An alternative view is that these changes may be the result of differential preservation of archaeological material and differences in research intensity.

For the historical period, differences in the social organisation and land tenure regimes of tribal groups across the arid-zone have been interpreted as adaptive responses to distinct environments. The Western Desert region is characterised by low average annual rainfall, uncoordinated drainage and limited drought refuges. Some arid-zone tribal groups, who traditionally occupied such marginal desert habitats, are characterised by fluidity in their social organisation, informal boundary maintenance and extensive kinship networks over large tracts of country. Historically the up-land regions of the Australian arid-zone contained more numerous water sources and supported higher population densities, while also functioning as refugia during periods of widespread or prolonged drought. The better-watered regions, characterised by coordinated drainage channels, more numerous water sources and food and plant resources, allowed for higher population densities, smaller territories and more active boundary management. Such differences in social organisation also shaped responses to drought.

Research question

There has been substantial archaeological research undertaken into the timing and strategies of early Australian arid-zone colonisation. This thesis will interrogate the historical and ethnographic record to consider how hunter-gatherers responded to climate change in the recent past, focusing on the effect of periods of severe drought on socio-cultural organisation and subsistence.[2] I consider the major recorded droughts since European colonisation but focus predominately on the drought years between 1925-1935 as a period of significant population movement.

My aims are firstly, to establish whether habitat tracking, local group extinction or a combination of the two were the more likely consequences of severe drought. To this end I will investigate the socio-cultural and behavioural mechanisms of recent hunter-gatherers that enabled fall back to environments with more favourable conditions. In circumstances of drought forced local group extinction, I will identify the constraining factors acting on populations that limited their capacity to respond to changing environmental conditions.

To do this I will evaluate the broad sweep of recent arid-zone population processes in response to drought. While not selecting specific case study groups, I will focus on the Arrernte, Pitjantjatjara and Ngaanyatjarra tribal groups within the Arandic and Western Desert language areas. There is a clear linguistic and cultural cleavage between the Arandic and Western Desert linguistic regions, providing an opportunity to comparatively evaluate cultural and economic strategies developed in response to distinct but connected environments (see Birdsell 1993 cited by McConvell 1996, 136).

My second aim is to apply the ethnographic data to the development of hypotheses regarding earlier population responses to climate change more broadly in similar climatic and ecological settings. It should be stated at the outset that there are inherent limitations to drawing comparisons between ancient and recent hunter-gatherer demography. Firstly as I will show, a range of external factors have influenced population dynamics of desert Aboriginal people since prior to European contact.

[2] The Australian Bureau of Meteorology describes drought simply as a period of acute water shortage. This is defined by examining rainfall periods of three months or more for selected regions to determine whether they lie below the 10th percentile (lowest 10% of records). Accessed 4/3/13 http://www.bom.gov.au.

Furthermore the impacts of European colonisation have often been most evident during periods of heightened environmental stress, making it impracticable to attempt an evaluation of drought-related population dynamics in isolation from such external factors (see Kimber 1990, 165; Davidson 1990, 51). Instead my approach will be to evaluate both European influences and drought simply as subsistence pressures and to consider how hunter-gatherer groups responded to the combined effects of these pressures.

Another limitation in applying ethnographic data to questions of occupation presence and absence in the archaeological record is related to the very different environments occupied by prehistoric and recent hunter-gatherers. As outlined in Chapter 2 there has been significant temporal climatic variability since the earliest human occupation of the arid zone requiring distinctive socio-cultural, economic and technological adaptive responses (Kuhn and Stiner 2001). The temporal scale of palaeoclimate and archaeological records do not provide sufficient detail to evaluate drought responses over short time frames, while the historical record does not allow for long-range projections. While recognising that different environmental conditions existed during the terminal Pleistocene and early-to-mid Holocene relative to the present, this thesis will show that the historical record of hunter-gatherer demography can shed some light on population processes at a coarse-grained level by demonstrating how populations employ socio-cultural mechanisms to minimise the risks associated with heightened aridity and drought (see Davidson 1990, 54).

Chapter outlines

In Chapter 1 I introduce the Arandic and Western Desert language groups that are the focus of this study. I detail the occupation history, land tenure regimes and social organisation of these groups and specific cultural adaptions to their distinctive environments. This chapter provides a background for establishing how desert hunter-gatherer groups responded to the onset of serious drought discussed in detail in Chapter 5.

In Chapter 2 I provide an outline of the history and timing of the initial colonisation of the arid-zone and the adaptions required to successfully maintain a foothold in this challenging environment. I focus on the LGM and mid-Holocene as periods of significant climate change and examine evidence of occupation presence and absence at key archaeological sites to provide an archaeological comparison with climate related behaviour documented in the ethnographic record.

In Chapter 3 I examine climate and ecological literature to develop an environmental framework for the Western Desert and Arandic areas. I summarise the significant droughts of the twentieth century and their relationship to El Niño-Southern Oscillation (ENSO) cycles identified in the preceding chapter as a major driver of climate processes throughout the Holocene.

Chapter 4 focuses on the impact of European colonisation on traditional social, economic and demographic processes. The devastating influence of European settlement presents problems for evaluating the effect of drought on traditional demographics. Here I consider such effects and their implications for understanding hunter-gatherer drought responses.

In Chapter 5 I describe drought avoidance strategies and provide specific examples of how groups responded to changing environmental conditions, facilitated by the social structures described in Chapter 1. There follows a discussion of drought forced migration and mortality during periods of serious drought. This chapter illustrates the effects of rapid climate change on arid-zone populations.

Chapter 6 focuses on the human ecology of the desert and discusses population density, group size, foraging strategies and territoriality. I employ Central Place Foraging (CPF) as a theoretical tool to evaluate resource exploitation behaviour in the case study area and suggest scenarios of hunter-gatherer responses to periods of severe drought in the pre-contact past. This chapter develops a framework based on behavioural ecology models to consider how subsistence and mobility strategies, based on socio-cultural and economic adaptions, enabled range shifts to neighbouring areas during periods of resource depletion.

CHAPTER 1: The Western Desert Cultural Bloc and the Arandic region

Introduction

In this chapter I introduce the study area, encompassing the Arandic and Western Desert dialect regions, and identify and describe the socio-cultural and economic adaptions of these tribal groups to their specific environments. Ethnographic data on arid-zone cultural organisation, land tenure and ceremonial and kinship networks is discussed in terms of the role social organisation played as a risk-mitigation strategy and its influence on population processes during periods of environmental stress.

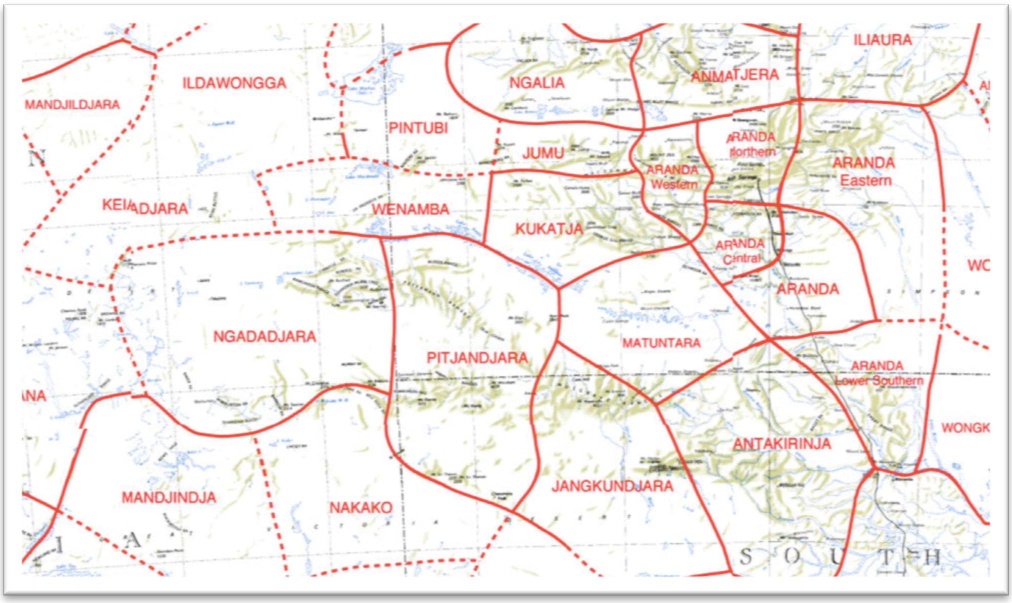

Figure 1: Detail from Tindale map of tribal boundaries showing the Ngadadjara [Ngaanyatjarra], Pitjandjara [Pitjantjatjara], Pintubi [Pintupi] and Aranda [Arrernte] tribal areas (Tindale 1974).

Arid-zone hunter-gatherers group structure

The 'local group', defined as a subset of the tribe, is the demographic unit that is the focus of this thesis. Figure 1 is a detail from Norman Tindale's map estimating the tribal boundaries that existed across Australia at the time of European contact and showing the tribal boundaries of the Ngadadjara (Ngaanyatjarra), Pitjandjara (Pitjantjatjara), Pintubi (Pintupi) and Aranda (Arrernte) tribal areas (Tindale 1974) referred to in this study. The basis of what constitutes the tribal unit has historically been a hotly debated topic in Australian anthropology. Radcliffe-Brown attempted a taxonomic definition of the tribe, defining it as comprising three nested levels: the family, the horde and the tribe (Radcliffe-Brown 1931, 34-36). According to Radcliffe-Brown the significant grouping across Australia was the horde (local group), which he defined as an autonomous, strictly bounded descent-based landholding group. A grouping of hordes sharing a common language constituted the tribe (Radcliffe-Brown 1931, 34-36). Elsewhere the tribe has been defined as the linguistic unit with which a collection of people identified (see Birdsell 1970, 124). In his landmark paper *The Lost Horde* Hiatt (1966) critiqued this definition of the horde arguing that in many parts of Australia such a grouping did not exist, rather local group composition was commonly characterised by a range of affiliations and local groups did not necessarily observe strict territorial boundaries in pursuing the food quest (Hiatt 1966). A detailed account of the various positions in this debate is beyond the scope of this enquiry (see Hiatt 1968, 99; Meggitt 1968, 177) but suffice to say, attempting to define the 'dialectal tribe' and its constituent parts has caused anthropologists a great deal of difficulty, particularly in regards to the flexibility of social relationships found in the Western Desert region which do not reflect the type of groupings and social organisation defined by Radcliffe-Brown and others (Radcliffe-Brown 1931; see also Berndt 1959; Stanner 1965; Sutton 1990).

Here I follow Peterson's definition of the local group (band), as a collection of families occupying a range that changed in size and composition according to ecological and socio-cultural imperatives (Peterson 2000, 207). Stanner was an early researcher to differentiate a group's 'estate' and 'range' on ecological grounds. According to Stanner a patrilineal descent group's estate, being the country surrounding a key totemic site, or site constellation, was distinct from a group's range, which is defined as the area over which it hunted and foraged. According to Stanner, in comparatively productive areas estate and range may completely overlap, while in more marginal country a range may incorporate an estate but cover a wider area including the estates of neighbouring groups. Together, estate and range 'constituted a domain, which was an ecological life-space' (Stanner 1965, 2; see also Maddock 1982, 33). While the local group was an identifiable unit often focussed on estates, it was not necessarily contiguous with estates as maintained by Radcliffe-Brown (1931). As discussed below, in the Western Desert context the 'estate group' was not a useful term due to the loose character of social organisation. Stanner's distinction has a neater fit in the Arandic area where estate groups more closely corresponded to Radcliffe-Brown's ideal of local groups, however even here a degree of fluidity in social organisation has been recognised (see Morton 1997).

Culture areas

Peterson proposed that geological features provided long-term stable boundaries that influenced the expression of social structures (Peterson 1976; Peterson 2000, 207; Tindale 1976, 14; see also Yengoyan 1968, 188). He employed the term 'culture-area' to describe the broadest level of cultural identification within which the community and local group sit (Peterson 1976, 61,68). Due to the critical role of water in determining desert hunter-gatherer subsistence patterns and population densities, Peterson suggested the drainage basin (Fig. 2) as the natural geographical unit that correlates with the culture-area. According to this view the inhabitants of such culture-areas developed specific subsistence patterns that reinforced culture-area boundaries due to the specialised resource exploitation skills required to occupy the region (Lawrence 1971, 253-254; Tindale 1976, 14). The culture-areas relevant to this thesis are the Western Desert, incorporating the Ngaanyatjarra and Pitjantjatjara tribal groups; and the Lake Eyre culture-area that encompasses all of central Australia including the Arandic dialect group (Peterson 1976, 60-61, 66).

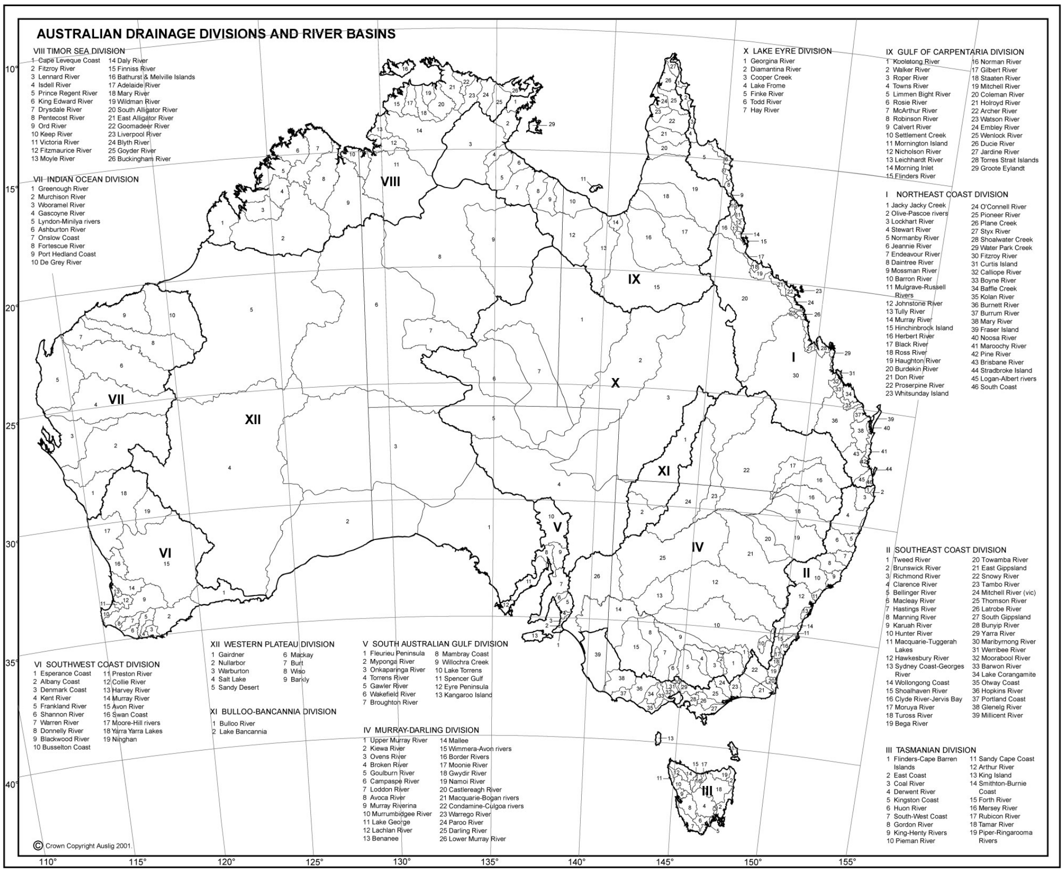

Figure 2: Drainage divisions: see X, Lake Eyre division, and XII, Western plateau/division[3]

The Western Desert Cultural Bloc

The Western plateau drainage basin is characterised by uncoordinated drainage and limited rainfall and encompasses the territory of Western Desert hunter-gatherers including the Pintupi, Ngaanyatjarra and Pitjantjatjara tribes belonging to the 'Western Desert Cultural Bloc'. This is a term first coined by Berndt (1959) referring to an area of linguistic and cultural homogeneity extending across approximately 600,000 km^2 of the Australian arid zone (see Fig. 3). Tindale proposed that the ever-present risk of drought exerted a long-term influence on the development of Western Desert social organisation by acting as an impetus for migration, which in turn facilitated the maintenance of common languages and cultural practices that define the Western Desert Cultural Bloc (Tindale 1940, 150).

[3] Drainage divisions. Retrieved 09/03/15: http://www.bom.gov.au.

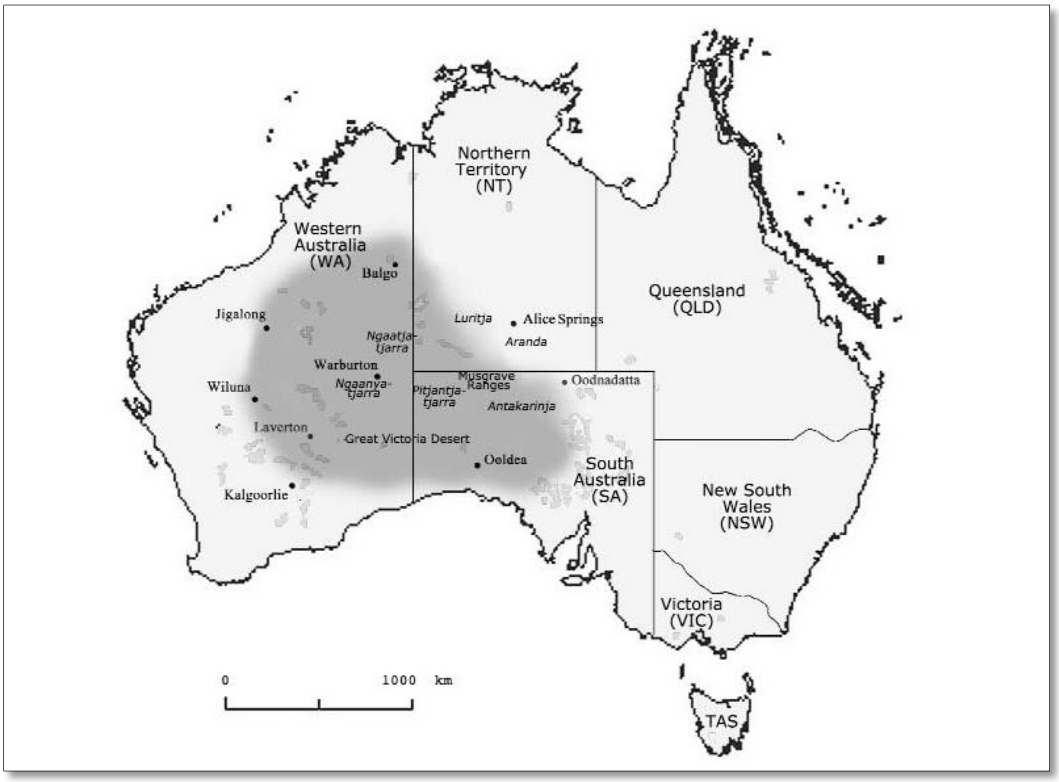

Figure 3: Approximate extension of the Western Desert Cultural Bloc and location of some dialectal groups (Dousset 2003, 46).

Historically, the Western Desert contained amongst the lowest population densities on the Australian continent due to low and unpredictable mean annual rainfall and associated resource fluctuations (Birdsell 1953; Layton 1986, 26; Smith 1989, 100). Extended kinship networks involving reciprocal rights and obligations could be activated during times when local resources were depleted, functioning as a risk-mitigation strategy in an environment of unreliable resource availability. Western Desert groups are distinguished from their Arandic neighbours occupying the Lake Eyre drainage basin to the east and north by the fluidity and inclusiveness of social relationships and the absence of sections and subsections. In contrast, the Arandic area contains more reliable water sources, greater resource abundance and consequently higher population densities. Arandic groups were less mobile and are characterised by strictly bounded patri-clans, or estate groups not found in the Western Desert (Smith 2013, 10).

Western Desert people believe that totemic ancestors bestowed the cultural laws that govern society and created all natural features of the landscape. This period of creation and the associated ceremonial song cycles, ritual designs, dances and song lines are collectively termed the *Tjukurrpa* (translated as stories/Dreamtime). Unlike their

Warlpiri and Arrernte neighbours who are organised through patrifilial descent into structured estate groups, Western Desert group membership can be traced through a wide range of kinship relations and life events (described below). Social organisation is therefore characterised by fluidity in social relationships and an absence of distinct landholding groups with clearly defined recruitment principles (see Dousset 2013, 5; Gould 1991, 24; Layton 1986, 27; Meggitt 1965; Morton 1997; Myers 1986; Strehlow 1947; 1965).[4] While there is a tendency amongst Western Desert people to align connections along patrifilial lines – and people will often employ a patrilineal bias in talking about country (see Berndt 1959, 96; Kenny 2008, 252; Layton 1983) – there is no consistent 'recruitment principle' such as that of patrilineal descent found amongst the Arrernte by which individuals become members of a landholding group (Kenny 2008 215-216; Myers 1986). Referring to the Western Desert Pintupi, Myers noted that individuals claim connection to particular places based on a range of claims including: conception at place A; conception at place B whose dreaming is associated with the dreaming at A (the story lines intersect); initiation at place A (for a male); birth at A; father conceived at A; mother conceived at A; grandparents conceived at A; residence around A; death of a close relative at or near A (Myers 1986, 127-158). Essentially, as Myers states, 'one can claim identification with any place with which one's close relatives are identified (Myers 1986, 129-130). Myers argues that what can be termed local groups in the Western Desert are the result of individual decisions and ego-centered affiliations rather than through recruitment to clearly defined bands (Myers 1986, 183).

Traditionally, Western Desert groups required extensive foraging areas to maintain subsistence. Following Howitt (1904, 143) many subsequent researchers have pointed out a connection between the marginal environment occupied by Western Desert hunter-gatherers and the flexibility of social institutions. Loose social organisation has been seen in part to be a risk-mitigation strategy during periods of environmental deterioration, providing opportunities for groups suffering habitat contraction to migrate to more favourable neighbouring areas through the activation of ceremonial and kinship networks (see Berndt 1959; Myers 1986; Strehlow 1965; Yengoyan 1976;

[4] Early researchers incorrectly projected models developed using data from other parts of Australia (local groups holding distinct territories) onto the Western Desert Cultural Bloc (see Tindale 1940, 150). Some background on debates concerning Western Desert land tenure can be found in Radcliffe-Brown (1931); Hiatt (1966), Berndt (1959) and Peterson (2006).

but see Hamilton 1980). A detailed discussion of the relationship between demographics and drought responses will be undertaken in Chapters 5 and 6.

