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The Gulf oil spill, miscarriage, and infertility: The GROWH Study

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Abstract

Purpose—To examine whether reported exposure to the Gulf oil spill (2010) was related to reproductive reported miscarriage or infertility.

Methods—1524 women aged 18–45 recruited through prenatal and Women, Infant, and Children (WIC) clinics, and community events were interviewed about their experience of the oil spill and reproductive history. 1434 women had information on outcomes of at least one pregnancy, and 633 on a pregnancy both before and after the spill. Generalized estimating equations were used to examine the relationship between contact with oil and economic and social consequences of the spill with postponement of pregnancy, miscarriage, and infertility (time to pregnancy >12 months or reported fertility issues), with adjustment for age, race, BMI, smoking, and socioeconomic status. Results were compared for pregnancies occurring prior to and after the oil spill.

Results—77 (5.1%) women reported postponing pregnancy due to the oil spill, which was more common in those with high contact with oil or overall high exposure (aOR 2.92, 95% CI 1.31–6.51). An increased risk of miscarriage was found with any exposure to the oil spill (aOR, 1.54, 95% CI 1.17–2.02). Fertility issues were more common in the overall most highly exposed women (aOR 1.88, 1.19–2.95), when the data were limited to those with pregnancies before and after. However, no particular aspect of oil spill exposure was strongly associated with the outcomes, and effects were almost as strong for pregnancies prior to the oil spill.

Conclusions—The oil spill appears to have affected reproductive decision-making. The evidence is not strong that exposure to the oil spill was associated with miscarriage or infertility.

Keywords

petroleum; abortion; spontaneous; fertility; pregnancy

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Conflict of interest

The authors declare that they have no conflict of interest.

Introduction

The alarming reports that dolphins in Barataria Bay are failing to calve in the aftermath of the 2010 Gulf oil spill (Lane et al. 2015) added to the already-expressed concerns of community members that the oil spill could have had adverse effects on pregnant women (Goldstein et al. 2011). Whether such concern is plausible is not completely clear. Although to our knowledge no studies have examined the relationship between oil spills and miscarriage or infertility specifically, petroleum production has been a source of concern as a possible danger to perinatal health under other circumstances, such as in petrochemical plants and near fracking sites (Colorado Department of Public Health and Environment 2014; Schlanger 2014; Xu et al. 1998). The environmental toxicants that were most likely to have been released by the oil spill are volatile organic compounds (VOCs), heavy metals, and polyaromatic hydrocarbons (PAHs); evidence for effects of these pollutants on reproductive failure, represented hereby infertility and miscarriage, in humans is mixed, with occasional studies finding substantially increased risk, many studies finding no effect, consistent concerns about recall bias and confounding, and reviews generally concluding "limited or inadequate evidence" (Bukowski 2001; Dechanet et al. 2011; Duong et al. 2011; Hertz-Picciotto 2000; Pineles et al. 2014; Wigle et al. 2008).

Although chemical exposures are perhaps the most immediate concern, social effects should be considered as well. Many people lost employment and income due to the fishing bans and drilling moratorium (Aldy 2014). Others found the spill (and associated images, such as oil-soaked pelicans) to be distressing (Osofsky et al. 2011). Stressful life events in the first trimester have been linked to spontaneous abortion (Neugebauer et al. 1996), as have economic downturns (Bruckner et al. 2016). More general collective trauma studies have sometimes found an increase in miscarriage after floods or tsunami (Fujimori et al. 2014; Neuberg et al. 2001), but the difficulties of assembling a reasonable control group makes interpretation of these studies difficult. In this study, we explored whether reported exposure to the oil spill – either direct contact with oil or related stressors – was related to reported miscarriage or infertility.

