

4. BIRTH WEIGHT

4.1 Introduction

The association between paternal dioxin and birth weight, expressed in grams, and abnormally low weight (birth weight less than 2500 grams) was investigated with Models 1, 2 and 3 without and with restriction to full siblings.

The rates throughout this section are expressed per 1000 children.

4.2 Pre-Post SEA Exposure Analyses

Birth Weight (All Children)

Model 1: Children of Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$

Without adjustment for covariates (Table 4-1 [a] and [b]), there is a borderline significant variation in the association between the average birth weight and initial dioxin with time of conception among children fathered by Ranch Hands having more than 10 ppt current dioxin ($p=0.073$) and a significant variation in this association among children fathered by Ranch Hands having more than 5 ppt current dioxin ($p=0.003$). For each exposure restriction the pre-SEA birth weights decrease with dioxin levels while the post-SEA birth weights remain stable over the dioxin levels.

Table 4-1

Pre-post SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: All Children of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 1: $\text{Log}_2(\text{Initial Dioxin})$

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Unadjusted

Time of Conception Relative
to the Father's Duty in SEA

Exposure Restriction	Initial Dioxin	Pre-SEA		Post-SEA		p-Value
		n	Mean	n	Mean	
a) D>10 ppt (n=1153)	Low	238	3314.4	106	3384.7	0.073
	Medium	314	3205.9	237	3386.8	
	High	105	3156.2	153	3364.5	
b) D>5 ppt (n=1666)	Low	275	3258.2	151	3245.9	0.003
	Medium	578	3271.9	299	3393.0	
	High	143	3142.3	220	3350.5	

Birth Weight (All Children)

Model 2: Children of Ranch Hands - $\text{Log}_2(\text{Current Dioxin})$ and Time

Without adjustment for covariates (Table 4-2 [a] and [b]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA and time of conception among children fathered by Ranch Hands having more than 10 ppt ($p=0.524$) or more than 5 ppt ($p=0.946$).

Table 4-2

Pre-post SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: All Children of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 2: $\text{Log}_2(\text{Current Dioxin})$, Time

Ranch Hands - $\text{Log}_2(\text{Current Dioxin})$, Time - Unadjusted						
Exposure Restriction	Time of Conception	Time Since SEA (years)	Birth Weight Mean/n Current Dioxin			p-Value
			Low	Medium	High	
a) D>10 ppt (n=1155)	Pre-SEA	≤18.6	3428.9 (130)	3174.4 (169)	3007.6 (35)	0.524
		>18.6	3235.6 (91)	3210.6 (161)	3214.9 (72)	
	Post-SEA	≤18.6	3447.2 (62)	3378.3 (131)	3307.2 (71)	
		>18.6	3375.8 (40)	3325.1 (104)	3406.4 (89)	
b) D>5 ppt (n=1666)	Pre-SEA	≤18.6	3222.2 (149)	3308.1 (293)	3011.6 (62)	0.946
		>18.6	3332.7 (145)	3227.6 (254)	3197.4 (93)	
	Post-SEA	≤18.6	3262.1 (87)	3369.0 (171)	3309.8 (109)	
		>18.6	3298.4 (60)	3428.1 (132)	3339.4 (111)	

Birth Weight (All Children)

Model 3: Children of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-3), there is significant variation in the overall association between birth weight and categorized current dioxin with time of conception ($p=0.018$). The association between birth weight and time of conception in children of Ranch Hands in the Low category differs significantly from that in children of Comparisons in the Background category ($p=0.044$) caused by a larger pre-SEA to post-SEA increase in mean birth weight in children of Ranch Hands in the Low dioxin category than in children of Comparisons in the Background category. The associations between birth weight and time of conception in children of Ranch Hands in the High ($p=0.120$) and Unknown ($p=0.135$) categories do not differ significantly from that in children of Comparisons in the Background category.

Table 4-3

Pre-post SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: All Children of Ranch Hands and Comparisons
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

Categorized Current Dioxin - Unadjusted

Time of Conception Relative
to the Father's Duty in SEA

Exposure Category	Pre-SEA n	Pre-SEA Mean	Post-SEA n	Post-SEA Mean	Category Contrast	p-Value
Background	1388	3294.4	954	3400.5	All Exp Categ	0.018
Unknown	556	3261.4	268	3298.5	Unk vs Bkgd	0.135
Low	271	3213.1	170	3433.4	Low vs Bkgd	0.044
High	155	3123.1	220	3324.8	High vs Bkgd	0.120
Total	2370		1612			

Birth Weight (Full Siblings)

Model 1: Children of Ranch Hands - Log₂(Initial Dioxin)

Without adjustment for covariates (Table 4-4 [a] and [b]), there is a significant variation in the association between birth weight and initial dioxin with time of conception among children of Ranch Hands having more than 10 ppt (p=0.039) and among children of Ranch Hands having more than 5 ppt (p=0.004). For each exposure restriction the pre-SEA birth weights decrease with dioxin levels while the post-SEA birth weights generally remain relatively stable or increase.

Table 4-4

Pre-post SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: Full Siblings of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 1: Log₂(Initial Dioxin)

Ranch Hands - Log₂(Initial Dioxin) - Unadjusted

Exposure Restriction	Initial Dioxin	Time of Conception Relative to the Father's Duty in SEA				p-Value
		Pre-SEA n	Mean	Post-SEA n	Mean	
a) D>10 ppt (n=1005)	Low	224	3316.2	78	3354.1	0.039
	Medium	266	3219.8	205	3388.4	
	High	97	3162.5	135	3377.9	
b) D>5 ppt (n=1451)	Low	250	3254.1	113	3220.8	0.004
	Medium	522	3288.8	242	3394.4	
	High	127	3136.4	197	3362.3	

Birth Weight (Full Siblings)

Model 2: Children of Ranch Hands - Log₂(Current Dioxin) and Time

Without adjustment for covariates (Table 4-5 [a] and [b]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA and time of conception among children of Ranch Hands having more than 10 ppt (p=0.689) or more than 5 ppt (p=0.668).

Table 4-5

Pre-post SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: Full Siblings of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 2: Log₂(Current Dioxin), Time

Ranch Hands - Log₂(Current Dioxin), Time - Unadjusted

Exposure Restriction	Time of Conception	Time Since SEA (years)	Birth Weight Mean/n Current Dioxin			p-Value
			Low	Medium	High	
a) D>10 ppt (n=1007)	Pre-SEA	≤18.6	3428.5 (120)	3182.3 (147)	3004.4 (34)	0.689
		>18.6	3238.7 (84)	3230.5 (139)	3235.0 (64)	
	Post-SEA	≤18.6	3431.8 (47)	3357.8 (114)	3307.4 (64)	
		>18.6	3368.1 (28)	3325.9 (92)	3512.2 (74)	
b) D>5 ppt (n=1451)	Pre-SEA	≤18.6	3210.1 (125)	3314.9 (264)	3012.6 (58)	0.668
		>18.6	3345.1 (142)	3246.1 (228)	3199.8 (82)	
	Post-SEA	≤18.6	3226.5 (58)	3335.5 (143)	3311.8 (98)	
		>18.6	3360.4 (52)	3445.2 (105)	3360.5 (96)	

Birth Weight (Full Siblings)

Model 3: Children of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-6), there is significant variation in the overall association between birth weight and categorized current dioxin with time of conception ($p=0.045$). Furthermore, the association between the birth weight and time of conception in children of Ranch Hands in the Unknown category differs borderline significantly from the children of Comparisons in the Background category ($p=0.096$). The associations between the birth weight and time of conception in children of Ranch Hands in the High ($p=0.133$) and Low ($p=0.206$) categories do not differ significantly from that of children of Comparisons in the Background category.

