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ARMSTRONG LABORATORY

THE AIR FORCE HEALTH STUDY

AN EPIDEMIOLOGIC INVESTIGATION OF HEALTH EFFECTS IN AIR FORCE PERSONNEL FOLLOWING EXPOSURE TO HERBICIDES

MORTALITY UPDATE 1996

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The Office of Public Affairs has reviewed this technical report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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13. ABSTRACT *(Maximum 200 words)*

The purpose of the Air Force Health Study is to determine whether those individuals involved in the spraying of herbicides in Vietnam during the Ranch Hand operation have experienced any adverse health effects as a result of their participation in that program. The study is designed to evaluate both the mortality (death) and morbidity (disease) in these individuals over a 20-year period beginning in 1982.

The Baseline Mortality Report was released in June 1983, the Baseline Morbidity Report in February 1984. Follow-up mortality reports were released in 1984, 1985, 1986, 1989, 1991, 1993 and 1994. This study has not demonstrated health effects which can be conclusively attributed to herbicide or dioxin exposure.

In summary, the overall all-cause mortality experience of the Ranch Hands is not significantly different from that expected. As of 31 December 1993, 118 (9.4%) of the 1261 Ranch Hands have died; the expected number of deaths is 119.95. The observed and expected numbers of deaths among all Ranch Hands were not significantly different for accidental deaths, suicides and deaths caused by malignant neoplasms and circulatory system diseases. However, there were borderline significant increased numbers of Ranch Hand deaths due to circulatory system diseases in nonflying enlisted Ranch Hands. In contrast to previous reports, deaths caused by digestive disease and deaths due to ill-defined and unknown causes in enlisted flyers are no longer significantly increased.

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EXECUTIVE SUMMARY

An evaluation of cumulative all-cause Ranch Hand mortality through 31 December 1993 found no statistically significant differences between the observed and expected number of deaths due to all causes (Standardized Mortality Ratio (SMR)=0.98, 95% Confidence Interval (CI) 0.82-1.17, p-value (p)=0.87). The adjusted all-cause Ranch Hand death rate is 3.34 deaths per 1000 person-years while the Comparison rate is 3.41 deaths per 1000 person-years. Furthermore, the observed number of deaths was not statistically different from the expected number in any of the four subgroups of Ranch Hands determined by rank (officer, enlisted) and job (flyer, nonflyer).

Adjusted cause-specific analyses revealed no overall significant differences between the observed and expected numbers of deaths for accidental deaths (SMR=1.17), suicides (SMR=0.69), homicides (SMR=1.17), deaths due to infectious or parasitic diseases (SMR=1.50), deaths due to malignant neoplasm (SMR=0.90), endocrine disease (SMR=0.92), respiratory disease (SMR=0.49), digestive disease (SMR=1.75), ill-defined or unknown causes (SMR=1.25) or deaths due to circulatory disease (SMR=0.98). However, there was a borderline significant excess due to circulatory system diseases among nonflying enlisted personnel (SMR=1.49, 95% CI 0.98-2.19, p=0.06). This excess was noted in the last report, but the number of these deaths remains at 24 and the SMR has decreased slightly from 1.60 to 1.49 since the last report.

Two causes of death that previously showed significant excesses of observed deaths but no longer show significant results are digestive disease and ill-defined or unknown causes. The number of Ranch Hand deaths due to digestive disease noted in the three previous reports is no longer significantly increased, with the number of such deaths remaining at nine since 1989. Similarly, there is no longer a significant increase in deaths due to ill-defined or unknown causes for Ranch Hand flying enlisted personnel, for which the observed number of deaths has remained at two since 1983.

Dioxin assays have been administered to 80% of the 1261 Ranch Hands. Of the 1008 who were administered the assay, a total of 991 Ranch Hands have quantifiable dioxin results. Analysis of survival status versus current dioxin levels found no significant difference between mean dioxin levels among the 968 living and 23 dead Ranch Hands with quantifiable dioxin results. Survival time was also not significantly associated with dioxin levels in Ranch Hands.

In summary, the overall all-cause mortality experience of the Ranch Hands is not significantly different from that expected. As of 31 December 1993, 118 (9.4%) of the 1261 Ranch Hands have died; the expected number of deaths is 119.95. The observed and expected numbers of deaths among all Ranch Hands were not significantly different for accidental deaths, suicides and deaths caused by malignant neoplasms and circulatory system diseases. However, there were borderline significantly increased numbers of Ranch Hand deaths due to circulatory system diseases in nonflying enlisted Ranch Hands. In contrast to previous reports, deaths caused by digestive disease and deaths due to ill-defined and unknown causes in enlisted flyers are no longer significantly increased.

1. INTRODUCTION

This report updates the findings of prior Air Force Health Study mortality reports released in 1983 [1], 1984 [2], 1985 [3], 1986 [4], 1989 [5], 1991 [6], 1993 [7] and 1994 [8]. The reader is referred to the baseline report [1] for information regarding the study design and the mortality determination process.

This report contrasts cumulative Ranch Hand mortality through 31 December 1993 (verified as of December 1995) with that expected based on the mortality experience of the Comparison population of 19,080 Air Force veterans who flew or serviced C-130 cargo aircraft in Southeast Asia (SEA) during the same calendar period that the Ranch Hand unit was active in Vietnam (1962-1971).

A person-year is the length of time lived by one person in one year. Persons surviving to 31 December 1993 (the cutoff date for analysis) contribute the time, in years, between the dates of entry into follow-up (the date of the start of duty in SEA) and 31 December 1993. Persons known to have died before 31 December 1993 contribute the time, in years, between the dates of entry into follow-up and death. All analyses are based on regression analysis of the SMR, the ratio of the observed to the expected number of deaths [9]. P-values and confidence intervals for the SMR were computed based on a Poisson model [10]. Except when otherwise noted, all death rates (per 1,000 person-years), expected deaths and SMRs are adjusted for year of birth, age, rank (officer, enlisted) and military occupation (flyer, nonflyer).

2. ALL-CAUSE MORTALITY

Summary mortality statistics for both populations are given in Table 1. In this table and throughout this report, "Flying Officers" refers to pilots and navigators, "Officers" are flying officers and nonflying officers, "Flying Enlisted" refers to enlisted flight engineers, and "Nonflying Enlisted" are enlisted ground personnel. Table 1 gives the number at risk, number dead, number of person-years and an adjusted death rate. Each adjusted rate [11] is the product of the Comparison death rate and the adjusted SMR given in Table 3. The result is then multiplied by 1,000 to give a death rate per 1,000 person-years.

Table 1

Summary Counts and Adjusted Death Rates
by Rank and Occupation, All Causes

	Ranch Hands				Comparisons			
Stratum	At Risk	Dead	Person Years	Rate*	At Risk	Dead	Person Years	Rate*
Flying Officers	441	39	11176	3.53	5242	483	134075	3.60
Flying Enlisted	207	21	5255	3.24	2829	312	71290	4.38
All Flyers	648	60	16431	3.41	8071	795	205365	3.87
Nonflying Officers	26	2	658	2.90	284	27	7436	3.63
Nonflying Enlisted	587	56	14845	3.49	10725	850	277991	3.06
All Nonflyers	613	58	15503	3.44	11009	877	285427	3.07
All Officers	467	41	11833	3.50	5526	510	141511	3.60
All Enlisted	794	77	20100	3.29	13554	1162	349281	3.33
All Personnel	1261	118	31934	3.34	19080	1672	490792	3.41

*per 1000 person-years

Unadjusted occupation and race-specific mortality is summarized in Table 2. One Ranch Hand death rate in Table 2 appears unusually high. The Ranch Hand death rate among Black enlisted flight engineers is 10.99 deaths per 1,000 person-years and the corresponding rate for all Comparison deaths in this stratum is 5.43 deaths per 1,000 person-years. The four Ranch Hand deaths in this stratum have occurred since 1980. One of the four deaths was a suicide, one was accidental, one was due to a digestive system disease and the last to ill-defined causes. An adjusted analysis shows that this increase is not statistically significant (SMR=1.7, 95% CI 0.55-4.20, p=0.28). In general, a death rate based on only a few deaths is not a reliable measure of mortality experience because one additional death can produce large changes in the death rate and the SMR.

