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Environmental Research 131 (2014) 181–187

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Drought as a mental health exposure

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ARTICLE INFO

Article history:
Received 20 May 2013
Received in revised form
20 January 2014
Accepted 12 March 2014
Available online 12 April 2014

Keywords:
Drought
Climate change
Mental health
Population health
Rural

ABSTRACT

The mental health impact of drought is poorly quantified and no previous research has demonstrated a relationship between distress and explicit environmentally based measures of drought. With continuing climate change, it is important to understand what drought is and how it may affect the mental health. We quantified drought in terms of duration and intensity of relative dryness and identified drought characteristics associated with poor mental health to evaluate any vulnerability in rural and urban communities. Our methods involved analysis of 100-year longitudinal records of monthly rainfall linked to one wave (2007–2008) of the Household, Income and Labour Dynamics in Australia Survey. Cluster analysis was used to characterise different patterns of dryness and linear regression analysis was used to examine associations with participant distress, as well as the moderating role of rural locality. The results showed that, during a seven-year period of major and widespread drought, one pattern of relative dryness (extreme cumulative number of months in drought culminating in a recent period of dryness lasting a year or more) was associated with increased distress for rural but not urban dwellers. The increase in distress was estimated to be 6.22%, based on 95% confidence intervals. Thus, we show that it is possible to quantitatively identify an association between patterns of drought and distress.

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1. Introduction

Drought is common in many parts of the world and climate change projections predict it will increase substantially in frequency and/or intensity over the next century (Dai, 2010; Hennessy et al., 2008). The implications of increased drought for population mental health are potentially significant as a growing body of qualitative research indicates that drought could create a mental health exposure (Berry et al., 2010; Hossain et al., 2008; Rigby et al., 2011; Sartore et al., 2005). The clear message of this research is that mental health resilience, the capacity to cope with adversity and to avoid mental health problems when confronted by stressors (WHO, 2005), can come under unmanageable stress in the presence of prolonged drought. However, thus far, quantitative research examining the relationship between drought and mental health has been rare and piecemeal. We therefore used sophisticated methods to quantify and characterise drought in Australia and linked purpose-designed drought measures with population data taken from the Household Income and Labour Dynamics in Australia (HILDA) Survey. The method and results reported here show how drought with certain characteristics can act as a mental health exposure.

A recent review identified that the relationship between drought and mental health is an emerging area with most research being conducted in Australia (Stanke et al., 2013). The prominence of Australia is unsurprising given that Australia has the world's most variable climate and there has been a recent and prolonged drought in Australia (2001–2008). Climate change projections predict an increase in such drought events both in Australia and world-wide (Stanke et al., 2013).

Drought can be defined in several different ways but, when studying human impacts of drought, it is common practice to use the agricultural drought definition. Agricultural drought involves a period of *below-average* precipitation and/or *intense but less frequent* rain events and/or *above-normal evaporation* resulting in dry soils, reduced plant growth and reduced crop production (Dai, 2010). Implicit in this definition is the assumption that the length of an "agricultural drought" can only be assessed in hindsight because a rainfall event may signify a brief break in an extended period of dryness rather than the end of prevailing drought conditions. Consequently, in practice, researchers variously use

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http://dx.doi.org/10.1016/j.envres.2014.03.014
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the term "drought" to mean prevailing drought conditions over time and also to refer to a specific period of dryness within the drought. For clarity, in this paper, we refer to prevailing drought conditions as "drought" and to specific periods of dryness within drought as "drought periods".

At the time of writing, the quantitative research most clearly linking drought and mental health has been focused on a specific and extreme aspect of mental health, which is suicide. Two studies using time series analysis have identified a relationship between reduced precipitation and a rise in the local suicide rate (Hanigan et al., 2012; Nicholls et al., 2006). However, of the few studies conducted using general mental health screening measures (e.g., the Kessler-10 and the SF-36), none has identified a relationship between mental health and explicit environmental measures of drought (Edwards et al., 2008; Kelly et al., 2011). This may be because these studies examined mental health in one year for the impact of low relative rainfall during a short preceding period (1–3 years), or because they did not attempt to define the nature of drought beyond identifying months of unusual dryness. In contrast, while not modelling the nature of drought, the time series suicide studies did examine trends in the impact of low relative rainfall over much longer periods known to include about a decade of prolonged drought. We therefore hypothesised that, when a drought exposure was quantified over the whole period of Australia's 2001–2008 drought (Verdon-Kidd and Kiem, 2009), it would be associated with the mental health.