Table 4-6

Pre-post SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: Full Siblings of Ranch Hands and Comparisons
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

Categorized Current Dioxin - Unadjusted

Time of Conception Relative
to the Father's Duty in SEA

Exposure Category	Pre-SEA n	Pre-SEA Mean	Post-SEA n	Post-SEA Mean	Category Contrast	p-Value
Background	1207	3292.0	803	3407.1	All Exp Categ	0.045
Unknown	502	3262.5	216	3293.2	Unk vs Bkgd	0.096
Low	234	3234.7	147	3427.0	Low vs Bkgd	0.206
High	140	3122.2	194	3335.9	High vs Bkgd	0.133
Total	2083		1360			

Low Birth Weight (All Children)

Model 1: Children of Ranch Hands - Log₂(Initial Dioxin)

Without adjustment for covariates (Table 4-7 [a] and [b]), there is no significant variation in the association between abnormally low birth weight and initial dioxin with time of conception among children of Ranch Hands having more than 10 ppt (p= 0.250) or more than 5 ppt (p=0.156).

Table 4-7

Pre-post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: All Children of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 1: Log₂(Initial Dioxin)

Ranch Hands - Log₂(Initial Dioxin) - Unadjusted

Time of Conception Relative
to the Father's Duty in SEA

Exposure Restriction	Initial Dioxin	Pre-SEA n	Low	Rate per 1000	Post-SEA n	Low	Rate per 1000	p-Value
a) D>10 ppt (n=1153)	Low	238	11	46.2	106	7	66.0	0.250
	Medium	314	19	60.5	237	17	71.7	
	High	105	11	104.8	153	13	85.0	
b) D>5 ppt (n=1666)	Low	275	16	58.2	151	14	92.7	0.156
	Medium	578	33	57.1	299	23	76.9	
	High	143	13	90.9	220	18	81.8	

Low Birth Weight (All Children)

Model 2: Children of Ranch Hands - Log₂(Current Dioxin) and Time

Without adjustment for covariates (Table 4-8 [a] and [b]), there is no significant variation in the association between abnormally low birth weight and current dioxin with time since duty in SEA and time of conception among children of Ranch Hands having more than 10 ppt (p=0.226) or more than 5 ppt (p=0.724).

Table 4-8

Pre-post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: All Children of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 2: $\text{Log}_2(\text{Current Dioxin})$, Time

Ranch Hands - $\text{Log}_2(\text{Current Dioxin})$, Time - Unadjusted								
Exposure Restriction	Time of Conception	Time Since SEA (years)	Rate(per1000)(No./n)			p-Value		
			Low	Medium	High			
a) D>10 ppt (n=1155)	Pre-SEA	≤18.6	30.8 (4/130)	59.2 (10/169)	114.3 (4/35)	0.226		
		>18.6	76.9 (7/91)	62.1 (10/161)	83.3 (6/72)			
	Post-SEA	≤18.6	32.3 (2/62)	91.6 (12/131)	70.4 (5/71)			
		>18.6	100.0 (4/40)	76.9 (8/104)	67.4 (6/89)			
	b) D>5 ppt (n=1666)	Pre-SEA	≤18.6	60.4 (9/149)	44.4 (13/293)		129.0 (8/62)	0.724
			>18.6	55.2 (8/145)	66.9 (17/254)		75.3 (7/93)	
Post-SEA		≤18.6	80.5 (7/87)	81.9 (14/171)	73.4 (8/109)			
		>18.6	133.3 (8/60)	45.5 (6/132)	108.1 (12/111)			

Low Birth Weight (All Children)

Model 3: Children of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-9), there is a significant variation in the association between abnormally low birth weight and categorized current dioxin with time of conception ($p=0.011$). The association between low birth weight and time of conception in children of Ranch Hands in the Unknown category differs significantly from the children of Comparisons in the Background category ($p=0.001$). The association between birth weight and time of conception in children of Ranch Hands in the Low category is borderline significantly different from that in children of Comparisons in the Background category ($p=0.088$). These findings are caused by an increase in the rate of abnormally low birth weight from pre-SEA to post-SEA in Ranch Hands children and a decrease in Comparisons children.

Table 4-9

Pre-post SEA Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: All Children of Ranch Hands and Comparisons
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

Categorized Current Dioxin - Unadjusted

**Time of Conception Relative
to the Father's Duty in SEA**

Exposure Category	Pre-SEA n	Rate Low	Rate per 1000	Post-SEA n	Rate Low	Rate per 1000	Odds Ratio	Category Contrast	p-Value
Background	1388	102	73.5	954	40	41.9	0.57	All Exp Categ	0.011
Unknown	556	34	61.2	268	25	93.3	1.58	Unk vs Bkgd	0.001
Low	271	15	55.4	170	11	64.7	1.18	Low vs Bkgd	0.088
High	155	15	96.8	220	20	90.9	0.93	High vs Bkgd	0.194
Total	2370			1612					

Low Birth Weight (Full Siblings)

Model 1: Children of Ranch Hands - Log₂(Initial Dioxin)

Without adjustment for covariates (Table 4-10 [a] and [b]), there is no significant variation in the association between abnormally low birth weight and initial dioxin with time of conception among full sibling children of Ranch Hands having more than 10 ppt (p= 0.326) or more than 5 ppt (p=0.279) current dioxin.

Table 4-10

Pre-post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: Full Siblings of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 1: Log₂(Initial Dioxin)

Ranch Hands - Log₂(Initial Dioxin) - Unadjusted								
		Time of Conception Relative to the Father's Duty in SEA						
Exposure Restriction	Initial Dioxin	n	Pre-SEA		Post-SEA		p-Value	
			Low	per 1000	n	Low	per 1000	
a) D>10 ppt (n=1005)	Low	224	11	49.1	78	5	64.1	0.326
	Medium	266	15	56.4	205	16	78.0	
	High	97	10	103.1	135	12	88.9	
b) D>5 ppt (n=1451)	Low	250	16	64.0	113	11	97.3	0.279
	Medium	522	30	57.5	242	20	82.6	
	High	127	11	86.6	197	17	86.3	

Low Birth Weight (Full Siblings)

Model 2: Children of Ranch Hands - Log₂(Current Dioxin) and Time

Without adjustment for covariates (Table 4-11 [a] and [b]), there is no significant variation in the association between abnormally low birth weight and current dioxin with time since duty in SEA and time of conception among full sibling children of Ranch Hands having more than 10 ppt (p=0.305) or more than 5 ppt (p=0.972).

Table 4-11

Pre-post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: Full Siblings of Ranch Hands
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 2: $\text{Log}_2(\text{Current Dioxin})$, Time

Ranch Hands - $\text{Log}_2(\text{Current Dioxin})$, Time - Unadjusted								
Exposure Restriction	Time of Conception	Time Since SEA (years)	Rate(per 1000)(No./n) Current Dioxin			p-Value		
			Low	Medium	High			
a) D>10 ppt (n=1007)	Pre-SEA	≤18.6	33.3 (4/120)	54.4 (8/147)	117.6 (4/34)	0.305		
		>18.6	83.3 (7/84)	57.6 (8/139)	78.1 (5/64)			
	Post-SEA	≤18.6	21.3 (1/47)	105.3 (12/114)	78.1 (5/64)			
		>18.6	107.1 (3/28)	76.1 (7/92)	67.6 (5/74)			
	b) D>5 ppt (n=1451)	Pre-SEA	≤18.6	72.0 (9/125)	45.5 (12/264)		120.7 (7/58)	0.972
			>18.6	56.3 (8/142)	65.8 (15/228)		73.2 (6/82)	
Post-SEA		≤18.6	86.2 (5/58)	90.9 (13/143)	81.6 (8/98)			
		>18.6	134.6 (7/52)	38.1 (4/105)	114.6 (11/96)			

Low Birth Weight (Full Siblings)

Model 3: Children of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-12), there is a significant variation in the association between low birth weight and categorized current dioxin with time of conception (p=0.014). Furthermore, the association between low birth weight and time of conception in full sibling children of Ranch Hands in the Unknown category differs significantly from the children of Comparisons in the Background category (p=0.002). The association between low birth weight and time of conception in full sibling children of Ranch Hands in the Low category and that in children of Comparisons in the Background category are borderline significantly different (p=0.084). There is no significant difference between this association in children of Ranch Hands in the High category and that in children of Comparisons in the Background category (p=0.169). These findings were caused by a decrease in the rate of abnormally low birth weight in children of Comparisons in the Background category from pre-SEA to post-SEA and a corresponding increase in children of Ranch Hands in the Unknown and Low categories.