Table 2

Unadjusted Occupation and Race Specific Cumulative All-cause Mortality

Nonblack Personnel

	Ranch Hand				Comparison			
Stratum	At Risk	Dead	Person Years	Rate*	At Risk	Dead	Person Years	Rate*
Pilots	351	31	8880	3.49	3417	348	87062	4.00
Navigators	82	8	2095	3.82	1773	134	45617	2.94
Nonflying Officers	25	2	633	3.16	280	27	7332	3.68
Flying Enlisted	192	17	4892	3.48	2607	282	65764	4.29
Nonflying Enlisted	534	51	13506	3.78	9689	743	251558	2.95
Total	1184	109	30006	3.63	17766	1534	457333	3.35

Table 2 (Continued)

Black Personnel

	Ranch Hand				Comparison			
Stratum	At Risk	Dead	Person Years	Rate*	At Risk	Dead	Person Years	Rate*
Pilots	6	0	151	0.00	20	1	528	1.89
Navigators	2	0	50	0.00	32	0	868	0.00
Nonflying Officers	1	0	25	0.00	4	0	104	0.00
Flying Enlisted	15	4	364	10.99	222	30	5526	5.43
Nonflying Enlisted	53	5	1339	3.73	1036	107	26433	4.05
Total	77	9	1927	4.67	1314	138	33459	4.12

All Personnel

	Ranch Hand				Comparison			
Stratum	At Risk	Dead	Person Years	Rate*	At Risk	Dead	Person Years	Rate*
Pilots	357	31	9031	3.43	3437	349	87591	3.98
Navigators	84	8	2145	3.73	1805	134	46485	2.88
Nonflying Officers	26	2	658	3.04	284	27	7436	3.63
Flying Enlisted	207	21	5255	4.00	2829	312	71290	4.38
Nonflying Enlisted	587	56	14845	3.77	10725	850	277991	3.06
Total	1261	118	31934	3.70	19080	1672	490792	3.41

* per 1000 person-years

Survival analyses were carried out to assess Ranch Hand all-cause mortality relative to the Comparison population. All analyses were adjusted for rank (officer, enlisted), occupation (flyer, nonflyer) and date of birth and age in 5-year intervals. The results are shown in Table 3. The expected numbers of deaths in this table are sums of expected numbers of deaths within 5-year intervals of year of birth.

Table 3

Adjusted All-cause Standardized Mortality Ratios
by Rank and Military Occupation Among Ranch Hands

Stratum	Dead	Expected Deaths	SMR	95% CI	P-value
Flying Officers	39	39.97	0.98	0.70-1.32	0.90
Nonflying Officers	2	2.50	0.80	0.13-2.64	0.83
All Officers	41	42.47	0.97	0.70-1.30	0.84
Flying Enlisted	21	28.40	0.74	0.47-1.11	0.16
Nonflying Enlisted	56	49.08	1.14	0.87-1.47	0.32
All Enlisted	77	77.48	0.99	0.79-1.24	0.97
All Flying Personnel	60	68.37	0.88	0.68-1.12	0.31
All Nonflying Personnel	58	51.58	1.12	0.86-1.44	0.37
All Ranch Hands	118	119.95	0.98	0.82-1.17	0.87

There are no significant differences between the observed and expected number of deaths from all causes in any stratum. The overall adjusted SMR for all Ranch Hands for all causes of death is less than 1 (SMR= 0.98, 95% CI 0.82-1.17, p=0.87) because the expected number of deaths (119.95) is slightly greater than the observed number of deaths (118).

One degree of freedom (DF=1) chi-square tests for trend [9] were applied to every stratum to assess the significance of trends in the SMR since 1987. These analyses were carried out twice, first with each of the years 1987 through 1993 separately contributing to the test statistic and again with 1987 through 1990 collapsed to a single stratum and 1991 through 1993 collapsed to a second stratum. All analyses are conditioned on survival to 1 January 1987 and, due to sparseness of data, were not adjusted for date of birth. These tests are two-tailed and therefore would detect upward or downward trends in the SMR. The results are shown in Table 4.

Table 4

All-cause Ranch Hand Mortality
Seven-year Trend Analysis

Flying Officers

Chi-square (single year) =3.08, DF=1, P =0.08
Chi-square (87-90,91-93) =2.09, DF=1, P =0.15

Year	Dead	Rate*	Expected Deaths	SMR
1987	5	11.94	2.55	1.96
1988	5	12.11	2.69	1.86
1989	2	4.88	1.85	1.08
1990	2	4.91	2.60	0.77
1991	1	2.46	2.02	0.50
1992	1	2.47	2.45	0.41
1993	2	4.96	1.69	1.18

Enlisted Flyers

Chi-square (single year) =0.33, DF=1, P =0.57
Chi-square (87-90,91-93) =0.73, DF=1, P =0.39

Year	Dead	Rate*	Expected Deaths	SMR
1987	1	5.11	0.89	1.12
1988	0	0.00	1.42	0.00
1989	2	10.27	0.82	2.43
1990	3	15.65	1.04	2.89
1991	3	15.86	1.25	2.40
1992	1	5.37	2.26	0.44
1993	0	0.00	1.25	0.00

All Flyers

Chi-square (single year) =3.19, DF=1, P =0.07
Chi-square (87-90,91-93) =2.91, DF=1, P =0.09

Year	Dead	Rate*	Expected Deaths	SMR
1987	6	9.77	3.41	1.76
1988	5	8.22	4.12	1.21
1989	4	6.62	2.67	1.50
1990	5	8.35	3.62	1.38
1991	4	6.72	3.30	1.21
1992	2	3.39	4.82	0.41
1993	2	3.39	2.99	0.67

Table 4 (Continued)

Nonflying Officers

Chi-square (single year) =0.03, DF=1, P =0.87
Chi-square (87-90,91-93) =0.44, DF=1, P =0.51

Year	Dead	Rate*	Expected Deaths	SMR
1987	0	0.00	0.37	0.00
1988	0	0.00	0.37	0.00
1989	1	40.54	0.19	5.37
1990	0	0.00	0.09	0.00
1991	0	0.00	0.00	0.00
1992	0	0.00	0.28	0.00
1993	0	0.00	0.19	0.00

Nonflying Enlisted

Chi-square (single year) =0.27, DF=1, P =0.60
Chi-square (87-90,91-93) =0.43, DF=1, P =0.51

Year	Dead	Rate*	Expected Deaths	SMR
1987	2	3.63	2.37	0.84
1988	6	10.96	2.69	2.23
1989	1	1.84	2.79	0.36
1990	4	7.38	3.12	1.28
1991	2	3.71	3.06	0.65
1992	3	5.60	3.17	0.95
1993	3	5.62	2.80	1.07

