Author's Accepted Manuscript

Effects of prenatal maternal stress on birth outcomes following tropical cyclone Yasi in Queensland, Australia (2011)

Cynthia Parayiwa, Alison M Behie

PII: S2212-4209(18)30155-9
DOI: <https://doi.org/10.1016/j.ijdr.2018.02.005>
Reference: IJDRR787

To appear in: *International Journal of Disaster Risk Reduction*

Received date: 18 May 2017
Revised date: 2 February 2018
Accepted date: 2 February 2018

Cite this article as: Cynthia Parayiwa and Alison M Behie, Effects of prenatal maternal stress on birth outcomes following tropical cyclone Yasi in Queensland, Australia (2011), *International Journal of Disaster Risk Reduction*, <https://doi.org/10.1016/j.ijdr.2018.02.005>

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting galley proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Effects of prenatal maternal stress on birth outcomes following tropical cyclone Yasi in Queensland, Australia (2011)

Running head: BIRTH OUTCOMES FOLLOWING TROPICAL CYCLONE YASI

Effects of Prenatal Maternal Stress on Birth Outcomes Following Tropical Cyclone Yasi in
Queensland, Australia (2011)

Cynthia Parayiwa^{1*} and Alison M Behie¹

The Australian National University

¹School of Archaeology and Anthropology, A.D. Hope Building, The Australian
National University, 14 Ellery Crescent, Acton, ACT, 2601, Australia.

*Corresponding Author: Cynthia Parayiwa

Email: cynthia.parayiwa@gmail.com

Postal address: 11/115 Lampard Circuit, Bruce, ACT, 2617, Australia.

Abstract

Tropical cyclones cause widespread devastation while having a negative impact on human health and well-being. Maternal exposure to prenatal environmental stressors can lead to a shift in reproductive strategies. This study aims to statistically analyse maternal and infant health risks by studying birth outcomes following maternal prenatal exposure to tropical cyclone Yasi in Queensland, Australia. Queensland state birth records collected under the

Australian National Perinatal Data Collection from January 2008 to December 2012 were analysed. A confounder controlled binary logistic regression model was used to statistically compare birth weight and gestation length in cyclone Yasi affected and unaffected Queensland local government areas (LGAs). Women in cyclone Yasi affected LGAs, had a significantly higher proportion (9.6%, $p=0.008$) and significantly higher odds (OR=1.26, 95% CI: 1.06 – 1.47) of having a preterm birth, compared to women in unaffected LGAs (7.9%). Women in affected LGAs during the year of cyclone Yasi (2011) also had a higher proportion of low birth weight births compared to women in the same LGAs during non-cyclone Yasi years (2008,2009,2010,2012). Our study supported a significant increase in the proportion of preterm births recorded for women pregnant in areas severely affected by cyclone Yasi. Our findings, and similar future research, will continue to inform the development of effective post-disaster perinatal health related policies and the continued improvement of disaster risk mitigation for vulnerable groups.

Key Words: stress, pregnancy, preterm, low birthweight, cyclone

Significance

Experiencing an environmental disaster can have a lasting negative impact on human health. Research has long supported the impact of maternal prenatal stressors on both maternal and infant perinatal health. Maternal stressors experienced in the wake of environmental disasters by pregnant women can result in restricted foetal development and pregnancy progression resulting in increased cases of lowered infant birth weight and preterm births. Understanding the potential impacts of perinatal environmental disaster exposure can inform key decision

makers and assist in future planning of pre- and post-disaster support leading to a reduction in the stressors experienced by pregnant women.

In Australia, such studies remain limited with no research currently available regarding perinatal health outcomes following Australian tropical cyclones. This study aimed to contribute towards filling this knowledge gap and overcoming previous study limitations with a more robust multivariate statistical model that allowed for the controlling of confounding variables.

Abbreviations

LBW – low birth weight

LGA – local government area

NPDC – National Perinatal Data Collection

OR – odds ratio

P-NMDS – Perinatal National Minimum Database

PNMS – prenatal maternal stress

1.

Introduction

On Thursday 3rd February 2011, tropical cyclone Yasi made landfall near Mission Beach, Queensland. A category five storm carrying heavy rains and damaging winds of up to 285km/h, Yasi was one of the most powerful cyclones to hit the Australian east coast since 1899 and the second most costly cyclone to strike Queensland after Cyclone Tracey in 1974 [1]. An estimated 150 homes were lost and 650 were left uninhabitable [2] with total damage

costs estimated at AU\$3.5 billion [3, 4]. Changes to disaster response protocol following cyclone Tracey lead to the early evacuation of over thirty thousand people before Yasi struck resulting in a single fatality [1]. Despite a reduction in the loss of lives directly linked to Yasi, experiencing an environmental disaster would still present widespread psychological and physical trauma due to financial losses, structural damage and widespread population displacement [5, 6]. It is therefore crucial to understand the risks faced by affected groups, notably those with increased vulnerability due to pregnancy.