Table 4-12

Pre-post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: Full Siblings of Ranch Hands and Comparisons
 Categories: Time of Conception Relative to the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

Categorized Current Dioxin - Unadjusted										
Time of Conception Relative to the Father's Duty in SEA										
Exposure Category	n	Pre-SEA		Post-SEA		Odds Ratio	Category Contrast	p-Value		
		Low	per 1000	n	Low				per 1000	
Background	1207	89	73.7	803	36	44.8	0.59	All Exp Categ	0.014	
Unknown	502	31	61.8	216	22	101.9	1.72	Unk vs Bkgd	0.002	
Low	234	12	51.3	147	10	68.0	1.35	Low vs Bkgd	0.084	
High	140	13	92.9	194	19	97.9	1.06	High vs Bkgd	0.169	
Total	2083			1360						

4.3 Post-SEA Analyses

The significance of the association between birth weight, measured in grams, and abnormally low birth weight (less than 2500 grams) and dioxin was assessed with Models 1, 2 and 3 in all post-SEA children and again with restriction to full siblings.

Birth Weight (All Children)

Model 1: Children of Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$

Without adjustment for covariates (Table 4-13 [a] and [b]), there is no significant association between birth weight and initial dioxin among children of Ranch Hands having more than 10 ppt ($p=0.911$) or more than 5 ppt ($p=0.138$) current dioxin.

After adjustment for covariates (Table 4-13 [c]), there is significant variation in the association between birth weight and initial dioxin with the father's race ($p=0.026$) and the mother's smoking during pregnancy ($p=0.042$) among children of Ranch Hands having more than 10 ppt current dioxin. The basis for this variation is displayed in Appendix Table B-1. Birth weight decreases borderline significantly with initial dioxin among children of mothers who smoked during pregnancy and whose father was nonblack (slope=-117.5, slope std dev=61.5, $p=0.060$) and significantly in children of mothers who did not smoke during pregnancy and whose father was Black (slope=-266.3, slope std dev=109.0, $p=0.020$). If this variation is ignored, there is no significant association between initial dioxin and birth weight ($p=0.129$).

After adjustment for covariates (Table 4-13 [d]), there is significant variation in the association between birth weight and initial dioxin with the father's race ($p=0.005$) and the mother's smoking ($p=0.045$) among children of Ranch Hands with more than 5 ppt current dioxin. The basis for this variation is displayed in Appendix Table B-1. Birth weight decreases significantly with initial dioxin (slope -254.1, slope std dev=85.7, $p=0.005$) in children of Black fathers and nonsmoking mothers but is otherwise not significantly associated with initial dioxin.

Table 4-13

Post-SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: All Children of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 1: $\text{Log}_2(\text{Initial Dioxin})$

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Unadjusted						
Exposure Restriction	Initial Dioxin	n	Mean	Adj. Slope (Std. Error)	p-Value	
a) D>10 ppt (n=496) (R ² =0.000)	Low	106	3384.7	-2.59(23.15)	0.911	
	Medium	237	3386.8			
	High	153	3364.5			
b) D>5 ppt (n=670) (R ² =0.003)	Low	151	3245.9	25.05(16.89)	0.138	
	Medium	299	3393.0			
	High	220	3350.5			

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Adjusted						
Exposure Restriction	Initial Dioxin	n	Adj. Mean	Adj. Slope (Std. Error)	p-Value	Covariate Remarks
c) D>10 ppt (n=456) (R ² =0.099)	Low	99	3132.0***	-40.55(26.64)	0.129***	RACE(p=0.059)
	Medium	216	3125.1***			OCC(p=0.001)
	High	141	2996.3***			DIOXIN*RACE (p=0.026) DIOXIN*SMOKE (p=0.042)
d) D>5 ppt (n=612) (R ² =0.084)	Low		****	****	****	RACE(p=0.010)
	Medium					OCC(p=0.002)
	High					DRINK(p=0.058) DIOXIN*RACE (p=0.005) DIOXIN*SMOKE (P=0.045)

Birth Weight (All Children)

Model 2: Children of Ranch Hands - \log_2 (Current Dioxin) and Time

Without adjustment for covariates (Table 4-14 [a]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA among children of Ranch Hands with more than 10 ppt current dioxin ($p=0.407$). Furthermore, there is no significant association between birth weight and current dioxin among children of Ranch Hands who had late ($p=0.469$) or early ($p=0.645$) tours.

Without adjustment for covariates (Table 4-14 [b]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA among children of Ranch Hands having more than 5 ppt current dioxin ($p=0.999$). Furthermore, there is no significant association between birth weight and current dioxin in children of Ranch Hands who had late ($p=0.300$) or early ($p=0.334$) tours.

After adjustment for covariates (Table 4-14 [c]), there is significant variation in the association between birth weight and dioxin with time since duty in SEA and the father's race ($p=0.043$) among children of Ranch Hands having more than 10 ppt current dioxin. The basis for this variation is displayed in Appendix Table B-1. Birth weight increases with current dioxin among children of nonblack fathers who had early tours and decreases among children of nonblack fathers who had late tours, among children of Black fathers who had early tours and among children of Black fathers who had late tours, although none of the within-stratum changes are significant.

If this variation is ignored, there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA ($p=0.412$) among children of Ranch Hands having more than 10 ppt current dioxin. However, birth weight decreases borderline significantly with current dioxin among children of Ranch Hands who had late tours (slope=-67.72, slope std dev=39.55, $p=0.088$). Birth weight does not change significantly with current dioxin among children of Ranch Hands who had early tours ($p=0.929$).

After adjustment for covariates (Table 4-14 [d]), there is significant variation in the association between birth weight and current dioxin with time since duty in SEA and with the father's race ($p=0.016$) among children of Ranch Hands having more than 5 ppt current dioxin. The basis for this variation is displayed in Appendix Table B-1. Birth weight increases with current dioxin among children of nonblack fathers with early tours and decreases with current dioxin among children of nonblack fathers with late tours and among children of Black fathers for both late and early tours, although none of the within-stratum changes are significant.

If this variation is ignored there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA ($p=0.614$) among children of Ranch hands having more than 5 ppt current dioxin. Furthermore, birth weight does not change significantly with current dioxin among children of Ranch Hands who had late ($p=0.520$) or early ($p=0.951$) tours.

Table 4-14

Post-SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: All Children of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 2: $\text{Log}_2(\text{Current Dioxin}), \text{Time}$

Ranch Hands - $\text{Log}_2(\text{Current Dioxin}), \text{Time}$ - Unadjusted						
Exposure Restriction	Time Since SEA (years)	Mean/(n)			Adj. Slope (Std. Error)	p-Value
		Current Dioxin Low	Medium	High		
a) D>10 ppt (n=497) ($R^2=0.001$)	≤ 18.6	3447.2 (62)	3378.3 (131)	3307.2 (71)	-23.80(32.84)	0.407 0.469
	>18.6	3375.8 (40)	3325.1 (104)	3460.4 (89)	16.22(35.13)	0.645
b) D>5 ppt (n=670) ($R^2=0.004$)	≤ 18.6	3262.1 (87)	3369.0 (171)	3309.8 (109)	24.74(23.82)	0.999 0.300
	>18.6	3298.4 (60)	3428.1 (132)	3339.4 (111)	24.71(25.54)	0.334

Table 4-14 (Continued)