All Nonflyers

Chi-square (single year) =0.31, DF=1, P =0.58
Chi-square (87-90,91-93) =0.60, DF=1, P =0.44

Year	Dead	Rate*	Expected Deaths	SMR
1987	2	3.47	2.63	0.76
1988	6	10.48	2.96	2.03
1989	2	3.52	2.95	0.68
1990	4	7.07	3.23	1.24
1991	2	3.56	3.12	0.64
1992	3	5.36	3.39	0.88
1993	3	5.38	2.96	1.01

Table 4 (Continued)

All Officers

Chi-square (single year) =2.91, DF=1, P =0.09
Chi-square (87-90,91-93) =2.37, DF=1, P =0.12

Year	Dead	Rate*	Expected Deaths	SMR
1987	5	11.27	2.90	1.73
1988	5	11.42	3.05	1.64
1989	3	6.91	2.03	1.48
1990	2	4.64	2.70	0.74
1991	1	2.33	2.03	0.49
1992	1	2.33	2.71	0.37
1993	2	4.68	1.87	1.07

All Enlisted

Chi-square (single year) =0.50, DF=1, P =0.48
Chi-square (87-90,91-93) =0.89, DF=1, P =0.34

Year	Dead	Rate*	Expected Deaths	SMR
1987	3	4.02	3.25	0.92
1988	6	8.08	4.00	1.50
1989	3	4.06	3.65	0.82
1990	7	9.54	4.17	1.68
1991	5	6.87	4.27	1.17
1992	4	5.54	5.19	0.77
1993	3	4.17	3.99	0.75

All Ranch Hands

Chi-square (single year) =3.03, DF=1, P =0.08
Chi-square (87-90,91-93) =3.21, DF=1, P =0.07

Year	Dead	Rate*	Expected Deaths	SMR
1987	8	6.72	5.93	1.35
1988	11	9.32	6.89	1.60
1989	6	5.12	5.71	1.05
1990	9	7.72	6.82	1.32
1991	6	5.18	6.42	0.94
1992	5	4.35	7.99	0.63
1993	5	4.36	5.98	0.84

*per 1000 person-years

Table 4 shows a borderline significant downward trend among flying officers (p=0.08) caused by relatively low death rates after 1988. This seven-year trend is also reflected among all flyers (p=0.07), all officers (p=0.09), and all Ranch Hands (p=0.08).

Lexis diagrams provide a view of the data that permits a visual assessment of mortality clustering with respect to age and calendar time. A lexis diagram [11] for Ranch Hand flying officers is shown in Figure 1. Follow-up time is indicated for each living subject with a straight line beginning at his age at the beginning of his first qualifying tour of duty in SEA and ending with his age at 31 December 1993. Follow-up lines for deceased subjects end with a square at the subject's age at death and date of death. The corresponding diagram without the follow-up lines is shown in Figure 2. Lexis diagrams for nonflying officers, flying enlisted and nonflying enlisted personnel, without follow-up lines, are shown in Figures 3 through 5. If a strong latency effect were occuring, it might be revealed in a Lexis diagram by a cluster of deaths approximately 20 years after entry into follow-up. No such clusters are apparent in these data.

