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ORIGINAL ARTICLE

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Inter-annual rainfall variations and suicide in New South Wales, Australia, 1964–2001

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Abstract The suicide rate in New South Wales is shown to be related to annual precipitation, supporting a widespread and long-held assumption that drought in Australia increases the likelihood of suicide. The relationship, although statistically significant, is not especially strong and is confounded by strong, long-term variations in the suicide rate not related to precipitation variations. A decrease in precipitation of about 300 mm would lead to an increase in the suicide rate of approximately 8% of the long-term mean suicide rate.

Keywords Suicide · Drought · Australia · Health · Climate

Introduction

Documented examples exist of Australian farmers committing suicide because, apparently, of stresses associated with drought (e.g., Conway 1990). Many agricultural scientists believe that there is a substantial increase in the suicide rate in rural Australia during droughts. This belief even leads to concerns that the prediction of an increased chance of drought (associated, for example, with evidence of an emerging El Niño episode) may itself lead to an increase in the suicide rate. However, there appears to be little documentary evidence that the suicide rate in Australia increases during droughts. This paper examines possible relationships between rainfall, an index of drought conditions, and suicide rate in New South Wales, a state on the eastern seaboard of Australia.

There have been various studies relating the suicide rate with meteorological factors per se. All these studies, however, refer to the impact on mental state of relatively short periods of negatively perceived weather. Dixon and Shulman (1983) reviewed early studies (between 1933 and 1973) of possible relationships between weather variables and suicide. They concluded that this early research had resulted in "often inconclusive and somewhat contradictory findings," possibly due to the use of unrepresentative meteorological data or too small a sample. Dixon and Shulman (1983) then examined a large sample of the daily occurrence of suicide in New York City and related this to daily meteorological variables such as temperature, precipitation, and cloud cover. Although "the data hinted that frontal passages and large daily temperature changes may occur on days with above average suicide rate, it was concluded that the influence of the weather parameters used, on the suicide rate, is a minor one, if indeed one exists." Plesko et al. (1991) compared 1 year of daily records of suicide attempts at Zagreb with weather variables. Suicide attempts increased if a cloudy period extended for three or more days. Preti (1998) found higher suicide rates in drier towns in Italy.

Deisenhammer (2003) reviewed 27 studies published between 1972 and 2002 that attempted to relate suicidal behaviour with weather variables and concluded that most studies reported a statistical association with at least one weather factor. However, the results were not conclusive and were, in part, contradictory. Thus, as many studies have found a higher incidence of suicidal acts on days with higher temperatures or during periods of or in regions with warm and sunny weather as have found the contrary. Deisenhammer considered that differences in methodology between studies could be one reason for the heterogeneity of the results. The studies assessed different weather variables and different averaging periods as well as different locations. Deisenhammer et al. (2003) investigated weather factors related to suicide in Tyrol, Austria, over 6 years and found that the risk of committing suicide was significantly

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higher on days with high temperatures, low relative humidity, or a thunderstorm or on days following a thunderstorm. They concluded that within "the interaction of psychological and environmental influences in the development of suicidal ideation and behaviour, specific meteorological conditions may additionally contribute to the risk of suicide in predisposed individuals."

None of the studies mentioned above or reviewed by Deisenhammer (2003) examined variations in suicidal behaviour in Australia. Nor did any of these studies examine whether drought occurrence was related to suicidal behaviour. Studies of suicidal behaviour in Australia have tended to focus on the large geographical variations (especially between rural areas and cities), the possible impacts of isolation, the availability of guns, and other economic and social factors such as unemployment, governance and gender imbalance (e.g., Burnley 1994; Morrell et al. 2002; Page and Fragar 2002; Stack 2002). In view of the widespread notion that drought may be a factor in suicidal behaviour in rural Australia, we have examined time series of suicide rates and inter-annual variations in precipitation to assess the evidence for such an effect.