Methods

Participants

The GROWH (Gulf Resilience on Women's Health) began in 2011; this analysis contains data collected through March 2016. Women were recruited from prenatal, health, and WIC clinics; day care centers; and community events and gathering places in southeastern Louisiana (targeting Lafourche, Plaquemines, St. Bernard, Terrebonne, and the West Bank of Jefferson and Orleans Parishes). Eligibility criteria include: aged 18–45, living in the Gulf area during the oil spill, and, if pregnant, carrying a singleton gestation. Women were interviewed, completed a questionnaire (usually on the spot, although taking it home and returning it by mail was allowed), and provided saliva and blood samples. 1620 filled out at least one questionnaire or interview, including 443 women who were pregnant at the time of the interview.

Measures

Exposures—Women were interviewed about their experience of the oil spill using measures from several sources, including questions about: (1) a participant's involvement in work on the clean-up and contact with oil, taken from the Gulf Workers' Study (National Institutes of Health); (2) direct exposure to the oil spill, taken from studies performed after the Exxon Valdez spill (Palinkas et al. 1993); (3) the social and economic effects of the oil spill, from a previous study (GUMBO, R03 NR012052), and (4) involvement in litigation, after Exxon Valdez studies (Palinkas et al. 1993; Picou et al. 2004). Confirmatory factor analysis was used to see if the patterns of grouping of similar response questions matched the underlying latent constructs: financial/income consequences; direct contact with oil (both dichotomized as any/none and none/some/a lot); oil spill-related trauma (damage to people or own property); loss of use of the coast (damage to areas where one or one's family fishes, boats, or goes to the coast or beach). In addition, separate variables for any exposure to the oil spill (0 versus 1) and total exposure to the oil spill (sum of the above individual experiences – money, direct contact, trauma, loss of use, and litigation, weighted equally; theoretical range was 0 to 10; range in this sample was 0 to 9) were created.

Outcomes—As part of a list of possible behavior changes due to the oil spill, women were asked, "As a result of the oil spill, have you postponed getting pregnant?" A second question included in the questionnaire was "Was there ever a time when you wanted to get pregnant, but weren't able to?", and, if so, how old was she when this happened. Based on her birthdate, this was translated into having occurred before or after the oil spill. Timings that were within six months of the oil spill and thus could not be precisely calculated as occurring before or after were omitted from analysis. All women were asked these questions, regardless of pregnancy history or status.

Each woman was also asked for a reproductive history including up to 8 pregnancies. Questions for participants included date of/age at each pregnancy and its outcome. The woman was also asked for how long she was having unprotected sex before she got pregnant (time to pregnancy [TTP]).

The start date of each pregnancy was determined to occur before (prior to April 20, 2010) or during or after the oil spill (on or after April 20, 2010). If the precise date of the start or end of pregnancy was not known (as was often the case for a miscarriage) and it was estimated to have occurred (based on age or year of occurrence) within 6 months of the oil spill, it was omitted from the analysis.

Sample

Reproductive decision-making—1524 women had data on at least one oil spill exposure and postponement of pregnancy (women lost to follow-up were less likely to be black ($p<0.01$) and older (mean difference 3.3 years, $p=0.02$); there were no differences in parity, income, BMI, pregnancy status, or parish of residence). Oil spill exposure was examined as a predictor of postponing pregnancy using logistic regression, first unadjusted, then with control for age at interview (continuous), BMI (continuous), race, income

(ordinal), education (ordinal), smoking (recent/not), year of interview, and age at first pregnancy (set to the mean for those with no pregnancies).

Miscarriage and infertility—1434 women reported on the outcome of at least one pregnancy, and for 1419 women (3504 pregnancies) these could be dated. 633 of these women had outcome data on a pregnancy both before and after the spill; compared to the women with pregnancies in only one time period, these women were more likely to be older, more parous, and from Jefferson or St. Bernard Parish (no differences in BMI, smoking status, income, or race).

The infertility analysis draws on two sources of information: reported time periods when a woman wished to become pregnant but was not able to, and TTP for each pregnancy. For the first analysis, fertility issues were defined as attempting pregnancy for ≥12 months, either with a "yes" response to the question "Was there ever a time when you wanted to become pregnant, but were not able to?" and answer to the follow-up question of "one year or more", or a reported TTP ≥ 12 months for any pregnancy. The analysis was limited to those who were 18 years or older at the time of the oil spill, and women with untested fertility (operationalized as "no" to the attempting pregnancy question and no reported pregnancies; n=41) were excluded as well. This left 1164 total women with post-oil spill data and 1046 women with pre- and post-oil spill data.