Figure 1
Lexis Diagram
Ranch Hand Flying Officers

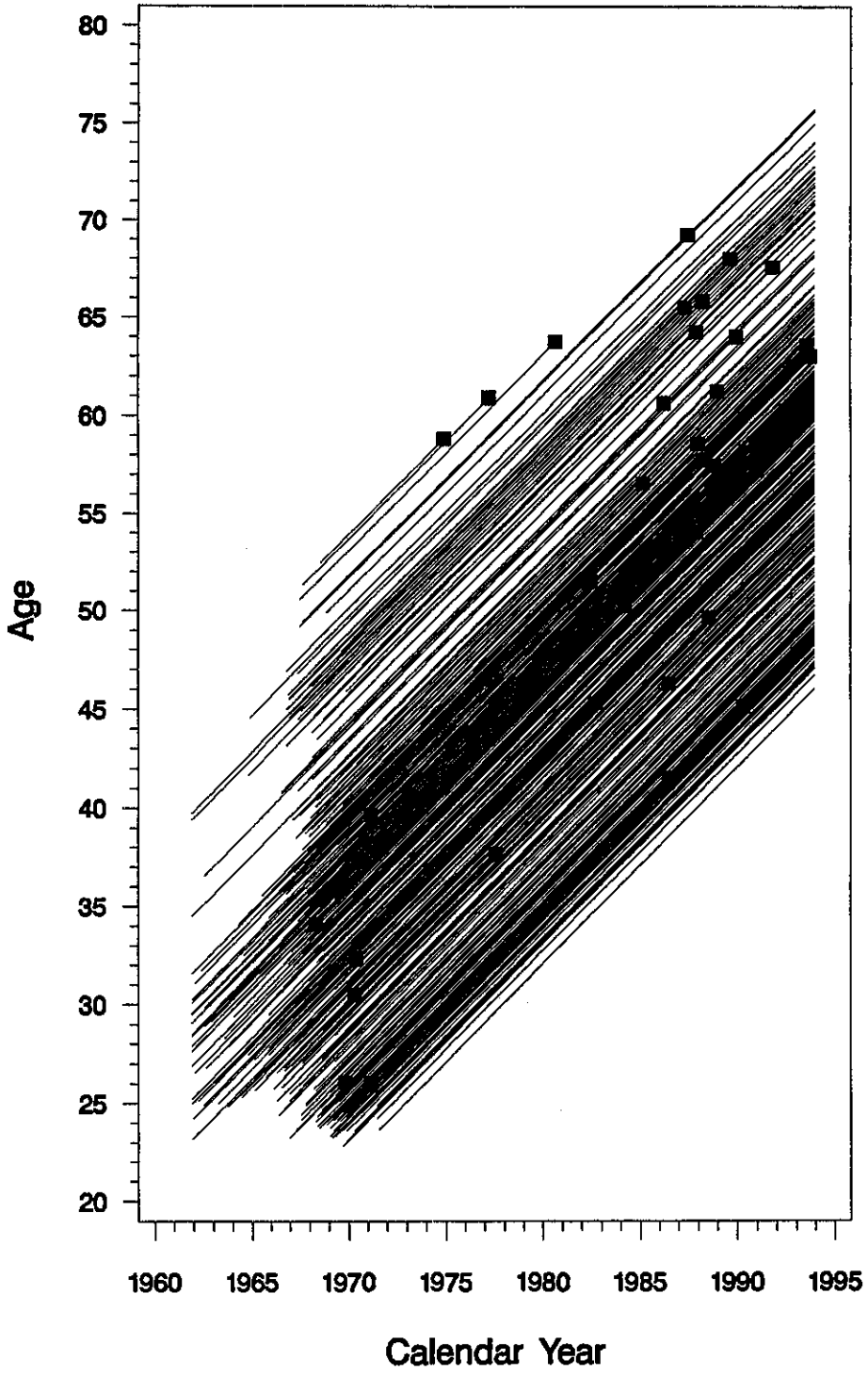


Figure 2
Lexis Diagram
Ranch Hand Flying Officers

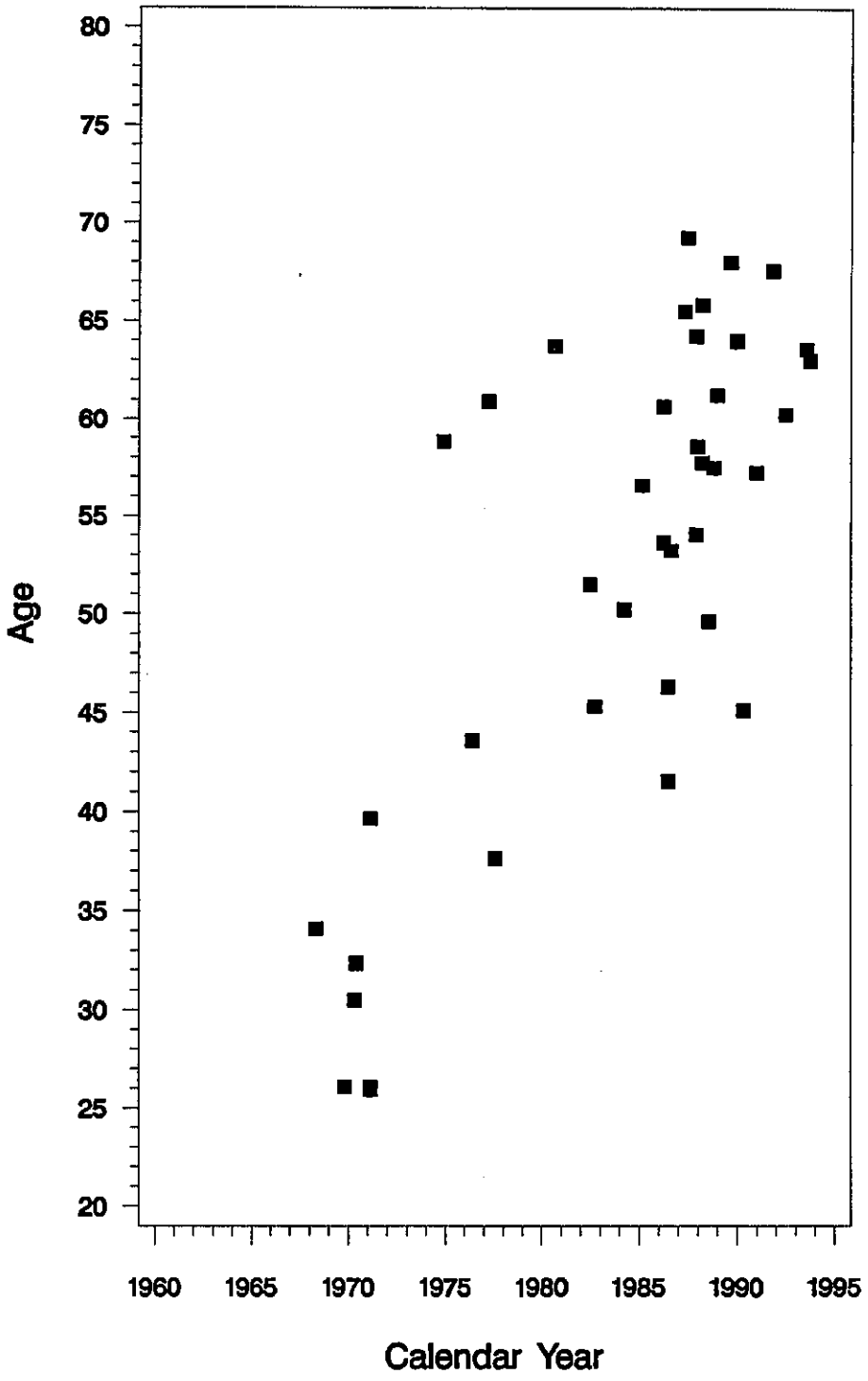


Figure 3
Lexis Diagram
Ranch Hand NonFlying Officers

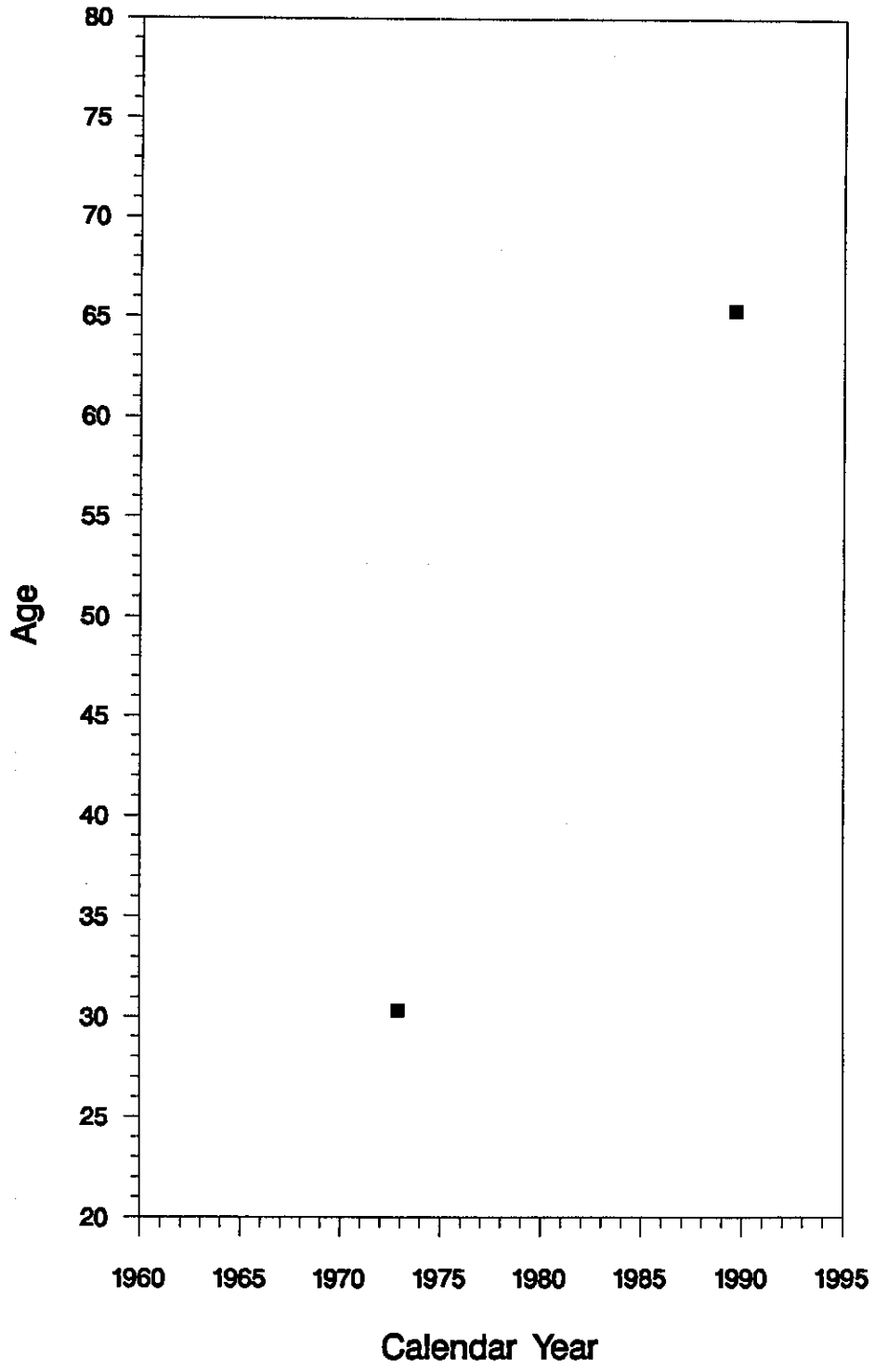


Figure 4
Lexis Diagram