The Arandic region

The Arrernte are an Arandic group (see Fig. 4) occupying a tract of country focussed around the MacDonnell Ranges within the Lake Eyre drainage system culture-area (see Peterson 1976, 65). The Arrernte believe that their society and culture originated in the *Altyerre* (a term first glossed by Spencer and Gillen as 'the Dreaming' [see Spencer 1896, 50; Spencer and Gillen 1897, 23]), a time in the remote past when totemic ancestors travelled across the landscape creating through their actions all the features of the country including landforms, water sources, plants and animals. Their journeys are inscribed upon the landscape and are referred to as dreaming tracks or story lines (Strehlow 1965, 134, 136).

Totemic ancestors are believed to have generated the laws and customs that define the society including laws of kinship, descent and inheritance and principles of land tenure. Communal observance of principles of descent, recruitment, marriage rules and group membership establish an indissoluble link between the *Altyerre* and the Arrernte (Spencer and Gillen 1897; Strehlow 1956, 13; Weiner 1992, 6; Yengoyan 1968, 198-199).

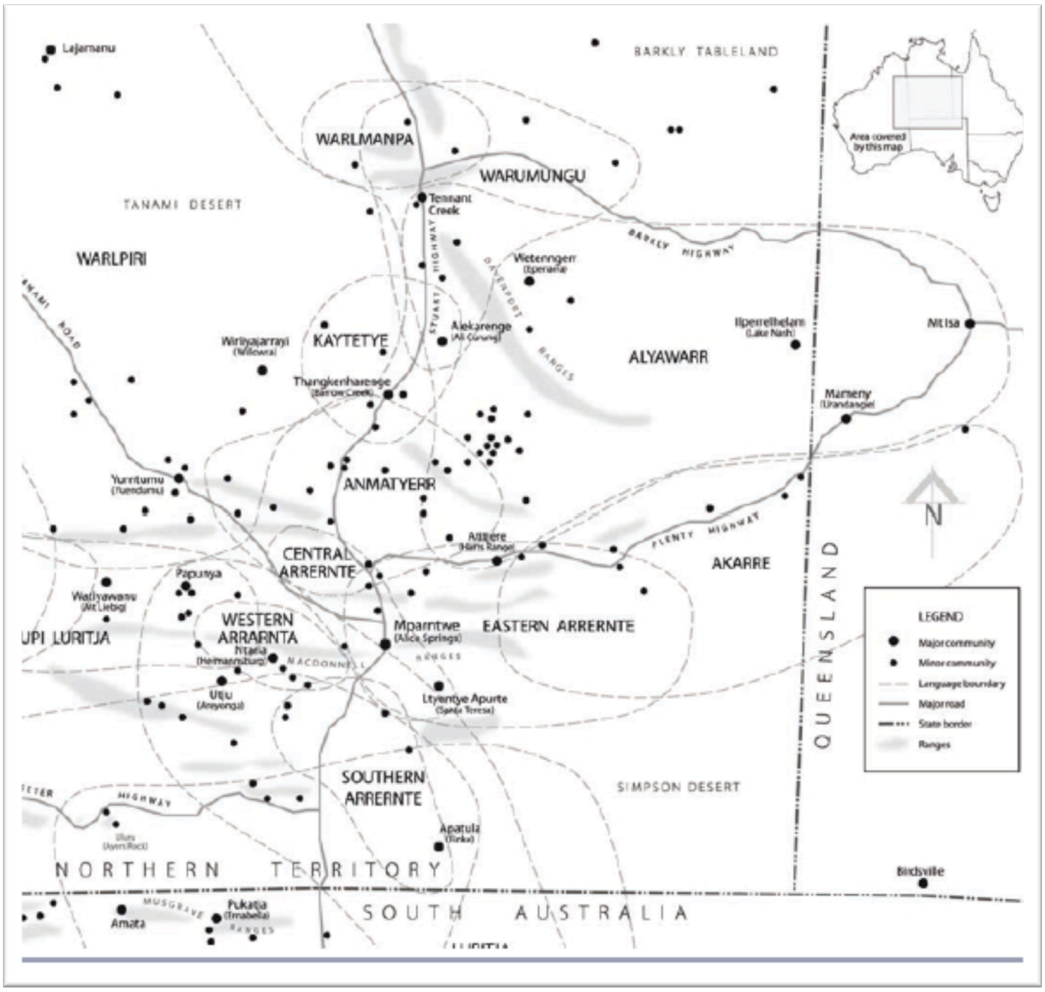

Figure 4: Arandic linguistic region (Arrernte, Anmatyerr, Alyawarr and Kayteye) and neighbouring Western Desert (Pintupi/Luritja, Pitjantjatjara) and Warlpiri languages (Data from Institute of Aboriginal Development (IAD) Press 2002).

Historically the Arrernte were comprised of largely autonomous local groups connected by marriage and ceremonial affiliations and occupying an expanse of comparatively well-watered country encompassing a continuous line of permanent soaks and waterholes between the MacDonnell Ranges in the north and the Krichauff Ranges in the south. Tribes occupying this resource-rich region did not require home ranges on the same spatial scale as their Western Desert counterparts and were therefore able to maintain more strictly bounded estate groups (Birdsell 1970, 121; Mabbutt 1971, 73; Pardoe 1990, 61; Strehlow 1947, 59; 1965, 143).

Arandic and Western Desert kinship systems

In common with other kinship systems across central Australia, in both the Arandic and Western Desert language areas society is organised into two patri-moieties. The patri-moiety system prescribes marriage rules and defines rules of resource use, social and ceremonial activity and behaviour between relations. Customary marriage rules stipulate that preferred marriage partners are drawn from the opposite moiety and strong cultural prohibitions exist regarding taking a marriage partner from one's own moiety (Strehlow 1997). Such unions are described as 'wrong way' marriages. The patri-moiety system allowed for the integration of individuals into existing groups and ethnographic documentation of frequent inter-tribal marriages between the Western Arrernte and the Mantuntara in the south-west, and Kukatja in the west, indicates that the incorporation of outsiders into local groups was a recognised practice in the Arrernte area (see Strehlow, 1970; C. Strehlow 1907, 490-492), a practice which also functioned as a risk mitigation strategy during periods of environmental stress by establishing relationships and alliances between tribal groups.

The Arandic type kinship system is characterised by four or eight primary lines of descent traced through an individual's paternal and maternal grandparents (Morton 2010, 332), and further organised into an eight-class subsection system (or four-class section system in the north-east).[5] The subsection system is a classificatory kinship system and provides the principle mechanism by which Arrernte society is organised. It provides a shorthand for categorising kinship relationships. All members of the society are born into a particular subsection according to the subsection affiliation of their mother and father. In the Arrernte region the eight subsections are: *Perrurle*, *Kemarre*, *Peltharre*, *Penangke, Pengarte, Ampetyane, Angale* and *Kngwarraye*. These are arranged into two patri-moieties referred to as such because all male members of an estate group remain within the same moiety while the children of female members cross into the opposite moiety (Radcliffe-Brown 1931, 19-28; Strehlow 1965). Class terms are extendable, meaning that an individual is related to every person within their social universe with clearly established reciprocal rights and obligations (see Spencer and Gillen 1904, 96-98; Strehlow 1997, 14; Yengoyan 1968, 198-199).

Patri-moieties produce patrilineal descent groups reckoned through one's father and father's father. For example, a *Kemarre* man's preferred wife is a *Peltharre* woman; their children's section affiliation will then be *Perrurle* (the same moiety as their father). The female *Perrurle* children will marry *Penangke* husbands and their children will be

[5] The Southern Arrernte followed a four-class section system until the turn of the twentieth century when they began adopting the subsection system of their Northern Arrernte neighbours (Strehlow 1947, 72).

Pengarte, the opposite patri-moiety to their mother's father. The male *Perrurle* children will marry *Penangke* wives and their children's section affiliation will be *Kemarre*. The children will remain in the same moiety as their father and their father's father. These patrilines are connected with particular estates and share the same moiety as the totemic ancestors associated with the estate. Figure 5 below shows the relationships between sections (eight class subsection system):

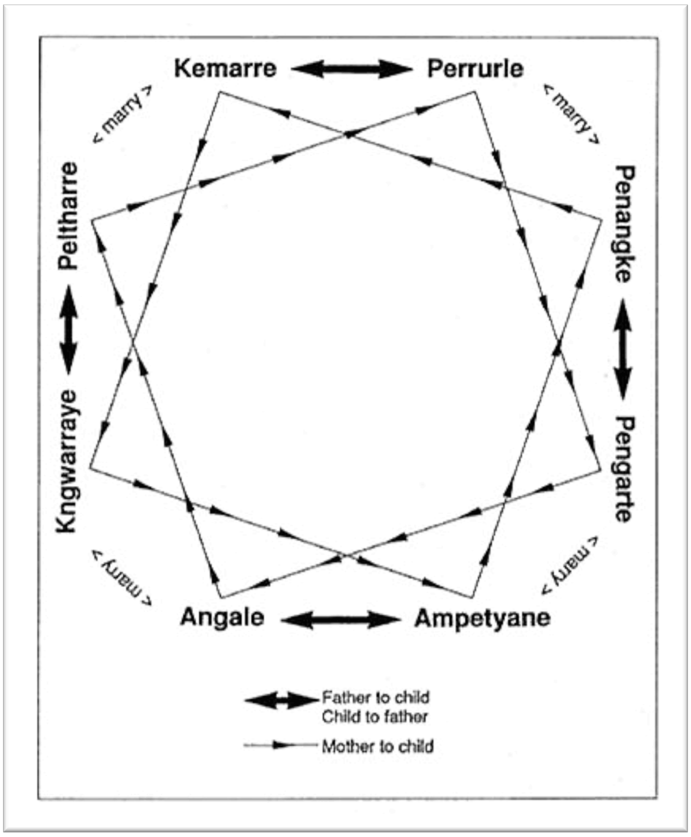

Figure 5: Diagram of Arrernte subsection relationships (Henderson and Dobson 1994, 42).

The tribal group is divided into local exogamous descent groups or patri-clan estates. Each estate is the property of a patrilineal descent group consisting of two subsections standing in a father-son relationship to each other (Morton 1997, 4). Each estate contains an important ceremonial centre or focal site and a number of minor totemic centres (Morton 1997, 4; Strehlow 1965, 136-141; 1947, 140-141). As a rule women from outside the descent group marry into the patri-clan estate. This system of patrilocal exogamy ensures that relationships with neighbouring local groups are maintained (Morton 1997, 12), providing a network of spatially distributed kin relationships that could be activated during periods of resource scarcity.

In contrast to the Arandic area, the Western Desert Aboriginals follow an Aluridja-type kinship system distinguished by the absence of sections and subsections (Keen 2013, 6; Layton 1985, 28). Unlike the Pitjantjatjara, the Ngaanyatjarra began adopting sections in the 1930's (Dousset 2003, 48). It is unclear whether this was the result of ongoing pre-contact cultural or physical migration processes (unrelated to European colonisation); or alternatively, the emergence of new patterns of communication, migration and inter-group relations associated with European settlement (see Kenny 2008, 219-221, 2013, 175).

The patri-moiety system and the question of environmental adaptation

The reason for the presence of sections and subsections in some regions and their absence from others has been a source of much debate in Australian anthropology. The section and subsection systems are thought to have diffused in a southeast direction from the Pilbara from approximately 1000 BP, and the Western Arrernte adopted subsections around the turn of the nineteenth century (Chapter 2 provides additional detail on the diffusion of the subsection system). It was Tindale's view that the absence of sections and subsections amongst the Pitjantjatjara and Ngaanyatjarra of the Western Desert was simply due to isolation (McKnight 1981, 76), while T.G.H. Strehlow attributed this absence to environmental conditions which made the more strictly bounded forms of social organisation found amongst neighbouring groups such as the Western Arrernte unsuited to the harsh economic environment of the Western Desert. Strehlow suggested that the Arrernte were able to sustain such a complex system as subsections because of the rich economic environment they occupied (1965, 131).

Arguing the opposite position, Yengoyan analysed data on the presence and absence of moieties, sections and subsections across Australia and proposed that occurrences of these categories increased across a spectrum as the environment became more marginal. Yengoyan correctly observed that in coastal areas population size and area are typically small while population densities are high. In comparatively resource poor areas such as the desert these elements are inverted with extensive territories supporting larger populations but at lower densities (see Chapter 6 on correlation between territoriality and population density). From his results Yengoyan concluded that in resource-rich areas tribes did not require subsections whereas kinship classes mitigated risks in circumstances where residential mobility was an adaption to a harsh environment (McKnight 1981, 81). McKnight was critical of Yengoyan's methodology, arguing that his sample sizes were small and he did not use the same data when analysing '… each component of the population parameter' (McKnight 1981, 80).

As elaborated by Myers, a key risk minimisation strategy in the Western Desert was the fluidity of social relations over large areas. Gould noted that such extensive long-distance social networks were made possible by a complex kinship system. He writes that:

> Each of these mechanisms works to restrict the number of eligible spouses a person will find within his or her own local area, compelling him to look further afield for potential marriage partners. This tendency is increased by the widespread occurrence of polygyny, which results in multiple in-law relationships over long distances and in all directions (Gould 1982, 72).

However, T.G.H. Strehlow showed that the relationship between social organisation and environment is complex, pointing out that while the Western Arrernte and some neighbouring Western Desert tribes such as the Kukatja maintained an eight class sub-section system '… the Matuntara groups of Ilara, Watarka, and Palmer River … remained classless in spite of the splendid springs and waterholes in their excellent game country' (1965, 143; see also McKnight 1981). The absence of sections or subsections amongst the Pitjantjatjara and recent adoption of sections by the Ngaanyatjarra challenges Yengoyan's hypothesis given the country occupied by these tribes was more marginal and resource-poor than their Arandic neighbours.

In my view, the absence of sections and subsections in the Western Desert would appear to support the maintenance of loose social organisation and flexibility required to maintain a foothold in a harsh environment. Strehlow points to tribes such as the Western Desert Kukatja as an exception to this rule, however a focus on kinship networks with their eastern neighbours, the Western Arrernte may have exerted a cultural influence that superseded ecological imperatives.

Discussion

Desert hunter-gatherer social organisation is anchored in the Dreaming, which provides cosmological authentication for social structures and connects groups across vast areas through shared responsibility for dreaming tracks. Through a comparative evaluation of the social structures of the Pitjantjatjara/Ngaanyatjarra and Arrernte, in this chapter I have shown that in desert Australia population size and density was constrained by environmental factors, which in turn influenced the expression of cultural and social institutions, and by extension population movements (Strehlow 1965, 122; see also Yengoyan 1976, 123-124; 1979, 399). The Western Desert was more marginal in terms of resource availability and hence social structures were more fluid allowing for greater mobility and habitat tracking. In the Arandic area, coordinated drainage, access to ranges and upland areas containing numerous permanent water sources and greater resource abundance sustained higher population densities and smaller territorial ranges than the marginal environment of the Western Desert culture area. For both the Pitjantjatjara/Ngaanyatjarra and the Arrernte, risks of resource scarcity during periods of environmental instability were mitigated by social structures that facilitated group movement to areas with better environmental settings.

CHAPTER 2: The archaeological record

Introduction

The LGM and the El Nino Southern Oscillation (ENSO) were important drivers of climate variability from 26.5-19 kya and from 5 kya respectively. In this chapter I contextualise how climate processes influenced population dynamics, technological and social innovations and adaptions in the prehistoric past. I follow with a broad overview of the nature and role of aridity refuges in the desert region from the LGM to the historical period, and review key arid-zone archaeological occupation sites to establish the temporal and spatial nature of occupation presence and absence.

Glacial and interglacial cycles

Population processes in response to climate change in prehistoric arid-zone Australia were broadly similar to those modelled for ice age Europe. For temperate adapted species in the Northern Hemisphere glacial cycles resulted in a southwards retreat and range contraction to Mediterranean refugia, notably the Iberian Peninsula, Italy and the Balkans, as northern latitudes became inhospitable (Bennett and Proven 2008; Hewitt 2000; Stewart *et al.* 2010, 662). In the Southern Hemisphere glacial cycles were associated with widespread aridity and increased aeolian activity, while wetter conditions correlated with interglacial periods (Bullard and McTanish 2003, 478; Kershaw *et al.* 2003, 1277; Pepper *et al.* 2011). The formation of extensive dune fields in arid Australia followed an increase in glacial and inter-glacial cycles from 800 kya. During peak glaciation events the environment became progressively arid, ephemeral and semi-permanent waters dried up and dune fields expanded into semi-arid environments making large parts of the arid zone inhospitable. While glacial refugia in Europe were confined to the southern latitudes, a patchwork mosaic of refugia characterised arid Australia (Byrne 2008, 4411).

These extreme climatic variations influenced prehistoric hunter-gatherer demographic processes. During the LGM many known occupation sites were no longer accessible and it has been suggested that 80 per cent of occupied territory may have been abandoned (Williams *et al.* 2013, 4612).

Early occupation of Australia and dispersal into the desert

Prior to sea level rises between 12-8 kya Australia and New Guinea formed a combined landmass known as Sahul (Redd and Stoneking 1999). The timing of the earliest occupation of Sahul has been hotly debated (Cosgrove 2006, 102; Denham *et al.* 2009, 30; O'Connell and Allen 2004). Archaeological evidence suggests that the continent was first colonised between 65-45 kya via southeast Asia with adaptions to new environments ensuing rapidly after colonisation (see Denham *et al.* 2009, 31; Gillespie 2002, 456; Redd and Stoneking 1999; Summerhayes *et al.* 2010). Migration modelling suggests that the most likely route by which people reached Australia was through Indonesia to Northern Australia (Fig. 6) (Balme *et al.* 2009, 61).

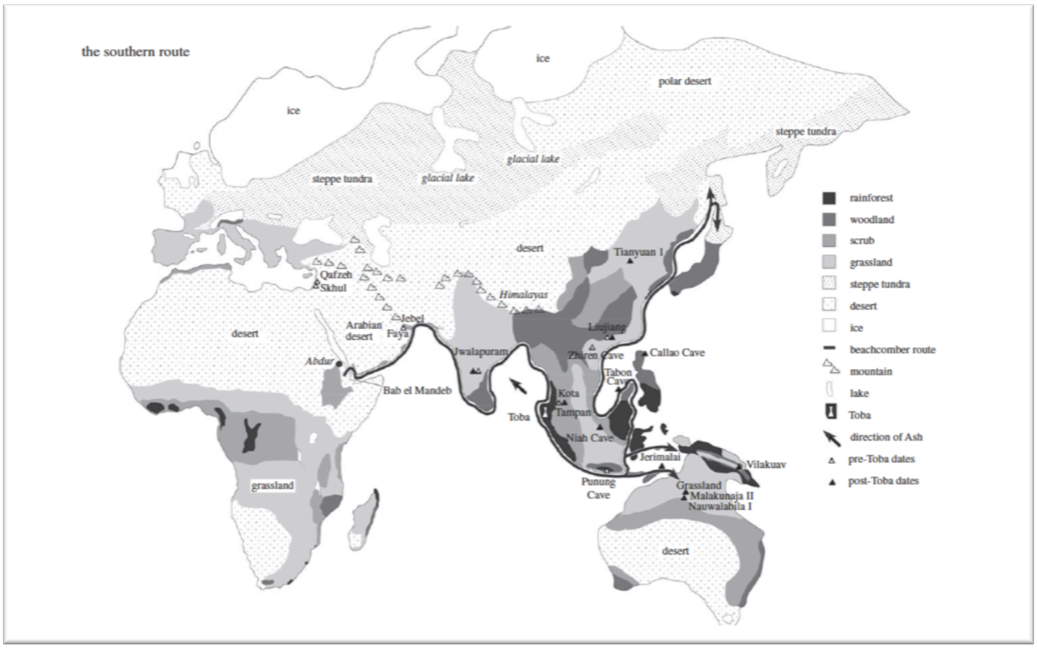

Figure 6: Map showing single southern route out of Africa and beachcomber arc route from the Red Sea along the Indo-Pacific coast to Australia. Vegetation and sea level shown as at Last Glacial Maximum (LGM) (Oppenheimer 2012, 778).

Determining the timing and location of first landfall is problematic, firstly because of sea level fluctuations, secondly because the tropical zone is unfavourable for archaeological preservation (Langley *et al.* 2011, 203) and thirdly, because the probable date of first occupation is at the limits of radiocarbon dating (Fifield *et al.* 2001; O'Connell and Allen 2004, 835-836; Turney and Bird 2002). Furthermore, issues of taphonomic disturbance and concerns regarding the stratigraphic integrity of many sites represent problems for precise dating (Hiscock and Wallis 2005, 35-36; see also Gillespie 2002, 469; Langley *et al.* 2011).

Some archaeological sites on the desert margins date to 50-45 kya, and dispersal into the arid-zone interior had commenced by 45-35 kya, possibly driven by population pressure and increased resource competition in existing habitats or an improvement in climate and foraging opportunities in previously marginal country (Smith 2013, 78). There are a range of theories regarding the process and dating of initial arid-zone colonisation. One view is that early desert hunter-gatherers applied the same social and economic strategies as those adapted to coastal environments and thus initial colonisation was constrained to riverine corridors and lacustrine environments. According to this view specific adaptions required to maintain a foothold in the interior were developed later, with the sandy deserts, which contain limited water sources in the form of small wells and soakages, only continuously occupied from the mid-Holocene (Smith 2013, 38; Thorley 1998, 34-35, 44). Another view posits that a range of desert habitats have been continuously occupied from between 45 and 30 kya. Consistent with this view, hunter-gatherers developed the strategies that facilitated occupation early on as they spread into the arid zone, but occupation was constrained to refuge areas during periods of increased aridity (Smith 2005(b); 1989; also see Thorley 1998).

Although there was a long-term trend towards increasing aridification, until 45-30 kya conditions were wetter than the present. It is therefore probable that the early technological, economic and social adaptions of colonisers to arid environments were different from those recorded during the recent past (Hiscock and Wallis 2005, 40-41). Increased aridity during the LGM means that much of the arid zone was likely to have been abandoned (this is indicated by archaeological sequences at key archaeological sites discussed below). In contrast to the historical period when foraging patterns were characterised by dispersal and resource exploitation over wide areas following rainfall, when ephemeral waters became temporarily available, late Pleistocene foraging strategies were probably restricted to montane regions in proximity to frequent and reliable water sources (Smith 1996, 66; Smith 2013, 116). Environmental conditions were likely to have largely restricted populations to refuges in the ranges linked by riverine corridors where permanent waters persisted, allowing for forays into high-risk areas and movement between refuges as conditions allowed (Williams *et al.* 2013, 4613).