Statistical analysis

To examine whether any relationships seen could be attributed to correlated errors or reporting, we examined pregnancies both before and after the oil spill. As the oil spill could not be the cause of pregnancy outcomes that occurred prior to the spill, this provides a check as to whether certain women are systematically likely to report both greater exposure to the oil spill and greater risk of the outcomes (or vice versa). A subanalysis was limited to women with data about pregnancies or infertility both before and after the spill, to allow for a repeated-measures analysis.

First, the woman's whole history was considered. For miscarriage, all pregnancies were examined. For infertility, pregnancies and the time period of attempting pregnancy were categorized as occurring prior to or after the pregnancy. Pregnancies/time periods prior to the oil spill were categorized as unexposed, while pregnancies after the oil spill categorized as exposed or unexposed, depending on the particular indicator under study. Generalized estimating equations, logistic models with an autoregressive correlation matrix, were used to control for correlation within woman (up to 8 pregnancies/woman for miscarriage, 2 observations/woman for infertility). Both unadjusted and adjusted logistic regression were used, Models of miscarriage were adjusted for age at pregnancy (continuous), gravidity at that pregnancy, BMI (continuous), income (ordinal), education (ordinal), smoking (dichotomous), and weight gain during pregnancy (continuous) (details of categories in table 1). Multiple imputation was used to deal with missing covariate data; most frequently missing was income (4%).

Infertility models were adjusted for BMI, race, income, education, smoking, year of interview, and age at interview. A second infertility analysis analyzed just the TTP

pregnancy data (up to 8 pregnancies/woman), with 857 total women and 428 women with TTP data both before and after the oil spill, with adjustment for age at pregnancy, gravidity at pregnancy, BMI, race, income, education, and smoking). A sensitivity analysis examined TTP ≥ 6 months as the cut-off instead of 12 months.

Second, a similar GEE model was run, limited to women who had both a pre- and post-oil spill pregnancy (for miscarriage) or information about the time frames pre- and post-oil spill (for infertility).

Sensitivity analyses limited the analysis to those whose pregnancies occurred within two years of the oil spill (n=707 overall and 437 with pregnancies both before and after). The effect of removing those who were pregnant at the time of the interview from the “non-miscarriage” group was also assessed, but most women were interviewed late enough in pregnancy that a miscarriage would have been unlikely.

Finally, an analysis was conducted to examine whether reporting bias or confounding was a likely explanation for observed associations. Models were run examining oil spill exposure as a fixed exposure, predicting pregnancy outcomes both before and after the oil spill, with an interaction term to test whether the estimates were statistically different. As the oil spill could not logically cause events prior to its occurrence, we examined whether the effect estimates were equivalent in the two time periods. The interaction between timing of the pregnancy (pre-/post-oil spill) and reported exposure was examined, and a stratified analysis performed for pre- and post-oil spill pregnancies.

The study methods were approved by the Institutional Review Boards of Tulane University, Ochsner, and WIC, and all participants provided written informed consent.

Results

Women were predominantly low-income and black, with a high BMI. A large majority had at least one child (Table 1). 145 (10.2%) reported miscarriage as the outcome of the first pregnancy. 77 (5.1%) women reported postponing pregnancy due to the oil spill, which was more common in those exposed to the spill (table 2). 19.4% of women had at least one indicator of infertility pre-oil spill, and 17.6% post-oil spill.