Ranch Hand Flying Enlisted

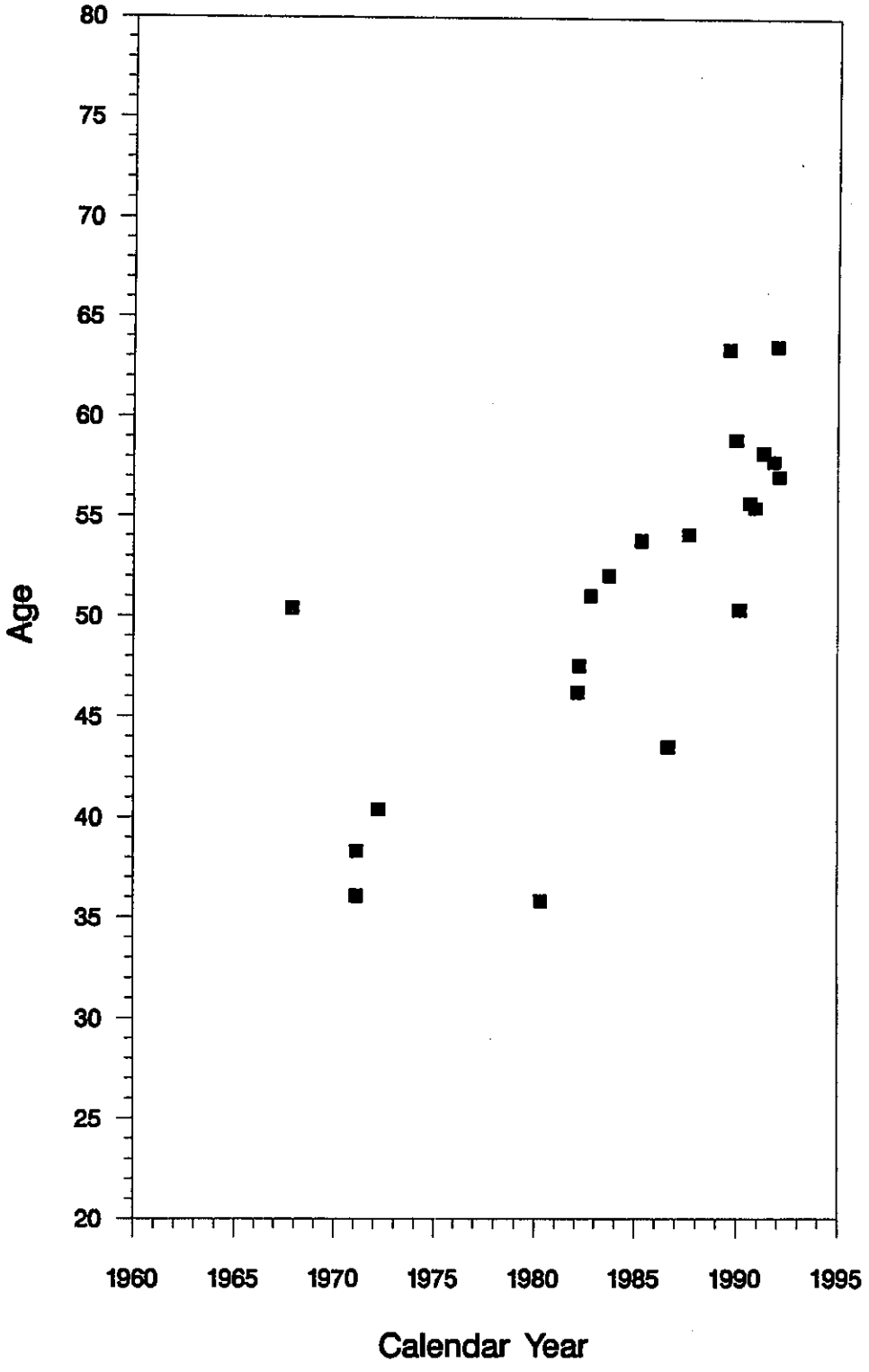
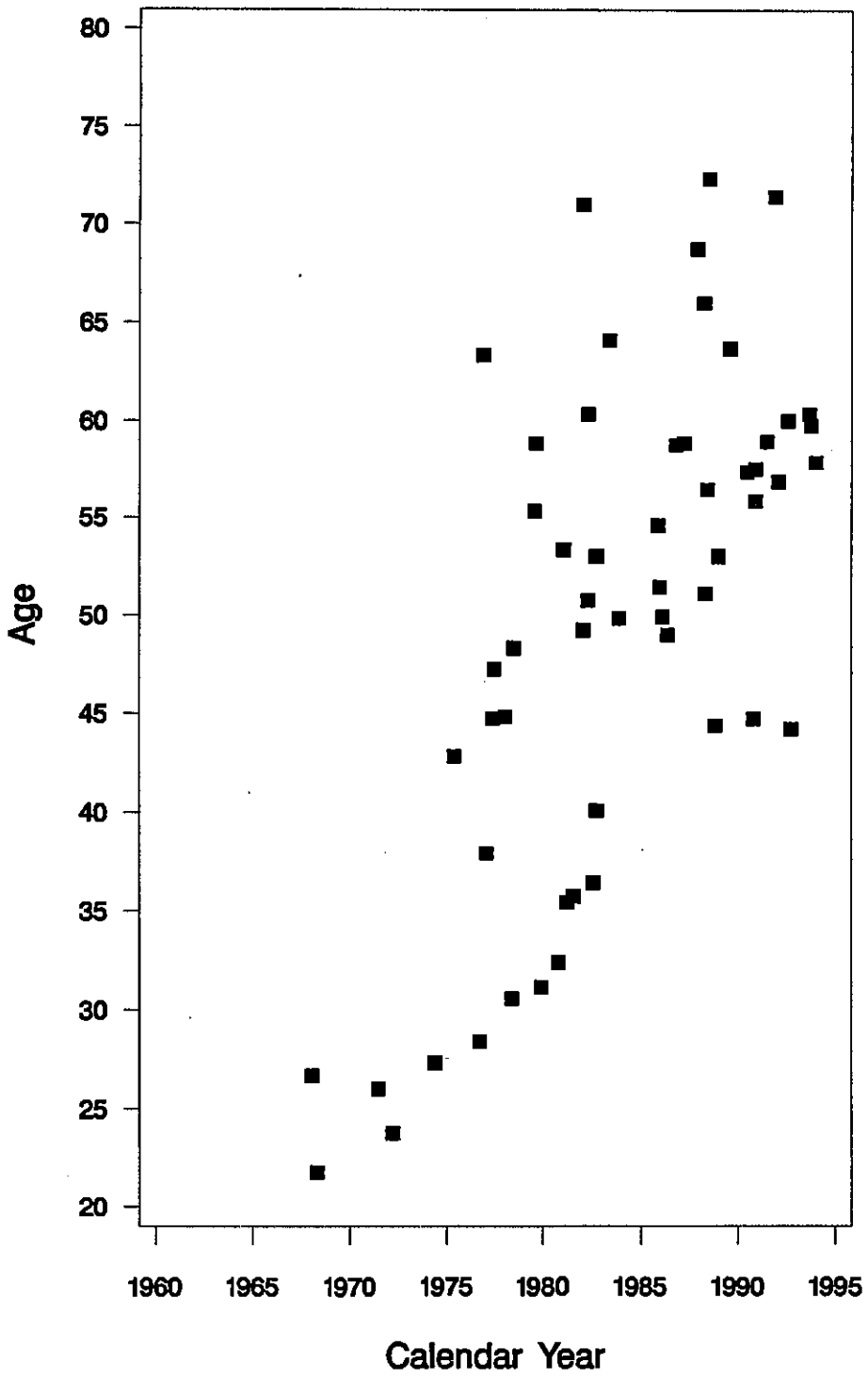


Figure 5
Lexis Diagram
Ranch Hand NonFlying Enlisted



3. CAUSE-SPECIFIC MORTALITY

Observed and adjusted expected Ranch Hand deaths by specific cause and stratum of rank and occupation are summarized in Table 5.