The Central Ranges and MacDonnell Ranges have been identified as glacial refugia and likely sustained populations when increased aridity made much of the arid zone uninhabitable (Fig. 7). Desert areas such as Puritjarra in the Cleland Hills (discussed below), containing networks of small wells accessible from range country may also have been habitable during the LGM (Smith 1996, 66; Smith 2013, 116; Williams *et al.* 2013, 4618). Desert-specific adaptions known from the anthropological record such as low population densities, high residential mobility, broad spectrum foraging, and flexible social organisation and technology then emerged in-situ in refuge areas (Bird and Bird 2005(a), 87; Hiscock and Wallis 2005; Smith 1989, 100; Smith 2005(b), 95, 103; Thorley 1998, 35). Following climatic amelioration these adaptions diffused throughout the arid zone during the early-mid Holocene (see Hiscock and Wallis 2005, 47-49).

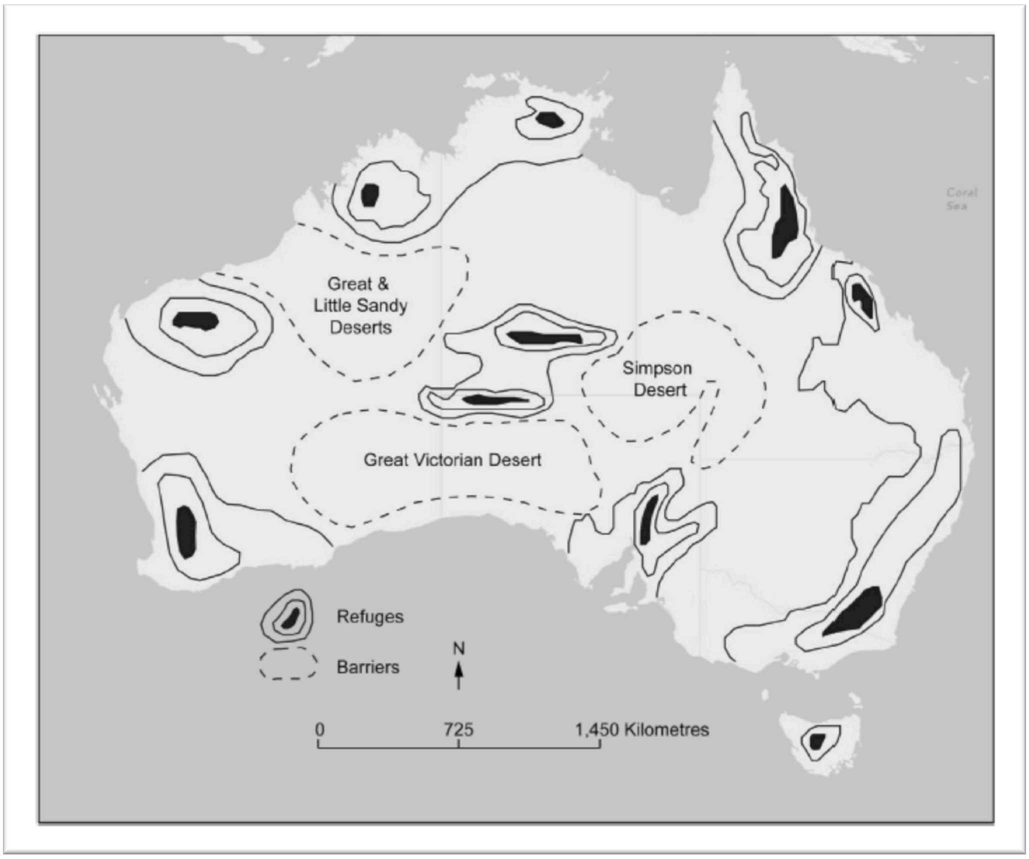

Figure 7: Map of refugia, barriers and corridors for human occupation through the Last Glacial Maximum (the MacDonnell Ranges are located in the centre, adjacent to the Simpson Desert. The Central Ranges are directly north of the Great Victorian Desert) (Williams *et al.* 2013, 4615).

El Niño-Southern Oscillation (ENSO)

The El Nino-Southern Oscillation (ENSO) has been identified as an important driver of climatic variability from the mid-Holocene through to the historical period. ENSO events are generated by interactions between atmosphere and ocean circulation processes in the central and eastern Pacific Ocean, producing a weakening of trade winds, cooling of the oceans surrounding Australia and reduced rainfall conditions in central Australia (Chiew *et al.* 1998; Williams *et al.* 2010, 835).

Modern ENSO cycles commenced at approximately 5 kya, increased in intensity and frequency between 3.7-2kya and reached peak aridity at approximately 1.5-1.2 kya (Cosgrove *et al.* 2007, 169; Fensham and Holamn 2001, 1036; McGowen *et al.* 2012; Nicholls 1989; Williams *et al.* 2008(a), 246). Early Holocene pollen records from Lake Frome in South Australia as well as macrofossil and pollen data from stick nest rat middens indicate the abundance of flora adapted to conditions of increased moisture relative to the present between 7.8-5.7 kya. The gradual replacement of this flora with arid-adapted *Chenopodiaceae–Asteraceae* shrub vegetation from 5.5 kya has been associated with the onset of ENSO related aridity at this time (Donders *et al.* 2007, 1632). Archaeological evidence also points to this period being a phase of hyper-aridity. A hiatus in rock art painting in the Kimberley between 5-3.8 kya has been attributed to an ENSO-associated mega-drought that resulted in ecosystem collapse and the disappearance of the Bradshaw (Gwion Gwion) artists (McGowen *et al.* 2012).

Intensification

An increase in ENSO activity and aridity between 3.7-2 kya coincided with an apparent intensification in late-Holocene technological innovation including the appearance of hafting technology, microliths and standardisation of tools (Hiscock 2002; Williams *et al.* 2010, 831-832). Some scholars have drawn links between these events, sparking the 'intensification debate' that began in the 1980s (Holdaway *et al.* 2008; Lourandos and Ross 1994). The debate was centered around patterns of demographic expansion during the Holocene observed in Africa and Asia associated with the advent of agriculture, which led some scholars to draw connections between these processes and those occurring in Australia (Holdaway *et al.* 2008, 404; Jones 2003, 509; McConvell 2005, 135). Proponents of intensification argue that there was a discernable shift towards broad-spectrum diets and an accompanying population increase during the mid-late

Holocene that blurred the traditional definitions of agricultural and hunter-gatherer economies (Edwards and O'Connell 1995; Lourandos and Ross 1994, 55-56; Smith and Ross 2008, 386).

From approximately 5 kya archaeological assemblages contain higher densities of seed-grinding implements suggesting increased reliance on grass seed as a low-risk resource and more intensive site use. O'Connell and Hawkes noted in their study of Alyawarr hunting and foraging strategies, that grass seed dropped from the diet during periods of resource abundance and re-entered the diet when higher ranked resources become scarce (see Chapter 6). Smith argued that the convergence of population growth and the onset of modern ENSO periodicities at 4 kya made seeds a viable resource category due to the reduced availability of higher-ranked resources (Smith 2013, 202; see also Smith and Ross 2008, 386). These changes have also been linked to the emergence of the 'Small Tool' tradition at approximately 4.5-4 kya which has been connected to increased mobility, and changes in economic and social organisation occurring at this time (Gagan *et al.* 2004, 139; Lourandos and Ross 1994, 55; Smith 2009, 758; Smith and Ross 2008, 380-381, 385; Williams *et al.* 2010, 835).

Hayden observed that technological innovation alleviated the risks associated with uncertain resource availability by enabling dietary diversification (Kelly 1995, 100). In an Australian context one view holds that such adaptions to high-risk environments facilitated reoccupation and persistence in the arid zone following climatic amelioration. (Hiscock 1994, 268; McConvell 2005, 126; Thorley 1998, 34, 43). Edwards and O'Connell have a differing view and argue convincingly that a shift to broad-spectrum diets was not related to climate change, pointing out that the perceived economic and technological innovations of the mid-to-late-Holocene did not emerge during the earlier and more intense LGM when grass seeds would be expected to have entered the diet. An alternative explanation is that seeds formed an integral part of the Pleistocene hunter-gather diet but are not visible in the archaeological record because of preservation issues and small sample sizes (Edwards and O'Connell 1995, 777-780).

Critics of 'intensification' maintain that its supporters are endeavouring to link the Australian archaeological record with archaeology from other parts of the world where there is a clear transition from hunter-gatherer lifestyle to agriculture (Holdaway 2000, 411). They argue that a perceived increase in Holocene sites could be attributed to a simplistic correlation between numbers of sites and numbers of people that ignores different processes in site formation such as changes in settlement patterns, better preservation of younger sites compared with older ones or the mistaken grouping of surface finds as contemporaneous (Holdaway 2008, 404; Williams *et al.* 2010, 831-832).

The Pama-Nyungan language family and diffusion of the section and subsection system

During approximately the same period as the mid-Holocene changes referred to as 'intensification' there is evidence that a sweeping language migration occurred across the continent. The Pama-Nyungan language family spread across Australia from a core area in north central Australia from approximately 6000 BP, supplanting existing language families except in isolated pockets in the central north of the continent and Tasmania, suggesting large scale migration and cultural diffusion at this time (see Fig. 8) (McConvell 1996, 128). Evans and McConvell argue that the radiation of the Pama-Nyugan language family is linked to the appearance of complex long-distance inter-group networks, technological innovation and more intensive use of marginal environments (Evans and McConvell 1998, 183-189).

The diffusion of the section and subsection systems,[6] which commenced approximately 1000 years ago from a focal point in the Pilbara, has been linked to the expansion of the Pama-Nyugan language family (see Fig. 9). It is estimated that the section system was adopted in the Arandic area approximately 850 years ago. The subsection system is thought to have arrived much later, in the early nineteenth century (McConvell 1996, 132; Smith 2005(a), 224). Genealogies recorded by the missionary Carl Strehlow (1907-1920) indicate that the Western Arrernte probably possessed subsections since at least the beginning of the nineteenth century and subsumed the southern Arrernte section system in the late nineteenth century (Austin-Broos 2004; Kenny 2008, 219-220; McConvell 1985; McKnight 1981, 77; Spencer and Gillen 1899, 72; Strehlow 1965, 136; Strehlow, C. 1907, 6-8).

[6] The section and subsection systems are classificatory kinship systems that extend across large areas of central Australia and provide a shorthand for categorising kinship relationships (see preceding chapter).

McConvell established a chronology of migration and cultural diffusion based on the correlation of loan word occurrences in various Aboriginal languages, the estimated dates of section and subsection diffusion into the Arandic and Warlpiri areas and material changes in the archeological record that indicate possible demographic shifts and/or cultural diffusion (McConvell 1996). Archaeological evidence of abandonment and subsequent reoccupation of parts of the arid-zone at approximately 3 kya supports the linguistic evidence of such a radiation implying a demographic event rather than processes of cultural diffusion alone (McConvell 1985, 139; Smith 2013, 30; Williams *et al.* 2008(a), 255).

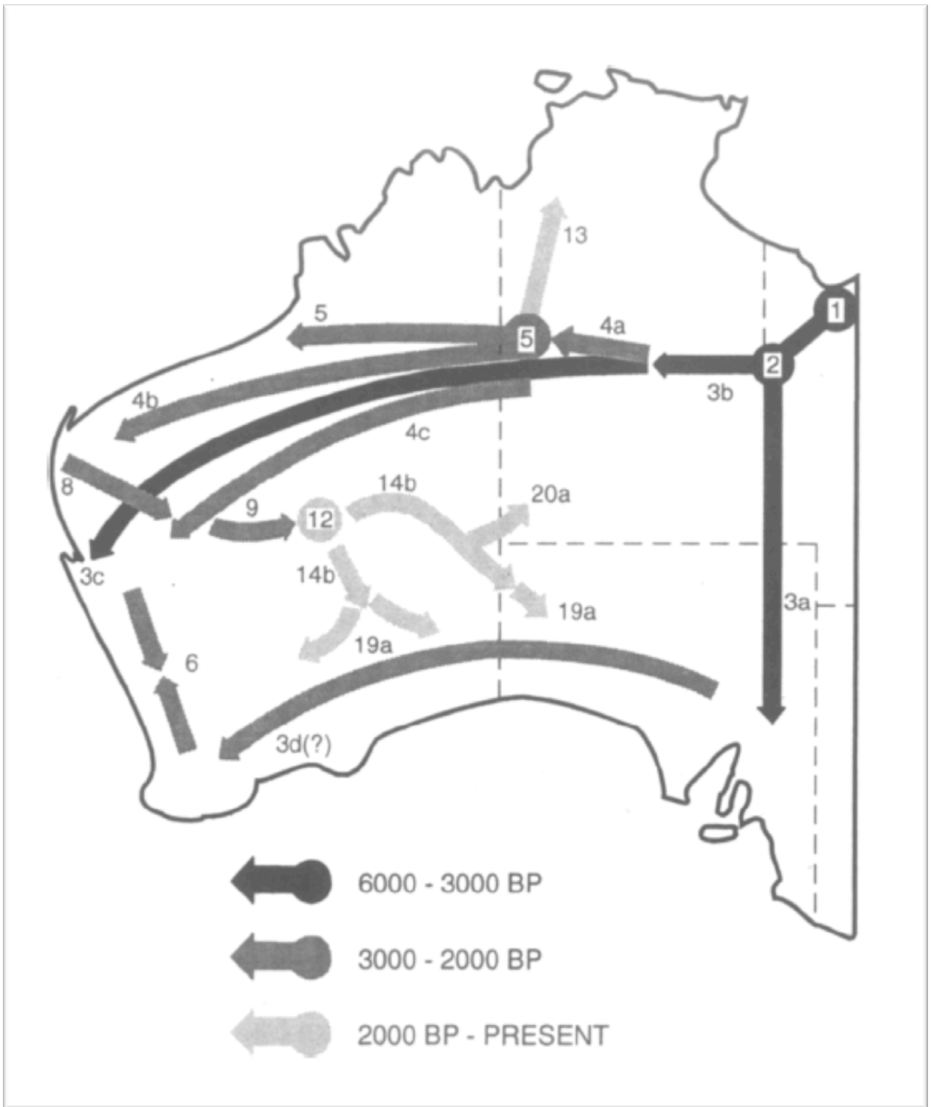

Figure 8: Western Pama-Nyungan expansion (McConvell 1996, 129).

The Arandic languages belong to a different linguistic subset of Pama-Nyungan to the neighbouring Western Desert 'Wati' language group (Ngaanyatjarra, Pitjantjatjara, Pintupi and Warlpiri) (McConvell 1996). Birdsell referred to this linguistic boundary as the 'Aranda Scarp' and estimated it to be approximately 1200-500 years old. It was Birdsell's view that this linguistic and cultural cleavage pointed to a recent Arandic migration to central Australia from the north-east (Birdsell 1993 cited by McConvell 1996, 136). Arrernte blood group and serum protein allele frequencies indicate isolation and differentiation from neighbouring tribal groups and genetic similarities with tribal groups in Arnhem Land in northern Australia (Alfonso-Sanchez *et al.* 2008, 96; Smith 2005(a), 230; Walsh *et al.* 2007, 725), however the genetic data only confirms there is a difference between the Arandic and Wati language groups and does not resolve which group were the later settlers. Contrary to Birdsell, McConvell infers from the genetic, linguistic and cultural homogeneity of the Western Desert Cultural Bloc that this group were in fact the more recent arrivals, having moved south-east from the Pilbara/Gascoyne in the last 1500-2000 years (McConvell 1985, 137; Smith 2005(a), 230). Although inconclusive regarding which group arrived first, the cultural and linguistic evidence indicates occupation of this region within the last 1-2 millennia by a group that genetically and linguistically swamped an established population or occupied a region that was abandoned by a different linguistic group.

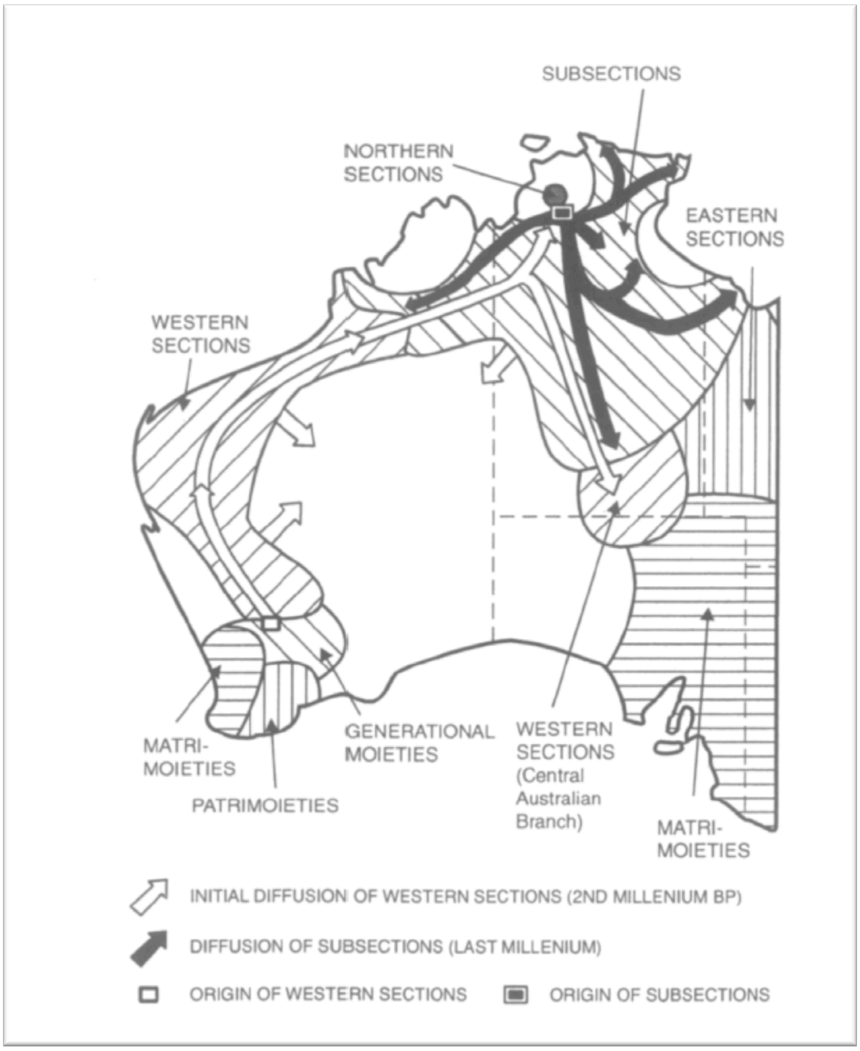

Figure 9: Sections and subsections: distribution and diffusion (McConvell 1996, 129).

Whether the perceived mid-Holocene changes referred to as 'intensification' are attributed to climate change or independently arising socio-cultural processes, it is improbable that they are simply the result of differential preservation given the evidence that cultural and demographic processes were concurrently driving the spread of the Pama-Nyungan language family and diffusion of the section and subsection system.

Key arid-zone archaeological sites

The earliest occupation sites in the Central and Western Desert regions are Puritjarra rock shelter, Kulpi Mara rock shelter and Serpent's Glen rock shelter. Culturally sterile layers in stratigraphic sequences from Kulpi Mara and Serpent's Glen correlate with peak aridity indicators, suggesting that increased aridification during the LGM resulted in the abandonment of marginal areas and contraction to more favourable habitats

(Hiscock and Wallis 2005, 45-46; Kimber 2009, 312; O'Conner *et al.* 1998; Smith 1996, 66; Veth 2005, 101, 103, 111-113). Another site, Puntutjarpa rockshelter, comprises a younger sequence that begins at 11.8 kya. All sites demonstrate extensive regional variability in regards to patterns of presence and absence. These key arid-zone archaeological sites are discussed below (see also Fig. 10).

Puntutjarpa rock shelter

Puntutjarpa rockshelter, excavated by Richard Gould between 1967 and 1970, is a Holocene sequence located near the old Warburton Ranges Mission close to a permanent water source known as Warapuju. The site was not connected to a system of water sources and appears to have been unoccupied during periods of increased aridity (Smith 2013, 179). Extensive long distance social networks are indicated by the presence of exotic lithic material at the site, dated to approximately 4000 years ago (Gould 1977, 177).

Puntutjarpa was the first stratigraphic excavation of an archaeological site in the Western Desert. Some scholars consider Puntutjarpa to represent a trans-Holocene sequence while others have argued that the site represents two distinct occupation sequences divided by a rockfall dated to approximately 7.5 kya which correlates with a break in the cultural sequence (Codding 2011, 222; Smith 2013, 179). The oldest layer contains a single hearth and is dated from 11.8 to 7.5 kya (Smith 2013, 179). There is limited evidence of subsequent occupation between 7.5 kya and 435 ± 90 BP (Gould 1977; Smith 2013, 181). Eight radiocarbon dates were obtained from the site, one of which was anomalous and was attributed to sample contamination (Gould 1977, 60). Interpretation of the Puntutjarpa sequence has been complicated by lack of stratigraphic control during the initial excavation and concerns regarding the accuracy of some radiocarbon dating (Smith 2013, 179; Codding 2011, 222).

Gould argued that tools recovered from the site correspond closely with those documented in the recent past suggesting that Western Desert technology had remained essentially unchanged from first occupation (Gould 1977; Smith 2005(a), 227; Veth *et al.* 1997, 23). He concluded that site archaeology supported the theory of cultural conservatism in the Western Desert. However, subsequent researchers have argued that there was greater temporal variability in technology and behaviour than initially thought (Hiscock and Veth 1991, 332; Smith 2005(a), 226; Smith 2013, 179-180).