Materials and methods

Human data

Suicide and population data for the period 1964–2001 were obtained from the Australian Bureau of Statistics (ABS). Ethics approval for this study was granted by the Australian National University human research ethics committee. Deaths were coded according to the International Classification of Diseases (ICD) codes, which changed four times in the period of analysis. The codes for suicide and intentional self-inflicted injury were E970–E979 from ICD7 (used by the ABS between 1958 and 1967), E950–E959 in ICD8 (used between 1968–1978), E950.0–E959.9 in ICD9 (used between 1979–1998), and X60–X84.9 in ICD10 (used from 1999 till present).

Suicide data for 2000–2002 are probably slightly underreported, due to the normal delay in the registration of suicidal deaths, many of which require coronial enquiry. The suicide data refer to the entire population of New South Wales (NSW). The size of the population, based on censuses performed every 5 years from 1966, was obtained from the ABS. These data sets were then used to calculate a crude annual rate for suicides for 1964–2001. In 1971, indigenous populations (who have a higher rate of many forms of mortality, possibly including suicide) were enumerated for the first time, and this probably led to an underestimate of the suicide rate before 1971. A proportion of single-person motor vehicle accidents may represent unrecognised suicide, but no adjustment was made for these data, as they are not readily available from the ABS.

Meteorological data and analysis

A time series of rainfall averaged across NSW was obtained using a gridded data set produced by the National Climate Centre of the Australian Bureau of Meteorology. Annual NSW precipitation for each year from 1964 to 2001 was calculated to compare with the annual suicide rates. Simple linear correlation was used to investigate the relationship between precipitation and the suicide rate. However, strong variations on decadal and longer time scales in the suicide rate (see Fig. 1), presumably associated with socio-economic factors and other non-climate factors, confound such an analysis. Therefore, year-to-year differences in the precipitation and suicide time series were calculated and also correlated. Taking year-to-year differences acts as a simple, high-pass filter, removing the confounding effects of the long-term variations. Multiple linear regression of

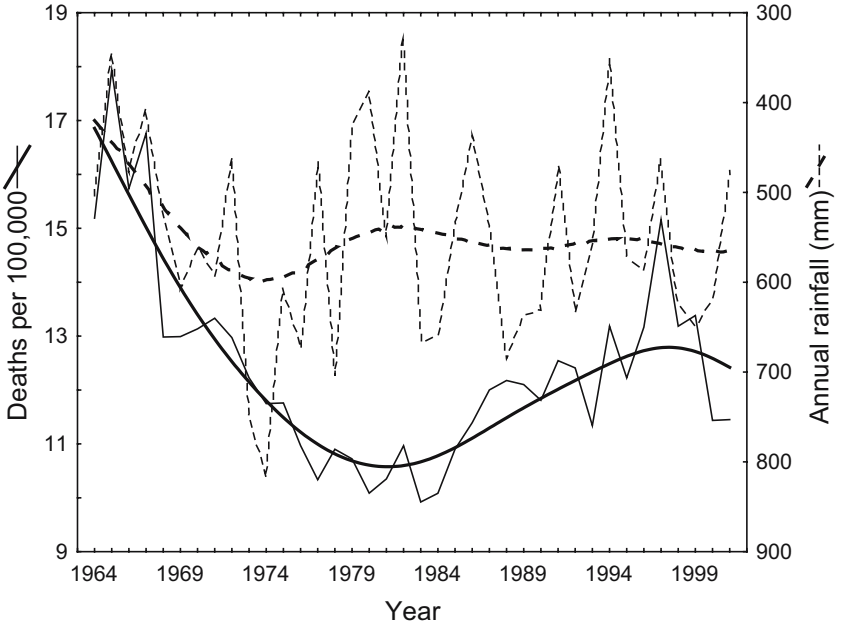

Fig. 1 Time series of New South Wales (NSW) suicide rate (per 100,000; *full lines, left-hand scale*) and NSW annual precipitation (*broken lines, right-hand scale*; note scale is reversed). Data from 1964 to 2001. *Thick lines* are distance-weighted least squares smoothed time series.

suicide rates including the previous year's suicide rate and the current year's rainfall as predictors was also used to investigate the effect of rainfall on suicide rate.