Ranch Hands - Log₂(Current Dioxin), Time - Adjusted

Exposure Restriction	Time Since SEA (years)	Adj. Means/(n) Current Dioxin			Adj. Slope (Std. Error)	p-Value	Covariate Remarks
		Low	Medium	High			
c) D>10 ppt (n=457) (R ² =0.038)					0.412	RACE (p=0.041)	
	≤18.6	3298.3 (55)	3236.6 (118)	3078.4 (68)	-67.72(39.55)	0.088*** OCC(p=0.001) DIOXIN* TIME*	
	>18.6	3197.4 (40)	3146.8 (96)	3229.8 (80)	-3.79(42.61)	0.929*** RACE (p=0.043) DIOXIN* TIME*	
						0.614 SMOKE (p=0.078)	
d) D>5 ppt (n=612) (R ² =0.08)	≤18.6	3180.6 (77)	3248.0 (156)	3157.4 (100)	-18.87(29.31)	0.520*** RACE (p=0.016) OCC(p=0.003)	
	>18.6	3248.6 (54)	3312.0 (124)	3144.3 (101)	-1.81(29.47)	0.951*** SMOKE (p=0.001) DRINK (p=0.072) DIOXIN* TIME* RACE (p=0.016)	

Birth Weight (All Children)

Model 3: Children of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-15 [a]), there is a significant overall association between birth weight and categorized current dioxin (p=0.017). The average birth weight of children of Ranch Hands in the Unknown category is significantly lower than the average birth weight of children of Comparisons in the Background category (p=0.010). There is a borderline significant difference between the average birth weight of children of Ranch Hands in the High category and children of Comparisons in the Background category (p=0.075) and no significant difference between the average birth weight of children in the Low category and the Background category (p=0.488).

After adjustment for covariates (Table 4-15 [b]), there is significant variation in the overall association between birth weight and categorized current dioxin with the father's race (p=0.048). The basis for this variation is displayed in Appendix Table B-1. The average birth weight of children of Ranch Hands in the High category is significantly lower than the average birth weight of children of Comparisons in the Background category for the nonblack (p=0.005) and the Black (p=0.006) races. The only other finding is a border-line significant difference (p=0.078) between the average birth weight of nonblack children of Ranch Hands in the Unknown category and the average birth weight of children of nonblack Comparisons in the Background category.

When this interaction is ignored, there is a significant overall association between birth weight and categorized current dioxin (p=0.002). The average birth weight of children of Ranch Hands in the High dioxin category is significantly lower than the average birth weight of children of Comparisons in the Background category (p=0.001). The average birth weight of children of Ranch Hands in the Low (p=0.389) and Unknown categories (p=0.137) are not significantly different from the average birth weight of children of Comparisons in the Background category.

Table 4-15

Post-SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: All Children of Ranch Hands and Comparisons
 Children Conceived during or after the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

a) Unadjusted

Exposure Category	n	Mean	Category Contrast	Difference of Means (95% C.I.)	p-Value
Background	954	3400.5	All Exp Categ		0.017
Unknown	268	3298.5	Unk vs Bkgd	-102.0(-179.1, -24.9)	0.010
Low	170	3433.4	Low vs Bkgd	32.9(-59.9, 125.7)	0.488
High	220	3324.8	High vs Bkgd	-75.7(-159.1, 7.7)	0.075
Total	1612	(R ² =0.006)			

Table 4-15 (Continued)

b) Adjusted

Exposure Category	n	Adj. Mean	Category Contrast	Diff. of Adj. Means (95% C.I.)	p-Value	Covariate Remarks
Background	837	3237.9***	All Exp Categ		0.002***	RACE
Unknown	244	3178.2***	Unk vs Bkgd	-59.7(-137.4,18.0)***	0.137***	(p=0.002)
Low	156	3279.2***	Low vs Bkgd	41.3(-51.8,134.4)***	0.389***	OCC
High	201	3089.7***	High vs Bkgd	-148.2(-232.1,-64.3)***	0.001***	(p=0.001) SMOKE (p=0.001) DRINK (p=0.020) RACE* DIOXIN (p=0.048)
Total	1438	(R ² =0.074)				

Birth Weight (Full Siblings)

Model 1: Children of Ranch Hands - Log₂(Initial Dioxin)

Without adjustment for covariates (Table 4-16 [a] and [b]), there is no significant association between birth weight and initial dioxin among full siblings fathered by Ranch Hands having more than 10 ppt (p=0.703); however, there is a borderline significant positive association between birth weight and initial dioxin among children fathered by Ranch Hands having more than 5 ppt (p=0.086) current dioxin.

After adjustment for covariates (Table 4-16 [c]), there is significant variation in the association between birth weight and initial dioxin level with the mother's smoking during pregnancy (p=0.032) among full siblings fathered by Ranch Hands with more than 10 ppt current dioxin. The basis for this variation is displayed in Appendix Table B-1. Birth weight decreases significantly with initial dioxin in children of mothers who smoked during pregnancy (slope=-127.6, slope std dev=64.5, p=0.052) and does not change significantly with initial dioxin in children of mothers who did not smoke during pregnancy (p=0.603). If this variation is ignored, there is no significant association between birth weight and initial dioxin (p=0.491).

After adjustment for covariates (Table 4-16 [d]), there is no association between birth weight and initial dioxin among full siblings fathered by Ranch Hands with more than 5 ppt current dioxin (p=0.951).

Table 4-16

Post-SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: Full Siblings of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 1: $\text{Log}_2(\text{Initial Dioxin})$

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Unadjusted						
Exposure Restriction	Initial Dioxin	n	Mean	Slope (Std. Error)	p-Value	
a) D>10 ppt (n=418) (R ² =0.004)	Low	78	3354.1	9.63(25.20)	0.703	
	Medium	205	3388.4			
	High	135	3377.9			
b) D>5 ppt (n=552) (R ² =0.0053)	Low	113	3220.8	32.33(18.82)	0.086	
	Medium	242	3394.4			
	High	197	3362.3			

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Adjusted						
Exposure Restriction	Initial Dioxin	n	Adj. Mean	Adj. Slope (Std. Error)	p-Value	Covariate Remarks
c) D>10 ppt (n=390) (R ² =0.012)	Low	74	3223.2***	-20.7(30.0)***	0.491***	RACE(p=0.042) OCC(p=0.001) DIOXIN*SMOKE (p=0.032)
	Medium	190	3218.6***			
	High	126	3144.7***			
d) D>5 ppt (n=511) (R ² =0.042)	Low	103	3123.7	1.41(22.93)	0.951	RACE(p=0.072) OCC(p=0.002) DRINK(p=0.060) DIOXIN*SMOKE (p=0.057)
	Medium	222	3306.5			
	High	186	3195.3			

Birth Weight (Full Siblings)

Model 2: Children of Ranch Hands - $\text{Log}_2(\text{Current Dioxin})$ and Time

Without adjustment for covariates (Table 4-17 [a]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA tour among full siblings fathered by Ranch Hands having more than 10 ppt current dioxin ($p=0.400$). Furthermore, there is no association between birth weight and current dioxin in children fathered by Ranch Hands who had late ($p=0.643$) or early ($p=0.471$) tours.

Without adjustment for covariates (Table 4-17 [b]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA among full siblings fathered by Ranch Hands having more than 5 ppt current dioxin ($p=0.783$). Furthermore, there is no association between birth weight and current dioxin in children fathered by Ranch Hands who had late ($p=0.222$) or early ($p=0.834$) tours.

After adjustment for covariates (Table 4-17 [c]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA among full siblings fathered by Ranch Hands having more than 10 ppt current dioxin ($p=0.386$). Birth weight changes borderline significantly with current dioxin in children fathered by Ranch Hands who had late tours ($p=0.100$) while no significant association with current dioxin is seen in children of Ranch Hands with early tours ($p=0.673$).

After adjustment for covariates (Table 4-17 [d]), there is no significant variation in the association between birth weight and current dioxin with time since duty in SEA tour among full siblings fathered by Ranch Hands having more than 5 ppt current dioxin ($p=0.707$). Furthermore, there is no association between birth weight and current dioxin in children fathered by Ranch Hands who had late ($p=0.423$) or early ($p=0.817$) tours.