In addition, although it has not previously been considered, the exact *pattern* of "drought periods" within a drought, broken by occasional rainfall events, may also influence mental health. A pattern of drought emerging over a long period of time, like the 2001–2008 drought in Australia (known as the 'Big Dry'), may take a variety of forms. Measures such as the Hutchinson indices of relative dryness can be used to provide the level of technical detail necessary to examine the emergence of these patterns. Using two different tracking methods, the Hutchinson count-method index and the Hutchinson sum-method index measure *relative* dryness across time and define benchmarks for the period of relative dryness needed before this dryness qualifies as a drought period (based on prior research examining drought in Australia: Smith et al., 1992).

Of the few studies using explicit measures of dryness, most use the Hutchinson Indices (e.g. Hanigan et al., 2012; Kelly et al., 2011; Stain et al., 2011). Although not attempted in previous studies, the Hutchinson Indices could be used to identify the number of months spent in a drought period, the duration of drought periods, how intensely "dry" the relative dryness was, and how many times an area cycled into and out of relative dryness. Measuring these characteristics would make it possible to trace how distinctive localised drought period patterns emerge within a larger region (here, a nation continent) experiencing prevailing drought conditions.

We expected that different drought period patterns (hereafter "drought patterns") would occur across the Australian continent during the 2001–2008 'Big Dry' but had no basis to make specific hypotheses about what these patterns would be or how individuals might react. We simply noted that people adapt to their environment (Hobfoll, 2002) and that mental resilience tends to break down in the face of stressors that are severe or prolonged (Pearlin, 1999). Therefore, we hypothesised that where (i) drought periods created patterns or a pattern, of *extreme* dryness conditions, that at least one of these drought patterns would create a mental health exposure, while (ii) people would adapt more easily to conditions of little or moderate drought. In addition, compared to city-dwellers, people living in rural communities live in an environmental, economic and social eco-system that is more directly connected to and reliant on the land (Connor et al., 2004). We therefore also hypothesised that rural locality would amplify any mental health impact of drought.

2. Methods

2.1. Measuring patterns of drought within the 'Big Dry' period

Extensive preparation of rainfall data was necessary to identify the drought patterns occurring in Australia during the drought of 2001–2008 known as the 'Big Dry'. The methodology used to measure dryness, drought periods and drought patterns for this study is complex and is described in detail in Appendix A of the online Supplementary materials. To briefly summarise the steps taken, we used (i) rainfall data supplied by the Australian Bureau of Meteorology to generate (ii) two 'Hutchinson Indices' of relative dryness (Hanigan, 2012). Each index used a different method of calculation (one called the 'count-method' and the other the 'sum-method') to track the dryness of different areas in Australia during the 'Big Dry'. The count method index tends to identify long drought periods while the sum method tends to identify very dry drought periods and, between them, these indices enabled us to identify when different areas entered and exited different kinds of drought conditions. (iii) Summary measures were then calculated to capture different drought characteristics experienced during the 'Big Dry'. These were: cumulative months spent in drought periods, the intensity of how relatively dry the drought period was, the number of times an area cycled into and out of a drought period, and the number of months spent in unbroken relative dryness during the last two years of the 'Big Dry'. (iv) Drought extremity measures were then calculated by dichotomising each summary measure at the 90th percentile (or as close as possible), with the exception that months spent in unbroken dryness during the last two years of the 'Big Dry' was instead dichotomised based on there being twelve straight months or more of relative dryness. Finally, (v) two-step cluster analysis in IBM SPSS 19 was used to identify the patterning of different extreme drought conditions across Australia, thereby characterising the different drought patterns Australian residents could have experienced.