Puritjarra rock shelter

Puritjarra rockshelter, located in the Cleland Hills, is connected by a series of permanent springs and soakages to the MacDonnell Ranges, which have been identified as sporadic refugia between 25-12 kya (Smith 1996, 66; Smith 2006, 372; Williams *et al.* 2013, 4612). The sequence comprises accumulated aeolian sediments and sandstone rock fragments from the shelter deposited in three distinct layers. Only the two upper layers contain archaeological debris (Smith *et al.* 1997, 303). Dates obtained from radiocarbon, thermoluminescence (TL) and optically stimulated luminescence (OSL) chronology indicate three phases of occupation. The second stratigraphic layer represents a predominately late Pleistocene sequence and correlates with the first occupation phase (35-8.3 kya), which was a period of light, intermittent site use. Phase two is represented by a period of increased archaeological deposition from 8.3 kya to 1000 BP. A further increase in archaeological materials over the past millennium suggests more intensive occupation during the third occupation phase (Smith *et al.* 1997, 303; Smith 2013, 89; Smith and Ross 2008, 323). Intrusion of charcoal from upper levels into lower deposits has been identified as the cause of some anomalous radiocarbon dates (see Edwards and O'Connell 1995, 776; Smith *et al.* 1997, 314).

Apparent occupation of Puritjarra rockshelter throughout the LGM, albeit in a more limited fashion as demonstrated by a slower rate of artefact deposition, provides compelling evidence that refugia in the MacDonnell Ranges provided a base for extended forays to outlying regions following networks of springs and wells during periods of hyper-aridity (Smith 1989; Smith 2005(b), 103-107; Thorley 1998, 42-43). Thorley points out that archaeological assemblages show a reduction in artefact discards at Puritjarra at this time suggesting population contraction to permanent refugia as conditions became increasingly arid (Veth 2005, 112; Thorley 1998, 43). The presence of ochre sourced from various ochre mines at a distance from the rockshelter, one located 125 km north-west, from as early as 32, 000 BP suggest that the people occupying Puritjarra were integrated into a regional system of social networks and trade routes (Smith et al 1998, 285; Rosenfeld and Smith 2002, 118).

Increased site use from 8.3 kya has been attributed to population growth and changes in land tenure regimes. From approximately 1.5 kya evidence from multiple archaeological sites across the arid zone suggest a further population increase accompanied by technological innovations and changed patterns of resource exploitation and land use (Smith and Ross2008, 386). The increased artefact density at Puritjarra correlates with these changes.

Kulpi Mara rock shelter

The Kulpi Mara rock shelter is located at the headwaters of a drainage system in the vicinity of a large ephemeral rock hole (Smith 2013, 133). Earliest occupation is dated to 34.2 kya (Smith 2013, 91; Thorley *et al.* 2011). Puritjarra rockshelter is located only 165 km away from Kulpi Mara and Thorley suggests that the occupation of both sites was linked to exploitation of regional riverine corridors and drainage systems (1998, 42).

The assemblage is comprised of three distinct layers containing evidence of occupation located within sedimentary deposits primarily composed of sand weathered from the walls and roof of the rock shelter and some windblown sands. The first layer extends from 34.2 to 29.1 kya. The next layer is dated from 15.3 to 10.9 kya and is probably linked to the amelioration of climatic conditions (Thorley 1998, 39-42; Veth 2005, 103). One radiocarbon date of 2500 BP was obtained from the middle of the uppermost layer. The archaeological sequences at Kulpi Mara show pulses of habitation separated by lengthy occupation breaks with the LGM appearing to be a period of complete abandonment. Reconstruction of site chronology has been constrained by the limited number of radiocarbon dates obtained and the slow rate of sediment deposition (Thorley *et al.* 2011, 48-49). In common with other arid-zone archaeological sites, grindstones are only found in large numbers in the uppermost layers of the assemblage from approximately 2500 BP (Thorley 1998, 43), suggesting that seed grinding was only practised intensively from the mid-late-Holocene.

Serpent's Glen rockshelter

Serpent's Glen is a key site supporting the hypothesis put forward by Hiscock that the LGM led to the abandonment of marginal habitats (O'Conner *et al.* 1998, 17, 20; Smith 2005(a), 227; Smith 2013, 91-92; Williams *et al.* 2013, 4163). Serpents Glen is an overhanging rockshelter located at the headwaters of a river system in the Carnarvon

Range. The rock shelter is strategically located in the vicinity of a number of springs and rock holes making it an important refuge during drought. The surrounding country is predominantly sand plains and dunes at the margin of the Little Sandy Desert. The ranges contain a number of springs and rock holes (O'Conner *et al.* 1998, 12-13). A sterile layer suggesting site abandonment at the onset of the LGM follows an initial minimum occupation date of 23.5 kya. Subsequent reoccupation did not occur until after 4.7 kya.

Figure 10: Key arid-zone archaeological sites referred to in text.

Discussion

Differences in socio-cultural, economic and technological adaptions between early colonisers of the arid zone and later Holocene populations are evident from archaeological sequences. These temporal variations present challenges to applying ethnographic data as a proxy for a fine-grained interpretation of economic and social behaviours of prehistoric hunter-gatherers. Differential preservation of archaeology and variations in research intensity over a wide geographic area also presents challenges, indicating that the arid-zone archaeological record is far from complete (Williams *et al.* 2010, 833).

What we do know is that the environmental parameters of the arid zone through the late Pleistocene and early Holocene were markedly different from modern conditions and it is unlikely that populations persisted in all habitats across the arid-zone during periods of hyper-aridity. Instead, prehistoric hunter-gatherer societies were likely characterised by population crashes followed by recoveries after such periods (Hiscock and Wallis 2005, 42, 44; Smith 2005(b), 103; Williams *et al.* 2010, 831).

I have shown that gaps in archaeological sequences from sites such as Serpents Glen and Kulpi Mara rock shelters correlate with the on-set of the LGM and other Holocene climatic events and may indicate population contractions to refugia until climatic amelioration. This may have been expressed as climate-related local group extinction as modelled by some researchers for the European Middle Pleistocene (Dennell et al. 2011; Hublin and Roebroeks 2009) or alternatively site abandonment, habitat tracking and migration to territories with better ecological settings.

Extensive social networks and trade routes were operating across the arid zone from the Pleistocene as evidenced by the presence of materials provenanced from sites located at a distance from archaeological sites such as Puritjarra and Puntutjarpa. Such regional networks may have functioned in the same way as recent hunter-gatherer social and economic networks (discussed in Chapter 1), to mitigate the risks associated with climatic variability.

It is probable that responses to climatic instability were characterised by a mixture of habitat tracking and in-situ extinction of sink populations in marginal environments. Improved climatic conditions following the LGM and peak ENSO events are indicated by an expansion of grasslands and evidence of increased use and re-occupation of archaeological sites, however, as the key archaeological sites discussed above show, there is no clear regional pattern of occupation and abandonment.

CHAPTER 3: Environmental context of the study area

Introduction

This section briefly outlines the arid zone environment to compare modern climatic conditions with those that influenced population processes from the period of initial colonisation through to the late Holocene, discussed in the preceding chapter. I describe the environmental parameters of the study area to understand environmental influences on socio-cultural, economic and technological adaptions and to contextualise the discussion of hunter-gatherer drought responses in Chapters 5 and 6.

Australian desert – overview

Arid-zone Australia covers approximately 3.5 million km^2 or 70 per cent of the continent including most of the western and central interior of the continent. Rainfall is highly variable from year to year and often localised so that it is difficult to obtain an accurate indication of how much rain could be expected in any one year (van Oosterzee and Morrison 1995, 66; Prior *et al.* 2010, 555-556). The arid-zone region receives an average of less than 250mm annual rainfall and average temperatures exceed 35°C in summer. A range of large-scale weather phenomena, including the northern summer monsoons, cyclones and frontal systems in the south, regulate the climate of the Central and Western Deserts. The summer tropical cyclones, which form off the north and northwest coasts, provide a significant proportion of the annual rainfall (Donders *et al.* 2007, 1622; Smith and Ross 2008, 385). Evaporation and rainfall levels are equivalent throughout much of the region meaning there is zero net accumulation of water. Evapotranspiration in the arid-zone is ten times the annual average rainfall in most regions (Duguid *et al.* 2005, 8; Trewin 2006, 2-7).[7]

Despite its low biomass and sparsely distributed plant and animal resources, arid Australia supports a rich variety of desert habitats that range from montane desert supporting low woodlands/shrublands (predominantly mulga [*Acacia aneura*] and other *Acacia* species) and grasses (mainly spinifex [*Triodia*] and hummock grasses); riverine desert dominated by grasses and woodlands; stony desert characterised by the

[7] Potential evapotranspiration measures the combined processes of evaporation and transpiration and provides a more accurate measure of aridity than evaporation alone (Trewin 2006, 2-7).

predominance of mulga communities; clay plains typically supporting perennial grasslands; sand desert mainly composed of spinifex communities, and shield desert supporting extensive mulga woodlands; and chenapod shrublands dominated by drought-resistant low growing plants such as saltbush [*Atriplex*] and spinifex grassland. These habitats support a diverse range of plant and animal species including reptile fauna and macropod and bird species (Mabbutt 1971, 71-73; Pavey 2006, 25-28; van Oosterzee and Morrison 1995, 65-67).

Bioregions

The Interim Biogeographic Regionalisation for Australia (IBRA) provides a useful tool for understanding the distinct ecological landscapes encompassed by the study area. IBRA is a framework used to categorise habitats and ecoregions according to geographically distinct areas of land with common geological, climatic and ecological features (see Thackway and Cresswell 1995). Williams *et al.* (2013) superimposed Australian bioregions over archaeological sites to develop a context for identifying refugia in response to climatic instability in the prehistoric past. There is a degree of fit between the arid-zone bioregions discussed below and the 'culture-areas' defined by Peterson (1976) discussed in this thesis (see Chapter 1).

The Central Ranges Bioregion

The Central Ranges Bioregion is located within the Western Desert Cultural Bloc area of the Ngaanyatjarra and Pitjantjatara people (see Chapter 1). It covers parts of Western Australia, South Australia and the Northern Territory and extends from the Warburton Ranges in the west to the Mann Ranges in South Australia in the east (Fig. 11). The Petermann, Rawlinson and Musgrave Ranges dominate this region and between them are numerous smaller hills, rocky outcrops and extensive tracts of red sand plains. The area includes some of the most marginal environments on the Australian continent due to high temperatures, high evaporation rates, lack of connected drainage, few permanent waters and unpredictable rainfall (see Cane 1987, 393; Gould 1977, 11). Temperatures range from a summer mean maximum and minimum of 36.3°C and 22.8°C respectively to a winter mean minimum and maximum of 21°C and 7.8°C.[8] The climate is arid with highly variable and erratic rainfall from year to year. Temperatures often exceed 35°C and prolonged hot periods are common (Beard 1969, 682-685; Trewin

[8] Retrieved 03/01/14: http://www.bom.gov.au.

2006, 2). The spatially averaged median rainfall is 177 mm[9] and water availability is generally higher in the ranges than in the surrounding low land areas due to the presence of water catchments (Cane 1987, 395; Mabbutt 1971, 72; Tindale 1940, 151; van Oosterzee and Morrison 1995, 66). Vegetation is predominantly comprised of mulga (*Acacia aneura)* and desert oak (*Allocasuarina decaisneana)* habitats and spinifex grasslands (Beard 1969, 687; Graham and Cowan 2001, 127; Tille 2006, 128).

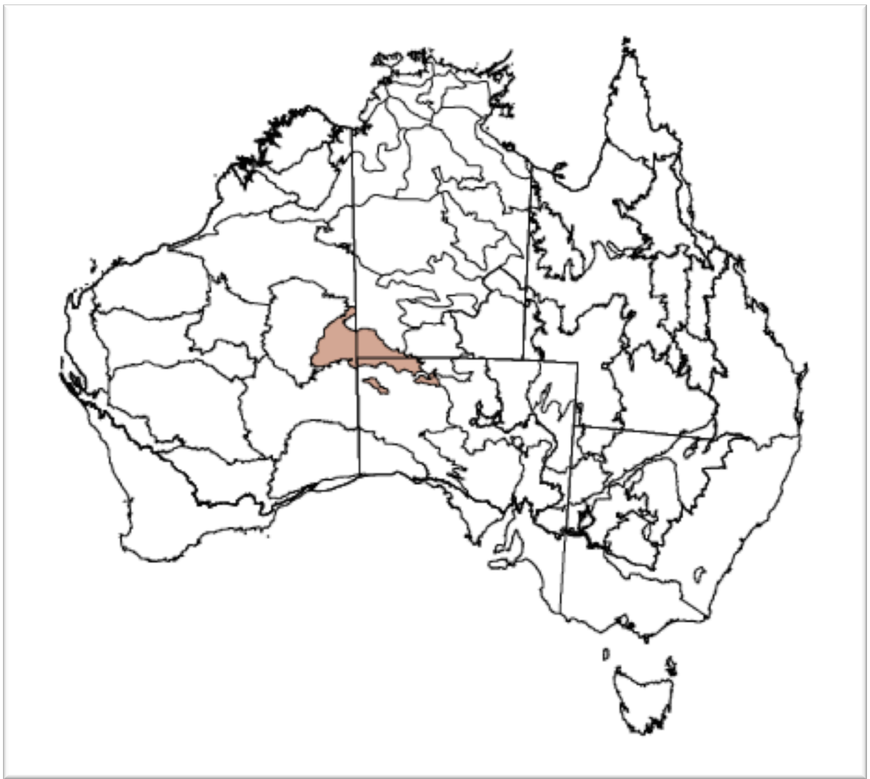

Figure 11: Central Ranges Bioregion.[10]

The MacDonnell Ranges Bioregion

The MacDonnell Ranges bioregion, located in the central southern Northern Territory (see Fig. 12), covers parts of the Central Desert tribal areas of the Arrernte, Anmatyerr, Alyawarr and Warlpiri (see Chapter 1). It contains the Heavitree, Chewings, Waterhouse, Macdonnell, Ooraminna, James, George Gill, Fergusson, Harts and Gardiner Ranges, interspersed with low relief plains and red sandhill desert. Climatic conditions range from a mean summer maximum of 36.4°C and a minimum of 21.5°C to winter maximum

[9] Central Ranges Bioregion information sheet, p. 1. Retrieved 03/01/14: http://www.environment.gov.au.
[10] Ibid.

and minim of 19.7°C and 4°C.[11] The MacDonnell Ranges extend approximately 420 kilometres along an east-west axis. Annual rainfall for the Western MacDonnell Ranges is approximately 228 mm[12], considerably higher than the Central Ranges bioregion. The Ranges are composed primarily of igneous and metamorphic rocks and the heavily weathered ridges and valleys are primarily sedimentary in composition. Gorges and gaps formed by fluvial processes cross cut the ranges and contain numerous permanent and semi-permanent waters. Drainage channels, creeks, rivers and the surrounding low relief plains support a rich diversity of plant communities including spinifex-dominated hummock grasslands and *Acacia* woodlands (Ingham *et al.* 2013, 308; van Oosterzee and Morrison 1995, 65-67; Trewin 2006, 20-25).

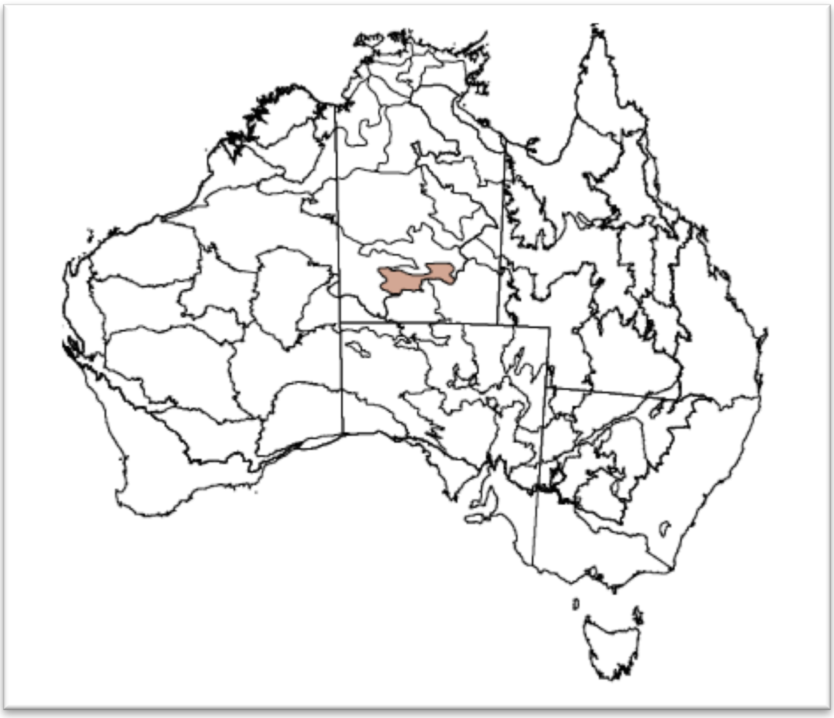

Figure 12: MacDonnell Ranges Bioregion.[13]

Rainfall

There is significant temporal and spatial variation in rainfall patterns across the study area (see Morton *et al.* 2011). Large tracts of land in the Western Desert are marginal in terms of resource availability and only habitable following periods of heavy rainfall. Due

[11] Retrieved 24/05/13 from: http://www.bom.gov.au.
[12] MacDonnell Ranges Bioregion information sheet, p. 1. Retrieved 03/01/14 from: http://www.environment.gov.au.
[13] Ibid.

to the often-localised nature of climate conditions and the spatial discontinuity in rainfall patterns, one localized area may experience average annual rainfall while a neighbouring region receives no rain at all (see Gould 1991, 26; Tindale 1974, 66, 68). This tremendous variability over short distances made it possible for hunter-gatherers to abandon territory during periods of intense drought and effectively track habitat in response to climate variability (Strehlow 1965, 124).

I have compared available rainfall records from weather stations within the MacDonnell Ranges and Central Ranges bioregions to provide a comparative chronological representation of rainfall across the study region. Rainfall data represented in the graphs at APPENDIX 1 was collected from the Australian Bureau of Meteorology (BoM). The weather stations relevant to the study area are: Warburton, located in the Warburton Ranges; Giles, situated in the Rawlinson Ranges adjacent to the Northern Territory-Western Australia border; and Hermannsburg Mission, in the West MacDonnell Ranges approximately 130 km west of Alice Springs (Fig. 13). These sites were selected as they provide good geographical coverage of the case study area.

Detailed rainfall records are available for Hermannsburg from 1888 due to the early establishment of the Hermannsburg Mission. Average rainfall recorded between 1888 and 2012 is 234 mm, with below average rainfall recorded for 52 of the 124 years of data collection. Average rainfall recorded at Giles between 1957 and 2012 is 287 mm, with below average rainfall recorded for 35 of the 55 years of data collection. Average rainfall at Warburton weather station between 1941 and 2014 is 245 mm with below average rainfall recorded for 36 of the 71 years of data collection.

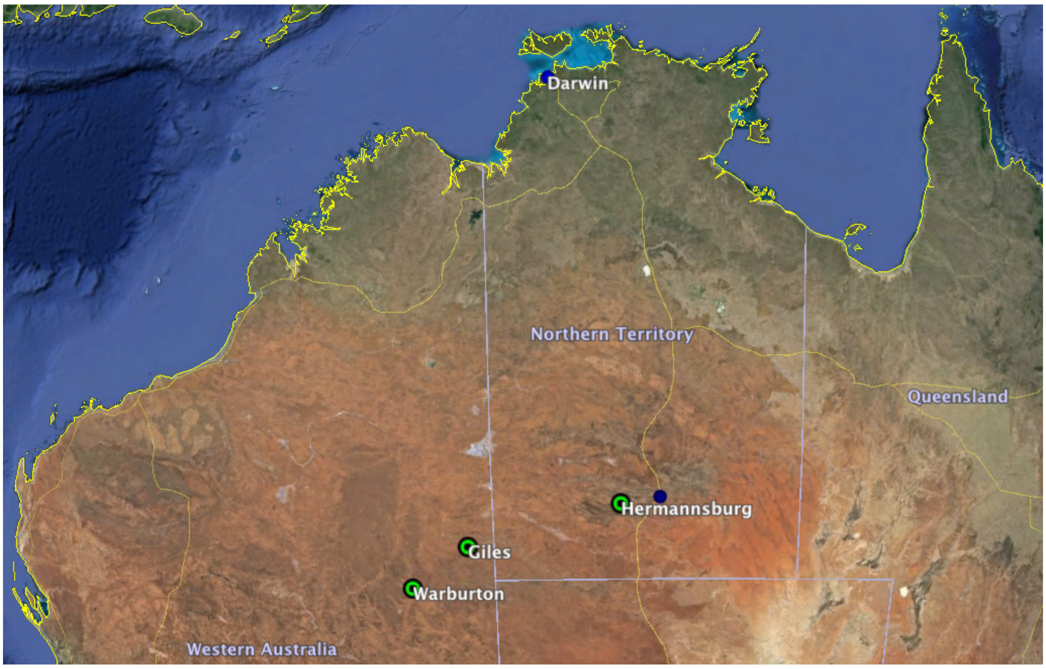

Figure 13: Location of weather stations referred to in text (Hermannsburg, Giles and Warburton).

As the rainfall graphs in APPENDIX 1 show, since records began Hermannsburg weather station has received lower average rainfall than Giles and Warburton weather stations. Given that the Western Desert is a more marginal environment than the Arandic area the higher average rainfall recorded at Giles and Warburton weather stations appears inconsistent with what we know of the environmental parameters of these regions. These anomalies seem primarily due to limitations in data collection as records for Warburton and Giles and do not record the six serious droughts that occurred between 1880 and 1941. The longer rainfall record from Hermannsburg weather station, which dates back to 1888, reflects the earlier history of European contact in the Arandic region. While not useful for establishing comparative long-term rainfall averages, these graphs illustrate the extreme variability in rainfall from year-to-year that influenced the specific social and economic adaptions of desert hunter-gatherers discussed in Chapter 1.

Looking at spatially averaged rainfall according to bioregion provides a more accurate picture of regional rainfall. As outlined above, the spatially averaged rainfall for the MacDonnell Ranges Bioregion, within which Hermannsburg weather station is located, is 228 mm. The spatially averaged rainfall for the Central Ranges Bioregion containing both the Warburton and Giles weather Stations is 177 mm.

Arid-zone droughts

Since climate records began there have been six major droughts recorded in the arid zone over an 87 year period between 1880 and 1967. Severe droughts during the historical period were significant drivers of population collapses and large-scale migration (see Chapters 4 and 5). APPENDIX 2 shows that all but the 1880-1884 drought (for which data is unavailable) are associated with ENSO events. This indicates that modern ENSO cycles that commenced during the mid-Holocene (see Chapter 2) continued to exert a strong influence on hunter-gatherer subsistence and socio-cultural, economic and technological adaptations throughout the historical period.