Table 4-17

Post-SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: Full Siblings of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 2: $\text{Log}_2(\text{Current Dioxin}), \text{Time}$

Ranch Hands - $\text{Log}_2(\text{Current Dioxin}), \text{Time}$ - Unadjusted

Exposure Restriction	Time Since SEA (years)	Mean/(n)			Slope (Std. Error)	p-Value
		Low	Medium	High		
a) D>10 ppt (n=419) (R ² =0.003)	≤18.6	3431.8 (47)	3357.8 (114)	3307.4 (64)	-16.80(36.22)	0.643
	>18.6	3368.1 (28)	3325.9 (92)	3512.2 (74)	27.40(37.94)	0.471
b) D>5 ppt (n=552) (R ² =0.009)	≤18.6	3226.5 (58)	3335.5 (143)	3311.8 (98)	33.36(27.28)	0.222
	>18.6	3360.4 (52)	3445.2 (105)	3360.5 (96)	22.74(27.28)	0.834

Table 4-17 (Continued)

Ranch Hands - Log₂(Current Dioxin), Time - Adjusted

Exposure Restriction	Time Since SEA (years)	Adj. Means/(n)			Adj. Slope (Std. Error)	p-Value	Covariate Remarks
		Low	Medium	High			
c) D>10 ppt (n=391) (R ² =0.048)	≤18.6	3285.3 (43)	3209.0 (107)	3070.1*** (62)	-72.4(43.9)	0.100	RACE(p=0.038) OCC(p=0.001) DIOXIN*TIME SMOKE(p=0.068)
	>18.6	3174.0 (28)	3139.0 (84)	3274.2*** (67)	20.2(47.9)	0.673	
d) D>5 ppt (n=511) (R ² =0.092)	≤18.6	3128.8 (51)	3183.6 (135)	3053.4 (92)	-27.5(34.3)	0.423	OCC(p=0.002) SMOKE(p=0.001) RACE(p=0.078) DRINK(p=0.094)
	>18.6	3279.3 (47)	3304.7 (98)	3064.5 (88)	-7.54(32.5)	0.817	

Birth Weight (Full Siblings)

Model 3: Children of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-18 [a]), there is a significant overall association between birth weight and categorized current dioxin among full siblings (p=0.032). There is a significant difference between the average birth weight of children of Ranch Hands in the Unknown category and the average birth weight of children of Comparisons in the Background category (p=0.008); however, there is no significant difference between the average birth weight of children of Ranch Hands in the Low (p=0.680) or High (p=0.113) categories and the birth weight of children of Comparisons in the Background category.

After adjustment for covariates (Table 4-18 [b]), there is a significant overall association between birth weight and categorized current dioxin among full siblings (p=0.001), with a significant difference between the average birth weight of children of Ranch Hands in the High (p=0.002) category and the average birth weight of children of Comparisons in the Background category. There is no significant difference between the average birth weight of children of Ranch Hands in the Low (p=0.575) or Unknown (p=0.166) categories and the average birth weight of children of Comparisons in the Background category.

Table 4-18

Post-SEA Birth Weight

Variable: Birth Weight (Grams)
 Restrictions: Full Siblings of Ranch Hands and Comparisons
 Children Conceived during or after the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

a) Unadjusted

Exposure Category	n	Mean	Category Contrast	Difference of Means (95% C.I.)	p-Value
Background	803	3407.1	All Exp Categ		0.032
Unknown	216	3293.2	Unk vs Bkgd	-113.9(-200.3, -27.5)	0.008
Low	147	3427.0	Low vs Bkgd	19.9(-81.2, 121.0)	0.680
High	194	3335.9	High vs Bkgd	-71.2(-161.4, 19.0)	0.113
Total	1360	(R ² =0.006)			

b) Adjusted

Exposure Category	n	Adj. Mean	Category Contrast	Diff. of Adj. Means (95% C.I.)	p-Value	Covariate Remarks
Background	713	3256.8	All Exp Categ		0.001	RACE(p=0.048)
Unknown	197	3194.2	Unk vs Bkgd	-62.6(-149.5, 24.3)	0.166	OCC(p=0.001)
Low	137	3285.9	Low vs Bkgd	29.1(-71.6, 129.8)	0.575	SMOKE(p=0.001)
High	180	3104.0	High vs Bkgd	-152.8(-242.9, -62.7)	0.002	DRINK(p=0.046) OCC*DIOXIN
Total	1227	(R ² =0.073)				(p=0.065)

Low Birth Weight (All Children)

Model 1: Conceptions of Ranch Hands - Log₂(Initial Dioxin)

Without adjustment for covariates (Table 4-19 [a] and [b]), there is no association between abnormally low birth weight and initial dioxin among children of Ranch Hands having more than 10 ppt (p=0.759) or more than 5 ppt (p=0.625) current dioxin.

After adjustment for covariates (Table 4-19 [c]), there is no significant association between abnormally low birth weight and initial dioxin among children of Ranch Hands with more than 10 ppt (p=0.250).

After adjustment for covariates (Table 4-19 [d]), there is significant variation in the association between the abnormally low birth weight and initial dioxin with the mother's drinking (p=0.014) and the father's race (p=0.040) among children of Ranch Hands with more than 5 ppt. The basis for this association in risk is displayed in Appendix B-1. There is a significant association between low birth weight and initial dioxin in children of non-black fathers whose mothers drank during pregnancy (p=0.017). A borderline significant association was observed in children of Black fathers whose mothers did not drink during pregnancy (p=0.084).

If this variation is ignored (Table 4-19 [d]), there is no significant association between abnormally low birth weight and initial dioxin among children of Ranch Hands having more than 5 ppt current dioxin (p=0.883).

Table 4-19

Post-SEA Low Birth Weight

Variable: Low Birth Weight
 Restrictions: All Children of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 1: $\text{Log}_2(\text{Initial Dioxin})$

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Unadjusted						
Exposure Restriction	Initial Dioxin	n	Abnormal Number	Rate	Est. Relative Risk (95% C.I.)	p-Value
a) D>10 ppt (n=496)	Low	106	7	66.0	1.05(0.79,1.38)	0.759
	Medium	237	17	71.7		
	High	153	13	85.0		
b) D>5 ppt (n=670)	Low	151	14	92.7	0.95(0.78,1.16)	0.625
	Medium	299	23	76.9		
	High	220	18	81.8		

Table 4-19 (Continued)

Ranch Hands - Log₂(Initial Dioxin) - Adjusted

Exposure Restriction	Adj. Relative Risk (95% C.I.)	p-Value	Covariate Remarks
c) D>10 ppt (n=456)	1.21(0.87,1.68)	0.250	RACE(p=0.042) SMOKE(p=0.045) OCC(p=0.001) SMOKE*DIOXIN(p=0.066)
d) D>5 ppt (n=612)	0.98(0.77,1.25)***	0.883***	SMOKE(p=0.036) OCC(P=0.017) RACE*DIOXIN(p=0.040) DRINK*DIOXIN(p=0.014)

Low Birth Weight (All Children)

Model 2: Conceptions of Ranch Hands - Log₂(Current Dioxin) and Time

Without adjustment for covariates (Table 4-20 [a] and [b]), there is no significant variation in the association between abnormally low birth weight and current dioxin with time since duty in SEA among children of Ranch Hands having more than 10 ppt (p=0.868) or more than 5 ppt current dioxin (p=0.977). Furthermore, there is no significant association between abnormally low birth weight and current dioxin among Ranch Hands with late or early tours for either exposure restriction.

After adjustment for covariates (Table 4-20 [c]), there is no significant variation in the association between abnormally low birth weight and current dioxin with time since duty in SEA among children of Ranch Hands having more than 10 ppt current dioxin (p=0.918). Furthermore, there is no association between low birth weight and current dioxin among children of Ranch Hands with late (p=0.378) or early (p=0.715) tours.