Our 'drought exposure' measures were calculated to the small-area geographical level of Australian 2001 Census Collection Districts ('Districts'). The median geographical size of Districts was 32 km^2 in urban areas and 62.45 km^2 in rural areas (where the population is less dense and links to agricultural industry makes rainfall relevant across a larger geographical region). The denomination of Districts was chosen so that drought measures could be linked with population data taken from the HILDA Survey, an annual cohort survey that began in 2001 and is collected and coded in terms of Districts (details below). As is standard for large, population-level surveys, for practical reasons, HILDA survey collection is conducted over several months (for the year relevant to our study, from August 2007 to February 2008). Daily rainfall data used for calculating the drought exposure experienced by individual respondents were therefore selected to exactly match a seven year timespan that ended on the date that each participant was interviewed. Consequently, the time period examined in this study is referred to below as 2001/02–2007/08.

2.2. The Household, Income and Labour Dynamics in Australia (HILDA) Survey

2.2.1. Survey details

The HILDA Survey is a government-funded panel survey of Australians aged 15 years and over that began in 2001 (Wave 1, $N=13{,}969$). Participants provide informed consent and, for those participants who are under the age of 18 (6.98% of the current sample), a legal guardian also provides consent for their participation. The participation rates from year to year within the HILDA survey are consistently high (86% retention in the second year and above 90% in all years thereafter). For details of the sampling strategy and conduct of data collection see Appendix B in online Supplementary materials.

The HILDA Survey is conducted annually (Wooden et al., 2002). It is designed to be nationally representative with the exception that people in remote and very remote areas of Australia are underrepresented because they were not included in the initial data collection (though some participants have since moved to remote areas). The survey asks respondents to report every year on a range of aspects of life, including labour market and family dynamics, wellbeing and socio-economic characteristics. This study used Wave 7 of the HILDA Survey, Wave 7 had a response rate of 94.7% and included 13,590 respondents of whom we selected 5012 who had been resident in the same location for the past seven years (so that their weather exposure was stable) *and* had completed the mental health outcome measure. To classify participants as either urban or rural dwellers we used the 'Section of State' Australian Standard Geographical Classification system devised by the Australian Bureau of Statistics (ABS, 2011). This system uses population counts to define urban centres as those with 1000 or more people in a community while the remainder of the population is classified as rural. Within our sample, 4093 participants dwelt in an urban area and 919 dwelt in a rural area.

Wave 7 is not the most recent wave available and was selected because its collection occurred just before the end of the 'Big Dry', allowing us to capture

a population *before* it had exited or recovered from prolonged drought conditions. Further, unlike other waves, Wave 7 included Kessler's 10-item measure of general psychological distress (Kessler et al., 2002).

2.2.2. Outcome measure

The Kessler-10 is a short measure of non-specific psychological distress based on questions about nervousness, agitation, psychological fatigue and depression. It was designed be used in the United States National Health Interview Survey, and to span the range from minimal to extreme levels of distress. It has since been shown to be a valid and reliable screening tool for the Australian population with population norms available (Slade et al., 2011). Participants respond to each item in the Kessler-10 (e.g. in the past four weeks how often have you felt so sad that nothing could cheer you up?) on a five-point scale (1=none of the time, 5=all of the time), with a total summed score ranging from 10 to 50. To classify the level of distress that a score indicates, the Australian Government's Bureau of Statistics recommends the following categories: low distress=10–15; moderate distress=16–21; high distress=22–30; very high distress=30+. Those with scores of 20 or above are likely to have a mental disorder requiring clinical treatment and those with scores in the subclinical 16–19 range have an increased risk of developing a mental disorder (Coombs, 2005; Cuijpers and Smit, 2004). Scores in the present sample ranged from 10 to 50, with mean scores (M=15.53, SE=0.13), slightly higher than in the Australian population the same year (M=14.5, SE=1, Slade et al. (2011)).

2.2.3. Confounders

As standard confounders for population health-related studies, we controlled for age, sex, relationship status and gross household income adjusted for the number of people in the household using the OECD method (household income/($\sqrt{}$no. in household)). Several other confounders were also included based on research showing that they are associated with mental health (Berry et al., 2008): ethnicity; left school early (at 15 years or younger), low educational attainment, divorced/separated, receiving > 30% of income from welfare, presence of a physical or mental health condition (either or both for 6 months or more) and satisfaction with local community.