In addition to the physical pressures placed on the human body during and after a disaster, survivors can further experience an increase in psychological stressors associated with the loss of possessions and financial stability. Pregnant women are particularly vulnerable as they are already physiologically taxed supporting foetal development [7]. Constant fluxes of regulatory hormones throughout gestation make pregnant women highly susceptible to the effects of stress [8-11]. Disaster related prenatal maternal stress (PNMS) has been associated with negative health impacts on both the mother and child. Such impacts can present as low birth weight (LBW) babies born at less than 2,500g and preterm births born at less than 37 weeks gestation [12, 13]. LBW has been long regarded as a strong indicator of infant health and has been frequently used as a predictor of mortality within the baby's first year [14], while both LBW and preterm births can result in increased morbidity throughout childhood [15, 16]. With a predicted rise in the number and intensity of environmental disasters associated with climate change, research into the effects of PNMS from such events is becoming a crucial contribution to inform policy and support effective disaster response strategies.

PNMS has been supported as causing physiological changes to the intrauterine environment, preterm deliveries, and inhibiting foetal growth [17, 18]. The negative impact of disasters on pregnancy outcomes has been widely reported following hurricanes in America, typhoons in the Philippines and the 2009 Black Saturday bushfires and the 2010 Queensland floods in Australia where an increase early births and lighter babies was observed [19-22]. Tropical cyclones are further closely associated with heavy flooding which frequently affects Queensland's tropical regions. Flooding similarly presents stressors due to displacement, isolation from services and the introduction of infected flood waters. Significantly higher cases of both LBW and preterm births have been recorded in women affected by heavy flooding such as during the 2011 Thailand floods, the 1997 Red River flood in North Dakota, USA and the 1997 flooding of the Klodzko Region in Poland [23-25].

Between 1967 and 1999, over half of the environmental disasters experienced in Australia were severe tropical storms, yet no studies have explored their impact on reproductive outcomes. This is despite the first of seven long term objectives identified by Australian state and territory governments being that, "Australians are born healthy and remain healthy" [26]. Often organisations and governments fail to anticipate lasting effects of disasters and this can result in miscalculated decisions such as the premature withdrawal of support services [27]. As environmental disasters remain to be strongly considered a perinatal health risk, this study aims to support the negative impact of maternal prenatal exposure to cyclone Yasi through a statistical analysis of birth weight and gestation length.

2.

Method

State legislation requires data on pregnancies and births in hospitals, birth centres and the community of each state and territory within Australia be collected under the National Perinatal Data Collection (NPDC) [28]. The NPDC incorporates the Perinatal National Minimum Data Set (P-NMDS) which is a standardised set of data elements agreed upon by the National Health Information Management Group for mandatory collection and reporting. We obtained perinatal data from the Queensland State Health Department with all births recorded within the Queensland NPDC from January 2008 to December 2012, inclusive ($n=311,389$).

The Queensland NPDC includes information on births, both live and stillborn, of at least 20 weeks gestation and 400g birth weight [29]. All births recorded are irrespective of maternal characteristics such as age, ethnicity, disability and socioeconomic background. Miscarriages, medically defined as fetal loss at <20 weeks gestation, were resultantly out of scope for this study due to P-NMDS data limitations. Stillbirths, defined in the P-NMDS as fetal death at >20 weeks gestation or a >400g birthweight, were excluded from analysis. This was based on preliminary analysis supporting stillbirths having a significant association ($p<0.001$) with LBW and preterm births but making up only less than 1% of sampled births.

As maternal residence was used to establish cyclone Yasi affectedness based on geography, and following O'Donnell and Behie, 2013, we removed women whose usual state of residence was not Queensland. We then divided the remaining births based on the mother's recorded area of usual residence, at the sub-state local government area (LGA) level, and then split LGAs into those affected or unaffected by cyclone Yasi in 2011. Literature supports the significance of when, during pregnancy, prenatal stressors are experienced [21, 30]. To factor this, we further grouped births into cohorts based on the

estimated pregnancy trimester during the month of the cyclone. As January births would occur prior to cyclone Yasi and December births would be over 9 months after Yasi they were excluded as there was a low chance their gestation period would have coincided with the cyclone. For non-cyclone Yasi years, we divided births based on the month groupings used for 2011 cohort analysis (Table 1).

Table 1. Estimated trimester birth groupings by birth year, birth month and gestation age.