After adjustment for covariates (Table 4-20 [d]), there is significant variation in the association between abnormally low birth weight and current dioxin with time since duty in SEA and conception time since end of tour among children of Ranch Hands having more than 5 ppt current dioxin (p=0.031). The basis for this variation is displayed in Appendix B-1. There is a borderline significant decrease in abnormally low birth weight with current dioxin in children of fathers with early tours for conceptions within 2 years of duty in SEA (p=0.060) and a significant increase in low birth rate with current dioxin in conceptions more the 6.5 years after SEA (p=0.030) fathered by Ranch Hands with early tours. The other four strata did not show a significant association between abnormally low birth weight and current dioxin.

If this variation is ignored (Table 4-20 [d]), there is no significant variation in the association between the low birth weight and current dioxin with time since duty in SEA among children of Ranch Hands having more than 5 ppt current dioxin (p=0.550). Furthermore, there is no significant association between the low birth weight and current dioxin among children of Ranch Hands with late (p=0.527) or early (p=0.894) tours.

Table 4-20

Post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: All Children of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 2: Log₂(Current Dioxin), Time

Ranch Hands - Log ₂ (Current Dioxin), Time - Unadjusted						
Exposure Restriction	Time Since SEA (years)	Abnormal (No./n) Current Dioxin			Est. Relative Risk (95% C.I.)	p-Value
		Low	Medium	High		
a) D>10 ppt (n=497)						0.868
	≤18.6	32.3 (2/62)	91.6 (12/131)	70.4 (5/71)	1.01(0.65,1.58)	0.959
	>18.6	100.0 (4/40)	76.9 (8/104)	67.4 (6/89)	1.06(0.72,1.56)	0.756
b) D>5 ppt (n=670)						0.977
	≤18.6	80.5 (7/87)	81.9 (14/171)	73.4 (8/109)	0.93(0.69,1.25)	0.623
	>18.6	133.3 (8/60)	45.5 (6/132)	108.1 (12/111)	0.92(0.70,1.22)	0.568

Table 4-20 (Continued)

Ranch Hands - Log₂(Current Dioxin), Time - Adjusted

Exposure Restriction	Time Since SEA (years)	Adj. Relative Risk (95% C.I.)	p-Value	Covariate Remarks
c) D>10 ppt (n=457)			0.918	RACE(p=0.039) OCC(P=0.001)
	≤18.6	1.26(0.75,2.12)	0.378	SMOKE(P=0.043)
	>18.6	1.22(0.42,3.55)	0.715	
d) D>5 ppt (n=612)			0.550***	SMOKE(p=0.018) OCC(p=0.022)
	≤18.6	0.89(0.62,1.27)***	0.527***	C-TIME*DIOXIN (p=0.031)
	>18.6	1.02(0.75,1.39)***	0.894***	

Low Birth Weight (All Children)

Model 3: Children of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-21 [a]), there is a significant overall association between abnormally low birth weight and categorized current dioxin (p=0.002). Furthermore, the rates of low birth weight among children of Ranch Hands in the High (p=0.003) and Unknown (p=0.001) categories are significantly higher than the rate among children of Comparisons in the Background category. The rate of abnormally low birth weight among children of Ranch Hands in the Low category is not significantly different from the rate among children of Comparisons in the Background category (p=0.189).

After adjustment for the covariates (Table 4-21 [b]), there is significant variation in the overall association between abnormally low birth weight and categorized current dioxin with the father's military occupation (p=0.004). The basis for this variation is displayed in Appendix B-1. For the enlisted flyers, the rates of abnormally low birth weight among children of Ranch Hands in the High (p=0.003) and Unknown (p=0.003) categories are significantly higher than the rate among children of Comparisons in the Background category. For the enlisted ground personnel, the rates of abnormally low birth weight among children of Ranch Hands in the High (p=0.007) and Unknown (p=0.003) categories are also significantly higher than the rate among children of Comparisons in the Background category.

For the officers, significance testing could be done only between the Unknown and the Background categories because of the small number of children in the other categories. No significant difference exists between the rate of abnormally low birth weight in children of Ranch Hands in the Unknown category and the rate in children of Comparisons in the Background category (p=0.215).

Table 4-21

Post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: All Children of Ranch Hands and Comparisons
 Children Conceived during or after the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

a) Unadjusted

Exposure Category	n	Abnormal Number	Abnormal Rate	Category Contrast	Est. Relative Risk (95% C.I.)	p-Value
Background	954	40	41.9	All Exp Categ		0.002
Unknown	268	25	93.3	Unk vs Bkgd	2.35(1.40, 3.91)	0.001
Low	170	11	64.7	Low vs Bkgd	1.58(0.79, 3.14)	0.189
High	220	20	90.9	High vs Bkgd	2.28(1.31, 4.00)	0.003
Total	1612					

b) Adjusted

Exposure Category	n	Category Contrast	Adj. Relative Risk (95% C.I.)	p-Value	Covariate Remarks
Background	837	All Exp Categ	****	****	SMOKE(p=0.001)
Unknown	244	Unk vs Bkgd			OCC*DIOXIN
Low	156	Low vs Bkgd			(p=0.004)
High	201	High vs Bkgd			
Total	1438				

Low Birth Weight (Full Siblings)

Model 1: Conceptions of Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$

Without adjustment for covariates (Table 4-22 [a] and [b]), there is no association between abnormally low birth weight and initial dioxin among full siblings fathered by Ranch Hands having more than 10 ppt ($p=0.743$) or more than 5 ppt ($p=0.629$) current dioxin.

After adjustment for covariates (Table 4-22 [c]), there is significant variation in the association between the abnormally low birth weight and initial dioxin with conception time since the end of the SEA tour ($p=0.038$) and the mother's smoking ($p=0.009$) among children of Ranch Hands with more than 10 ppt. The basis for this interaction is displayed in Appendix B-1. In children of mothers who did not smoke during pregnancy and whose conceptions occurred within 2 years after the father's SEA tour there is a borderline significant decrease in the rate of abnormally low birth weight with initial dioxin ($p=0.082$). None of the remaining five combinations of conception time since SEA and mother's smoking show any significant association between abnormally low birth weight and initial dioxin.

After adjustment for covariates (Table 4-22 [d]), there is significant variation in the association between the abnormally low birth weight and initial dioxin with the mother's smoking ($p=0.032$) and conception time since the SEA tour ($p=0.021$) among children of Ranch Hands with more than 5 ppt. The basis for this interaction is displayed in Appendix B-1. In children of mothers who did not smoke during pregnancy and whose conceptions occurred within 2 years after the father's SEA tour there is a significant decrease in the rate of abnormally low birth weight with initial dioxin ($p=0.006$). None of the remaining five combinations of conception time since SEA duty and the mother's smoking show any significant association between abnormally low birth weight and initial dioxin.

If this interaction is ignored (Table 4-22 [d]), there is no significant association between abnormally low birth weight and initial dioxin among children of Ranch Hands having more than 5 ppt current dioxin ($p=0.984$).

Table 4-22

Post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: Full Siblings of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 1: $\text{Log}_2(\text{Initial Dioxin})$

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Unadjusted						
Exposure Restriction	Initial Dioxin	n	Abnormal Number	Abnormal Rate	Est. Relative Risk (95% C.I.)	p-Value
a) D>10 ppt (n=418)	Low	78	5	64.1	1.05(0.78,1.42)	0.743
	Medium	205	16	78.0		
	High	135	12	88.9		
b) D>5 ppt (n=552)	Low	113	11	97.3	0.95(0.77,1.17)	0.629
	Medium	242	20	82.6		
	High	197	17	86.3		

Ranch Hands - $\text{Log}_2(\text{Initial Dioxin})$ - Adjusted			
Exposure Restriction	Adj. Relative Risk (95% C.I.)	p-Value	Covariate Remarks
c) D>10 ppt (n=390)	****	****	RACE(p=0.028) OCC(p=0.001) SMOKE*DIOXIN(p=0.009) C-TIME*DIOXIN (p=0.038)
d) D>5 ppt (n=511)	1.01(0.93,1.09)***	0.984***	RACE(p=0.065) OCC(p=0.011) SMOKE*DIOXIN(p=0.032) C-TIME*DIOXIN (p=0.021)

Low Birth Weight (Full Siblings)

Model 2: Conceptions of Ranch Hands - $\text{Log}_2(\text{Current Dioxin})$ and Time

Without adjustment for covariates (Table 4-23 [a] and [b]), there is no significant variation in the association between abnormally low birth weight and current dioxin with time since duty in SEA among full siblings fathered by Ranch Hands having more than 10 ppt ($p=0.921$) or more than 5 ppt current dioxin ($p=0.863$). Furthermore, there is no significant association between abnormally low birth weight and current dioxin among children of Ranch Hands with late or early tours for either exposure restriction.