2.2.4. Missing data

Once the HILDA Survey data were restricted to participants who had completed the dependent variable measure (Kessler 10), there were only five participant cases with missing data. The missing data was on four covariates: education, health condition, ethnicity and satisfaction with local community and there was less than 1% of missing data on each variable. To avoid loss of power, missing data were imputed using an iterative regression-based approach called Expectation Maximisation (Enders, 2001). Expectation Maximisation uses a two-step iterative process where missing values are replaced with their best estimates based on the complete data. The first step (the 'E Step'), replaces missing values with the conditional expected value given the observed data. The second step (the 'M Step') uses the estimations from the first step to produce means and covariance matrices as if there were no missing data. The mean scores and standard deviations for all the variables before and after estimation are then compared and, if the scores are sufficiently similar, the estimations can be accepted. The algorithm is repeated until the solution reaches convergence. Note that sensitivity tests showed that reducing the sample to cases with no imputed data did not change the pattern of results or introduce overlap between confidence intervals. All analyses were therefore conducted using the dataset with imputation.

2.3. Statistical analysis

Drought patterns were identified by performing cluster analyses on the drought extremity measures. Next, the drought patterns were used to predict mental health, via multiple linear regression analysis, with the five drought pattern categories coded as five categorical (dummy) variables and zero-to-moderate drought as the reference category. To examine whether rural locality would amplify any mental health impact of drought, interaction terms between drought pattern category and rural/urban locality were included. All analyses adjusted for the socio-demographic confounders and the confounders known to be related to mental health as listed in the confounders subsection above. Analyses were conducted using Stata 12 survey commands, applying the HILDA Survey sample weights and clustering at the District level, which also accounts for clustering within households. For more detail on the complex survey techniques see Appendix B in Supplementary materials.

3. Results

3.1. Patterns of dryness

Repeated cluster analyses using the measures of extreme cumulative dryness (Table 1) showed that, while drought period *cycles* were not consistently informative, a highly stable cluster solution was returned when three indicators of extreme conditions were used: (i) an extreme number of months qualifying as drought periods, (ii) extremely dry drought periods and (iii) the presence of a recent long unbroken dry period. During the 'Big Dry' these characteristics were distributed across the population in a way that created five distinct drought patterns, termed: (1) zero-to-moderate drought, (2) very dry drought, (3) recent long period, (4) constant drought, and (5) constant drought with a recent long period. See Table 1 for further description of these drought patterns, and the bottom of Table 2 for drought pattern distribution and the means of related drought extremity measures split by urban/rural locality.

Note that the total number of months spent in drought was similar across the 'constant' drought and the 'constant drought with a recent long period' categories. We also reiterate that, except for the zero-to-moderate drought classification, the drought patterns identified were focused on *extreme* dryness, or dryness over and above an allowance for normal variability (which, in Australia, is substantial). Thus, for example, a 'recent long dry period' typically signalled around 16 months in unbroken dryness during the past 24 months.

3.2. Socio-demographic characteristics

Descriptive characteristics for rural and urban dwellers are reported in Table 2. The rural population tended to be slightly more clustered around early retirement age, and had a greater proportion of men. Rural dwellers were more likely to have left school early and were less likely to have completed a university degree. They tended to have lower adjusted household income and were also slightly more likely to obtain more than 30% of their income from government pensions and allowances. There were also markedly fewer non-English-speaking migrants in rural areas compared to urban settings. Rural Australians were overall somewhat less distressed and less likely to have reported a pre-existing mental health condition (not an uncommon finding for rural regions (Smith et al., 2008)). They were also more likely to be married and to be satisfied with their local community.

Table 1
Distribution of extreme conditions and dryness patterning in Australian population sample (N=5012).

Drought pattern	Description of conditions	% Population exposed
Zero to moderate	Drought was either not present or not extreme.	47.26
Very dry	Drought period(s) were intensely dry (top 10% of sum-method drought periods).	12.30
Recent long period	An unbroken period of relative dryness lasted for at least 12 straight months in the last 24 months of the 'Big Dry'.	30.10
Constant	Cumulatively experienced 20–32 months in drought that met both the sum and count method definition (top 10% of months in drought).	3.41
Constant and recent long period	Both 'Recent long period' and 'Constant' drought conditions are present.	6.94

Table 2
Characteristics of rural and urban respondents in Wave 7 of the Household Income and Labour Dynamics in Australia Survey who have lived in the same location for at least seven years.