Gestational age	Cyclone Yasi Year (2011)		Non-Cyclone Year (2008, 2009, 2010, 2012)	
	Trimester	Birth month (inclusive)	Group	Birth month (inclusive)
0 weeks – 12 weeks	1	August –November (2011)	1	August – November (2008, 2009, 2010, 2012)
13 weeks – 26 weeks	2	May– July (2011)	2	May – July (2008, 2009, 2010, 2012)
27 weeks – 40 weeks	3	February– April (2011)	3	February – April (2008, 2009, 2010, 2012)

Note: Birth record groupings for analysis run on births during the year of cyclone Yasi (2011) and non-cyclone Yasi years (2008, 2009, 2010, 2012). Pregnancy trimester during month of cyclone Yasi, February 2011, estimated off recorded birth month. During non-cyclone years, births grouped based on estimated gestational age during February of each year as proxies for trimester exposure during 2011.

Low birth weight (LBW) was defined using the World Health Organization's (WHO) classification of birth weights recorded at less than 2,500g. Preterm births were defined using the WHO classification of any live births recorded at less than 37 weeks gestation. As LBW and preterm births can occur for a variety of reasons, we screened our data and identified seven confounding variables, based on *a priori* analysis of literature, collected in the NPDC (Table 2). Confounders were controlled for using a binary logistic regression model. Regression analysis provides a statistical model commonly applied in relational studies such as those investigating disasters and pregnancy outcomes. The model effectively allows for the inclusion of known confounders of pregnancy independent of the disaster to better present disaster related outcomes [23, 31]. A notable limitation of research into disasters and pregnancy outcomes is the use of inconsistent sampling and statistical methodologies across separate studies. Regression modelling selected for this study continues to be effectively applied in a number of causal studies including those investigating birth outcomes and

disasters [30]. All analysis was run in IBM's Statistical Package for the Social Sciences (SPSS) version 22 with a set 95% confidence interval and an alpha of 0.05.

Statistical analysis included the conversion of all research variables into binary variables with 1 = condition present and 0 = condition not present or not reported as done by Zahran et. al, 2010. Maternal residence determined stress experienced based on geographic location therefore LGAs were categorised into binary variables based on cyclone Yasi impact (1 = affected and 0 = unaffected). Cases of LBW and preterm births were also entered as binary dependent variables with the odds of their occurrence in affected LGA's analysed while adjusting based on confounders.

Table 2. Selected confounders of preterm and low birth weight births available through the perinatal national minimum dataset (P-NMDS), presented with supporting literature.

Confounder	Notes
<i>Maternal age</i>	Advanced maternal age, women aged 35 yrs and above, has a supported association to obstetrical and perinatal complications [32, 33]. Research has supported that women aged 35 yrs and older are significantly more likely to experience miscarriages and experience negative birth outcomes such as low birthweight and preterm births [34]. 1 = > 35yrs, 0 = <35 yrs.

<i>Maternal ethnicity</i>	Represented by maternal Aboriginal and Torres Strait Islander status as entered in the P-NMDS. Within Australia, Indigenous status is highly associated to lower socio-economic status and an increased risk of perinatal health complications [35, 36]. 1 = Indigenous, 0 = Non-Indigenous.
<i>Maternal marital status</i>	Maternal marital status can influence access to resources and financial stability supporting increased prenatal maternal stress due to a limited support network during pregnancy [37]. 1 = Married, 0 = Unmarried.
<i>Maternal smoking status (at any point during pregnancy)</i>	Smoking during pregnancy has a supported association with cases of miscarriage/perinatal mortality, low birth weight, and premature births [38]. 1 = Yes, 0 = No.
<i>Antenatal care provided</i>	Regular maternal health screening for sexually transmitted infections, high blood pressure, and diabetes in addition to the monitoring of maternal behavioural changes during pregnancy can reduce the rate of adverse birth outcomes [39, 40]. 1 = Yes, 0 = No.
<i>Plurality</i>	A 2014 survey of Australian women supported low birth weight in over half of live-born twin births (53.1%) and in almost all higher order multiple births (96.0%) compared with 4.8% low birth weight cases in singleton births [26]. 1 = Singleton, 0 = Multiple (twins or higher order).
<i>Infant sex</i>	Infant sex has been supported as having varied adverse effects on birth weight, infant mortality and morbidity. Specifically, male foetus have been repeatedly supported as being more sensitive, <i>in utero</i> , to maternal stressors [41, 42]. 1 = Female, 0 = Male.