Discussion

As outlined above, the MacDonnell and Central Ranges bioregions are ecologically and climatically distinct areas. The Central Ranges bioregion encompassing the tribal lands of the Pitjantjatjara and Ngaanyatjarra people is one of the most marginal areas on the Australian continent comprising uncoordinated drainage and low rainfall (Peterson 1976, 65). The MacDonnell Ranges bioregion, which encompasses the territory of the Western Arrernte people, by comparison experiences higher average rainfall and contains a higher density of reliable water sources and plant and animal refuges. In Chapter 1 I discussed how differences in the social organisation of Western Desert and Arandic hunter-gatherers (specifically the Ngaanyatjarra/Pitjantjatjara and Arrernte) were reflected in the distinct climate and resource availability of these regions.

As discussed in Chapter 2, ENSO periodicities have dominated the Australian climate since approximately 5 kya and have exerted a significant influence on Australian flora and faunal assemblages (Letnic and Dickman 2006), while also reconfiguring hunter-gatherer population processes, socio-cultural organisation, mobility and subsistence strategies (Smith 2013, 162; Williams *et al.* 2010). Records discussed in this chapter indicate the ongoing relevance of ENSO events to hunter-gatherer subsistence strategies and social organisation throughout the historical period. Chapter 5 will examine the range of hunter-gatherer responses to major droughts documented during the historical period.

CHAPTER 4: The impact of colonisation

Introduction

The overlay of colonisation presents a considerable challenge to reconstructing pre-contact hunter-gatherer ecology, as evaluating traditional responses to drought is complicated by the impracticability of isolating post-contact influences of colonisation on hunter-gatherer subsistence patterns. Gould noted during his field work that:

> Empirically, the greatest problem for the observer in the Western Desert then was the difficulty of controlling for factors arising from conditions brought about by depopulation of Aboriginal groups from the desert and, in some cases, their relocation at various missions and reserves ... (Gould 1991, 25).

Historical records of encounters between Europeans and desert hunter-gatherers date back approximately 155 years. Central Australia was settled relatively late due to an inhospitable climate, unpredictability of rainfall, isolation from the settled coastal areas of Australia and early reliance on horses which were unsuited to the harsh desert environment (Stevens 2002, 28). I have included this section to illustrate the quality of earliest sources and provide a context for understanding how traditional subsistence strategies and demographic responses to drought documented in the historical record were influenced by colonisation.

The early explorers

Early explorers and government survey parties provide us with the earliest historical information relating to Aboriginal occupation of the arid zone. These accounts are problematic as the early explorers were not trained ethnographers, their goals were primarily economic, and observations of Aboriginal people were generally recorded incidentally. It was often while searching for water that European survey parties encountered Aboriginal people, as predictably camp sites were often located in proximity to water sources, and thus it is in this context that encounters are frequently described (see Basedow 1914, 128; Carruthers 1892, 4; Giles 1874, 17, 1889; Gosse 1973, 10,13; Hubbe 1897, 24; Lindsay 1893, 21).

The indefatigable explorer John McDouall Stuart was the first European to encounter desert Aboriginal people in 1860 while mapping a route through the harsh terrain of central Australia in an attempt to reach the north coast (Stuart 2012, 177-178). The construction of the Overland Telegraph Line between Adelaide and Darwin was completed in 1872 and closely followed Stuart's route, tracking chains of permanent and semi-permanent waters through central Australia. The use of water sources by construction workers and pastoralists inevitably led to tensions and clashes, as these were also crucial resource sites to the Aboriginal inhabitants of the region (see Kimber 1990(a), 2; Maclean 2009, 452)

Following its construction the Overland Telegraph Line was used as a launching point to stage subsequent expeditions into the unmapped country to the west. The first were the Giles and Gosse expeditions, which recorded the earliest encounters between Europeans and Aboriginal groups to the west of the Overland Telegraph Line. In 1873 Ernest Giles embarked from central Australia in an attempt to reach the west coast of the continent. Giles relied on horses for the journey which were ill-equipped to handle the lack of water, and after enduring considerable hardship he abandoned his first attempt shortly after crossing the West Australian border (Beard 1969, 679; Giles 1889). Giles was the first European to make contact with Ngaanyatjarra people while travelling through the Petermann and Rawlinson Ranges and describes sighting numerous signs of native camps, campfires and hunting-related burning, as well as the curation of water holes.

In 1873 the South Australian government mounted an expedition led by W.C. Gosse, which also set off from Central Australia with the objective of reaching the west coast of Australia. The expedition crossed over the West Australian border travelling as far as the Warburton Ranges before being forced to turn back due to water scarcity (Gosse 1973, 15). Perhaps unsurprisingly the first Aboriginal word recorded by Gosse was *carpee* (i.e. kapi), the Yankunytjatjara word for water on 4 August 1873 (Gosse 1973, 11).

In 1889 Tietkins led an expedition from Alice Springs and travelled west to Glen Helen Station in Western Arrernte country before continuing further west to Lake Macdonald, the Kintore Range and the Cleland Hills, then returning to the Charlotte Waters

Telegraph Station south of Alice Springs.[14] Illustrative of the enormous amounts of water required by an expedition team, Tietkins describes filling 16 buckets of water in one night from a native well to supply his men and camels (Tietkins 1889, 11, 25). A thirsty camel can drink 200 litres of water in half an hour (Watson 2014, 135) and an expedition party could quickly exhaust crucial water sources that Aboriginal people relied upon.

Incorporation of European resources into traditional subsistence strategies

There is substantial evidence that European materials, while scarce, were circulating amongst central Australian Aboriginal people from at least the mid-nineteenth century, preceding the arrival of the first European explorers. In 1873 the explorer P.E. Warburton observed an iron axe and sharpened hoop iron in an Aboriginal camp in a previously unexplored region of the Western Desert. Warburton believed the hoop iron to have been scavenged from water kegs abandoned on the eastern fringe of the Great Sandy Desert in 1856 by the explorer Augustus Gregory (Jones 2007, 102-103). In 1886 the explorer David Carnegie encountered Aboriginal people in the Great Sandy Desert carrying iron relics, one of which was subsequently identified as a tent peg belonging to Dr Ludwig Leichardt whose expedition vanished into the desert in 1848 (Jones 2007, 103, 115). In 1897 in the Winnecke Hills 500 km west of Alice Springs, the explorer David Carnegie reported surprising '…two gins hunting and, amongst their spoils of the chase, were astonished to see a common domestic black cat, evidently just killed' (Carnegie 1989, 396-397). The earliest account of a domestic cat sighting in the Central Desert was by the explorer Charles Winnecke's expedition in 1883 (Letnic and Dickman 2006, 3857, 3871).

These earliest accounts indicate that European materials and introduced species were being incorporated into hunter-gatherer toolkits and diets long before regular contact. As European-obtained tools became increasingly integrated into traditional toolkits, the time taken and necessity of certain foraging activities and behaviours was drastically reduced (see O'Connell and Hawks 1981, 110, 115).

[14] *Australian Dictionary of Biography*. Retrieved 6 January 2014: http://adb.anu.edu.au.

European settlement

European settlement rapidly followed the construction of the Overland Telegraph Line, and significantly impacted on traditional mobility strategies (Austin-Broos 2009, 16). Many large-scale migrations of Aboriginal people from their traditional lands to European settlements were linked to periods of severe drought (Kimber 2001; Maclean 2009, 453; Meggitt 1962, 24; Myers 1986, 32). Other factors included access to new technologies (such as metal and glass) and resources (such as sugar, flour, tobacco and tea); seeking asylum from traditional conflicts; and refuge from police punitive parties and pastoralists who often forcibly moved or massacred Aboriginal people and frequently abducted Aboriginal women (Kimber 1990(a), 166; 1990(b), 5; Schulze 1891, 218; see also Carment 1991, 5; Kenny 2008, 22).

In the Western Arrernte region intensive contact with Europeans began with the establishment of the Hermannsburg Mission in 1877 (Brock 2008, 111; Carment 1991, 18). Some Western Arrernte people converted to Christianity and settled on the Mission while others incorporated the Mission in their seasonal round, temporarily visiting relatives and obtaining rations. The adjacent cattle stations of Henbury, Tempe Downs and Glen Helen were all settled by 1879 and engaged Aboriginal people as cooks, housemaids and station hands (Austin-Broos 1994, 132; Kimber 1990(b), 8). The discovery of gold at Arltunga in 1887, the establishment of native ration depots and the construction of the railway line between Adelaide and Oodnadatta in 1890 also encouraged large-scale migration into areas of European settlement (Bucknall 1990, 1; Carment 1991, 39; Kenny 2008, 20; Kimber 2011, 46, 50). Moreover, as Strehlow observed, some Arrernte people living in resource-poor country took advantage of the upheaval and disruption to traditional social organisation caused by the arrival of Europeans to move to better-watered Western Arrernte country and closer to the Hermannsburg Mission (Austin-Broos 1994, 133).

In the Western Desert, the discovery of gold at Kalgoorlie during the 1890s drew Europeans to the south-eastern fringes of the Western Desert and triggered the gradual movement of Aboriginal people towards the towns that sprang up to resource the gold diggings (Bates 1938). Over time European settlement significantly affected the economic and demographic balance of the Western Desert. Pintupi contact with Europeans was limited and sporadic until well into the twentieth century as their traditional lands were not favourable for the development of pastoralism nor economically viable for minerals exploration due to vast distances and the absence of infrastructure required for transportation (Meggitt 1965, 148; Myers 1986, 27). In the 1930's Pintupi people migrated towards Hermannsburg Mission from the west in response to drought and the depopulation of traditional lands that made traditional subsistence living increasingly unviable as critical population size dropped below sustainable levels (Myers 1986, 32). As Myers noted:

> The unreliability of rainfall necessitated continual interdependence among people in a wide area for water and resources. Social isolation in other words was, ecologically impossible (Myers 1986, 27).

Extensive abandonment meant that there was no longer an effective critical population remaining on traditional lands to maintain ceremonial and economic links and social organisation (Anderson 1988, 142; Myers 1986, 32). Large-scale abandonment of country likely also reduced the remaining population's capacity to endure drought.

It was Birdsell's opinion that introduction of post-contact influences had such a profound impact on Aboriginal lifeways that all ethnography undertaken after the 1930s is questionable (Birdsell 1970). He argued that even for those groups that continued to live largely traditional lifestyles after contact, the overall population reduction on traditional lands caused by out-migration to European settlements irrevocably changed the ecological balance of the environment due to a decline in Aboriginal usage of resources (Birdsell 1970, 118). While the effect of European contact on hunter-gatherer subsistence patterns cannot be overstated, Birdsell's characterisation of pre-contact Aboriginal societies as closed, static environments ignores their complex histories.

While European settlement had a devastating effect on desert Aboriginal populations, it should be noted that extensive demographic restructuring as a result of external influences may not have been exceptional. Smallpox was introduced prior to European contact by Indonesian Macassans who annually traded for sea cucumber with Arnhem Land Aboriginal people from as early as the seventeenth century (Clarke and May 2013). Epidemics are recorded in 1789 and 1830, spreading rapidly throughout the country and are known to have decimated tribes in the settled regions. Smallpox may also have drastically reduced populations in the desert prior to settlement, triggering demographic movements that appear to have been continuing to play out at the time of contact (Gara 1995, 29; Kimber 1990(a), 165; Tindale 1953, 172). Giles, one of the earliest European explorers to make contact with Western Desert hunter-gatherers recorded encountering an individual bearing the scars of smallpox in the Rawlinson Ranges in 1873 (Giles 1889, 20).

Discussion

Social and economic networks were crucial to Australian desert societies maintaining a foothold in a harsh and unpredictable environment (see Myers 1986; Birdsell 1970). The convergence of both severe drought and colonisation pressures in the early twentieth century resulted in profound changes to hunter-gatherer population processes and subsistence patterns, significantly disrupting these networks. Many affected groups were rapidly depleted, making traditional responses to drought, which were dependent on extensive kinship and ceremonial networks for access and trade in resources, unviable due to reduced critical population size. This triggered or accelerated permanent out-migration and territorial abandonment in some tribal areas as critical population sizes dropped below sustainable levels to maintain traditional subsistence living. However, as outlined above large-scale demographic restructuring had occurred prior to European contact. The introduction of smallpox by Macassan traders in the seventeenth century, the diffusion of the section and subsection system and the migration of the Pama-Nyugan language family (see Chapter 2) are examples of such restructuring.

The extent to which early European contact influenced traditional hunter-gatherer demographics and responses to drought cannot be conclusively established, however there is no doubt that European settlement exerted a profound influence on hunter-gatherer population processes. Having said this, in evaluating demographic movement during the early contact period, rather than attempting to isolate European influences, I suggest that the combined effect of drought and colonisation can be interpreted as subsistence pressures, the pattern of demographic movement in the early contact period likely reflecting Aboriginal pre-contact responses to periods of severe environmental stress consistent with traditional mobility and subsistence strategies. For example, local group responses to subsistence pressures (both European and environmental) involved habitat tracking through the activation of kinship and economic networks to shift to areas that were more conducive to on-going survival. Most significantly, the devastating effect of colonization demonstrated the crucial role that critical population size played in desert Aboriginal societies.

CHAPTER 5 – Drought: the key challenge to subsistence

Introduction

Severe droughts during the historical period resulted in major demographic reconfigurations expressed by range-shifts, territorial abandonment, succession in areas where territorial abandonment created population vacuums and long-distance permanent migration. In Chapter 1 I discussed the differences in social structure between the Arandic and Western Desert culture areas and the role of social organisation as an adaptive response to specific environments. In order to understand how climate influenced population demographics and mobility strategies, this chapter will outline the range of strategies local groups employed to mitigate the risks associated with drought.

Curation of water sources

Water scarcity is the ever-present challenge to subsistence in Australian desert environments. In much of the Western Desert there are few permanent waterholes and most water sources consist of native wells and soakages. An intimate knowledge of where and when waters were available was crucial to hunter-gatherer mobility strategies, making movement opportunistic in response to water availability and the foraging areas accessible from water sources (Gould 1969, 265; Long 1971, 266). As discussed in Chapter 1, Western Desert hunter-gatherer social structures were loosely organised providing the flexibility for long-range opportunistic movement through the activation of extensive kinship networks.

The random nature of rainfall meant that hunter-gatherers could not follow a predictable circuit of their range. In referring to the unpredictability of rainfall in the Western Desert Gould writes that ‘… people must literally “chase rain” in order to live’ (Gould 1982, 71). However, arid-zone hunter-gatherers also actively curated precious water sources to alleviate the perils of water scarcity. In 1883 in the northeastern Arrernte region on the northern fringes of the Simpson Desert, stockman and pastoralist Ridley Williams described encountering people using kangaroo skin water bags and also reported seeing waterholes covered with bushes to protect supplies (Kimber 1980, 53-55). On the eastern fringe of the Simpson Desert in 1884 the South Australian government surveyor Charles Winnecke observed the 'fencing of springs and construction of dams to conserve water sources' (Kimber 1984, 12). Other water collection and conservation techniques included digging holes in claypans and covering the holes with brushwood to collect water and prevent evaporation; sinking wells with a slight curve to block exposure to direct sunlight, and using brushwood and sticks to protect wells from contamination (Kimber 1984, 12; Magarey 1895-1896, 79).

The relationship between water and the totemic landscape

Given the significant ceremonial, economic and social importance of water in pre-contact Aboriginal societies it is no coincidence that greater densities of named ceremonial sites clustered around permanent and ephemeral waters and resource rich upland country (Kimber 2009, 304). Within the Arrernte area such productive country would invariably fall within one or another group's estate (Pink 1936, 284; Strehlow 1965, 133, 138). Conversely, areas that were inaccessible due to an absence of water points and containing limited food resources had a much-reduced frequency of named landscape features attached to them:

> … there are numbers of small areas of about 200 square kilometers or so that are considered dangerous and/or 'rubbish' country because they have no water and very little food potential. Traditionally the walking routes went about such areas, or they were passed over quickly by a very direct route: they were similar to the totally unproductive route over the firm salt-surface of Lake Mackay, where the purpose was to reach a known site near the distant shore-line with water, shelter, firewood and food-potential as soon as possible. They have no place names in themselves, but are affiliated on the periphery into the foraging zone of named sites. These named sites are as though fitted with a dimmer-light (Kimber 2009, 303).

Olive Pink elicited the term *endotha* from her Northern Arrernte informants to describe expanses of trackless, economically unproductive country containing no permanent water sources (Pink 1936, 284). Pink makes the observation that these were shared zones beyond the limits of an estate group's territorial boundary. Such country was described as:

> … 'no good', having no *andatha* 'paint'[15], nor *altjeringa*[16] associations and therefore no ritual songs … (Pink 1936, 283-284).

Drought avoidance strategies

Strehlow estimated that during drought, up to four-fifths or seven-eighths of a given tribal area could be temporarily abandoned, with local groups retreating to permanent waters usually located in the rugged range country (Strehlow 1965, 124). Western Desert people forced by drought to abandon less productive areas exploited range country as well as networks of native wells, or sought refuge with neighbouring local groups (1965, 124). In the better-watered Western Arrernte region populations could fall back to permanent and semi permanent waterholes and springs located in the ranges and riverine corridors when ephemeral waters failed (Box *et al.* 2008, 1396; 1405).

Such strategies are recorded in the journals of early explorers. During a survey south-west of the Everard Ranges, South Australian Government Surveyor John Carruthers recorded that most Aboriginal people (whom we know to be Pitjantjatjara or Yankunyatjatjara) in the region had retreated to the Musgrave and Mann Ranges, presumably due to the drying up of ephemeral waters (the map at Fig. 14 shows some of the site locations referred to in this chapter). Describing a waterhole-tethered local group Carruthers writes, 'We met with very few [Aborigines] south of the ranges, and those we did see were emaciated by semi-starvation, as they were unable to go very far from the little water they depend upon to hunt for food' (Carruthers 1892). Another South Australian Government Surveyor, W.R. Murray recorded that the hill tribes '…are now scattered about working the sandhill country to the south, reserving the country around the main waters in the ranges until hot weather sets in' (Maurice 1901, 13). Explorer, David Carnegie noted that Aborigines only made use of permanent waters as a last resort after the smaller rock holes and native wells were depleted (1898, 274).

Subsequent researchers confirmed these early observations of Aboriginal water management. Northern Territory Patrol Officer Jeremy Long noted that limited fuel and food resources around permanent waters acted as a disincentive to exhaust supplies

[15] Used for ritual purposes.

[16] represented as '*Altyerrenge*' in the current Eastern Arrernte orthography, meaning Dreaming/Dreamtime (Henderson and Dobson 1994, 105).

(Long 1971, 267). Gould made similar observations of water use in the Warburton Ranges. People would forage around smaller waterholes until either the water dried up or food supplies were exhausted before moving to more secure water sources and finally to permanent waterholes (Gould 1968, 104-105). Key permanent waters and surrounding foraging areas were always reserved until absolute necessity forced groups to retreat to them.

Tindale referred to permanent water sources as 'central' and 'peripheral' refuges respectively. According to Tindale a 'central' refuge signified a water source or constellation of waters located in the core of a group's territory, the site of last resort from which further retreat was not possible. During serious and prolonged drought groups could risk becoming stranded at a central refuge due to the drying of surrounding ephemeral waters that linked to other permanent water sources. This is referred to as waterhole tethering and could lead to starvation once food resources where exhausted within the foraging radius of a camp (1974, 68-69; 1940, 150). Peripheral refuges were certain key peripheral water sources that were shared to some extent and would be visited by three or more tribes (1974, 69; 1940, 150). As outlined in Chapter 3, the often highly localised nature of climatic processes in the Western Desert meant that while one group's territory could be severely impacted by drought, a neighbouring territory might receive normal rainfall. As Strehlow put it:

> Hence even during the worst droughts the survival of Western Desert folk was assured, as long as their social organisation contained enough flexibility to enable any stricken group to find temporary asylum within the food area of one of the more fortunate groups (Strehlow 1965, 124).

During times of widespread drought however, such strategies could fail as ephemeral waters disappeared and the distance between permanent water sources increased, making them unreachable (see Cane 1990, 157).

Ethno-archaeologist Richard Gould observed that Ngaanyatjarra people minimised drought risks by an approach he labelled 'strategy switching' (Gould 1991). This involved two alternative approaches to risk mitigation: 'drought evasion' and 'drought escape'. Gould's modelling of drought avoidance behaviour is analogous to Tindale's 'core/periphery' hypothesis. According to Gould, drought evasion involved retreat to areas within a group's home territory where permanent waters existed (Gould 1991, 15; see also Pate 1986, 110). Drought escape was employed during absolute drought and involved the temporary abandonment of a group's territory, and migration to the territory of a neighbouring local group (Gould 1991, 14). Drought escape presupposed a high degree of residential mobility and social flexibility and relied upon social relationships and reciprocal obligations existing between neighbouring groups (Gould 1991, 26; see also Strehlow 1965, 124). Gould emphasised that the key to survival was the flexibility of Western Desert society, enabling hunter-gatherers to shift from one strategy to the other in response to changing environmental conditions (1991, 26).

The flexibility of Western Desert social structures discussed in Chapter 1, importantly the multiple avenues by which an individual may claim a connection to heterogeneous tracts of country over wide areas facilitated the drought avoidance strategies described by Gould. In the Arandic region higher population density and access to upland resource-rich refuge areas to an extent obviated the need for such flexible social organisation to mitigate risks associated with water scarcity.

Migration and permanent territorial abandonment

During the 1925-1935 drought (see APPENDIX 2), the failure of traditional food sources in the Western Arrernte, Pintupi and Kukatja region triggered a surge of Aboriginal out migration forcing weakened and starving people to seek refuge in European settlements such as the Hermannsburg Mission, Alice Springs township and surrounding pastoral stations (Kimber 2001, 1; Tindale 1974, 69). The Kukatja, who are referred to today as the Luritja or Kukatja-Luritja, originally occupied a tract of country between the tribal lands of the Pintupi and Western Arrernte. By the 1930s they had been dispersed or fallen victim to epidemics, drought and starvation, the survivors migrating southeast towards Hermannsburg Mission (Kenny 2008, 24; Tindale 1974, 138, 227-228). The Pintupi were initially forced from their traditional lands by the 1916 drought and migrated southeast approximately 80-160 km over a number of generations, driven by successive droughts during the late 1920s, early 1940s, mid 1950s and early 1960s[17] (Myers 1986, 28-29; Tindale 1953 and 1972). The Pintupi and Warlpiri moved into the

[17] See Chapter 2, APPENDIX 2: Recorded droughts correlated with weather station rainfall records and ENSO Events – Central Australia and Western Desert.

abandoned Kukatja-Luritja territory in response to resources availability, a shift that subsequently became permanent (Myers 1986, 32). This process has been described elsewhere as a chain migration of desert people into the settled districts (Smith 2005(a), 1).