Variables	Proportion[a] (%)	Rural (N=919)	Urban (N=4093)
Distress (K10)	*Mean*	15.08 (0.28)	15.61 (0.14)
Age (years)	15–25 years	13.34 (0.02)	16.79 (0.01)
	26–39 years	10.20 (0.01)	10.43 (0.01)
	40–55 years	33.04 (0.02)	31.38 (0.01)
	56–65 years	22.73 (0.02)	18.50 (0.01)
	66–79 years	17.97 (0.02)	17.15 (0.01)
	80+ years %	2.72 (0.01)	5.76 (0.01)
Gender	Male	51.62 (0.01)	47.28 (0.01)
Ethnicity	Indigenous/Torres Strait Islander Australian	1.54 (0.01)	1.32 (0.004)
	English-speaking immigrant	9.31 (0.01)	9.77 (0.01)
	Non-English-speaking immigrant	5.17 (0.01)	17.08 (0.01)
Left school at 15 years or younger		42.08 (0.02)	36.22 (0.01)
Education	Year 11 or less	45.20 (0.02)	37.25 (0.01)
	Year 12	14.96 (0.01)	14.55 (0.01)
	Certificate or diploma	30.49 (0.02)	28.77 (0.01)
	Tertiary degree	3.58 (0.01)	11.11 (0.01)
	Higher degree	5.77 (0.01)	8.32 (0.01)
Married		56.61	66.05
Gross household income (AUD$)	nil-$31,199	23.54 (0.03)	19.32 (0.01)
	$31,200–$51,999	22.47 (0.03)	16.74 (0.01)
	$52,000–$77,999	19.13 (0.03)	23.43 (0.01)
	$78,000–$114, 399	22.11 (0.03)	21.86 (0.01)
	$114,400+	12.76 (0.03)	18.65 (0.01)
Pensions/allowances > 30% of income		31.57 (0.04)	29.68 (0.01)
Health condition		31.12 (0.02)	30.63 (0.01)
Mental health condition		2.25 (0.005)	3.69 (0.004)
Farm-related household		15.58 (0.03)	0.82 (0.002)
Satisfaction with local community (average 0–10)	*Mean*	7.46 (0.10)	6.92 (0.06)
Months in sum drought	*Mean*	14.15	14.54
Months in count drought	*Mean*	19.21	20.86
Months in drought (both methods)	*Mean*	13.85	14.48
Dryness intensity measure	*Mean*	5.58	5.80
No. months in recent count index dryness	*Mean*	4.93	7.15
Dryness pattern	Zero to moderate	65.54	44.31
	Very dry	5.49	13.44
	Recent long period only	18.08	32.10
	Constant drought only	5.83	3.00
	Constant drought and recent long period	5.63	7.15

Note 1: Although equivalised income was included in analysis, for clarity and descriptive purposes income is displayed here in terms of distribution across five different income brackets.
Note 2: Robust standard errors generated by a clustered and weighted survey design are included in brackets for the person-related variables.
[a] Unless otherwise specified.

In terms of their environment, urban dwellers less likely to live in conditions classified as zero-to-moderate drought and more often experienced intensely dry periods or a recent long period of unbroken dryness. However, urban and rural areas were similar in the total number of months spent in drought (see also Table C, in the online supplementary materials).