A proxy for maternal cyclone Yasi exposure related stress was developed using an assessment of cyclone impact levels in different Queensland LGAs. Assessment was based on requests for disaster relief assistance under the Commonwealth/State Natural Disaster Relief Recovery Arrangements (NDRRAs). We identified 11 LGAs as severely affected by the cyclone based on an activation of over 90% of the available NDRRAs (Figure 1) [43].

Figure 1. A map of Queensland local government areas (LGAs) with shaded regions indicative of LGAs severely affected^a by cyclone Yasi (February 2011) (Burdekin, Cairns, Cassowary Coast, Charters Towers, Croydon, Etheridge, Hinchinbrook, Palm Island, Tablelands, Townsville, Yarrabah).

a. Cyclone impact based on a recorded activation of over 90% of available assistance requests through the Natural Disaster Relief and Recovery Arrangement (NDRRA), as of May 2011 (NDRRA, 2011).

Studies support an association between geographic proximity to a disaster and adverse birth outcomes [44]. We analysed births recorded in 2011 by grouping them into affected and unaffected LGAs based on the maternal usual residence. The odds ratio (OR) for observing LBW and preterm births for pregnancies in these two groupings was calculated for women categorised by their estimated trimester in February 2011 (Table 1). To statistically compare births during the year of cyclone Yasi and non-cyclone years, we divided all births into those during 2011 and grouped births in 2008, 2009, 2010 and 2012 (Figure 2). Within these two periods, we analysed births in affected LGAs to determine whether there was a significant change in birth outcomes for women in the same areas based on the period they were pregnant. Like the first model, the OR for observing a LBW or preterm birth in 2011 was calculated within affected LGAs and compared to these birth outcomes in the same areas in other years.

Figure 2. A flow chart of developed birth sample groupings by Queensland local government area (LGA) of usual residence, birth year, and pregnancy trimester during February, month of 2011 cyclone Yasi (February used as control month in all other years). Groups statistically analysed in this study taken from severely affected LGAs.

3.

Results

Pregnant women, in their first trimester, who were residing in LGAs severely affected by cyclone Yasi had a significantly higher proportion (9.6%, $p=0.008$) and higher odds of having a preterm birth, even after adjustment for confounding variables (OR=1.26, 95% CI: 1.06 – 1.49) compared to women in unaffected LGAs (7.9%) (Figure 3 and Table 3a). No statistically significant variation in preterm births was observed for women in their second or third trimester. We also found no significant variation in the proportions and odds of having a LBW birth in affected and unaffected LGAs across all three trimester groups.

Figure 3. A comparative bar graph of the proportion of preterm births recorded in 2011 for women in Queensland local government areas (LGAs) affected and unaffected by cyclone Yasi by trimester reached during month of cyclone Yasi (February 2011).

ACCEPTED MANUSCRIPT

We further found a higher proportion of LBW births recorded for women residing in affected LGAs in their second trimester in February 2011 when compared to births in the same LGAs in non-cyclone Yasi years, 7.2% and 6.2% respectively, $p = 0.073$ (Figure 4 and Table 3b). While not significant with $p > 0.05$, and a small sample size, this still represents a notable trend. There was no significant support for a change in LBW births for the first and third trimester pregnancies and preterm births between the study years.

Figure 4. A comparative bar graph of the proportion of low birth weight (LBW) births recorded for women in Queensland local government areas (LGAs) affected by cyclone Yasi, by birth year (year of the cyclone Yasi (2011) and non-cyclone Yasi years (2008,2009,2010,2012)) and birth month.

Source: Queensland Perinatal Data Collection, 2008–2012

4.

Discussion

This study aimed to investigate birth outcomes of women prenatally exposed to cyclone Yasi in Queensland, Australia. We found that women residing in Yasi affected areas in their first trimester had higher odds of having a preterm birth than women residing in unaffected areas. Increased cases of preterm births following disaster related stress can be explained using the evolutionary life history theory and the presence of a trade-off of between current vs. future reproduction. The presence of evolved maternal reproductive trade-offs would support that resource restrictions in unstable environments would create an unpredictable *in- utero* environment. To prioritise survival and future reproduction, a maternal energy investment shift away from supporting pregnancy progression would lead to an increase in the energy available for the pregnant woman to survive for future reproduction, despite resulting in lower quality offspring. Preterm births would allow for the birth of viable offspring, however, the crucial final weeks of gestation (that include foetal fat accumulation and brain development) would be missed, along with the associated maternal energy investment [45]. Higher odds of preterm births in cyclone Yasi affected women are further in line with findings in existing literature around increased preterm births following environmental disasters [21, 30, 46]. There is, however, a level of contention within present literature regarding the specific triggers and regulators of parturition [39].