Tindale recorded that during the 1914-1916 drought Pitjantjatjara people living west of the Musgrave Ranges were forced to move eastwards where the country had remained largely unaffected. In doing so they violently appropriated the territory of their eastern neighbours, the Yankunytjatjara, many of whom were killed and the survivors forced southeast of the Musgrave Ranges by 225 to 260 km. According to Tindale the Pitjantjatjara transferred site names and myths to the former Yankunytjatjara territory thereby sanctioning their claim to the newly acquired territory (Tindale 1953, 171-173; 1974, 69-70). The Pitjantjatjara migration east became permanent because important game sources such as wallaby and mala populations had crashed and not recovered following the drought in their western traditional lands, and certain key permanent waters had dried up completely (Tindale 1974, 69-70). The catastrophic crash in small native mammal populations in the 1930s was most likely caused by introduced exotic species such as foxes, cats, rabbits and cattle reaching a critical mass (Finlayson 1979; see also Burbridge *et al.* 1988; Letnic 2000; Robinson *et al.* 2003, 22). According to Robinson *et al.* the late 1920s to early 1930s drought, which extended across the entire tribal territories of the Pitjantjatjara and Yankunytatjara, permanently reconfigured the environment and resulted in drought related mortality (Robinson *et al.* 2003, 22). Tindale does not explore the social-cultural or economic dynamics at play that motivated the Pitjantjatjara to forcibly occupy Yankunytjatjara territory rather than activating kinship networks to migrate from drought-affected country. In this case a convergence of factors including drought and the crash of small mammal populations may have created conditions of unprecedented subsistence pressure. Added to this, proximity to European settlements may already have altered Yankunytjatjara demographics when the Pitjantjatjara moved east, thus reducing the risks associated with territorial conquest. The establishment of the Ernabella Mission in 1937 and availability of rations also provided an incentive for the recent immigrants to remain (Kral 2007, 45; Young and Doohan 1989, 83-84).

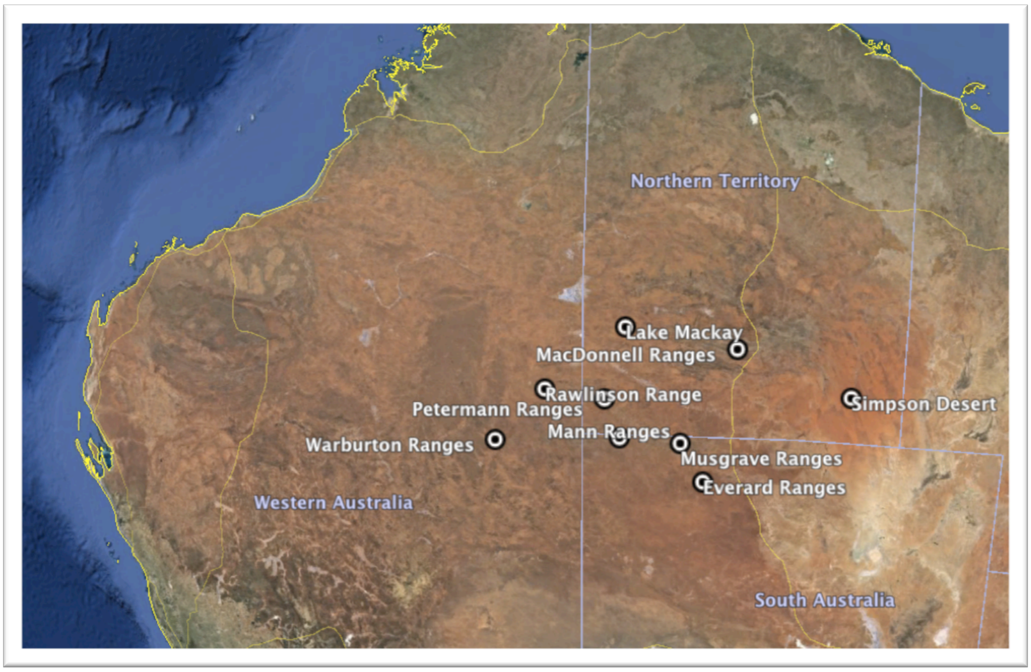

Figure 14: Locations referred to in the text including: The Warburton, Rawlinson, Petermann, Mann, Musgrave, Everard and MacDonnell Ranges, Lake Mackay and the Simpson Desert.

As reflected by the above responses to drought, a shift to the country of a neighbouring group was a strategy employed when resource availability was insufficient to maintain survival in a group's own territory. Tindale outlines two options available to groups forced to abandon drought-stricken territory and migrate to a neighbouring group's territory. If migration occurred into an area that was recovering from drought it may have already been depopulated, or the local group may have been weakened and unable to resist a forced incursion into their territory. Alternatively a group forced to seek refuge in an area where the carrying capacity was already at maximum was likely to encounter conflict. Weakened by drought and entering unfamiliar territory they would likely be at a disadvantage. In such cases the asylum seekers could offer wives in exchange for sanctuary (Tindale 1974, 70-71). Witnessing a drought-forced encounter between the Ngadadjara and the Nana tribes at a permanent water source called Warapuju Soak in the Warburton Ranges (close to Puntutjarpa rock shelter), Tindale describes a ritual defence of the soak by the Ngadadjara, after which the strangers were given permission to access the water source (Tindale 1974, 70).
Tindale goes on to observe that:

> This seems likely then to be a continuing state of affairs in desert areas with the 'surplus' population being forced to redistribute itself continually into any

> favorable niches not yet fully occupied. Those who fail take their chances by centrifugal movement into areas where the physical climate would be better but the social climate very unfavorable for survival, unless new bonds of friendship could be established before annihilation (1974, 71).

Meggitt writes of the Warlpiri, that during the 1909 Tanami gold rush, conflict over water sources in the Tanami region north-west of Alice Springs, claimed by the neighbouring Waringari tribe resulted in the Warlpiri ‘driving the Waringari from the area’ (Meggitt 1965, 42). Meggitt notes that according to published accounts of Aboriginal societies such invasions of neighbouring tribal lands appear to have been rare events but may have been a more regular occurrence than has been recorded in the ethnographic literature (Meggitt 1965, 42; see also Sutton 2003, 21).

While there were mechanisms in place to enable drought-affected groups to seek asylum in neighbouring territories and avoid conflict over scarce resources, Meggitt’s observations show that territorial exclusion and defence was also practised in circumstances of resource scarcity (1965, 42). I will discuss territorial boundary management in detail in Chapter 6.

Drought-related mortality

While arid-zone hunter-gatherers had developed superb adaptions to living in a high-risk environment, accounts of drought-related mortality in the literature show that in the event of unusually fierce or prolonged droughts (and on a larger spatial scale than those discussed above) such strategies could, and sometimes did fail.

Extensive kinship networks and ceremonial affiliations across wide areas, facilitated migration and temporary abandonment of drought affected country in the Arandic region. Nevertheless, despite the relative security of drought refuges such as those located in the Western MacDonnell Ranges, periods of widespread and long-term drought impacted on Arrernte subsistence. For example, people residing at Hermannsburg Mission were badly hit by the 1925-1935 drought (see APPENDIX 2) notwithstanding the limited availability of rations at the Mission. Traditional food resources such as kangaroo, grass seed, fruits and tubers failed and infant mortality was as high as 85 percent (Austin-Broos 2009, 62-64).

Berndt noted that drought brought death 'for the old, the physically unfit or the very young' (Berndt 1972, 179). Pastor Albrecht at Hermannsburg Mission recounted groups becoming stranded and perishing at ephemeral waters, unable to retreat to permanent water sources. He estimated that groups of 20 to 70 people died in these circumstances (Albrecht 1943 cited by Kimber 1990(a), 161). Tindale and Meggitt both mention people perishing during the 1929 drought (Meggitt 1968, 24; Tindale 1974, 69), and more than 30 people perished near Lake Mackay in the 1940s after reaching a waterhole that had dried up (Cane 1990, 157).

Kimber estimates that between 10-25 per cent of a tribe could die out every 30 to 40 years as a result of successive droughts (Kimber 1990(a), 161), a surprisingly high mortality rate given the low population levels of the Australian desert. However studies of Pitjantjatjara people suggest that in this region mortality was offset by fertility rates high enough to enable swift population recovery, doubling the population every 25 to 50 years (Smith and Ross 2008, 387; see also Pennington 2001, 176-177).

Local group extinction, fission and fusion

There is limited information on cases of biological extinction, and instead here I focus on recorded occurrences of cultural extinction, defined as instances where the distinctive cultural traits of local groups are lost due to depletion, dispersal or extinction of the local group and the absorption of surviving group members into new host groups (see Soltis *et al.* 1995).

Soltis *et al.*, who examined patterns of group extinction and group formation in Papua New Guinea, define group dispersal as a form of cultural extinction, as dispersing individuals have limited capacity to influence the cultural behaviours of their new host population and therefore cultural traits of incoming individuals to a group are lost. They make the distinction between group fission and groups that are forced to migrate but remain intact and are thus able to maintain their cultural distinctiveness (Soltis *et al.* 1995, 475-476). In the case study area the former ensued when migration and abandonment of traditional lands triggered the permanent breakup and dispersal of local groups. This occurred to an extent with respect to the Southern Arrernte previously mentioned in Chapters 1 and 2, who had historically possessed a section system but after being decimated by disease and out-migration in the late nineteenth and early twentieth century, were gradually incorporated into the Western Arrernte subsection system (Strehlow 1965, 136). The wholesale eastward movement of Pitjantjatjara people in the early 1920s discussed above, tracking habitat to a more favourable environment, is an example of the latter. In this case cultural distinctiveness was preserved in spite of forced migration.

The small average size of Aboriginal groups (approximately 25-30 people)[18] made them vulnerable to extinction through subtle variations in mortality, fertility, sex ratio, and marriage rules (Kelly 1995, 210). Predictive computer modelling by Wobst for palaeolithic social systems suggested that:

> …the half-life of a group of 25 people was 180 years and that in a regional population of 19 bands each with 25 members, 5 nuclear families would be discontinued in an average year (Wobst 1974 cited by Peterson 1983, 135).

Wobst concluded that groups comprising fewer than 25 people were unlikely to be reproductively viable (Kelly 1995, 211). As the maintenance of viable group size under normal conditions was sensitive to small changes in population dynamics, the occurrence of harsh and prolonged droughts placed severe stress on desert hunter-gatherer populations in the pre-contact past. The introduction of post-contact mortality factors (discussed in Chapter 4) combined with the usual perils of subsistence living in the face of drought significantly increased the instances of local group extinction. However, as Sutton notes, similar widespread mortality events may have occurred prior to the colonial era from time to time. For example, as discussed in Chapter 2, the disappearance of the Bradshaw artists has been attributed to a 1500 year mega-drought related population collapse linked to the onset of modern ENSO cycles during the mid-Holocene (McGowan *et al.* 2012; Sutton 2003, 5-6; Williams *et al.* 2013, 4620).

In both the Western Desert and Arandic areas, the occupation of vacated territory by a neighbouring group is mediated according to traditional law and custom. When the territory of an extinct group is subsumed by an extant neighbour this is referred to as 'group succession'. When an estate group is dispersed or has become extinct, principles of succession ensure that rights and interests in country are preserved and ritual links

[18] see Chapter 6 for a full discussion of group size.

associated with the travels of dreaming beings are not disrupted (see Davidson 1990, 51). In 1899 Spencer and Gillen documented the succession of the Central Arrernte 'Unchalka'[19] (elephant grub caterpillar, *Hippotion celerio*) group to the 'Echunpa'[20] (perentie, *Varanus giganteus*) estate following the extinction of the 'Echunpa' patriline. They noted that succession strictly followed processes of inheritance, firstly observing that according to traditional law, succession occurs between two estate groups sharing the same patri-moiety (see Chapter 1), and secondly, that the local group could be revived through the conception of a child in the totemic area to which the original estate group was connected (Spencer and Gillen 1899, 152-154, 301-302; see also Sutton 2003, 21-22). In this way the cultural group might be renewed despite all previously existing members having died out. Principles of succession form part of the traditions practised by the Arrernte today and it is reasonable to assume that they were also practised in the pre-contact past. It is thus evident that group extinction or dispersal occurred with sufficient regularity prior to European settlement that succession processes were embedded in traditional law and custom to manage the transfer of country from one group to another.

Discussion

In this chapter I noted that local groups employed strategies including high residential mobility and extensive kinship networks to mitigate the risks associated with drought. I discussed drought avoidance strategies including strategy switching, migration and territorial abandonment. I then outlined historical records of drought related mortality and the implications for group fission and extinction. The small size of hunter-gatherer groups made them sensitive to extinction precipitated by subtle demographic and environmental variations. However as shown by the data on high Pitjantjatjara fertility rates, rapid population recovery prevented extinction at the tribal level (as distinct from the local group level – see Chapter 1).

I conclude that both permanent and temporary territorial abandonment (sometimes for a number of years) was a common drought avoidance strategy employed in the Western Desert. In some cases, depopulation diminished cultural distinctiveness such as in the

[19] Current Eastern Arrernte orthography represents 'Unchalka' as '*Ntyarlke'* (Henderson and Dobson 1994, 509).
[20] Current Eastern Arrernte orthography represents 'Echunpa' as '*Atyunpe* ' (Henderson and Dobson 1994, 332).

case of the Southern Arrernte, who were largely incorporated into the cultural and social practices of more rigorous neighbouring groups through a process of fission. In the case of the Kukatja-Luritja, extensive out-migration led to the permanent abandonment of traditional lands by local groups seeking refuge on the margins of European settlements and their subsequent occupation by Pintupi migrating from the northwest. In contrast the Pitjantjatjara responded to drought and resource depletion on their traditional lands by tracking habitat to the east and in doing so displaced the Yankunytjatjara.

CHAPTER 6 – Arid-zone cultural ecology

Introduction

Recent hunter-gatherer subsistence strategies are characterised by a wide spectrum of foraging behaviours dictated by the ecological settings of specific environments (Kelly 1995, 67-69). The preceding chapter documented the range of responses to drought. This chapter explains how climate influenced population demographics and mobility strategies were facilitated by the social structures outlined in Chapter 1 and describes how the interaction between population density, group size, socio-economic structures, territorial boundaries and environment influenced foraging systems and mobility strategies in the Australian arid-zone. Here I develop a framework based on behavioural ecology models for relating mobility strategies to environmental conditions. I apply Central Place Foraging (CPF) theory to the case study area to model the risk mitigation strategies employed by hunter-gatherers during periods of severe and prolonged drought in the historical past in order to understand the outcomes of group movement into neighbouring areas.

While there is robust data available for Western Desert subsistence strategies (see for example Bird *et al.* 2008; Bird and Bird 2005(b); Cane 1987, 1990; Gould 1991; 1969; 1977), detailed quantitative data for traditionally orientated diets in the Arandic area is scarce (see Cane 1987, 414; White 2001). I therefore employ CPF as a theoretical model to consider how variations in aridity, water availability and the distribution of other groups affected foraging capacity and demographics.

Central Place Foraging Theory

Central Place Foraging (CPF) theory describes a model whereby foragers 'radiate from and return to a central site' (Winterhalder 2001, 19). This mode of subsistence is practised when mobility is constrained by the availability of critical resources such as water (2001, 21). Kelly notes that Western Desert hunter-gatherers foraged further from camp then non-water tethered foragers due to the greater distances between water sources and hence the energy expenditure and risk associated with moving to a new area (Kelly 1995, 127; see also Gould 1991, 20).

The CPF model assumes that resources are distributed evenly around a campsite and hunter-gatherers forage around this focal point, moving outwards as resources in close proximity are depleted, producing '… a gradient of resource availability' (Winterhalder 2001, 21). This means the foraging distance hunter-gatherers must travel from their campsite increases over time, making it necessary at a certain point to move camp as the energy expended in traveling to productive hunting and foraging grounds increases. A fine balance exists between food and water availability, the depletion of either necessitating a move to a new patch (see Sweeney 1946, 297).

Foraging behaviour and drought

Australian desert hunter-gatherer subsistence strategies were adapted to significant temporal and spatial variation in resource availability, and were characterised by a broad spectrum diet primarily based around processed grass and acacia seeds, native fruits, tubers, reptiles, macropods, birds and insects (Bird and Bird 2005(b), 88; Cane 1987, 399; Edwards and O'Connell 1995, 771; White 2001, 355; Pate 1986, 98). Meat comprised approximately 30 percent of the traditional diet (Smith and Smith 2003, 46). Certain food categories were only available or became more abundant seasonally. While game animals and especially kangaroo were highly prized, plant foods comprised the bulk of foraging returns (Myers 1982, 176-177; Pate 1986, 103). In the Western Desert acacia seeds and goanna made up much of the diet during summer months, however there was significant variation in seasonal productivity (Cane 1987, 423). Cane writes that in the Tanami Desert summer is known as the 'hungry time' and is characterised by frequent camp moves due to general food scarcity (1987, 394, 396). In typical seasons during the cooler months when rainfall was less reliable but food more abundant, diet predominantly consisted of grass seeds, roots, *Solanum* fruit and goanna (Bird and Bird 2005(b), 88; Cane 1987, 394).

Extreme and protracted drought has a deleterious effect on resource availability. While many desert plants are adapted to short-term drought (Pate 1986, 106), during prolonged droughts overall ecosystem stress and resource depletion occurs as animals and plants struggle to cope with a lack of water, leading to an overall trend in the decline of resources (Beard 1969, 685; Gould 1991, 23; Letnic and Dickman 2006, 3872; Pate 1986, 105; Smith 1989, 101). Extended drought can drive rapid ecosystem change by causing widespread dieback of even drought-adapted plants, leading to a decline in both floral and faunal population viability. This occurred during the 1925-1935 drought during which time the Western Arrernte experienced extensive failure of traditional resources leading to high mortality.

Resource categories are differently affected by drought and acted as a constraining factor on movement during drought times. Dietary diversity mitigated risks associated with unpredictable resource availability by expanding the range of accessible food categories. Grass seeds were one of the more abundant resources but have low calorific returns and high processing costs (Edwards and O'Connell 1995, 774; O'Connell and Hawkes 1981; Smith and Ross 2008, 386). In reference to the Pintupi, Thomson reported that grass seeds 'could support several Aboriginal families at one water source for weeks at a time' (Thomson 1964 cited by Pate 1986, 97; see also Smith and Smith 2003, 46). Some researchers consider that grass seeds were critical resources during dry periods (see Chapter 2) when groups were constrained to permanent waters and would quickly deplete higher ranked resources (Edwards and O'Connell 1995, 771; O'Connell and Hawkes 1981, 110; Pate 1986).

In their study of Alyawarr people's foraging strategies, O'Connell and Hawkes applied the diet breadth model to investigate why Alyawarr women focussed on certain resources while disregarding grass seeds which were abundant and had formerly constituted an important part of their pre-contact diet. They found that grass seeds had largely dropped out of the Alyawarr diet following the introduction of European flour. The high processing costs relative to nutritional value of grass seeds meant it was often ignored in favour of other resources that were less labour intensive to prepare and provided a higher energy return rate. They predicted that prior to European contact, grass seeds would have dropped from the Alyawarr diet when higher ranked resources were available and returned during droughts when other resources became scarcer and less reliable (O'Connell and Hawkes 1981).

Population density

Resource availability in the Australian desert was characterised by boom-bust cycles. Populations would increase during a run of good seasons, however these were interspersed with long periods of low resource availability during which time associated mortality would bring populations back to an equilibrium (Pavey and Nano 2009, 634;

Smith 2005(b), 94; Strehlow 1965, 122; Tindale 1974, 70). Accessibility of permanent and ephemeral waters set the primary constraints on arid-zone population densities, which were kept in check by low rainfall and the spatial and temporal discontinuity of game and plant food availability (Smith 1989, 100; see also Box *et al.* 2008, 1396-97; Myers 1986, 26; Smith 2005(b), 95; Veth 2005, 100). Thus populations were not distributed uniformly across the desert but would cluster around 'linking pathways' of relative resource abundance (Bird *et al.* 2008, 14800). Areas containing higher resource density also contain greater densities of named sites (see Chapter 5). Such linking pathways have been identified as the initial routes of desert colonisation prior to the LGM due to higher resource predictability (see Chapter 1) (Smith 2013, 38; Thorley 1998, 34-35, 44).

In describing the spatial distribution of a Southern Arrernte group, Strehlow observed that foraging strategies concentrated on the Finke and Hugh Rivers, while hunting and foraging in the surrounding sand hill country was only temporarily possible following episodic rain events (Strehlow 1947 cited by Maddock 1982, 23). Strehlow's observation of foraging behaviour corresponds with that of W.R. Murray mentioned in Chapter 5 who recorded that the hill tribes exploited more marginal habitats where possible '…reserving the country around the main waters in the ranges until hot weather sets in' (Maurice 1901, 13).

As discussed in Chapter 3, in contrast to the Western Desert, the MacDonnell Ranges is a comparatively resource rich region with a historically greater population density in the well-watered Central and Western Arrernte territories. The Central Australian ranges and surrounding country where water sources are concentrated supported about one person per 13 km^2 (Edwards and O'Connell 1995; Kimber 1990(a), 161; Strehlow 1965), one person per 50 km^2 in other parts of the ranges and up to one person per 90-200 km^2 in the more resource poor sand deserts. For the Western Desert Berndt estimated a total population of approximately 18,000 people across an area of up to 250,000 mi^2 (402,336 km^2) prior to European contact (Berndt 1959, 86; see also Cane 1990, 151; Gould 1969, 256). Long estimated that there were 125 Pintupi people residing in a 52,000 km^2 area around Lake Mackay in 1962 (approximately one person per 415 km^2) (Long 1971, 264-265). Yengoyan estimated population density in the Rawlinson Ranges at one person per 30-40 $mi.^2$ [48-64 km^2] (1968, 189). This is significantly higher than

Long's estimate of one person per 200 km^2 for the adjacent Pintupi to the north (Long 1971, 276) suggesting the region was comparatively better watered (see Table 1).