Results

Between 1964 and 2001, the population of NSW increased by 57% and became older. Average age increased from 32 to 37. Time series of NSW annual precipitation and annual NSW suicide rates are shown in Fig 1. The age-unadjusted suicide death rate varied from 9.9/100,000 to 17.8/100,000. The rate was particularly high for 1964–1967. This is attributed to the then ready availability of barbiturates, since replaced by sedatives and antidepressants that are less likely to be fatal in either accidental or deliberate overdose (Oliver and Hetzel 1972). Broadly speaking, the suicide rate fell steadily until 1983 and then gradually increased until the late 1990s. The decline in the last two years of the analysis may be an artefact caused by delays in reporting due to coronial inquests (as noted earlier) rather than a true decline. The rate for deaths in police custody (many of which would be classified as suicide) varied between 0.9 and 1.4 per 100,000, with the important exception of 1997 when the deaths in police custody rate peaked at 2.1, a year when the overall suicide death rate also crested.

Close examination of the time series suggests that, superimposed on these broad trends, there is a relationship between inter-annual variations of precipitation and suicide rates, with most "peaks" and "troughs" aligning (note that the scale for the precipitation time series has been inverted). The alignment between the peaks and troughs is clearest before about 1972 and after about 1990. The correlation between the two time series is −0.30 (n=38; p=0.06). A scatter diagram of the two variables is shown in Fig. 2 along with a linear regression line. There is considerable scatter, as would be expected from such a moderate correlation, but there is an indication that the suicide rate increases in drier years. For instance, the 5 years with the highest suicide rate occurred in years with less than 500 mm (the mean annual rainfall is 551 mm).

It is, however, clear from Fig. 1 that long-term variations in suicide rates occur that do not reflect changes in precipitation. For instance, very low suicide rates occurred around 1980 even though rainfall was low in these years. The trend towards higher suicide rates from around 1980 to the late 1990s also was not associated with a reduction in precipitation. These periodic variations in suicide rates confound the relationship with precipitation variations, so a simple, high-pass filter (year-to-year differences) was used to remove the effect of long-term variations. The correlation between year-to-year differences in the suicide rate and year-to-year differences in rainfall was −0.42 (n=37; p<0.01). The increase in the magnitude of the correlation (and its statistical significance) relative to the correlation between the "raw" time series confirms that the periodic variations in suicide are confounding the relationship between fluctuations in precipitation and suicide rate. A scatter diagram of year-to-year differences in suicide rates versus year-to-year differences in precipitation is shown in Fig. 3 along with the linear regression between these variables. As was the case with the scatter diagram using the "raw" data, there is considerable scatter. However, there is also, clearly, a negative relationship, with an increase in suicide rate usually accompanying a decrease in precipitation. A decline in precipitation of 300 mm could be expected to be accompanied by an increase in the suicide rate of about 0.96 per 100,000 (i.e., an increase of about 8% of the mean suicide rate of 12.4 per 100,000).

A different approach to estimating the effect of precipitation on suicide rate, but to include the effect of long-term variations in suicide rate, is to use multiple regression with precipitation in the current year and suicide rate in the previous year as predictors of the suicide rate in the cur-