Premature births are thought to result from a variety of factors affecting the uterine cervix, fetal membranes, placenta or myometrium resulting in an activation before 37 weeks gestation of the parturition pathway [47]. Factors medically associated with the premature triggering of this pathway are complex and include genetic predisposition, infection, disease, pregnancy complications or stress [48]. Following a cyclone, such risk factors can be

amplified by polluted flood waters and structural damage limiting access to medical care services. The complexity of not only the biology behind human parturition but also its premature activation would therefore need to be carefully considered when associating preterm births with women residing in cyclone Yasi affected areas. While not the goal of this study, future studies aiming to explore the specific cause of this activation following a disaster would benefit from evaluating stressors experienced by women in affected areas in consultation with high risk obstetrics to improve our current understanding of the medical position on birth outcomes and their drivers.

The infant health risks associated with preterm births are commonly and closely connected with those for low birth weight (LBW) births making it rare to observe one outcome without the other [46]. Lower quality offspring resulting from a maternal energy shift in unpredictable environments could also present as LBW babies [49]. We found that women in affected LGAs had a higher proportion of LBW births during the year of cyclone Yasi (2011) compared to births recorded in the same areas during non-cyclone years (2008–2010 & 2012). The proportion of LBW births recorded in Yasi affected areas in 2011 further exceeded Queensland state-wide proportions for LBW births, recorded over the same period, ranging from 6.3% in 2008 to 6.6% in 2012 [28].

Increased cases of LBW births following exposure to tropical storms have been previously found in studies following hurricane Katrina in America and typhoons in the Philippines [19, 20] and have been attributed to prenatal maternal stress (PNMS). Our results would, however, need to be interpreted with caution given that despite controlling for other confounders of birth weight (Table 2), maternal stress was only inferred from maternal geographic location. That said, with LBW being associated with an increase in infant

mortality and morbidity [46], it is crucial to acknowledge the potential risks faced by pregnant women in areas susceptible to cyclones as a way to better understand the environmental drivers governing these birth outcomes.

Adherence to human research ethics protocols resulted in limitations in the data provided. Continuous variables such as birthweight were provided as grouped variables to avoid re-identification and during analysis all study variables were further grouped into binary variables restricting results to only binary responses. The exclusion of stillbirths, though justified in section 2, is acknowledged as introducing selection bias to our sample which needs to be considered in future analysis [30]. As the human stress response can be subjective and therefore complex to analyse, finding a proxy for cyclone related stress without individual survey data or biological samples was difficult. Without records of individual experience, any proxy selected to represent maternal stress would be working upon the assumption that women recorded as residing in affected LGAs experienced trauma based on their geographic proximity to the disaster. Using the Queensland Natural Disaster Relief and Recovery Arrangement (NDRRA) activations allowed for an effective measure of the level of financial and infrastructural assistance given at the LGA level but not individual stress experienced as a result. Future research will benefit from qualitative stress data, such as interviews, which can provide insights into a pregnant woman's experiences during a disaster capturing stressors due to feelings of guilt, uncertainty, future prospects and fractured social networks making them an aim of our future research [50].

Isolating risk factors can help to develop effective, situation-specific interventions to improve the perinatal health of Australians. It further provides insight into mechanisms contributing to adverse birth outcomes; particularly after something as unpredictable, yet

common, as experiencing an environmental disaster [51]. When developing disaster related policies within Australia, state and territory governments are involved in planning relevant laws, organising emergency services, developing effective action plans, and educating the public to minimise risk of injury [52]. This study aims to provide population specific analysis that would need to be considered at all these points of governance within Queensland when conducting future cyclone related risk assessment.

5.

Conclusion

At the 2015 United Nations conference world leaders gathered to tackle poverty, inequality, and climate change. They adopted the 2030 Agenda for Sustainable Development made up of 17 Sustainable Development Goals (SDGs) that aim to improve global health and wellbeing in a continuously changing environment [53]. This research's objectives and findings look to support the SDGs by contributing towards the knowledge base required for an informed reduction of climate related health risk and the improvement of maternal and infant health.

Given this study's support of a significant increase in preterm births to women residing in cyclone Yasi affected Queensland LGAs, the need for ongoing prioritisation of climate related health risks and the improvement of perinatal health was also supported. Because of the potential threat posed by environmental disasters to maternal and infant health it becomes more crucial to acknowledge and continue research of this nature to support the development of more robust and effective health policies and disaster management schemes.

Ethical Statement

Full human ethical approval (unconditional) was granted by the Australian National University Human Research Ethics Committee under protocol #2015/162. In order to access health data held by Queensland Health for approved research projects the *Public Health Act 2005* (PHA) required was granted by the Director-General of Queensland Health.