Table 1: Arid-zone population density.

Region	People per km^2	Reference
Ranges and riverine corridors	1-2 persons per 13-50km^2	See Smith and Ross 2008, 386
Outlying spinifex and sandhill country	1 person per 90-200 km^2	Meggitt, 1962; Long, 1971; Cane, 1990
Western Desert	1 person per 130 km^2	Tindale 1974, 70
Pintupi	1 person per 200-260 km^2 (Long also estimated 1 person per 415 km^2 near Lake Mackay in 1962)	Long 1971, 264

Group size

Average Arrernte group size was estimated at 25-40 people (Murdock 1967 cited by Kelly 1983, 282; Spencer and Gillen 1899, 9). Estimates for Ngatatjara group size range from 20-70 people (Tindale 1972, 224; Yengoyan 1970-264-5), and 22 people as the maximum Pintupi group size encountered (Long 1970, 264-265). While researching Pitjantjatjara women's cultural life on Everard Park Station in 1970-71, Hamiliton observed that camp sizes fluctuated between 10 and 80 people, and estimated that pre-contact group size would have been between 15 to 30 people (Hamiliton 1980, 4). The Pintupi camps observed by Thomson typically consisted of two-to-three families. He describes one camp as comprising 15-16 people and he reports groups staying at wells or rock holes for between a few days to several weeks depending on food availability (Thomson 1962(a), 13; 1962(b), 154).

Table 2: Arid-zone group size.[21]

Region	Group size	Reference
Central Arrernte	25-40	Spencer and Gillen 1899, 9
Western Desert	20-70	Yengoyan 1970, 265-5
Western Desert	20-40	Tindale 1972, 24
Western Desert	2-22	Long 1971, 264

These figures (Table 2; see also Table 1 above) show that while population density varied depending on the spatial distribution of resources at any given time, irrespective of ecological parameters, average minimum group size was around 30 people in both the Western Desert and Arandic areas (Gould 1969, 256; Kimber 1990(a), 161; Long

[21] Radcliffe-Brown stated that there was no available data to estimate the population of arid western Australia (Cane 1990, 150).

1971, 265; Pate 1986, 97; Smith 2013, 12; see also Kelly 1995, 210). This figure, while approximate, is supported by other data that indicates an ideal group size of 25 people for mobile foraging societies based on the need to avoid rapid resource depletion while maintaining a minimum viable reproductive group size (Kelly 1995, 212). As discussed in the preceding chapter, computer modelling by Wobst suggestested that group sizes smaller than 25 individuals would be unlikely to be reproductively viable.

In relation to drought, Peterson and Long note that decisions to abandoned territory would not be made en-masse but would be decided at the individual or family level (Peterson and Long 1986, 35). Consequently, drought-forced migration often caused a schism in local groups and in some instances people would never see each other again following an individual's decision to migrate (Tindale 1974, 71). Dispersals in response to severe and prolonged subsistence pressures resulted in the cultural extinction of local groups discussed in Chapter 5. To a lesser extent flexibility in activating kinship networks was also a feature of Arandic social organisation (Austin-Broos 2004, 62-64; Morton 1997 118-122), however these groups were characterised by a greater degree of cohesiveness due to higher populations densities, more predictable resource availability and smaller more defined territories.

During the onset of drought groups would gradually move from ephemeral and semi-permanent water sources, contracting to permanent water sources as drought conditions worsened. During normal seasons following good rains groups would disperse across the country taking advantage of opportunities to access territory which was usually inaccessible due to water scarcity (Cane 1990, 154; Kimber 2009, 303). The best foraging opportunities occurred following one or more seasons of heavy summer rains during which times large gatherings would congregate for ceremonial activities at reliable water sources, however such large congregations were transitory as they would quickly exhaust local resources (Cane 1990, 154; Pate 1986, 102). In the previous chapter I discussed how groups would implement a range of strategies to avoid drought. When ephemeral waters dried up, local groups would contract to fallback waters usually located in proximity to the ranges as conditions worsened (Gould 1969, 266; Myers 1986, 26). Western Desert populations were thus in a state of flux characterised by seasonal aggregation and dispersal depending on environmental conditions (Gould 1969, 256-258; Peterson 1983, 134).

Territorial defence and migration-related conflict

Studies in human behavioural ecology have shown that there is typically an inverse relationship between territory size and rainfall (Cashdan 1983, 48; Kimber 1990(a), 161; Kelly 1995, 63-64; Layton 1986, 26). Describing the environmental setting of Aboriginal people occupying the resource-rich River Murray region of south-eastern Australia, Pardoe characterises social relations as tending towards 'exclusivity', meaning local groups were more assertive in maintaining and defending their territorial integrity. In contrast, the comparatively resource poor, desert regions sustained lower population densities across wider areas. In Chapter 1 I compared social organisation and land tenure regimes in the Western Desert and Arandic dialect areas. When correlated with the population density data (see Table 1) it is clear that higher population density is associated with areas of higher resource abundance and predictability. In these areas territorial behaviour tends towards smaller, more clearly bounded estates, whereas high risk and low resource environments are associated with extensive foraging ranges and more permeable territories.

In the Western Desert where population densities were some of the lowest on record (Smith 1989, 100) territories were vast and could not practically be patrolled or physically defended to exclude intruders (Pardoe 1990, 61). A more efficient and effective territorial management strategy was to regulate boundaries by granting groups or individuals standing permission to access resources. This is termed Social Boundary Defence (Cashdan 1983, 49) and required a high degree of residential mobility linked with the capacity to activate extensive kinship networks. Referring to Australian Aboriginal control of territorial permissions more broadly, Sutton writes, 'The right of exclusion is exercised only in exceptional circumstances, in which there is an actual or pretended drain on the resources of the land…' (2003, 24). Social Boundary Defence not only functioned to regulate and manage territorial intrusions but also established formal relationships of reciprocal obligation that conferred a survival advantage for groups during periods of climatic deterioration (Strehlow 1965, 131; see also Kelly 1995, 192; Kenny 2008, 252; Myers 1986, 101). Gould provides a useful précis of social factors that informed comparative boundary management according to resource availability:

> In considering access to resources, one should be able to predict that the greater the risks imposed by limiting factors in a particular habitat, the wider

and more coherent the 'envelope' of social networks will be, and the less one would expect to find any mechanisms that would restrict the mobility of people, goods or information from one sub area to another. Conversely, the more suitable a given habitat is for maximization of resources based upon strategies of individual or family exploitation, the smaller and more restrictive this 'envelope' will be …' (Gould 1982, 88).

Table 3: Four sets of relationships between foraging bands defined by resource predictability and density (after Kelly 1995, 190).

Resource density \ Resource predictability	Low	High
High	**A** - High mobility - Information sharing - Spatio-temporal territories	**B** - Geographically stable territorial system
Low	**C** - Increased dispersion and mobility	**D** - Home-range system 'passive territoriality'

The table (Table 3) above is a simple model that allows us to predict how groups manage territorial boundaries according to environment and resource availability. The Western Desert approach correlates with 'Case C', where conditions of low resource predictability and density require high mobility and dispersal subsistence strategies. In such conditions the defence of territorial boundaries is impracticable due to large territories and low population densities. In characterising Western Desert boundary management Gould preferred the term 'boundary behaviour' in contrast to the concept of clearly defined tribal boundaries as elaborated by Radcliffe-Brown and Tindale among others. According to Gould, 'boundary behaviour' was characterised by '… increasing degrees of uneasiness by Aborigines as they enter an unfamiliar region where they could inadvertently trespass on a sacred site' (Gould 1982, 87). Gould's notion equates essentially to the notion of 'spheres of influence' in land, conceptualised as a gradient or spectrum. This is a more coherent characterisation of Western Desert and Arandic land tenure and boundary management than the classical concept of static and cellular tribal boundaries defined by Radcliffe-Brown (see Chapter 1).

The Arrernte patri-estate model leans more towards ‘Case D’ (Table 3). As outlined in this chapter, here resource density remained relatively low, however predictability was higher due to extensive upland areas and greater densities of reliable water sources. Population densities, while low, were substantially higher than in the Western Desert, thus mobility was less extreme as groups remained in areas of predictable resource occurrence. These conditions lead to the development of more clearly bounded home ranges. Of course neither example is an exact fit for the on-ground reality of boundary management. Rather, territory was managed along a spectrum, and responses depended on a range of factors. During times of low resource availability and high competition Western Desert groups may have tended towards behaviour more closely resembling ‘Case D’. For example, as outlined in Chapter 5, during the 1916 drought the Pitjantjatjara forcibly occupied the territory of the Yankunyatjatjara displacing them to the east, likely due to increased tensions related to resource scarcity.

Foraging and camp moves

The length of time a group can stay in one place before moving camp is dependant on the distance individuals must travel daily to productive foraging patches. Sahlins referred to this as the ‘imminence of diminishing returns’ (1972, 33), meaning that over time the rate of return within the foraging radius decreases, while the time and energy expended to reach a productive patch increases (Kelly 1995, 132-133). It is the threshold between energy gain and expenditure that constrained camp stay duration, and made ‘…movement fundamental to the hunter-gatherer adaption’ (Peterson 1976, 58). Essentially, foraging distance and mobility strategies were tied to the relative productivity of the environment. Figure 15 provides a simple schematic of the relationship between foraging radius and residential moves.

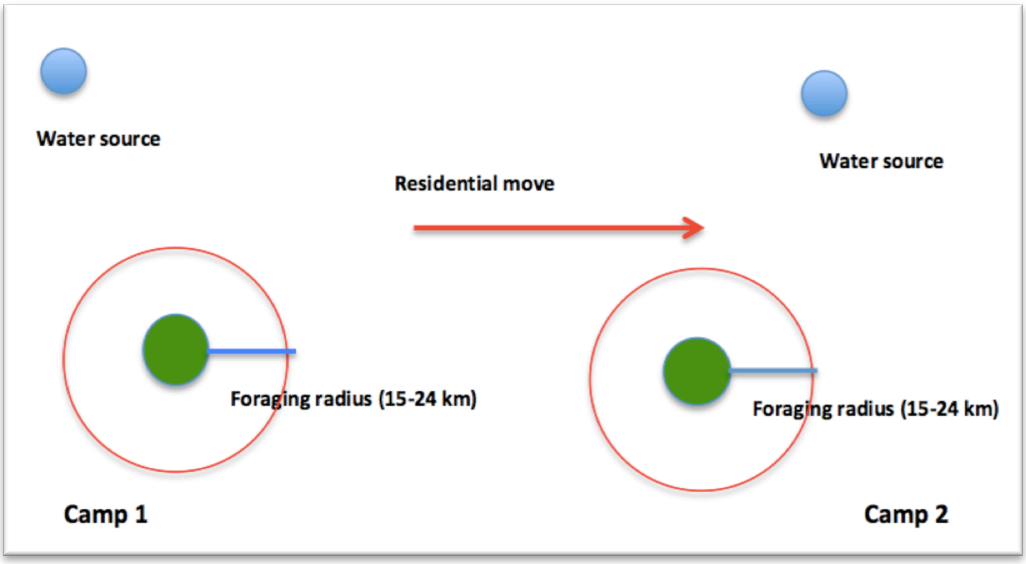

Figure 15: Schematic of residential moves.

A camp was invariably in the vicinity of a water source, whether a spring or waterhole in the range country, or a native well in the spinifex and sandhill country, and camp stay duration was constrained not only by the availability of food resources within foraging distance of the camp, but also the availability of water at the campsite. Amongst the Ngaanyatjarra, the general pattern was for groups to forage within a 10-15 mile (15-24 km) radius of a water source before shifting camp (Gould 1968, 104-105; see also Cane 1987, 395). During drought times, Western Desert local groups would retreat to reliable water sources, usually located in upland country, until food resources in the area had been exhausted before shifting to another reliable water source where the process was repeated (Tindale 1974, 69; see also Cane 1987, 395; Cane 1990, 155). In his study of Ngatatjara camp spacing behaviour Gould recorded group size and number of days spent at a particular camp and found that the longest and shortest duration of camp stays was 26 and 3 days respectively with an average camp stay of 10 days (Gould and Yellen 1987, 85). Assuming an average group size of 30 people and average camp stays of ten days before resources were exhausted or cultural imperatives necessitated a move to a new area, groups moved camp on average 36.5 times seasonally. This average is consistent with data collated by Kelly on Ngatatjara residential moves and is in contrast with the Arrernte for whom an average of ten annual residential moves are recorded (Kelly 1995, f122). These figures are of course highly approximate and do not take into account seasonal variability in rainfall and resource availability. During a drought ephemeral waters were limited and poor quality resource yields would logically necessitate more frequent moves.

Discussion

As outlined above there was significant variation in population density across the arid zone, however group size remained relatively constant at around 25-30 people. Such small groups were vulnerable to extinction through subtle changes in demographics and/or environmental changes and subsisted in a delicate balance between the opposing constraints of remaining small enough to avoid rapid resource depletion while being large enough to reproductive viability. Broad-spectrum diets mitigated the risks associated with unpredictable resource availability and resource categories such as grass seeds that remained abundant during drought were thus a staple of arid-zone hunter-gatherer diets. Due to high processing costs and low calorific returns grass seed was ignored in favour of other higher-ranked resources when available but returned to the diet during droughts.

During severe drought the productivity of resource patches was reduced and more frequent residential moves were necessary. Ephemeral and semi-permanent waters would be exhausted quickly, reducing the number of available water sources, and necessitating more frequent residential moves. Here it is worth reiterating Strehlow's statement that during drought, up to four-fifths or seven-eighths of a given tribal area could be temporarily abandoned (Strehlow 1965, 124). Once temporary water sources were exhausted groups retreated to permanent waters at which point the frequency of camp shifts were reduced as groups attempted to conserve resources. However, a group could only remain at a permanent water source until food resources within the maximum viable foraging radius were exhausted before risking becoming water-tethered. At this point Gould's strategy switching model is relevant (see Chapter 5), whereby groups could escape drought by abandoning their territory and seeking refuge with a neighbouring group. The success of this strategy relied upon drought being localised rather than regional as well as good relations with neighbouring groups.

As shown above, the number of camp moves made annually by a local group was dependant on water and food availability and camp stay duration was constrained by the tension between energy expenditure and calorific returns. Local groups were further constrained by the number of water sources available within their territory. The Ngatatjara made approximately 36 residential moves in an average year, meaning each group required access to the same number of water sources annually. In the Arrernte region where resources were more abundant and reliable groups moved on average 10 times per year.

During periods of widespread and protracted drought, the decline in resource availability focussed populations along riverine corridors and in montane country where a higher density of permanent waters existed. In Chapter 5 I summarised the observations of some early explorers regarding subsistence strategies and drought responses that are consistent with the drought-related mobility strategies outlined above. In 1892 Carruthers observed that Pitjantjatjara or Yankunyatjatjara groups retreated to the Musgrave and Mann Ranges while those that remained in the sandhill country to the south of the ranges were in a state of semi-starvation due to waterhole-tethering (Carruthers 1892). In the same region Murray observed that groups took the opportunity to forage in the more resource-poor sandhill country and reserved foraging patches in the vicinity of permanent waterholes located in the ranges for dry periods (Maurice 1901, 13). The explorer David Carnegie noted that permanent waters were only exploited after ephemeral waters were depleted (Carnegie 1898, 274).

Under drought conditions boundary defence and conflict was more likely to ensue due to competition for limited resources, as shown by the conflict between the Pitjantjatjara and Yankunyatjatjara, and the Waringari and Warlpiri discussed above and in Chapter 5. Traditional mobility strategies outlined above facilitated the southeast Pintupi migration, triggered by the 1916 drought; while principles of succession (described in Chapter 5) provided a framework for sanctioning claims to the newly occupied Kukatja-Luritja territory which had been depopulated by the 1930s due to a combination of introduced epidemics and the 1925-1935 drought (Myers 1986, 28-29; Tindale 1953; Tindale 1974, 138, 227-228; see also Burke 2011, 216).

CHAPTER 7 – Conclusion

I started this thesis with an examination of the social organisation of the Pitjantjatjara/Ngaanyatjarra and Arandic dialect groups to provide a context for understanding the role of social organisation in responding to periods of climatic instability. I followed with a discussion of prehistoric arid-zone hunter-gatherer responses to climate change and evidence of presence and absence evident in the archaeological record to provide a comparative framework of arid-zone population processes over longer periods. Next I described the modern climatic and environmental parameters of the Australian desert and study region to provide a background to the influences acting on recent hunter-gatherers and discussed documented droughts since historical records commenced. Afterwards I outlined how European colonisation acted on desert hunter-gatherers' capacity to respond to climate change and its effect on traditional subsistence practices and drought responses. There followed a discussion of the range of strategies local groups employed to mitigate the risks associated with drought, and afterwards, a description of how the interaction between population density, group size, socio-economic structures, territorial boundaries and environment influenced foraging systems and mobility strategies.

This was largely a speculative study that aimed to evaluate the effects of severe environmental conditions on recent arid-zone hunter-gatherers as a way to better understand the archaeological record of presence and absence. My focus has been on evaluating social and economic organisation and human ecology during the historic period to provide the basis for more detailed comparative research into climate related population processes.

As stated in the Introduction to this thesis, the limitations of this approach are that it is predicated upon assuming a direct relationship between recent and prehistoric hunter-gatherers populations. However as I have shown with regards to climate, demography technology and social organisation, the history of hunter-gatherer populations is characterised by temporal and geographical variability. Despite this, in the absence of detailed socio-cultural data on the life-ways of earlier humans, the relationship between recent Australian arid-zone hunter-gatherers and their environments provides a useful starting point to theorise how earlier populations occupying similar ecological habitats and with a broadly similar technological repertoire may have interacted with their environments.

This thesis was guided by two primary research aims. The first aim was to identify the social and cultural mechanisms that facilitated habitat tracking and migration to more favourable environments in response to drought and to also identify the factors constraining groups from tracking habitat, leading to local group extinction. The second aim was to compare historic hunter-gatherer responses to climate change with the archaeological record to consider how earlier populations may have responded to climatic variability in similar ecological and environmental settings. I discuss these in sequence below.

Research Question 1

Habitat tracking and migration

Here I showed that recent hunter-gatherers adapted resource procurement strategies to local conditions, dependant on the extent and type of water sources that were available. Differences in hunter-gatherer social organisation, group size, population density, land tenure regimes, territorial behaviour and mobility strategies were influenced by variations in resource predictability and abundance (see Chapters 1 and 6). The linguistic and cultural cleavage between Western Desert and Arandic groups, referred to by Birdsell as the 'Aranda scarp' (Birdsell 1993 cited by McConvell 1985, 136), reflects the boundary between the Western Plateau and Lake Eyre drainage basins (see Chapter 1, Fig. 9) supporting the premise of a relationship between environment and cultural differentiation in this region.

Groups routinely employed habitat tracking and migration as a strategy to mitigate the risks associated with periods of drought and accompanying resource depletion. The socio-cultural and behavioural mechanisms that facilitated population movements to environments with more favourable conditions during periods of climatic instability included high residential mobility, broad-spectrum diets, extensive kinship and ceremonial networks over wide areas, territorial boundary management and relationships of reciprocal obligation. The capacity of local groups to shift their range in response to climatic variability was dependent on small group size, and the complex network of kinship connections, economic and ceremonial affiliations enumerated in Chapters 1, 5 and 6.

While I employed the term 'local group' (defined in Chapter 1) as the definitive unit when evaluating drought responses, it should be restated that there are limitations to this approach in the Western Desert context due to the fluidity of social and cultural organisation (see Chapters 1 and 5). Average local group size in both the Western Desert and Arandic regions at any one time was approximately 25-30 people (see Table 2). Under normal conditions groups of this size were small enough to avoid rapid resource depletion while remaining just large enough to be reproductively viable and sustain complex economic and social networks. However, during drought times ephemeral waters and food resources were quickly depleted necessitating more regular residential moves. Under these conditions local groups would typically track habitat to an adjacent region with more favourable environmental settings in the territory of a neighbouring group.

Mobility strategies in response to drought included temporary and permanent territorial abandonment and out-migration to the periphery of European settlements, missions and cattle stations. Colonisation significantly affected the capacity of groups to respond to climatic variability. However, while the scale of these changes was exceptional, it should be noted that large-scale population movements are also thought to have occurred prior to European contact (see Chapters 2 and 4). Separating the influence of European settlement from the effects of drought on population movements is problematic. Instead I have taken both of these factors simply as subsistence pressures and considered how Aboriginal groups countered decline in resource abundance or accessibility by activating traditional networks that facilitated habitat tracking and migration. This approach allows us to draw coarse-grained inferences regarding traditional hunter-gatherer options for responding to drought despite the veneer of colonisation.

Under conditions where territorial abandonment and habitat tracking to environments with more favourable environmental conditions was possible, a range of cultural and behavioural mechanisms facilitated such migrations. In the Western Desert groups required extensive hunting and foraging ranges that extended far beyond territorial boundaries. Due to small group size, low population density and large territories, the integrity of territorial boundaries could not be practically maintained (see Table 3). Instead standing permission, or customary license, was extended to neighbouring groups to access country, thereby establishing relationships of reciprocal obligation that functioned as a safety net during periods of resource depletion. Permeable territorial boundaries, extensive kinship and ceremonial networks and economic ties across wide areas facilitated the strategy-switching approach to drought avoidance suggested by Gould. In contrast Arandic local groups were more bounded and maintained a greater degree of overlap between territory and range due to the greater abundance of resources and higher population density. Standing permission was however typically extended to related kin across a wide area to access an estate group's resources.

Local group extinction

Investigating the genetic evidence of extinction and survival is problematic due to small sample sizes (see Smith 2013:92) and was beyond the scope of this thesis. Instead, to address the question of local group extinction, I considered incidences of cultural extinction. As described in Chapter 5 there are two routes by which cultural extinction may ensue. All members of a group may die out, being analogous to biological extinction; or a group may disperse with distinctive cultural traits being lost, as group members are absorbed into new host groups. The combined effects of drought and European settlement led to the depopulation of large tracts of country. These factors resulted in reduced critical population size amongst those Aboriginal people who remained on their traditional country, disrupted group cohesion and precipitated permanent territorial abandonment and cultural extinction. The erosion of social and economic networks, which were crucial to maintaining a foothold in the harsh desert environment, combined with increased subsistence pressures, led to cascading out-migration to European settlements and in some cases in-situ cultural group extinction. Territorial voids were filled by adjacent groups moving into vacated country, resulting in what has elsewhere been referred to as a chain migration out of the desert. While European colonisation was undoubtedly a major contributing factor to group extinction in the historical period, extinction or dispersal due to environmental and social factors has been documented in the historical and ethnographic literature (Chapter 4).