Table 5

Adjusted Cause-specific Ranch Hand Mortality
by Rank and Occupation

Cause	Stratum	Dead	Expected Deaths	SMR	95% CI	P-value
Accident	Flying Officers	11	8.30	1.32	0.70- 2.30	0.35
	Flying Enlisted	4	5.45	0.73	0.23- 1.77	0.57
	Nonflying Officers	0	0.10	0.00		
	NonFlying Enlisted	11	8.43	1.30	0.69- 2.27	0.37
	All Ranch Hands	26	22.29	1.17	0.78- 1.68	0.43
Suicide	Flying Officers	0	1.37	0.00		
	Flying Enlisted	2	1.59	1.26	0.21- 4.16	0.69
	NonFlying Officers	1	0.15	6.82	0.33-32.88	0.15
	NonFlying Enlisted	1	2.66	0.38	0.02- 1.85	0.33
	All Ranch Hands	4	5.77	0.69	0.22- 1.67	0.49
Homicide	Flying Officers	0	0.29	0.00		
	Flying Enlisted	0	0.42	0.00		
	NonFlying Officers	0	0.00	0.00		
	NonFlying Enlisted	2	1.01	1.99	0.33- 6.54	0.35
	All Ranch Hands	2	1.71	1.17	0.20- 3.86	0.76
Infectious-	Flying Officers	1	0.71	1.40	0.07- 6.95	0.67
Parasitic	Flying Enlisted	0	0.10	0.00		
	NonFlying Officers	0	0.00	0.00		
	NonFlying Enlisted	1	0.52	1.92	0.10- 9.48	0.50
	All Ranch Hands	2	1.33	1.50	0.25- 4.97	0.53
Malignant	Flying Officers	10	11.48	0.87	0.44- 1.55	0.69
Neoplasm	Flying Enlisted	8	7.85	1.02	0.47- 1.94	0.91
	NonFlying Officers	1	0.58	1.73	0.09- 8.50	0.56
	NonFlying Enlisted	11	13.32	0.83	0.43- 1.44	0.55
	All Ranch Hands	30	33.22	0.90	0.62- 1.27	0.59

Table 5 (continued)

Cause	Stratum	Dead	Expected Deaths	SMR	95% CI	P-value
Endocrine Disease	Flying Officers	0	0.25	0.00		
	Flying Enlisted	0	0.21	0.00		
	NonFlying Officers	0	0.00	0.00		
	NonFlying Enlisted	1	0.63	1.58	0.08- 7.83	0.60
	All Ranch Hands	1	1.09	0.92	0.05- 4.52	0.96
Circulatory Disease	Flying Officers	12	12.98	0.92	0.50- 1.57	0.82
	Flying Enlisted	3	9.17	0.33	0.08- 0.89	0.02
	NonFlying Officers	0	1.38	0.00		
	NonFlying Enlisted	24	16.09	1.49	0.98- 2.19	0.06
	All Ranch Hands	39	39.61	0.98	0.71- 1.33	0.94
Respiratory Disease	Flying Officers	0	0.81	0.00		
	Flying Enlisted	0	1.22	0.00		
	NonFlying Officers	0	0.11	0.00		
	NonFlying Enlisted	2	1.93	1.04	0.17- 3.42	0.88
	All Ranch Hands	2	4.08	0.49	0.08- 1.62	0.31
Digestive Disease	Flying Officers	4	1.78	2.24	0.71- 5.42	0.14
	Flying Enlisted	2	1.54	1.30	0.22- 4.29	0.66
	NonFlying Officers	0	0.21	0.00		
	NonFlying Enlisted	3	1.60	1.87	0.48- 5.10	0.30
	All Ranch Hands	9	5.14	1.75	0.85- 3.21	0.11
Ill Defined- Unknown	Flying Officers	1	0.52	1.91	0.10- 9.48	0.50
	Flying Enlisted	2	0.56	3.57	0.60-11.80	0.13
	NonFlying Officers	0	0.00	0.00		
	NonFlying Enlisted	0	1.33	0.00		
	All Ranch Hands	3	2.41	1.25	0.32- 3.39	0.66

There are no overall or within-stratum significant differences between observed and expected numbers of deaths due to accidents, suicides, homicides, infectious or parasitic diseases, malignant neoplasms, endocrine diseases, respiratory diseases, digestive diseases or ill-defined or unknown causes (Table 5). There is a borderline significant increase in the number of deaths caused by diseases of the circulatory system among Ranch Hand nonflying enlisted personnel (SMR=1.49, 95% CI 0.98-2.19, p=0.06). By contrast, the 3 flying enlisted deaths for circulatory disease are significantly less than the 9 expected deaths (SMR=0.33, 95% CI 0.08-0.89, p=0.02).

Table 6 shows cumulative site-specific malignant neoplasm mortality among Ranch Hands.

Table 6

Site-specific Malignant Neoplasm Ranch Hand Mortality

ICD* Code	Site	Dead	Expected Deaths
140-149	Lip,Oral Cavity and Pharynx		
140.9	Lip, Unspecified	0	0.092
141.9	Tongue, Unspecified	0	0.285
144.9	Floor of Mouth, Unspecified	0	0.181
145.3	Soft Palate	0	0.092
145.9	Mouth, Unspecified	0	0.156
146.0	Tonsil	0	0.097
147.9	Nasopharynx, Unspecified	0	0.092
148.1	Pyriform Sinus	0	0.158
149.0	Pharynx, Unspecified	0	0.184
150-159	Digestive Organs and Peritoneum		
150.3	Oesophagus, Upper Third	0	0.052
150.5	Oesophagus, Lower Third	0	0.064
150.9	Oesophagus, Unspecified	1	1.037
151.9	Stomach, Unspecified	1	0.667
152.2	Cancer, Ileum	0	0.089
153.4	Colon, Caecum	0	0.090
153.5	Colon, Appendix	0	0.140
153.9	Colon, Unspecified	1	2.564
154.0	Rectosigmoid Junction	0	0.375
154.1	Rectum	0	0.391
154.3	Anus, Unspecified	0	0.092
155.0	Liver, Primary	0	0.478
155.1	Intrahepatic Bile Ducts	0	0.147
155.2	Liver, Unspecified	1	0.000
156.0	Gall Bladder	0	0.089
157.4	Islets of Langerhans	0	0.176
157.9	Pancreas, Unspecified	1	1.314
159.0	Intestinal Tract, Unspecified	0	0.092
160-165	Respiratory and Intrathoracic Organs		
160.9	Accessory Sinus, Unspecified	0	0.052
161.1	Supraglottis	0	0.087
161.9	Larynx, Unspecified	0	0.397
162.2	Main Bronchus	0	0.064
162.3	Upper Lobe, Bronchus or Lung	0	0.151
162.4	Middle Lobe, Bronchus or Lung	0	0.066
162.9	Bronchus and Lung, Unspecified	12	13.008
163.9	Pleura, Unspecified	0	0.064
164.9	Mediastinum, Unspecified	1	0.110