Acknowledgements

We would like to thank Dr Geoff Kushnick and Dr Megan O'Donnell from The Australian National University for their helpful comments on previous drafts of this research paper. We would further like to thank Professor Alexander and two anonymous reviewers from the International Journal for Disaster Risk Reduction for providing invaluable feedback on a previous version of this Manuscript. The findings and views reported in this paper are those of the author and should not be attributed to The Queensland State Health Department, to whom we are grateful for data access. We also wish to thank Pauline Ding at the ANU Statistical Consulting Unit for her valuable guidance with our statistical methods.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

- [1] Rowlands, A., *Disaster recovery management in Australia and the contribution of social work*. Journal of Social Work in Disability & Rehabilitation, 2013(12): p. 19-38.DOI: <https://doi.org/10.1080/1536710x.2013.784173>.
- [2] O'Brien, C. and M. Howells. *Disaster Damage Bill to Cost Queensland Almost \$1.5b*. ABC News 2011 [cited 2014 28 October]; Available from: <http://www.abc.net.au/news/2011-02-16/disaster-damage-bill-to-cost-queensland-almost-15b/1946092>.
- [3] Hurst, D. *Yasi Bill Revealed: \$800 Million in Damages*. Brisbane Times 2011 [cited 2014 28 October]; Available from: <http://www.brisbanetimes.com.au/queensland/yasi-bill-revealed-800-million-in-damages-20110216-1avvu.html>.
- [4] Rowlands, A., *Disaster recovery management in Australia and the contribution of social work*. Journal of Social Work in Disability & Rehabilitation, 2013. **12**(1-2): p. 19-38.DOI: <https://doi.org/10.1080/1536710x.2013.784173>.
- [5] Steinglass, P. and E. Gerrity, *Natural disasters and post-traumatic stress disorder short-term versus long-term recovery in two disaster-affected communities*. Journal of Applied Social Psychology, 1990. **20**(21): p. 1746-1765.DOI: 10.1111/j.1559-1816.1990.tb01509.x.
- [6] Cordero, J.F., *The epidemiology of disasters and adverse reproductive outcomes: lessons learned*. Environmental Health Perspectives, 1993. **101**(Suppl 2): p. 131-136.DOI: 10.1289/ehp.93101s2131.
- [7] Middelmann, M.H., *Natural Hazards in Australia : Identifying Risk Analysis Requirements*. 2007, Australian Government: Canberra.
- [8] Ellison, P.T., *On fertile ground: a natural history of human reproduction*. 2009: Harvard University Press.
- [9] McEwen, B.S., *Protection and damage from acute and chronic stress: allostasis and allostatic overload and relevance to the pathophysiology of psychiatric disorders*. Annals of the New York Academy of Sciences, 2004. **1032**(1): p. 1-7.DOI: <https://doi.org/10.1196/annals.1314.001>.
- [10] Lukanova, A., et al., *Insulin-like growth factor I in pregnancy and maternal risk of breast cancer*. Cancer Epidemiology Biomarkers & Prevention, 2006. **15**(12): p. 2489-2493.DOI: 10.1158/1055-9965.EPI-06-0625
- [11] Hedegaard, M., et al., *Psychological distress in pregnancy and preterm delivery*. BMJ, 1993. **307**(6898): p. 234-239.DOI: <https://doi.org/10.1136/bmj.307.6898.234>.
- [12] King, S., et al., *Using Natural Disasters to Study the Effects of Prenatal Maternal Stress on Child Health and Development*. Birth Defects Research Part C: Embryo Today: Reviews, 2012. **96**(4): p. 273-288.DOI: 10.1002/bdrc.21026.
- [13] Cao-Lei, L., et al., *DNA Methylation Signatures Triggered by Prenatal Maternal Stress Exposure to a Natural Disaster: Project Ice Storm*. PLoS ONE, 2014. **9**(9): p. e107653.DOI: 10.1371/journal.pone.0107653.
- [14] Mace, R., *Evolutionary ecology of human life history*. Animal Behaviour, 2000. **59**(1): p. 1-10.DOI: <https://doi.org/10.1006/anbe.1999.1287>.
- [15] Goldenberg, R.L., et al., *Epidemiology and causes of preterm birth*. The Lancet, 2008. **371**(9606): p. 75-84.DOI: [https://doi.org/10.1016/S0140-6736\(08\)60074-4](https://doi.org/10.1016/S0140-6736(08)60074-4).
- [16] McIntire, D.D., et al., *Birth weight in relation to morbidity and mortality among newborn infants*. New England Journal of Medicine, 1999. **340**(16): p. 1234-1238.DOI: <https://doi.org/10.1056/nejm199904223401603>.