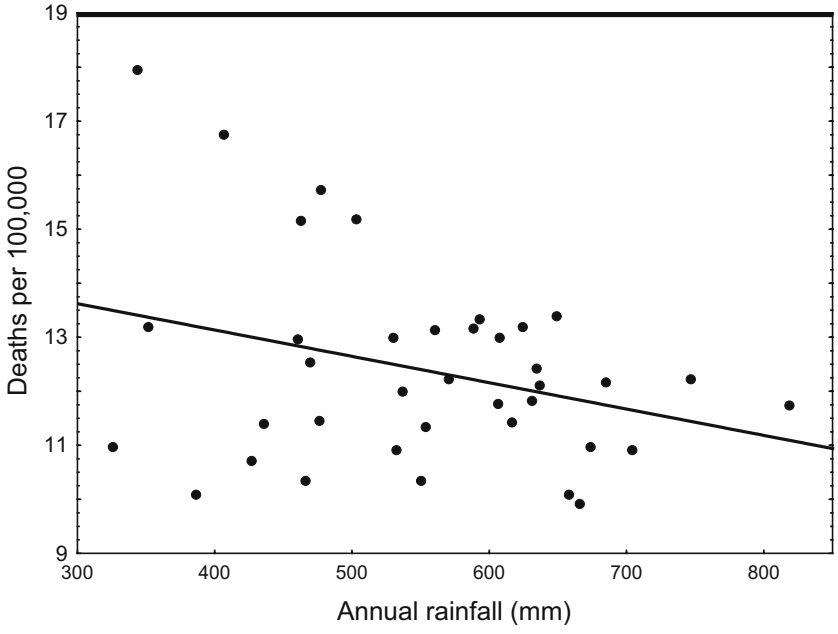

Fig. 2 Scatter diagram of New South Wales (NSW) suicide rate (per 100,000) versus NSW annual precipitation. Data from 1964 to 2001. Linear regression line included.

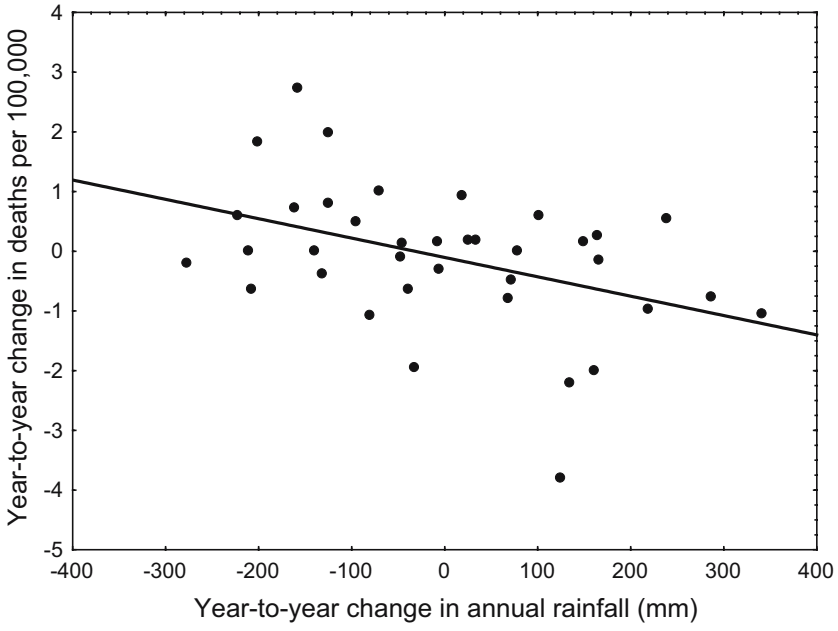

Fig. 3 Scatter diagram of year-to-year differences in New South Wales (NSW) suicide rate (per 100,000) versus year-to-year differences in NSW annual precipitation. Data from 1964 to 2001. Linear regression line included.

rent year. This was done using the 1964–2001 data. The regression equation was:

$$\begin{aligned}&\text{Rate(this year)}\\&\quad = 5.17 + 0.74\text{Rate(last year)}\\&\qquad - 0.00377\text{Precipitation(this year)}\end{aligned}$$

Both last year's suicide rate and this year's precipitation were statistically significant predictors [n=37; multiple r^2=0.67; p=0.02 for Precipitation (this year) and p<0.01 for Rate (last year)] in this equation.