Overall risk of miscarriage was lower for pregnancies after the spill, although this was likely due partly to the relatively large number of currently pregnant women – when women with ongoing pregnancy were excluded, the protective effect disappeared (aOR 0.89, 0.66–1.20). An increased risk of miscarriage was found with any reported exposure to the oil spill (aOR 1.54, 1.17–2.02), an effect that was similar or stronger when limited to those with pregnancies before and after the spill (aOR 1.79, 1.25–2.55), or which occurred within two years of the spill (table S1, aOR 1.87, 1.12–3.12 and 2.56, 1.37–4.79 for those with both a pre- and post-oil spill pregnancy). No specific aspect of oil spill exposure (income, contact, trauma, etc.) could be identified as a stronger predictor than any other. However, reported exposure to the oil spill was also associated with miscarriage in pregnancies prior to the oil spill (aOR 1.64, 1.06–2.54; table 4). No significant interactions indicating stronger effects on pregnancies after the oil spill.

Fertility issues were equally commonly reported before and after the spill, and were more common with the highest overall oil spill exposure (Table 5). Long TTP was also more common in those reporting income loss (aOR 1.44, 1.01–2.07; Table S2). Results were similar if 6 months instead of 12 months was used as the cut-off (Table S2). No significant interactions indicated stronger effects on pregnancies after the oil spill.

Discussion

In this study of the 2010 Gulf oil spill, few aspects of oil spill exposure were associated with miscarriage or infertility. In a few cases, general indicators of exposure were associated with these outcomes; this could be a chance finding given that multiple comparisons were conducted (given approximately 10 indicators of exposure, at least one or two chance associations would be expected across the miscarriage and infertility analyses). Still, the size of the association is consistent with the size of the effects seen in previous studies indicating associations between psychological or economic stress and miscarriage or infertility (Bruckner et al. 2016; Lynch et al. 2014). Stress could affect conception and miscarriages through behavioral pathways, such as reduced frequency of intercourse or increased smoking by a woman (controlled for, though residual confounding is a possibility) or her partner, and hormonal or immunological changes (Ferin 1999; Kwak-Kim et al. 2014; Whirledge and Cidlowski 2013). Overall, however, the effect of the oil spill on risk of miscarriage was similar in pregnancies pre- and post-oil spill, suggesting minimal effects.

No associations were found with reported direct contact with oil. We are not aware of any studies that have examined the relationship between oil spills and miscarriage or infertility specifically, although petroleum production has been a source of concern under other circumstances (Colorado Department of Public Health and Environment 2014; Schlanger 2014; Xu et al. 1998) Evidence is inconsistent for effects on miscarriage or fertility for the three major types of environmental pollutants associated with the spill: VOCs, metals, and PAHs (Bukowski 2001; Duong et al. 2011; Wigle et al. 2008)(Detmar et al. 2006; Hertz-Picciotto 2000; Hombach-Klonisch et al. 2005; Wu et al. 2010). There is little evidence on the human reproductive effects of dispersants, a major public concern; animal studies are mixed in their conclusions (Pollino and Holdway 2002; Rowe et al. 2009; Van Scoy et al. 2012; Wooten et al. 2012). Overall, however, the lack of effect was not surprising given the fairly low levels of exposure and the mixed evidence for effects of related toxicants on the outcomes studied.

We examined all reported pregnancies, and also the subset of women with a pregnancy both before and after the spill. As the oil spill could not logically have caused outcomes that happened prior to its occurrence, this provides some check on the possibility of correlated over- or under-reporting, as each woman serves as her own control. However, women included in this analysis are necessarily older and higher gravidity at the later pregnancy, which means the earlier pregnancies are an imperfect control and residual confounding is possible. If the oil spill caused women to postpone pregnancy, they would be older at time of pregnancy and thus could have increased risk for infertility or miscarriage, another possible behavioral pathway. If women postponed pregnancy completely, the most highly exposed could be selected out of the miscarriage analysis altogether, although given a fairly small