3.3. Dryness patterns and mental health

In a multiple regression model, adjusted for confounders, the interaction between locality and drought type was statistically significant (reference category: zero-to-moderate: t=2.22, p=0.03). Mean distress scores for respondents in the five drought pattern categories split by locality are shown in Fig. 1. Fig. 1 also includes two shaded bands showing the moderate distress and low distress diagnostic bands of the Kessler-10 measure. (Note that the confidence intervals displayed should not be used to compare across drought categories because confidence intervals for mean values are calculated using standard errors rather than the square-rooted standard errors used for t-statistic confidence intervals that are appropriate when comparing across means.) For rural participants, only those in the 'constant' and 'constant and recent long' drought categories had a mean distress confidence interval that crossed into the moderate distress band. In fact, rural participants in the 'constant and recent long' category had a mean distress confidence interval that was above the diagnostic low distress band of the Kessler-10 distress measure. These mean scores suggested that

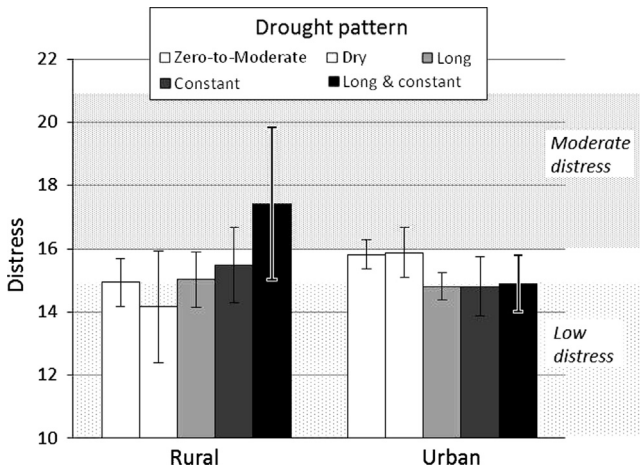

Fig. 1. Mean distress for rural and urban participants experiencing different dryness patterns. *Note*: Confidence intervals should be used to assess distress levels in terms of the Kessler 10 distress classifications 'low' and 'moderate' rather than to compare distress across categories.

Table 3
Distress predictors for rural and urban respondents with zero-to-moderate drought as the reference category.

	Rural			Urban		
	Regression coefficient	95% CI		Regression coefficient	95% CI	
Dryness pattern (Ref.: zero-to-moderate)						
Dry	−0.29	−2.11	1.52	−1.94 e−03	−0.67	0.66
Long	−0.51	−1.48	0.47	−0.17	−0.68	0.35
Constant	0.31	−0.73	1.35	−0.53	−1.22	0.15
Long & constant	2.49	0.59	4.39	−0.81	−1.70	0.09
Age (Ref.: 15–25 years)						
26–39 years	−1.18	−3.26	0.89	0.06	−1.00	1.13
40–55 years	−0.60	−2.14	0.94	−0.85	−1.77	0.07
56–65 years	−0.98	−3.10	1.14	−1.83	−2.84	−0.82
66–79 years	−3.02	−4.62	−1.42	−2.40	−3.33	−1.48
80+years %	−3.63	−5.94	−1.32	−3.44	−4.53	−2.36
Female	0.49	−0.14	1.11	0.79	0.38	1.21
Married	−1.07	−2.37	0.22	−1.06	−1.59	−0.52
Equivalised household income	−4.58 e−06	1.69 e−05	7.70 e−06	1.08 e−05	1. 08 e−05	−3.68 e−06
Non-English speaking background	1.17	−0.25	2.59	2.45	1.66	3.24
Australian Aboriginal	−1.89	−3.12	−0.67	−1.77	−3.67	0.13
Education (Ref.: 11 years or less)						
Year 12	−0.40	−1.54	0.75	0.22	−0.69	1.13
Certificate or diploma	−0.14	−1.08	0.80	−0.61	−1.17	−0.05
Tertiary degree	−0.62	−1.77	0.52	−0.87	−1.57	−0.16
Higher degree	0.30	−1.20	1.80	−0.85	−1.65	−0.05
Health condition	2.63	1.58	3.68	2.44	1.86	3.03
Mental health condition	6.24	3.15	9.32	6.81	4.87	8.75
Satisfaction with local community	−0.89	−1.23	−0.55	−0.45	−0.57	−0.34
Constant	22.62	19.62	25.63	19.64	18.56	20.72
R^2	0.25			0.21		

Note: Multiple regression analyses were adjusted for survey clustering at the collection district level and HILDA Survey sample weights.

rural respondents were more likely to have increased distress if they experienced an extreme number of months in drought, particularly if they also experienced a recent long period of unbroken dryness. In contrast, in the urban population, there was a trend for *less* distress in the 'long', 'constant-only' and 'constant and recent long' drought categories, with these means having confidence intervals below the moderate distress band.