After adjustment for covariates (Table 4-23 [c] and [d]), there is no significant variation in the association between abnormally low birth weight and current dioxin with time since duty in SEA among full siblings fathered by Ranch Hands having more than 10 ppt ($p=0.819$) or 5 ppt ($p=0.655$) current dioxin. Furthermore, there is no significant association between abnormally low birth weight and current dioxin among children of Ranch Hands with late or early tours for either exposure restriction.

Table 4-23

Post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: Full Siblings of Ranch Hands
 Children Conceived during or after the
 Father's Duty in SEA
 Model 2: $\text{Log}_2(\text{Current Dioxin}), \text{Time}$

Ranch Hands - $\text{Log}_2(\text{Current Dioxin}), \text{Time}$ - Unadjusted						
Exposure Restriction	Time Since SEA (years)	Abnormal (No./n) Current Dioxin			Est. Relative Risk (95% C.I.)	p-Value
		Low	Medium	High		
a) D>10 ppt (n=419)						0.921
	≤18.6	21.3 (1/47)	105.3 (12/114)	78.1 (5/64)	1.04(0.66,1.64)	0.856
	>18.6	107.1 (3/28)	76.1 (7/92)	67.6 (5/74)	1.08(0.70,1.64)	0.734
b) D>5 ppt (n=552)						0.863
	≤18.6	86.2 (5/58)	90.9 (13/143)	81.6 (8/98)	0.95(0.69,1.31)	0.763
	>18.6	134.6 (7/52)	38.1 (4/105)	114.6 (11/96)	0.92(0.49,1.70)	0.782

Table 4-23 (Continued)

Ranch Hands - Log₂(Current Dioxin), Time - Adjusted

Exposure Restriction	Time Since SEA (years)	Adj. Relative Risk (95% C.I.)	p-Value	Covariate Remarks
c) D>10 ppt (n=391)			0.819	RACE(p=0.025) SMOKE(p=0.109) OCC(p=0.003)
	≤18.6	1.31(0.77,2.23)	0.318	
	>18.6	1.21(0.75,1.97)	0.438	
d) D>5 ppt (n=511)			0.665	RACE(p=0.076) OCC(p=0.024)
	≤18.6	0.91(0.62,1.35)	0.640	
	>18.6	1.01(0.72,1.41)	0.944	

Low Birth Weight (Full Siblings)

Model 3: Conceptions of Ranch Hands and Comparisons - Categorized Current Dioxin

Without adjustment for covariates (Table 4-24 [a]), there is a significant overall association between abnormally low birth weight and categorized current dioxin among full siblings (p=0.004). Furthermore, the rates of low birth weight among children of Ranch Hands in the High (p=0.004) and Unknown (p=0.001) categories are significantly higher than the rate among children of Comparisons in the Background category. The rate of abnormally low birth weight among children of Ranch Hands in the Low category is not significantly different from the rate among children of Comparisons in the Background category (p=0.228).

After adjustment for covariates (Table 4-24 [b]), there is significant variation in the overall association between abnormally low birth weight and categorized current dioxin with the father's military occupation (p=0.004) and race (p=0.021) among full siblings. The basis for this variation is displayed in Appendix B-1. In children of nonblack enlisted flyers, the rates of abnormally low birth weight among children of fathers in the High (p=0.012) and Low (p=0.011) categories are significantly higher than the rate among children of fathers in the Background category. In children of nonblack enlisted ground personnel, the rates of abnormally low birth weight among children of fathers in the High (p=0.039) and Unknown (p=0.038) categories are significantly higher than the rate among children of fathers in the Background category.

In children of Black fathers, significance testing could be done only in children of officers in the Unknown and the Background categories because of sparse data. No significant difference exists between rate of abnormally low birth weight in children of fathers in the Unknown category and the rate in children of fathers in the Background category (p=0.180).

Table 4-24

Post SEA Low Birth Weight

Variable: Low Birth Weight (Discrete)
 Restrictions: Full Siblings of Ranch Hands and Comparisons
 Children Conceived during or after the
 Father's Duty in SEA
 Model 3: Categorized Current Dioxin

a) Unadjusted

Exposure Category	n	Abnormal Number	Rate	Category Contrast	Est. Relative Risk (95% C.I.)	p-Value
Background	803	36	44.8	All Exp Categ		0.004
Unknown	216	22	101.9	Unk vs Bkgd	2.42(1.39,4.20)	0.001
Low	147	10	68.0	Low vs Bkgd	1.56(0.75,3.21)	0.228
High	194	19	97.9	High vs Bkgd	2.31(1.30,4.13)	0.004
Total	1360					

b) Adjusted

Exposure Category	n	Category Contrast	Adj. Relative Risk (95% C.I.)	p-Value	Covariate Remarks
Background	713	All Exp Categ	****	****	SMOKE(p=0.001)
Unknown	197	Unk vs Bkgd			RACE*DIOXIN(p=0.021)
Low	137	Low vs Bkgd			OCC*DIOXIN(p=0.004)
High	180	High vs Bkgd			
Total	1227				

4.4 Conclusion

Throughout this section, nonsignificant results are indicated by NS, borderline significant results are indicated by NS* and the presence of interactions with the p-value greater than or equal to 0.01 and less than 0.05 are indicated with a preceding asterisk (**). Four asterisks (****) represent the presence of an interaction between a covariate and dioxin with a p-value less than 0.01.

Assessments of the association between paternal dioxin and birth weight and abnormally low birth weight were carried out based on pre-SEA and post-SEA children using Models 1, 2 and 3. Each analysis was carried out without adjustment for covariates. All analyses were first based on all children and again on full sibling children. The results are summarized in Tables 4-25 through 4-27.

Table 4-25

P-Value Summary of Initial Dioxin (Model 1) Analyses
of Pre-Post Birth Weight
(Children of Ranch Hands)

a) All Children

Variable	Unadjusted	
	D>10 ppt	D>5 ppt
Birth Weight	NS*	0.003
Low Birth Weight	NS	NS

b) Full Siblings

Variable	Unadjusted	
	D>10 ppt	D>5 ppt
Birth Weight	0.039	0.004
Low Birth Weight	NS	NS

Table 4-26

P-Value Summary of Current Dioxin and Time Analyses (Model 2) of
Pre-Post SEA Birth Weight
(Children of Ranch Hands)

a) All Children

Variable	Unadjusted	
	D>10 ppt	D>5 ppt
Birth Weight	NS	NS
Low Birth Weight	NS	NS

b) Full Siblings

Variable	Unadjusted	
	D>10 ppt	D>5 ppt
Birth Weight	NS	NS
Low Birth Weight	NS	NS

Table 4-27

P-Value Summary of Pre-Post SEA Categorized Current Dioxin (Model 3)
Analyses of Birth Weight (Children of Ranch Hands and Comparisons)

a) All Children

Variable	All	Unadjusted Contrasts with Background		
		Unknown	Low	High
Birth Weight	0.018	NS	0.044	NS
Low Birth Weight	0.011	0.001	NS*	NS

b) Full Siblings

Variable	All	Unadjusted Contrasts with Background		
		Unknown	Low	High
Birth Weight	0.045	NS*	NS	NS
Low Birth Weight	0.014	0.002	NS*	NS

Assessments of the association between paternal dioxin and birth weight and abnormally low birth weight were carried out based on post-SEA children using Models 1, 2 and 3. Each analysis was carried out without and then with adjustment for covariates. All analyses were first based on all post-SEA children and again on post-SEA full sibling children. The results are summarized in Tables 4-28 through 4-30.