proportion of women who reported postponing pregnancy, the number of women this would affect is most likely small relative to the number included in the analysis and is unlikely to be a source of major bias. It is possible that women might have become more vigilant in noticing or reporting miscarriages and delayed fertility in the aftermath of the oil spill, but pregnancies after the spill were not more commonly reported to have ended in miscarriage, nor was reported infertility more common. Nonetheless, this cannot be completely ruled out as a cause of associations seen. A true effect could have been masked if the most exposed people moved to another region or state and thus could not be included in the sample. An overrepresentation of women who were both highly-exposed and who experienced or were at high risk for pregnancy complications could produce a spurious association, but the demographics, geographical distribution, and medical outcomes of the sample do not suggest this is likely. Compared to the population of births in the parishes we were studying (based on vital statistics), our sample is more likely to be black, somewhat older, and less likely to be married, most likely due to the extensive recruitment in WIC clinics and the retrospective report of pregnancy history. The proportion of women reporting a miscarriage is within the range that would be expected, given a young population (Lang and Nuevo-Chiquero 2012), and the reported prevalence of lifetime infertility is similarly comparable with national studies (Schmidt 2009).

Studying reproductive failure in humans presents challenges. Early miscarriages frequently are not reported to medical providers, and may not even be noticed. Many women meet the clinical definition of infertility (>12 months of unprotected sex without becoming pregnant) without considering themselves infertile. Many others desire pregnancy but do not seek medical treatments. One strength of this study is the unselected nature of the population with respect to fecundability; many of the women reported having a TTP longer than a year but not infertility, and women were asked about their pregnancy postponement and issues getting pregnant regardless of pregnancy history. For these reasons, self-report often provides a fuller picture of these outcomes, though the outcomes cannot always be independently verified. Validation studies of self-report find reasonable if not excellent agreement with medical records and prospective data (Joffe et al. 1995; Kristensen and Irgens 2000); late miscarriages and long TTPs (dichotomized) are particularly well-reported (Cooney et al. 2009; Wilcox and Horney 1984). Similarly, no biomarker exists that could independently verify exposure to the oil spill, especially during the time frame of this study (2011–2016; the oil spill occurred in 2010). It is possible that detailed biomarker measurements taken close in time to the spill would demonstrate stronger associations.

This study provides some moderate evidence for a combined effect of behavioral, social, and economic effects of the oil spill on miscarriage or infertility, but no particular evidence for effects of chemical exposure. Future studies should focus on identifying chemical signatures that can be directly related to oil spill exposures, and attempting to understand mechanisms by which social or economic stressors might affect reproductive success.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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The study methods were approved by the Institutional Review Boards of Tulane University, Ochsner, and WIC, and all participants provided written informed consent.

Abbreviations

WIC	Women, Infants, and Children (supplemental nutrition program)
BMI	body mass index
TTP	time to pregnancy
VOC	volatile organic compounds
PAH	polycyclic aromatic hydrocarbons
OR	odds ratios
CI	confidence intervals

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Table 1

Characteristics of women participating the GROWH study, south Louisiana, 2011–2016.

	data on oil spill exposure and postponing pregnancy (n=1524)		any pregnancy with outcome data (n=1434)		both a pre- and post-oil spill pregnancy (n=633)	
	N	%	N	%	N	%
Participant characteristics						
Age						
18–25	467	31.8	407	29.9	101	16.6
>25–30	418	28.4	393	28.8	226	37.2
>30–35	302	20.5	290	21.3	172	28.3
>35	283	19.3	273	20.0	109	17.9
Partnered						
yes	621	39.7	561	40.3	264	42.4
no	944	60.3	832	59.7	358	57.6
Race						
white	439	28.3	398	28.0	181	28.8
black	949	61.2	894	62.9	392	62.3
other	164	10.6	130	9.1	56	8.9
Income						
<$15K	677	46.0	638	46.4	293	47.5
$15K–35K	495	33.7	463	33.7	210	34.0
>=$35K	299	20.3	275	20.0	114	18.5
Smoker (any smoking, last two years)						
Yes	415	27.3	404	28.4	191	30.4
no	1104	72.7	1021	71.7	438	69.6
BMI						
<=20	103	6.8	81	6.0	37	6.1
>20–25	350	23.0	306	22.5	122	20.2
>25	378	24.9	341	25.0	159	26.3
>30	690	45.4	634	46.6	286	47.4
Parish of residence						
Jefferson	582	40.4	563	40.7	203	44.4