A multiple linear regression analysis conducted within the rural sub-population indicated that people in the 'constant and recent long' drought category tended to experience more distress than those in the 'zero-to-moderate' drought category (Table 3). Based on 95% confidence intervals, the rate of change for the conditional mean of distress with respect to 'constant and recent long' drought was estimated to be an increase of 6.22% in distress compared with other participants (95% Confidence Interval: 1.46–10.98). This was substantial: nearly half the size of the rate of change for the conditional mean of distress with respect to having a pre-established mental health condition; estimated to be an increase of 15.59% more distress (95% CI: 7.87–23.31).

In contrast, a multiple linear regression analysis conducted within the urban sub-population indicated that the trend for people to have less distress in 'constant and recent long' drought could not quite be accepted with 95% confidence because the confidence interval for the estimated effect crossed zero (Table 3). Amongst the confounders, there were also non-trivial estimates for the association between worse mental health and several confounders: being of Indigenous Australian Ethnicity, being younger, having a health condition and being dissatisfied with one's local community. Although interaction terms were not tested as part of the planned analyses, readers should note that the higher estimates in the urban sample for the association between mental health and income, education and relationship status is consistent with the different lifestyle demands of rural and urban localities in Australia.

Table 4
Summary table for the relationship between distress and rural/urban locality within the five dryness pattern categories.

Dryness pattern	Regression coefficient	95% CI	
Zero-to-moderate	−0.01	−0.74	0.72
Dry	−0.22	−1.76	1.32
Long	−0.36	−1.17	0.44
Constant	0.77	−0.24	1.78
Long and constant	2.69	0.43	4.95

Note: Within each dryness pattern category, distress was regressed on locality (rural=1) using a multiple regression analysis with survey clustering and weighting, adjusting for all covariates.

Comparisons across locality, also using multiple regression analyses adjusted for confounders (Table 4), indicated that rural people experiencing the 'constant and recent long' drought pattern tended to be more distressed than were urban people living in the same conditions. The rate of change for the conditional mean of distress with respect to locality for people living in 'constant and recent long' drought was estimated to be a percentage change of 6.73% (95% CI: 1.08–12.38%). The similar but much weaker trend for 'constant' drought to be related to worse mental health in rural but not urban localities could not be accepted with 95% confidence because the confidence interval for the estimated effect crossed zero. Similarly, mean distress in 'zero-to-moderate' drought tended to be lower in rural localities, but overlapping confidence intervals indicated that this difference was not necessarily meaningful.

4. Discussion

We hypothesised that drought would become an exposure for mental health when drought was examined across a long period of

time, taking into account patterns of different drought characteristics and underlying capacity for resilience. Our findings most strongly showed that an extreme cumulative number of months in drought period conditions (20–32 months) over the seven-year 'Big Dry', culminating in a recent period of unbroken dryness lasting a year or more, was associated with increased distress in rural areas (i.e., the 'constant and recent long' drought pattern). The importance of locality was consistent with our second hypothesis, that drought would have an amplified effect in rural areas where residents would be more sensitive to drought conditions, while no consistent effects for drought were found in urban areas.

Our analysis benefited from examining relative dryness over a longer time period than has been examined in past quantitative studies examining drought and mental health. However, our more novel contribution was to show that the pattern of extreme dryness occurring within a drought itself matters for mental health. Hence, an association between drought and mental health was found for rural people experiencing the 'constant and recent long' drought pattern but not the 'constant' or 'long' drought pattern, despite each of these categories involving a similar number of total months in drought. On a clinical level, rural people living with 'constant and recent long' drought tended to experience a subclinical level of moderate distress, indicating that this subpopulation had an increased risk of developing a mental health problem requiring treatment in the future.