- [17] DiPietro, J.A., *Maternal stress in pregnancy: considerations for fetal development*. Journal of Adolescent Health, 2012. **51**(2, Supplement): p. S3-S8.DOI: <http://dx.doi.org/10.1016/j.jadohealth.2012.04.008>.
- [18] Mulder, E.J., et al., *Prenatal maternal stress: effects on pregnancy and the (unborn) child*. Early Human Development, 2002. **70**(1): p. 3-14.DOI: [https://doi.org/10.1016/s0378-3782\(02\)00075-0](https://doi.org/10.1016/s0378-3782(02)00075-0).
- [19] Xiong, X., et al., *Exposure to Hurricane Katrina, post-traumatic stress disorder and birth outcomes*. The American Journal of the Medical Sciences, 2008. **336**(2): p. 111-115.DOI: <https://doi.org/10.1097/maj.0b013e318180f21c>.
- [20] Morrow, S., *Typhoons and lower birth weight in the Philippines*, in *Economics*. 2014, University of San Francisco.
- [21] O'Donnell, M.H. and A.M. Behie, *Effects of bushfire stress on birth outcomes: A cohort study of the 2009 Victorian Black Saturday bushfires*. International Journal of Disaster Risk Reduction, 2013. **5**(0): p. 98-106.DOI: <http://dx.doi.org/10.1016/j.ijdrr.2013.08.002>.
- [22] McFarlane, L. and A. Behie, *The effects of parental stress on birth outcomes following the 2010 - 2011 Queensland floods*, in *College of Arts and Social Sciences*. unpublished results, The Australian National University: ongoing study.
- [23] Tong, V.T., M.E. Zotti, and J. Hsia, *Impact of the Red River catastrophic flood on women giving birth in North Dakota, 1994–2000*. Maternal and Child Health Journal, 2011. **15**(3): p. 281-288.DOI: <https://doi.org/10.1007/s10995-010-0576-9>.
- [24] Sanguanklin, N., et al., *Effects of the 2011 flood in Thailand on birth outcomes and perceived social support*. Journal of Obstetric, Gynecologic, & Neonatal Nursing, 2014. **43**(4): p. 435-444.DOI: <https://doi.org/10.1111/1552-6909.12466>.
- [25] Neuberg, M., et al., *The analysis of the course of pregnancy, delivery and postpartum among women touched by flood disaster in Kotlin Kłodzki in July 1997*. Ginekologia polska, 1998. **69**(12): p. 866-870.
- [26] Hilder, L., et al., *Australia's Mother's and Babies 2012*, in *Perinatal Statistics Series*. 2014, Australian Institute of Health and Welfare: Canberra.
- [27] Isaranuwatthai, W., et al., *Patterns of health service utilization following the Tsunami in Thailand*. International Journal of Disaster Risk Reduction, 2016. **20**: p. 14-18.DOI: <https://doi.org/10.1016/j.ijdrr.2016.09.011>.
- [28] AIHW, *Australia's Mothers and Babies*, in *Perinatal Statistics Series*. 2008-2012, Australian Institute of Health and Welfare: Canberra.
- [29] AIHW, *Perinatal National Minimum Data Set: National Health Data Dictionary*, in *National Health Dictionary. Version 12*. 2003, Australian Institute of Health and Welfare: Canberra.
- [30] Zotti, M., et al., *Post-disaster reproductive health outcomes*. Maternal and Child Health Journal, 2013. **17**(5): p. 783-796.DOI: [10.1007/s10995-012-1068-x](https://doi.org/10.1007/s10995-012-1068-x).
- [31] Zahran, S., et al., *Maternal hurricane exposure and fetal distress risk*. Risk Analysis, 2010. **30**(10): p. 1590-1601.DOI: <https://doi.org/10.1111/j.1539-6924.2010.01453.x>.
- [32] AlShami, H.A., et al., *Pregnancy outcome in late maternal age in a high-income developing country*. Archives of Gynecology and Obstetrics, 2011. **284**(5): p. 1113-1116.DOI: <https://doi.org/10.1007/s00404-010-1821-6>.
- [33] McMahon, C.A., et al., *Age at first birth, mode of conception and psychological wellbeing in pregnancy: findings from the parental age and transition to parenthood Australia (PATPA) study*. Human Reproduction, 2011. **26**(6): p. 1389-1398.DOI: <https://doi.org/10.1093/humrep/der076>.