	data on oil spill exposure and postponing pregnancy (n=1524)		any pregnancy with outcome data (n=1434)		both a pre- and post-oil spill pregnancy (n=633)	
	N	**%**	**N**	**%**	**N**	**%**
Orleans	312	20.4	275	19.9	74	16.2
Plaquemines	145	10.2	138	10.0	35	7.7
St. Bernard	128	7.4	125	9.0	47	10.3
Lafourche	122	8.6	117	8.5	46	10.1
Terrebonne	137	9.9	130	9.4	40	8.8
Other	42	3.1	34	2.5	12	2.5
Outcome of first pregnancy	among those with a pregnancy					
livebirth	1117	78.2	1117	78.2	508	80.6
stillbirth	31	2.2	31	2.2	18	2.9
miscarriage	145	10.2	145	10.2	77	12.2
abortion	33	2.3	33	2.3	23	3.7
molar/ectopic/etc.	2	0.1	2	0.1	2	0.3
still pregnant	100	7.0	100	7.0	2	0.3
Exposure to the oil spill						
any exposure	796	51.7	747	52.3	326	51.7
Income loss due to oil spill	448	29.1	420	29.4	169	26.7
Trauma/property damage	88	5.8	85	6.0	43	6.9
Loss of use of the coast due to the oil spill	615	41.3	579	41.8	236	38.5
litigation	373	24.5	352	24.6	155	24.5
Indicators of contact with oil						
0	1256	81.3	1160	81.2	520	82.4
1	173	11.2	161	11.3	71	11.3
2+	116	7.5	107	7.5	40	6.3
Indicators of total oil spill exposure						
0	685	44.2	623	43	290	45.8
1–2	460	29.7	432	432	187	29.5
3–4	261	16.8	239	239	97	15.3
5+	145	9.4	140	140	59	9.3

Table 2

Oil spill exposure and reported postponement of pregnancy after the Gulf oil spill (2010) in a cohort of Southern Louisiana women, 2011–2016.

			unadjusted		adjusted[a]	
	N with outcome	**%**	**OR**	**95% CI**	**OR**	**95% CI**
Any oil spill exposure			1.78	1.11–2.88	1.92	1.17–3.15
Yes	50	6.4				
No	27	3.7				
Income loss due to oil spill			1.42	0.88–2.29	1.55	0.95–2.55
Yes	28	6.3				
No	49	4.5				
Trauma/property damage			1.43	0.60–3.38	2.00	0.82–4.89
Yes	6	6.9				
No	70	4.9				
Loss of use of the coast due to the oil spill			1.50	0.93–2.39	1.58	0.97–2.57
Yes	37	6.1				
No	36	4.2				
Litigation			2.89	1.82–4.59	2.72	1.70–4.35
Yes	36	9.7				
No	41	3.6				
contact with oil						
low	56	4.5	1.00		1.00	
medium	10	6.0	1.34	0.67–2.69	1.38	0.68–2.80
high	10	8.8	2.03	1.01–4.10	2.13	1.04–4.39
total oil spill exposure						
low	20	3.0	1.00		1.00	
medium-low	27	6.0	2.06	1.14–3.71	2.08	1.14–3.77
medium-high	20	7.8	2.75	1.46–5.21	2.86	1.49–5.48
high	10	6.9	2.43	1.11–5.30	2.92	1.31–6.51

[a] adjusted for age at interview, BMI, race, income, education, smoking, year of interview, and age at first pregnancy. In all cases, reference group is those without the specified type of exposure; those unexposed in one analysis might be exposed in another.