We had conservatively hypothesised that rural locality would amplify people's responses to different drought conditions; the differences were even more striking than we had anticipated. Rather than having a similar but less intense pattern of responses, urban dwellers showed a mean-level trend to do *better* in response to spending more time in the kind of drought pattern that tended to elevate the distress of rural people. Confidence intervals indicated that this trend in the distress levels of urban participants was highly variable, and both the presence and variability of this trend highlights the very different practical and psychological significance that drought has for urban versus rural society. Drought in the country means failing crops and starving livestock, with obvious and potentially disastrous flow-on effects for farm enterprises and rural communities. In contrast, while city-dwellers are not necessarily insensitive to the impact of drought, the endless sunny days may sometimes simply mean more opportunities to get together out-of-doors with friends.

In the introduction to this study, we suggested that drought would act as a mental health exposure when it challenged people's resilience. The rural communities in our study, adapted though they are to Australia's harsh conditions, appeared to have particular difficulty managing life under 'constant and recent long' drought conditions. The noticeable similarity between distress levels in all other comparisons suggests that it is not how dry the weather gets during periods of relative dryness that matters but how long the weather stays dry. Taken separately, a drought period lasting over a year or multiple drought periods cumulatively adding to many months in drought were not associated in our study with discernible population-level mental health harm. However, our findings suggest that people may begin to doubt their capacity to outlast a drought that initially has multiple drought periods and then settles into unbroken dryness (which may continue indefinitely).

On a positive note, all of the city people and most of the rural people in our sample appeared to be able to manage the pressures of the 'Big Dry' without evident mental health impacts. However, in the context of climate change, dealing with an increasingly drought stricken 'new normal' is a challenge that rural societies and policy-makers must face the world over. Given likely future warming and drying scenarios, the limits of people's resilience in certain settings must be considered and addressed as an emerging priority in population health.

4.1. Limitations and future directions

This study is a first step towards quantifying how wellbeing will be affected by projected increases in the frequency or intensity of drought. Our methodology needs to be replicated using data from many different countries and larger samples. It could also be expanded using person-tracking across space to quantify the weather experience of migratory people, since their socio-economic and personal characteristics may differ systematically from people who stay in the same place for very long periods. In addition, while data are often not available, more comprehensive quantification of weather conditions (e.g., temperature, humidity, wind speed and direction and soil moisture) would provide a richer and potentially more robust quantification of drought as a mental health exposure. In particular, though we have appropriately examined the measurement of *relative* dryness, it will be necessary to simultaneously investigate the potential for *absolute* measures to explain variance in mental health outcomes, or to control for absolute conditions in considering relative exposures.

Finally, this paper does not address the mechanisms by which drought has its impact. Low rainfall creates the risk that people will not have sufficient water to meet their needs but the capacity, water level and accessibility of local reservoirs and other fresh water sources, such as rivers, will moderate the level of this risk. In addition, while rural communities are much more likely to be vulnerable to weather conditions because of their close connection to the agricultural industry and distance from services, there is much unexamined variation in the strength and nature of these relationships. For example, agricultural pursuits have different water requirements (e.g. dryland versus irrigated farming) and the timing of rainfall can be as important as the amount of rain. Finally, the way that people and communities deal with scarce resources will be affected by factors like adequate mental and physical health services, social capital and the ability and willingness to be innovative in finding new ways to prosper under changed circumstances (OBrien et al., 2012; Schirmer et al., 2013). Understanding the social and economic ways in which these kinds of factors moderate and mediate the impact of drought is a complex project, probably best explored by longitudinally examining rural and urban communities over long periods of time using customised data collections.

4.2. Conclusions

The study of drought and mental health is an emerging field and, to our knowledge, this is the first paper that identifies an association between explicit, modelled measures of drought and levels of distress in the resident population. We took the novel approach of examining cumulative rainfall conditions over a relevant and long period (the critical seven years of Australia's 'Big Dry') and identifying different patterns of extreme drought. Using robust and validated relative dryness indices as a starting point, we calculated and examined many different characteristics of drought. We found that an extreme number of months in relative dryness culminating in a long period of unbroken drought was associated with an accumulated mental health exposure for people living in rural areas.

Acknowledgment

The research reported in this article was partly supported by a grant from the Australian National Health and Medical Research Council (NHMRC 585482) paid to the Australian National University, which funded a Research Fellowship position for Léan OBrien. The NHMRC is a Federal Australian Government institution. There are no other interests to declare.

Appendix A. Supplementary materials

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2014.03.014.

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