Discussion

These results support the assumption that drought increases the suicide rate in NSW. There are several mechanisms through which low rainfall, including drought, may plausibly increase the suicide rate. First, a drought increases the financial stress on farmers and is likely to be especially burdensome if occurring in conjunction with other economic stresses, such as large loans, high interest rates, or low commodity prices. As well, the stress associated with having to sell or in some cases physically destroy starving animals or otherwise dispose of valued stock, often nurtured for generations, would take its toll on farmers and their families, including by reducing the cultural ecosystem services of stock (Butler et al. 2003). More widely, a reduction in rainfall, especially its most extreme manifestation—drought—depresses rural economic activity on both farm and in rural towns. In some cases, the national and urban economy is also harmed by drought.

Rural downturns associated with droughts are also likely to accelerate migration to urban areas, enhancing rural depopulation (especially of young women) and leading to reduced social interaction and ever more stressed support systems. Counter measures, such as extenuating circumstances (which include drought assistance) packages and counselling are unlikely to fully compensate these adverse effects.

The concern that rural stress can contribute to a higher rate of suicide in Australian farming populations is supported by Page and Fragar (2002). These workers reported rates of suicide substantially higher than the general Australian population in both male farm managers (24.8–51.4/100,000) and male agricultural workers (23.5–41.9/100,000) during the period 1988–1997. They also found that the rate increased over this period, but they did not examine the relationship between suicide and rainfall.

In the data in our study, the actual association of precipitation (as indicator variable) on suicide rate is quite small relative to other influences. This is indicated by the modest correlations, the large scatter around the regression lines in Figs. 2 and 3, and the existence of very strong, long-term variations in suicide rates (Fig. 1) that are not generally associated with changes in precipitation. It is plausible that the adverse psychological impact of drought in NSW has been mitigated by counter-measures, including governmental economic assistance, which attenuate the harmful effect. We also recognise that suicide is an extreme psychological event, a measurable indicator of a much larger, but less quantifiable, degree of human suffering.

It should also be noted that the current study does not differentiate between deaths in rural and urban areas and thus does not directly address the question of whether drought leads to increased rural suicide. Further research is underway to examine the differences in the relationship between precipitation and suicide rates by gender and by rural and urban status in NSW, and it is also intended to undertake similar studies in other Australian states. Finally, a more detailed study of the seasonality of the rainfall–

suicide relationship will be undertaken to investigate, inter alia, whether the analysis presented here may disguise the effects of shorter droughts.

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References

Burnley IH (1994) Differential and spatial aspects of suicide mortality in New South Wales and Sydney, 1980 to 1991. Aust J Public Health 18:293–303

Butler CD, Chambers R, Chopra K et al (2003) Ecosystems and human well-being. In: Millennium Ecosystem Assessment (ed) Ecosystems and human well-being. A framework for assessment. Island Press, Washington, pp 71–84

Conway JK (1990) The Road from Corain. Alfred A Knopf, New York NY

Deisenhammer EA (2003) Weather and suicide: the present state of knowledge on the association of meteorological factors with suicidal behaviour. Acta Psychiatr Scand 108:402–409

Deisenhammer EA, Kemmler G, Parson P (2003) Association with meteorological factors with suicide. Acta Psychiatr Scand 108:455–459

Dixon KW, Shulman MD (1983) A statistical investigation into the relationship between meteorological parameters and suicide. Int J Biometeorol 27:93–105

Morrell S, Page A, Taylor R (2002) Birth cohort effects in New South Wales suicide, 1865–1998. Acta Psychiatr Scand 106:365–372

Oliver R, Hetzel B (1972) Rise and fall of suicide rates in Australia: relation to sedative availability. Med J Aust 2:919–923

Page A, Fragar L (2002) Suicide in Australian farming, 1988–1997. Aust NZ J Psychiatry 36(1):81–85

Plesko N, Jasprica-Hrelec V, Bosan-Kilibarda I, Banek B (1991) Correlation of psychosis and suicide attempts with meteorological factors. Hrvat Meteorol Cas 26:77–86

Preti A (1998) The influence of climate on suicidal behaviour in Italy. Psychiatry Res 78 (1–2):9–19

Stack S (2002) Political regime and suicide: some relevant variables to be considered. J Epidemiol Community Health 56:727