Table 3

Reported oil spill exposure and miscarriage in a cohort of southern Louisiana women, 2011–2016

			any pregnancy with outcome data (n=1419 women/3504 pregnancies)				both a pre- and post-oil spill pregnancy, outcome data on both pregnancies (n=633/n=2011)			
	N with outcome	%	unadjusted		adjusted[a]		unadjusted		adjusted[a]	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
pregnancy after spill			0.76	0.59–0.98	0.68	0.51–0.92	0.86	0.73–1.00	0.66	0.41–1.06
yes	120	8.0								
no	199	10.0								
any exposure			1.69	1.29–2.20	1.54	1.17–2.02	2.06	1.46–2.91	1.79	1.25–2.55
yes	205	11.1								
no	113	6.9								
income			0.97	0.66–1.44	0.85	0.58–1.25	1.23	0.78–1.94	1.24	0.76–2.03
yes	35	9.1								
no	284	9.1								
trauma			1.07	0.50–2.30	0.95	0.45–1.99	1.08	0.47–2.50	1.05	0.44–2.50
yes	9	10.5								
no	308	9.1								
coast			1.13	0.79–1.62	1.05	0.70–1.57	1.16	0.76–1.76	1.18	0.72–1.91
yes	57	10.3								
no	255	8.8								
litigation			0.88	0.56–1.40	0.88	0.55–1.42	0.99	0.57–1.70	1.20	0.67–2.15
yes	30	8.3								
no	289	9.2								
contact with oil										
low	290	8.9	1.0		1.0		1.0		1.0	
medium	16	10.3	1.13	0.63–2.03	0.98	0.55–1.77	1.20	0.59–2.44	1.06	0.49–2.29
high	13	14.4	1.65	0.74–3.66	1.55	0.63–3.78	0.75	0.22–2.57	0.68	0.19–2.41
total oil spill exposure										
low	242	9.0	1.0		1.0		1.0		1.0	
medium-low	39	8.4	0.86	0.56–1.32	0.87	0.56–1.36	0.84	0.48–1.45	0.97	0.53–1.76
medium-high	28	12.1	1.33	0.82–3.15	1.21	0.71–2.04	1.58	0.94–2.63	1.63	0.94–2.84

			any pregnancy with outcome data (n=1419 women/3504 pregnancies)				both a pre- and post-oil spill pregnancy, outcome data on both pregnancies (n=633/n=2011)			
	N with outcome	%	unadjusted		adjusted[a]		unadjusted		adjusted[a]	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
high	10	8.3	0.92	0.46–1.86	0.75	0.36–1.54	0.88	0.38–2.07	0.82	0.34–2.00

[a]adjusted for age, gravidity, weight gain during pregnancy, BMI, race, income, education. In all cases, reference group is those without the specified type of exposure; those unexposed in one analysis might be exposed in another. Generalized estimating equations used to predict outcome of pregnancies with oil spill exposure as a time-varying exposure. First columns include all women with at least one post-oil spill (2010) pregnancy. Second columns include only those women with a pregnancy before and after the oil spill.

Table 4

Reported oil spill exposure and miscarriage as outcome of pregnancy, limited to those with both a pre- and post-oil spill pregnancy, reported oil spill exposure as a predictor of pregnancy outcomes occurring prior to and after the oil spill (n=633 women, 2011 pregnancies)

	unadjusted				adjusted[a]			
	Pregnancy occurred pre-oil spill		Pregnancy occurred post-oil spill		Pregnancy occurred pre-oil spill		Pregnancy occurred post-oil spill	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
any exposure	2.00	1.29–3.10	2.15	1.27–3.64	1.64	1.06–2.54	1.98	1.15–3.41
income	2.01	1.33–3.04	1.92	1.14–3.23	1.80	1.18–2.74	1.65	0.98–2.76
contact with oil	1.41	0.87–2.30	1.40	0.73–2.66	1.29	0.79–2.12	1.10	0.56–2.16
trauma	0.93	0.42–2.05	1.36	0.57–3.23	0.76	0.35–1.66	1.27	0.55–2.92
coast	2.08	1.37–3.15	2.06	1.21–3.50	1.81	1.19–2.75	1.73	0.98–3.03
litigation	1.40	0.89–2.21	1.34	0.74–2.44	1.58	1.01–2.47	1.40	0.76–2.56
contact with oil								
low	1.00		1.00		1.00		1.00	
medium	1.26	0.69–2.30	1.60	0.77–3.30	1.20	0.68–2.12	1.25	0.57–2.72
high	1.70	0.84–3.42	1.05	0.32–3.45	1.45	0.67–3.13	0.85	0.25–2.89
total oil spill exposure								
low	1.00		1.00		1.00		1.00	
medium-low	1.80	1.08–3.00	1.60	0.82–3.11	1.72	1.02–2.90	1.46	0.73–2.92
medium-high	2.67	1.53–4.68	3.08	1.65–5.75	2.70	1.56–4.68	2.56	1.38–4.74
high	2.04	1.04–4.01	1.68	0.67–4.19	1.65	0.83–3.31	1.32	0.54–3.24