- [34] Cleary-Goldman, J., et al., *Impact of maternal age on obstetric outcome*. Obstetrics & Gynecology, 2005. **105**(5, Part 1): p. 983-990.DOI: 10.1097/01.AOG.0000158118.75532.51.
- [35] Fulda, K.G., et al., *Paternal race/ethnicity and very low birth weight*. BMC Pregnancy and Childbirth, 2014. **14**(1): p. 1.DOI: <https://doi.org/10.1186/s12884-014-0385-z>.
- [36] AIHW, *Birthweight of Babies Born to Indigenous Mothers*. 2014, Australian Institute of Health and Welfare: Canberra.
- [37] Sperlich, S., M.N. Maina, and D. Noeres, *The effect of psychosocial stress on single mothers' smoking*. BMC Public Health, 2013. **13**(1): p. 1.DOI: <https://doi.org/10.1186/1471-2458-13-1125>.
- [38] Hackshaw, A., C. Rodeck, and S. Boniface, *Maternal smoking in pregnancy and birth defects: a systematic review based on 173 687 malformed cases and 11.7 million controls*. Human Reproduction Update, 2011. **17**(5): p. 589-604.DOI: <https://doi.org/10.1093/humupd/dmr022>.
- [39] Dimes, M.O., *Born Too Soon: The Global Action Report on Preterm Births*, in *Save The Children*, C.P. Howson, M.V. Kinney, and J.E. Lawn, Editors. 2012, World Health Organisation: Geneva.
- [40] WHO, *Low Birthweight: Country, Regional and Global Estimates*. 2004, United Nations Children's Fund and World Health Organisation: New York.
- [41] Catalano, R., et al., *Selection against small males in utero: a test of the Wells hypothesis*. Human Reproduction, 2012. **27**(4): p. 1202-1208.DOI: <https://doi.org/10.1093/humrep/der480>.
- [42] Stevenson, D., et al., *Sex differences in outcomes of very low birthweight infants: the newborn male disadvantage*. Archives of Disease in Childhood-Fetal and Neonatal Edition, 2000(83): p. F182-F185.DOI: <https://doi.org/10.1136/fn.83.3.f182>.
- [43] NDRRA. *Disaster Event - Severe tropical Cyclone Yasi, 2 February 2011*. 2011 [cited 2015 23 May]; Available from: http://disaster.qld.gov.au/Financial%20Support/Documents/V20_Activation_Summary_TC_Yasi_Feb_11.pdf
- [44] Harville, E.W., et al., *Birth outcomes in a disaster recovery environment: New Orleans women after Katrina*. Maternal and Child Health Journal, 2015. **19**(11): p. 2512-2522.DOI: <https://doi.org/10.1007/s10995-015-1772-4>.
- [45] Pike, I.L., *Maternal stress and fetal responses: evolutionary perspectives on preterm delivery*. American Journal of Human Biology, 2005. **17**: p. 55-65.DOI: <https://doi.org/10.1002/ajhb.20093>.
- [46] Simeonova, E., *Out of sight, out of mind? Natural disasters and pregnancy outcomes in the USA*. CESifo Economic Studies, 2011. **57**(3): p. 403-431.DOI: <https://doi.org/10.1093/cesifo/ifr005>.
- [47] Torricelli, M., et al., *Epidemiology of early pre-term delivery: relationship with clinical and histopathological infective parameters*. Journal of Obstetrics and Gynaecology, 2013. **33**(2): p. 140-143.DOI: <https://doi.org/10.3109/01443615.2012.743980>.
- [48] Romero, R., et al., *The preterm parturition syndrome*. BJOG: An International Journal of Obstetrics & Gynaecology, 2006. **113**(s3): p. 17-42.DOI: 10.1111/j.1471-0528.2006.01120.x.
- [49] McEwen, B.S. and J.C. Wingfield, *The concept of allostasis in biology and biomedicine*. Hormones and Behavior, 2003. **43**(1): p. 2-15.DOI: [https://doi.org/10.1016/s0018-506x\(02\)00024-7](https://doi.org/10.1016/s0018-506x(02)00024-7).

- [50] Badakhsh, R., E. Harville, and B. Banerjee, *The childbearing experience during a natural disaster*. Journal of Obstetric, Gynecologic, & Neonatal Nursing, 2010. **39**(4): p. 489-497.
- [51] Currie, J. and M. Rossin-Slater, *Weathering the storm: hurricanes and birth outcomes*. Journal of Health Economics, 2013. **32**(3): p. 487-503.DOI: <https://doi.org/10.3386/w18070>.
- [52] Middlemann, M.H. and M. Middelmann, *Natural hazards in Australia: identifying risk analysis requirements*. 2007: Geoscience Australia.
- [53] UNDP. *A New Sustainable Development Agenda 2015* [cited 2017 May]; Available from: <http://www.undp.org/content/undp/en/home/sustainable-development-goals/background.html>.