Table 4-28

P-Value Summary of Initial Dioxin (Model 1) Analyses
of Post-SEA Birth Weight
(Children of Ranch Hands)

a) All Children

Variable	Unadjusted		Adjusted	
	D>10 ppt	D>5 ppt	D>10 ppt	D>5 ppt
Birth Weight	NS	NS	**NS	****
Low Birth Weight	NS	NS	NS	**NS

b) Full Siblings

Variable	Unadjusted		Adjusted	
	D>10 ppt	D>5 ppt	D>10 ppt	D>5 ppt
Birth Weight	NS	NS*	**NS	NS
Low Birth Weight	NS	NS	****	**NS

Table 4-29

P-Value Summary of Current Dioxin and Time Analyses (Model 2) of
Post-SEA Birth Weight
(Children of Ranch Hands)

a) All Children

Variable	Unadjusted					
	D>10 ppt Dioxin by			D>5 ppt Dioxin by		
	Time	Late	Early	Time	Late	Early
Birth Weight	NS	NS	NS	NS	NS	NS
Low Birth Weight	NS	NS	NS	NS	NS	NS

Table 4-29 (Continued)

Variable	Adjusted					
	D>10 ppt Dioxin by			D>5 ppt Dioxin by		
	Time	Late	Early	Time	Late	Early
Birth Weight	**NS	**NS*	**NS	**NS	**NS	**NS
Low Birth Weight	NS	NS	NS	**NS	**NS	**NS

b) Full Siblings

Variable	Unadjusted					
	D>10 ppt Dioxin by			D>5 ppt Dioxin by		
	Time	Late	Early	Time	Late	Early
Birth Weight	NS	NS	NS	NS	NS	NS
Low Birth Weight	NS	NS	NS	NS	NS	NS

Variable	Adjusted					
	D>10 ppt Dioxin by			D>5 ppt Dioxin by		
	Time	Late	Early	Time	Late	Early
Birth Weight	NS	NS*	NS	NS	NS	NS
Low Birth Weight	NS	NS	NS	NS	NS	NS

Table 4-30

P-Value Summary of Categorized Current Dioxin Analyses (Model 3)
of Post-SEA Birth Weight
(Children of Ranch Hands and Comparisons)

a) All Children

Variable	All	Unadjusted Contrasts with Background		
		Unknown	Low	High
Birth Weight	0.017	0.010	NS	NS*
Low Birth Weight	0.002	0.001	NS	0.003

Table 4-30 (Continued)

Variable	All	Adjusted Contrasts with Background		
		Unknown	Low	High
Birth Weight	**0.002	**NS	**NS	**0.001
Low Birth Weight	****	****	****	****

b) Full Siblings

Variable	All	Unadjusted Contrasts with Background		
		Unknown	Low	High
Birth Weight	0.032	0.008	NS	NS
Low Birth Weight	0.004	0.001	NS	0.004

Variable	All	Adjusted Contrasts with Background		
		Unknown	Low	High
Birth Weight	0.001	NS	NS	0.002
Low Birth Weight	****	****	****	****

Pre-post SEA analyses of birth weight were generally negative. The few significant findings were not suggestive of a dioxin effect. For example, a Model 1 analysis of birth weight (Table 4-1) found a significant interaction with time since tour caused by decreasing birth weights in pre-SEA children and increasing birth weights in post-SEA children. This change was caused by an increase in mean birth weight from pre- to post-SEA in children of Ranch Hands with the highest dioxin levels. Because low birth weights are considered the adverse direction, this finding was not interpretable as an adverse effect of dioxin. A similar significant change in slope was found after restriction to full sibling children. In a Model 3 analysis of abnormally low birth weight (Table 4-9), a significant interaction was found with time of conception in the contrast of children of Ranch Hands in the Unknown category with children of Comparisons in the Background category. Among pre-SEA children, the rate of abnormally low birth weight in Ranch Hand children (61.2 per 1000) was less than that in children of Comparisons (73.5 per 1000) and in post-SEA children, the rate in Ranch Hand children (93.3 per 1000) was greater than that in children of Comparisons (41.9 per 1000), but this change was due more to the decrease in the Comparison rate than to the increase in the Ranch Hand rate, a pattern that cannot be attributed to dioxin. A similar finding was revealed after restriction to full sibling children (Table 4-12).

Post-SEA analyses of birth weight were also generally negative or were complicated by interactions with covariates that lack coherent explanation. For example, a Model 1 analysis of birth weight found a significant interaction with the father's race and the mother's smoking (Table 4-13 [c]), caused by a significant decrease in birth weight with dioxin in children of Black fathers whose mother did not smoke during pregnancy and a borderline significant weight reduction in children of nonblack fathers whose mother did smoke during pregnancy. After restriction to full sibling children, a significant interaction with only the mother's smoking was found (Table 4-16 [d]). In that analysis, there was a significant reduction in birth weight with dioxin in children of mothers who smoked during pregnancy and no significant reduction in children of mothers who did not smoke during pregnancy. A Model 2 analysis of birth weight found a significant interaction with the father's race (Table 4-14 [c]); birth weight decreased borderline significantly with dioxin in children of Black fathers who had early tours but there were no significant associations in the other 3 strata. A Model 3 analysis of birth weight found significant interaction with the father's race (Table 4-15 [b]); the birth weight of children fathered by Black Ranch Hands in the High category was significantly less than that of children born to Black Comparisons in the Background category and a weaker reduction was found in children of nonblack Ranch Hands in the High category. After restriction to full siblings (Table 4-18 [b]), children of Ranch Hands in the High category were found to have significantly lower birth weight than children of Comparisons in the Background category.

Post-SEA analyses of abnormally low birth weight were generally negative or were complicated by interactions with covariates. For example, a Model 1 analysis (Table 4-19 [d]) found a significant interaction with the father's race and with the mother's drinking during pregnancy. This interaction was caused by a significant increase in the rate of abnormally low birth weight in children of nonblack fathers whose mother drank during pregnancy, however, the number of children (35) and the number with abnormally low birth weight (3) in this stratum were small; no significant associations were found in the other 3 strata. After restriction to full siblings (Table 4-22 [d]), a significant interaction was found with the mother's smoking during pregnancy and with the time of conception. This interaction was caused by a significant reduction in the risk of abnormally low birth weight in children conceived within 2 years of the father's departure from SEA whose mother did not smoke during pregnancy. A Model 2 analysis of abnormally low birth weight (Table 4-20 [d]) found a significant interaction with time of conception. This interaction was caused by a significant increase in risk in children conceived more than 6.5 years after the father's departure from SEA whose father had an early tour. In the same analysis, however, there was a borderline significant decrease in risk in children conceived within 2 years of the father's departure from SEA whose father had an early tour. After restriction to full sibling children (Table 4-23), no significant associations were found between abnormally low birth weight and dioxin and no significant interaction with covariates were found. A Model 3 analysis of abnormally low birth weight (Table 4-21 [b]) found a significant interaction with the father's military occupation in SEA,

caused by a significant increase in risk in children of father's who were enlisted ground personnel. After restriction to full sibling children (Table 4-24 [b]), a significant interaction with the father's race and military occupation in SEA were found, caused by significant increases in risk in children of nonblack Ranch Hands in the High category who were enlisted flyers or who were enlisted ground personnel.

These findings are inconsistent because the nature of an interaction sometimes changes after restriction to full sibling children and because birth weight decreases with dioxin in some strata and increases in others. These findings are also weak because many of the interactions are based on sparse data. Therefore these results appear unrelated to dioxin. We find no evidence in these data that birth weight is adversely associated with the father's dioxin exposure.