Table 6 (continued)

ICD* Code	Site	Dead	Expected Deaths
170-175	Bone,Connective Tissue, Skin and Breast		
170.9	Bone and Articular Cartilage,Unspecified	0	0.058
171.0	Head, Face and Neck	0	0.052
171.3	Lower Limb, Including Hip	1	0.000
171.8	Connective, Soft Tissue, Other	0	0.087
171.9	Site Unspecified	0	0.273
172.5	Skin, Trunk	0	0.065
172.9	Skin, Unspecified	0	0.614
179-189	Genitourinary Organs		
185	Prostate	2	0.629
188.9	Bladder, Unspecified	0	0.503
189.0	Kidney, Except Pelvis	1	0.598
190-199	Other and Unspecified Sites		
191.1	Brain, Frontal Lobe	0	0.052
191.3	Parietal Lobe	0	0.058
191.4	Occipital Lobe	0	0.092
191.7	Brain Stem	0	0.116
191.9	Brain, Unspecified	1	0.990
193	Malignant Neoplasm, Thyroid Gland	0	0.052
195.0	Head, Face and Neck	0	0.513
195.8	Other Unspecified Site	0	0.064
199.1	Other, Unspecified	4	2.433
200-208	Lymphatic and Haematopoietic Tissue		
200.0	Reticulosarcoma	0	0.179
200.8	Reticulolymphosarcoma	0	0.092
201.9	Hodgkin's Disease, Unspecified	0	0.140
202.8	Other Lymphomas	1	0.452
203.0	Multiple Myeloma	1	0.865
204.0	Acute Lymphoid Leukaemia	0	0.122
204.1	Chronic Lymphoid Leukaemia	0	0.268
204.9	Lymphoid Leukaemia, Unspecified	0	0.118
205.0	Acute Myeloid Leukaemia	0	0.624
205.1	Chronic Myeloid Leukaemia	0	0.118
205.3	Myeloid Sarcoma	0	0.087
206.0	Acute Monocytoid Leukaemia	0	0.063
207.8	Lymphosarcoma Cell Leukaemia	0	0.087
208.0	Acute Leukaemia, Unspecified	1	0.222
208.9	Unspecified Leukaemia	0	0.052
210-229	Benign Neoplasms		
213.0	Benign, Bone, Articular Cartilage	0	0.087
	Totals	30	34.015

*International Classification of Diseases

The 30 Ranch Hand deaths due to malignant neoplasm do not appear to aggregate in an unusual pattern relative to that expected (Table 6).

The morphology of cumulative malignant neoplasm deaths is summarized in Table 7.

Table 7

Morphology of Ranch Hand Malignant Neoplasms

Code	Morphology	Dead	Expected Deaths
M800	Neoplasms NOS*		
150-159	Digestive Organs and Peritoneum	1	3.225
160-165	Respiratory and Intrathoracic Organs	6	5.211
179-189	Genitourinary Organs	1	0.664
190-199	Other and Unspecified Sites	2	1.333
M801-M804	Epithelial Neoplasms NOS*		
140-149	Lip,Oral Cavity and Pharynx	0	0.529
150-159	Digestive Organs and Peritoneum	3	2.155
160-165	Respiratory and Intrathoracic Organs	7	6.172
179-189	Genitourinary Organs	1	0.566
190-199	Other and Unspecified Sites	1	0.843
M805-M808	Papillary and Squamous Cell Neoplasms		
140-149	Lip,Oral Cavity and Pharynx	0	0.718
150-159	Digestive Organs and Peritoneum	0	0.295
160-165	Respiratory and Intrathoracic Organs	0	0.842
190-199	Other and Unspecified Sites	1	0.460
M814-M838	Adenomas and Adenocarcinomas		
150-159	Digestive Organs and Peritoneum	1	2.182
160-165	Respiratory and Intrathoracic Organs	0	1.517
179-189	Genitourinary Organs	1	0.500
190-199	Other and Unspecified Sites	1	0.764
M872-M879	Naevi and Melanomas		
170-175	Bone,Connective Tissue, Skin and Breast	0	0.679
M880	Soft Tissue Tumors & Sarcomas NOS*		
170-175	Bone,Connective Tissue, Skin and Breast	0	0.267
M881-M883	Fibromatous Neoplasms		
140-149	Lip,Oral Cavity and Pharynx	0	0.089
170-175	Bone,Connective Tissue, Skin and Breast	1	0.000
M885-M888	Lipotamous Neoplasms		
170-175	Bone,Connective Tissue, Skin and Breast	0	0.058
M905	Mesothelial Neoplasms		
160-165	Respiratory and Intrathoracic Organs	0	0.156

Table 7 (continued)

Code	Morphology	Dead	Expected Deaths
M906-M909	Germ Cell Neoplasms		
160-165	Respiratory and Intrathoracic Organs	0	0.052
190-199	Other and Unspecified Sites	0	0.058
M921-M924	Chondromatous Neoplasms		
210-229	Benign Neoplasms	0	0.087
M926	Miscellaneous Bone Tumours		
170-175	Bone,Connective Tissue, Skin and Breast	0	0.058
M938-M948	Gliomas		
190-199	Other and Unspecified Sites	0	0.911
M949-M952	Neuroepitheliomatous Neoplasms		
170-175	Bone,Connective Tissue, Skin and Breast	0	0.087
M959-M963	Lymphomas NOS* or Diffuse		
200-208	Lymphatic and Haematopoietic Tissue	1	0.543
M964	Reticulosarcomas		
200-208	Lymphatic and Haematopoietic Tissue	0	0.179
M965-M966	Hodgkin's Disease		
200-208	Lymphatic and Haematopoietic Tissue	0	0.140
M973	Plasma Cell Tumours		
200-208	Lymphatic and Haematopoietic Tissue	1	0.865
M980	Leukaemia NOS*		
200-208	Lymphatic and Haematopoietic Tissue	1	0.273
M982	Lymphoid Leukaemias		
200-208	Lymphatic and Haematopoietic Tissue	0	0.508
M985	Lymphosarcoma Cell Leukaemias		
200-208	Lymphatic and Haematopoietic Tissue	0	0.087
M986	Myeloid Leukaemias		
200-208	Lymphatic and Haematopoietic Tissue	0	0.742
M989	Monocytic Leukaemias		
200-208	Lymphatic and Haematopoietic Tissue	0	0.063
M990	Miscellaneous Leukaemias		
160-165	Respiratory and Intrathoracic Organs	0	0.052
200-208	Lymphatic and Haematopoietic Tissue	0	0.087
	Totals	30	34.015

*Not otherwise specified

Although the adjusted SMR for all Ranch Hand deaths due to malignant neoplasm is less than 1.0 (Table 5), there are morphologic subcategories of malignancies for which the SMR is greater than 1.0. For example, there are 12 Ranch Hand deaths from epithelial neoplasms not otherwise specified and the expected number of deaths in this category is 10.3. However, this excess is not significant (SMR=1.21, 95% CI 0.62-2.09, p=0.51).

4. MORTALITY VERSUS CURRENT DIOXIN LEVELS

Since the introduction of the dioxin assay into the morbidity component of this study, all health data has been assessed for associations with dioxin [12]. All dioxin assay results are qualified by a result comment defined in Table 8.