The existence of cultural mechanisms to manage vacated country, indicates that group extinction or dispersal was not an uncommon occurrence prior to European colonisation. These mechanisms, referred to as principles of succession, form part of the traditions practised by both Western Desert and Arandic tribal groups. Processes of succession have continued to the present and in the Arandic region enable neighbouring groups to take on responsibility for an estate for which there are no remaining patrilineal descendants. Principles of succession were operating at the time of European contact with the Arrernte and it is therefore reasonable to assume these mechanisms evolved prior to colonisation to provide a basis for groups to resolve issues around vacated country. By inference group extinction or dispersal occurred with sufficient regularity for principles of succession to be embedded in traditional land tenure regimes prior to colonisation.

In Chapters 5 and 6 I outlined the factors that constrained local groups from migrating to environments with more favourable ecological settings during drought periods. Territories located in the more marginal spinifex and sandhill country contained limited drought refuges capable of supporting populations during periods of long-term drought. In the Western Desert this constraint was counterbalanced by the often localised nature of droughts, enabling range shifts to better-watered country in the territory of adjacent groups connected by ceremonial, economic and kinship links. However during widespread droughts, or in areas of inter-group conflict migration was inhibited resulting in group dispersal and high mortality rates.

It is relevant here to reiterate Kimber's estimate that up to 25 per cent of a tribal group could be wiped out every 30-40 years as a result of drought. Waterhole tethering was a common cause of drought-related mortality. This occurred when groups became trapped due to the drying of ephemeral waters, unable to escape due to the spacing and distribution of permanent waters. Given the surprisingly high estimated mortality rate at the tribal level, it is probable that droughts sometimes resulted in the extinction of entire local groups due to issues of critical population size (see Chapter 4).

As outlined above, during the historic period drought avoidance was facilitated by extensive social and economic networks that enabled local groups to migrate to areas with more favourable environmental settings. As would be anticipated, critical population size was a key element to mobility strategies, providing social, economic and ceremonial networks that enabled population shifts in response to drought. Widespread drought and associated resource depletion, and reduced critical population size were the key factors constraining groups from activating social networks to track habitat into areas of higher resource abundance. Those groups occupying more favourable habitats containing substantial drought refuges could wait out lengthy periods of drought while those inhabiting more marginal habitats faced high mortality rates at these times. Population density increased as populations contracted to areas of remaining resource availability and territorial integrity was more vigorously maintained, in some cases resulting in the dispersal and/or extinction of local groups occupying marginal habitats. Following climatic amelioration, neighbouring groups occupied vacated territories.

Research question 2

Historical demographic movement and the archaeological record

My second aim was to apply ethnographic data on population movements and drought responses to the development of hypotheses regarding earlier population responses to climate change more broadly in similar climatic and ecological settings. This was problematic due to the short record of climatic processes acting on recent hunter-gatherers in contrast to the prehistoric period, where changes in socio-cultural organisation, population density and technology in response to climatic variability are documented over millennia.

There is no direct empirical evidence of how prehistoric local groups responded to periods of climatic instability, however, palaeoclimate and flora and fauna proxy data indicate that arid Australia experienced periods of hyper aridity during LGM and ENSO cycle peaks which correlate with archaeological sequences indicating phases of occupation absence suggestive of major demographic reconfigurations. The radiation of the Pama-Nyungan language family and the diffusion of the section and subsection systems have also been interpreted as indicators of extensive population movements.

Socio-cultural adaptions to climate change are not directly visible in the archaeological record, however the presence of exotic materials such as lithics and ochres in archaeological sequences suggest that extensive social and trade networks were important factors to desert subsistence in the prehistoric period. Indications of population contraction to aridity refugia in the archaeological record are consistent with demographic ebb and flow documented in the historical record, however it is unclear from archaeological sequences whether population contractions resulted in outlying groups retreating to aridity refuges, or whether these were sink populations that went extinct, with marginal country being resupplied from source populations occupying refuges in the ranges following climatic amelioration. Puritjarra rock shelter in the Cleland Hills preserves the only evidence of occupation in this region throughout the LGM where intermittent and light use of the rockshelter is indicated. The MacDonnell Ranges have been identified as a refuge (see Fig. 7) during the LGM and supported populations that probably accessed Puritjarra, which was connected to the MacDonnell Ranges by a network of springs and native wells. The MacDonnell Ranges were also a favourable habitat throughout the historic period, the social organisation of the Western Arrernte being geared towards an environment of higher resource abundance, meaning fewer annual residential shifts and comparatively smaller territories (see Chapter 1, 5 and 6).

As mentioned in the Introduction to this study, critical population size has been identified elsewhere as a crucial element in providing early humans with a buffer to environmental change. However, in the prehistoric period it is probable that during periods of extreme and widespread climatic variability, adaptions such as interdependence between people for water and resources, expressed through social and economic networks (if part of prehistoric hunter-gatherer repertoires) were insufficient to maintain continued occupation of large parts of the desert. It has been estimated that during the LGM as much as 80 per cent of the arid zone may have become uninhabitable, at which time it is likely that populations contracted to rangeland refuges and riverine corridors, abandoning the marginal sand-plain and spinifex country. In my view it is probable that a considerable element of in-situ extinction resulted from such prehistoric climate instability, as even during periods of comparative resource abundance arid-zone populations' size and density is estimated to have been extremely low. Thus, while habitat tracking and migration to drought refuges may have been possible, extensive population contractions would have exceeded the carrying capacity of aridity refuges (see Figure 2), forcing remaining populations into less desirable niches and leading to local group extinction during periods of heightened aridity.

Further avenues of research

This thesis has demonstrated the benefits of applying detailed ethnography as a basis for drawing inferences with regards to the responses of earlier populations to climate change at a broad level. As would be expected, this thesis has shown that water availability is the major constraint to occupation of arid environments, with access to reliable water sources and foraging areas available from water points being a precondition of occupation for both recent and prehistoric arid-zone hunter-gatherers and the primary constraint on population distribution. Population densities were concentrated along riverine corridors and in the vicinity of montane regions. More marginal environments were habitable during periods when climatic conditions were favourable and abandoned during periods of increased aridity. Extensive social and economic networks linking groups, who were dependent on one another for access to water and resources, were crucial for successful occupation of the Australian desert during the historical period and relied on critical population size, particularly during periods of climatic instability. While the precise social organisation and subsistence strategies employed by prehistoric groups is invisible in the archaeological record, I would suggest that such social and economic networks were likely equally crucial to the survival of prehistoric hunter-gatherers. In the event that critical population size dropped below the threshold for maintaining such networks, continued occupation of marginal environments would be unviable.

Further research into pre-contact demographic processes, and analysis of ethnographic sources relating to arid-zone plant and animal use and subsistence behaviour would provide a clearer picture of how local groups responded to environmental variability and a more fine-grained understanding of climate related population dynamics. Pre-contact demographic processes could be better understood through a detailed analysis of genealogies collected by ethnographers such as Carl Strehlow and Norman Tindale that date back before the contact period, allowing for more accurate inferences regarding population processes.

ABSTRACT

In this thesis I examine the ethnographic record of recent arid-zone Australian hunter-gatherers to consider how prehistoric populations may have responded to climate change in similar climatic and ecological settings.

The archaeological record of population presence and absence indicates that pulses of territorial abandonment and reoccupation correspond with periods of significant climatic variability, with the Last Glacial Maximum (LGM) and the on-set of modern El Niño-Southern Oscillation (ENSO) cycles during the mid-Holocene being identified as significant periods of increased environmental stress and associated habitat abandonment.

However modelling such population processes at a fine-grained level is constrained by the differential preservation of archaeological material, dating limitations, issues with chronological control at some sites, and differences in research intensity. As a result the archaeological record is unclear as to whether such population processes involved habitat tracking to more favourable areas, or alternatively resulted in extinction of local groups in areas that became unviable for continued occupation. My thesis addresses this lack of clarity by relating recent hunter-gatherer drought responses to prehistoric population process evident from the archaeological record.

I start with an examination of the Arandic and Western Desert societies to provide a background for establishing how desert hunter-gather groups responded to serious drought in the recent past. I look at the cultural and economic strategies developed by these tribal groups in response to distinct but connected environments, and discuss how differences in social organisation between groups occupying distinct ecological regions shaped drought responses.

I investigate the socio-cultural and behavioural mechanisms of desert hunter-gatherers that facilitated habitat tracking and develop a framework based on behavioural ecology models to consider how subsistence and mobility strategies enabled range shifts to neighbouring areas during periods of resource depletion. Where drought forced local group extinction is evident, I identify the constraining factors acting on populations that limited their capacity to respond to changing environmental conditions.

I argue that water availability is the major constraint to occupation of arid environments, with access to reliable water sources and foraging areas available from water points being a precondition of occupation for both recent and prehistoric arid-zone hunter-gatherers and the main factor limiting population distribution. I propose that extensive social and economic networks linking groups, who were dependent on one another for access to water and resources, were crucial for successful occupation of the Australian desert during the historical period and relied on critical population size, particularly during periods of climatic instability. While the precise social organisation and subsistence strategies employed by prehistoric hunter-gatherer groups is invisible in the archaeological record, I hypothesise that such social and economic networks were likely equally crucial to the survival of prehistoric hunter-gatherers. In the event that critical population size dropped below the threshold for maintaining such networks, continued occupation of marginal environments was unviable.

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APPENDIX

Appendix 1: Rainfall records Hermannsburg, Giles and Warburton weather stations

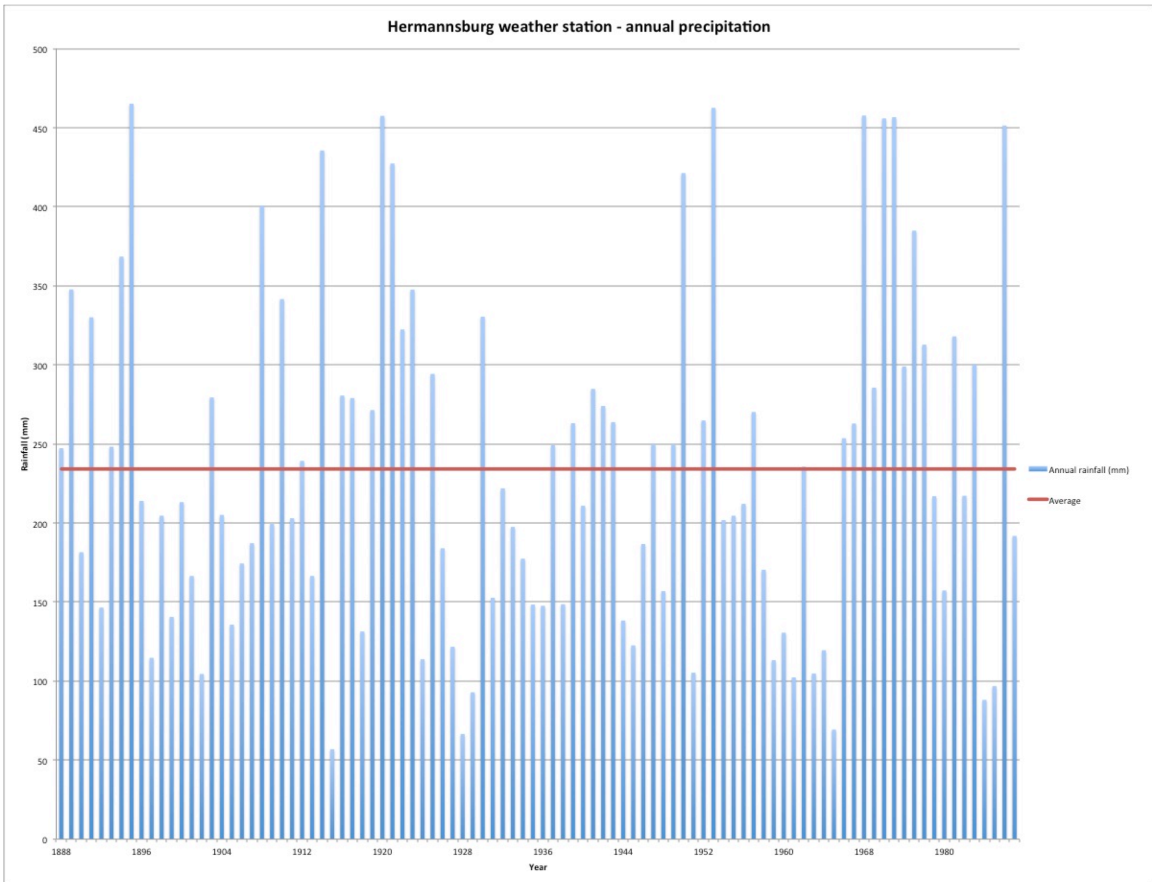

Figure 16: Rainfall records: Hermannsburg Weather Station 1888-2012.[22]

[22] Retrieved 11/03/15 from: http://www.bom.gov.au.

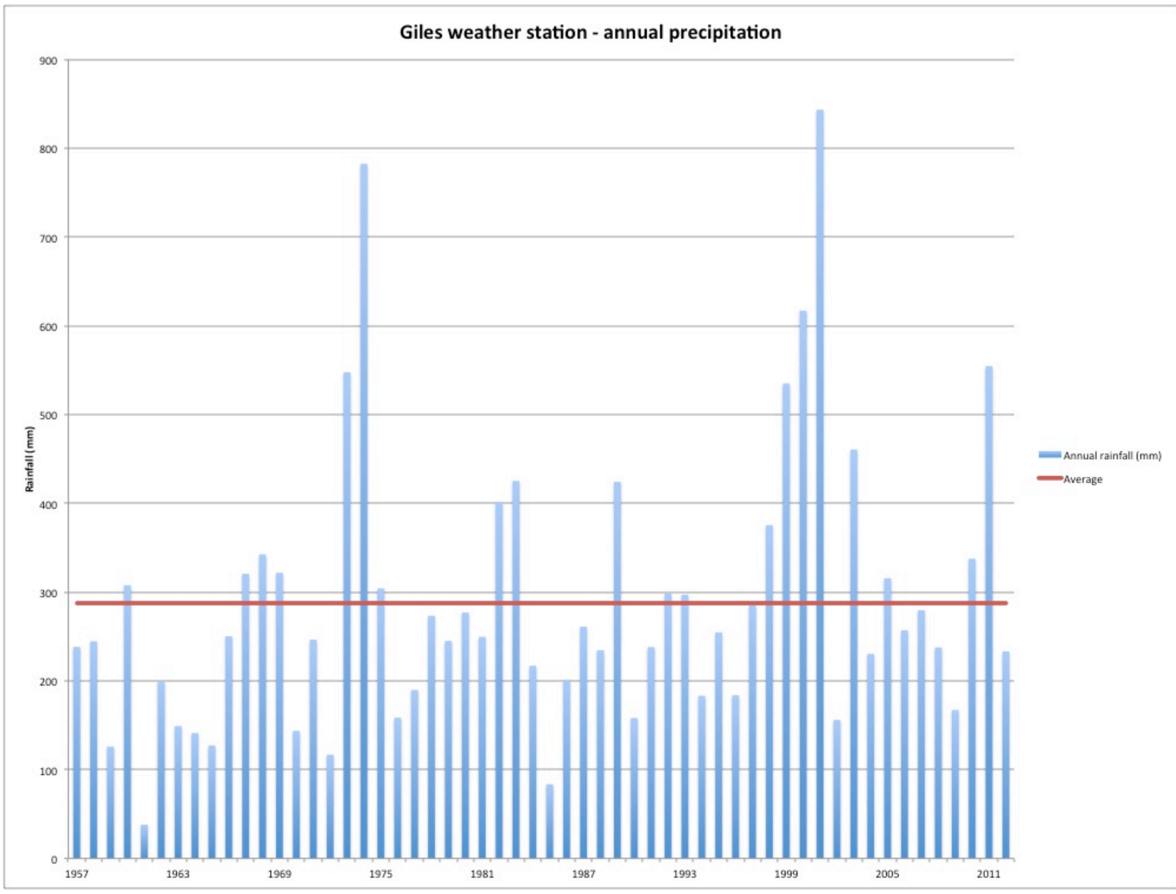

Figure 17: Rainfall records: Giles Weather Station 1957-2012.[23]

[23] Retrieved 11/03/15 from: http://www.bom.gov.au.

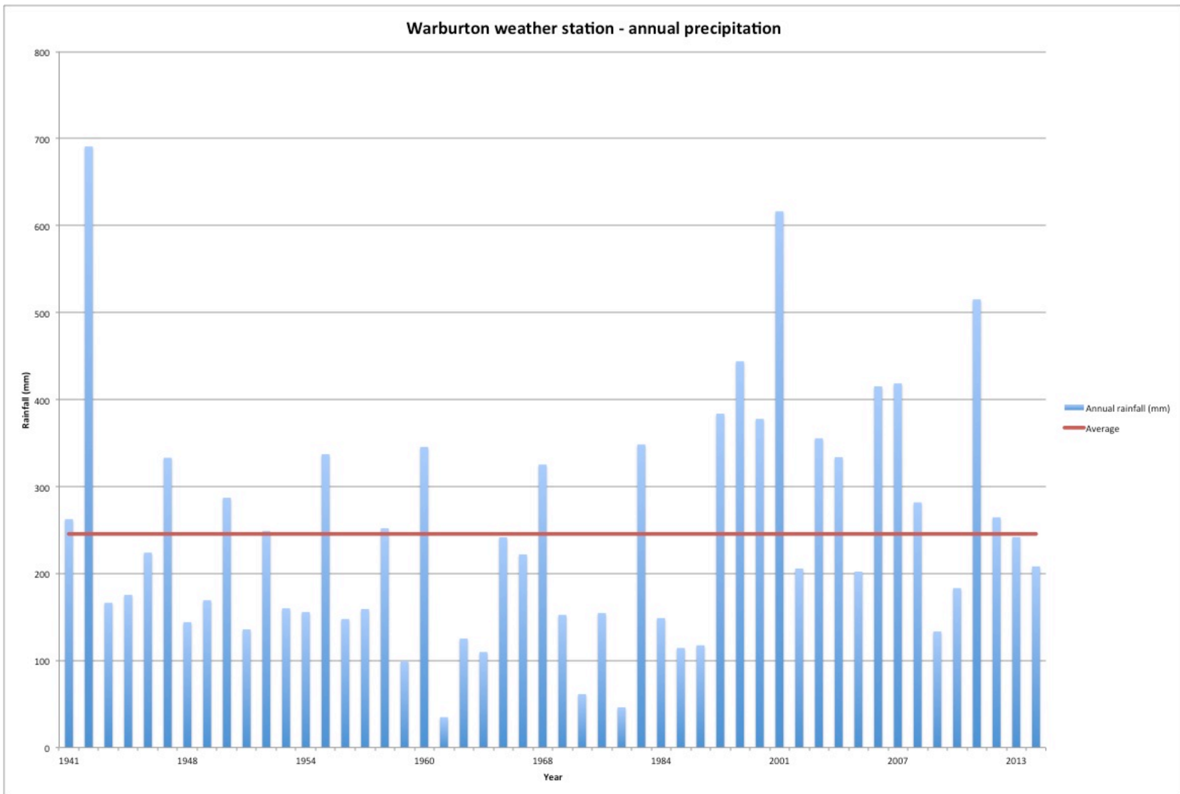

Figure 18: Rainfall records: Warburton Weather Station 1941-2014.[24]

[24] Retrieved 11/03/15 from: http://www.bom.gov.au.

Appendix 2: Recorded droughts correlated with weather station records (see Appendix 1) and ENSO events – Central Australia and Western Desert.

Year	Region	Comment	Weather station	Years of below average rainfall (see APPENDIX 1)	El Nino event/s[25]	Reference
1880-1884	Central Australia	The 1880-84 drought was the most severe experienced by European colonists in central Australia and resulted in increased tensions between Aboriginal people and pastoralists due to competition for scarce water resources. 1882 has been described as the most severe drought year experienced in central Australia at that time.	Hermannsburg	Data unavailable	No records available	Kimber 1990(b), 9-10
			Giles	Data unavailable		
			Warburton	Data unavailable		
1895-1903 Federation drought[26]	Central Australia/Western Desert	The drought of 1901-1902, which was enveloped within the protracted Federation drought (1895-1903) and affected much of the continental landmass including central Australia.[27]The Federation Drought was due to persistent El Nino effect and was so severe that it influenced the six states to unite.[28]	Hermannsburg	1896-1902	1896–1897; 1902-1903.	Trewin 2006, 5; Garden 2010, 273
			Giles	Data unavailable		

[25] McKeon *et al.*. 2004 cited by Letnic and Dickman 2006, 3859
[26] Retrieved 03/01/14 from: http://www.bom.gov.au/lam/climate/levelthree/c20thc/drought1.htm.
[27] Retrieved 28 May 2013 from: http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20Features~Australia%27s%20climate~143.
[28] Retrieved 03/01/14 from: http://www.bom.gov.au/climate/drought/livedrought.shtml.

			Warburton	Data unavailable		
1911-1916	Western Desert	1914-1916 Drought.	Hermannsburg	1911, 1913 and 1915	1911–1912 and 1913–1914.	Gara 1995, 3; Tindale 1974, 212; Chiew *et al.* 1998, 140; Gould 1991
			Giles	Data unavailable		
			Warburton	Data unavailable		
1925-1935	Central Australia and Western Desert	Central Australia/Western Desert.	Hermannsburg	1926, 1929 and 1931-1935	1925–1926; 1932–1933.	Chiew *et al.* 1998, 140; White *et al.* 2004, 1918; Tindale 1974, 69; Gara 1995, 13
			Giles	Data unavailable		
			Warburton	Data unavailable		
1935-1941	Western Desert	Consistently low rainfall.	Hermannsburg	1935-1936 and 1941	1940-1941; 1941-1942.	Chiew *et al.* 1998, 140; Gould 1991
			Giles	Data unavailable		
			Warburton	NA		
1958-67	Central Australia and Western Desert	1958-1967 – longest drought recorded in central Australia.[29]	Hermannsburg	1958-1962, 1963-1965	1957–1958; 1963–1964; 1965–1966.	Chiew *et al.* 1998, 140
			Giles	1958-1959 and 1960-1966		
			Warburton	1959, 1961 and 1967		

[29] Ibid.