[a]adjusted for age, gravidity, weight gain during pregnancy, BMI, race, income, education. In all cases, reference group is those without the specified type of exposure; those unexposed in one analysis might be exposed in another.

Table 5

Oil spill exposure and self-reported issues becoming pregnant in a cohort of southern Louisiana women, 2011–2016

			all with data (n=1164)				All with data on pre- and post-oil spill time frames (n=1046)			
	N with outcome	%	unadjusted		adjusted[a]		unadjusted		adjusted[a]	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
post-oil spill			0.90	0.74–1.10	0.89	0.73–1.09	0.99	0.80–1.22	0.99	0.80–1.22
Yes	192	17.6								
No	216	19.4								
any exposure			0.91	0.72–1.15	0.87	0.68–1.10	0.99	0.78–1.27	0.97	0.75–1.25
Yes	101	17.5								
No	307	18.9								
Income			1.20	0.90–1.59	1.16	0.87–1.55	1.32	0.98–1.78	1.33	0.98–1.79
Yes	69	21.4								
No	339	18.0								
Trauma			0.96	0.53–1.75	0.95	0.51–1.76	1.01	0.54–1.88	1.04	0.55–1.96
Yes	13	18.6								
No	393	18.5								
Coast			0.97	0.75–1.26	0.92	0.71–1.20	1.06	0.80–1.38	1.03	0.78–1.36
Yes	81	18.4								
No	321	18.5								
litigation			1.15	0.85–1.56	1.17	0.85–1.61	1.26	0.92–1.74	1.27	0.91–1.77
Yes	55	20.1								
No	353	18.3								
contact with oil										
low	366	18.2	1.0		1.0		1.0		1.0	
medium	27	22.9	1.28	0.83–1.99	1.30	0.84–2.01	1.40	0.89–2.22	1.46	0.93–2.29
high	15	19.2	1.01	0.58–1.77	1.01	0.58–1.78	1.09	0.61–1.97	1.14	0.64–2.04
total oil spill exposure										
low	292	18.4	1.0		1.0		1.0		1.0	
medium-low	56	16.9	0.91	0.68–1.23	0.90	0.66–1.23	0.98	0.71–1.35	0.97	0.70–1.35
medium-high	32	17.3	0.96	0.65–1.40	0.89	0.60–1.33	1.01	0.67–1.52	0.96	0.63–0.47

			all with data (n=1164)				All with data on pre- and post-oil spill time frames (n=1046)			
	N with outcome	%	unadjusted		adjusted[a]		unadjusted		adjusted[a]	
			OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
high	28	26.9	1.52	0.97–2.38	1.50	0.96–1.36	1.80	1.14–2.85	1.88	1.19–2.95

[a]adjusted for age, gravidity, BMI, income, education, smoking, year of interview, weight gain during pregnancy. In all cases, reference group is those without the specified type of exposure; those unexposed in one analysis might be exposed in another. Self-reported issues during pregnancy=time to pregnancy≥12 months or time of attempting pregnancy without success of 12 months or more. “All with data” refers to all women who provided TTP or pregnancy attempt information; data on the pre- and post-oil spill time frame refers to those who provided TTP or pregnancy attempt information for the time frames before and after the Gulf oil spill (2010).