Table 8

Result Comment Definition

Result Comment	Definition
G	Good result
GND	Good result, below limit of detection
GNQ	Good result, below limit of quantification
NR	No result

Dioxin results of assayed participants from the 1992 physical examination, the 1987 physical examination and the pilot study conducted in April 1987, were combined into the dioxin data base used in this report. Dioxin assays have been administered to 1008 (80%) of the total 1261 Ranch Hands. Table 9 shows a cross classification of all 1261 Ranch Hands by survival status (dead, alive), assay status (yes, no) and result comment.

Table 9

Ranch Hand Dioxin Assay Status versus Survival

		Survival Status		
Dioxin Assay	Result Comment	Alive	Dead	Total
No		161	92	253
Yes	G	958	22	980
	GND	10	1	11
	GNQ	3	2	5
	NR	11	1	12
Total		1143	118	1261

Some participants were assayed more than once and may have up to three assay results each. When a participant had multiple assay results, the earliest quantifiable result was used. First priority was given to 1987 pilot study dioxin results, second priority to results derived from serum collected at the 1987 physical examination and third priority was given to the 1992 results. The dioxin level of most (82%) of the 1008 participants with dioxin results was derived from serum collected in 1987. If a Ranch Hand had a 1992 dioxin result and did not have a 1987 dioxin result, and if the 1992 result surpassed 10 parts per trillion (ppt), the 1992 result was extrapolated to a 1987 level because statistical analyses were based on 1987 dioxin levels. The extrapolated dioxin values were calculated using a first order decay model with a half-life of 8.7 years [13].

Ranch Hands with missing dioxin results (no assay or assayed with result comment NR) and nonquantifiable results (result comment GNQ) were excluded from subsequent analyses of survival versus dioxin. After these exclusions, 968 living Ranch Hands and 23 dead Ranch Hands had dioxin results. Dioxin results are lognormally distributed, hence the logarithm of dioxin was used in the analysis, with a value of 1 added to the dioxin value before taking the logarithm. Univariate summaries of dioxin, expressed in ppt, and its logarithm, in log(ppt), are summarized in Table 10.

Table 10

Dioxin Summary

	Dioxin		Log(dioxin+1)	
Statistic	Alive	Dead	Alive	Dead
n	968	23	968	23
Minimum	0	0	0	0
Maximum	617.8	211.1	6.4	5.3
Mean	26.7	35.0	2.7	2.8
Median	12.2	11.6	2.6	2.5
Standard Deviation	44.9	54.7	1.0	1.3

The mean values of log(dioxin+1) do not differ significantly with survival status (alive, dead); mean difference(2.8-2.7)=0.10, 95% CI -0.35, 0.50, p=0.79. Of the 23 deceased Ranch Hands with quantifiable dioxin results, 2 died of digestive disease, 7 died of malignant neoplasms, 10 died of circulatory disease, 1 died of respiratory disease, 2 died of accidents and 1 committed suicide.

An accelerated failure time model for right-censored survival data was fitted to assess the relationship, if any, between survival time and the logarithm of dioxin level in Ranch Hands. In this analysis, the survival time of dead Ranch Hands is the time in years between the beginning of their tour in Vietnam and death. The survival time of living Ranch Hands is the time, in years, between the beginning of their tour of duty in Vietnam and 31 December 1993. The analysis was unadjusted, due to the small number of dead Ranch Hands (23) with dioxin values. The dependent variable was the logarithm of survival time and the independent variable was log(dioxin+1). The results are summarized in Table 11. There is no significant association between dioxin level and survival time among Ranch Hands (p=0.55).

Table 11

Survival Time versus Dioxin in Ranch Hands

Coefficient	95% CI	Chi-square	Degrees of Freedom	P-value
-0.0177	(-0.076,0.040)	0.36	1	0.55

5. CONCLUSIONS

An evaluation of cumulative all-cause Ranch Hand mortality through 31 December 1993 revealed no statistically significant differences between the observed and expected number of deaths (SMR=0.98, 95% CI 0.82-1.17, p=0.87). The adjusted all-cause Ranch Hand death rate is 3.34 deaths per 1000 person-years while the Comparison rate is 3.41 deaths per 1000 person-years. Furthermore, without regard to cause, the observed and expected number of deaths did not show a significant difference in any of the four subgroups of Ranch Hands determined by rank (officer, enlisted) and job (flyer, nonflyer).

Adjusted cause-specific analyses found no overall significant difference between the observed and expected numbers of deaths for accidental deaths (SMR=1.17), suicides (SMR=0.69), or deaths due to malignant neoplasm (SMR=0.90). There was no significant excess of deaths due to circulatory system diseases among all Ranch Hands combined (SMR=0.98, 95% CI 0.71-1.33, p=0.94); however, among nonflying enlisted Ranch Hands a borderline significant excess of deaths was observed (SMR=1.49, 95% CI 0.98-2.19, p=0.06). This increase was noted in previous reports, but the number of such deaths has remained at 24 and the SMR has decreased from 1.60 to 1.49 since the last report. By contrast, the 3 deaths of flying enlisted Ranch Hands were significantly less than the 9 deaths expected (SMR=0.33, CI 0.08-0.89, p=0.02).

Two causes of death that previously showed significant excess of observed deaths but no longer show significant results are digestive disease and ill-defined or unknown causes. The excess of Ranch Hand deaths due to digestive system diseases noted in previous reports is no longer significant. The number of such deaths has remained at 9 and the SMR has decreased from 2.07 to 1.75 since the last report. Similarly, the excess of flying enlisted Ranch Hand deaths due to ill-defined or unknown causes noted in previous reports is no longer significant, with the number of deaths in this stratum remaining at 2 and the SMR decreasing from 6.11 to 3.57 since the last report.

The 30 Ranch Hand deaths due to malignant neoplasm did not appear to aggregate in an unusual pattern relative to that expected. The adjusted SMR for deaths due to malignant neoplasm was less than 1.0. Even so, the morphologic subcategory of malignancies called epithelial neoplasms accounted for 12 Ranch Hand deaths compared to the 10.3 expected deaths. However, this excess was not significant (SMR=1.21, 95% CI 0.62-2.09, p=0.51).

Dioxin assays have been administered to 80% of the 1261 Ranch Hands. Of the 1008 who were administered the assay, a total of 991 Ranch Hands have quantifiable dioxin results. Analysis of survival status versus current dioxin levels found no significant difference between mean dioxin levels among the 968 living and 23 dead Ranch Hands with quantifiable dioxin results. Survival time was also not significantly associated with dioxin levels in Ranch Hands.

In summary, the total all-cause mortality experience of the Ranch Hands was not significantly different from that expected based on the mortality experience of the Comparison population. As of 31 December 1993, 118 (9.4%) of the 1261 Ranch Hands have died; the expected number of deaths is 119.95. Although the observed number of Ranch Hand deaths is less than expected, the difference is not significant. The overall observed and expected numbers of deaths were not

significantly different for accidental deaths, suicides and deaths caused by malignant neoplasms and circulatory system diseases. In contrast to previous reports, the number of Ranch Hand deaths due to digestive disease and the number of deaths due to ill-defined or unknown causes in Ranch Hand enlisted flyers are no longer significantly increased, although borderline significant increases in Ranch Hand deaths due to circulatory system diseases, in nonflying enlisted personnel, continue to be seen. This increase has been noted in previous reports and is, as yet, unexplained.

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