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ABSTRACT

Divided into three sections, this research bulletin presents: (1) a brief review of changes in the American Indian mortality and fertility rates, illustrating a transition process much like that experienced by developing nations; (2) an analysis of variations in the social and economic organization of different parts of the Navajo Reservation; (3) a study of the correlation between the Navajo economic variations and their mortality and fertility rates. The study employs data derived from U.S. Public Health Service Publications for the years 1968 and 1969 and examines the following variables: birth weight; birth order; age of mother and father; age of death; % of unknown fathers; % of male mortality; infant mortality; % on welfare; death rate per 1,000 population (accident, crude, and infectious); and crude birth rate. Using the eight Indian Health Service Units located on the Navajo Reservation as regional designators, this study indicates that: the eastern end of the Reservation is more highly developed economically than the western end; there are higher mortality and fertility rates in the west; there are higher male death rates in the east; and there is a tendency for causes of death in the west to be infectious rather than man-made in origin. It is suggested that accidents, the most important cause of Navajo deaths, are not susceptible to the kind of curative medicine practiced so successfully in the past. (Author/JC)

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STEPHEN J. KUNITZ

National Science Foundation
Research Applied to National Needs

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THE RELATIONSHIP OF ECONOMIC VARIATIONS TO MORTALITY AND FERTILITY PATTERNS ON THE NAVAJO RESERVATION

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April 1976

LAKE POWELL RESEARCH PROJECT

The Lake Powell Research Project (formally known as Collaborative Research on Assessment of Man's Activities in the Lake Powell Region) is a consortium of university groups funded by the Division of Advanced Environmental Research and Technology in RANN (Research Applied to National Needs) in the National Science Foundation.

Researchers in the consortium bring a wide range of expertise in natural and social sciences to bear on the general problem of the effects and ramifications of water resource management in the Lake Powell region. The region currently is experiencing converging demands for water and energy resource development, preservation of nationally unique scenic features, expansion of recreation facilities, and economic growth and modernization in previously isolated rural areas.

The Project comprises interdisciplinary studies centered on the following topics: (1) level and distribution of income and wealth generated by resources development; (2) institutional framework for environmental assessment and planning; (3) institutional decision-making and resource allocation; (4) implications for federal Indian policies of accelerated economic development of the Navajo Indian Reservation; (5) impact of development on demographic structure; (6) consumptive water use in the Upper Colorado River Basin; (7) prediction of future significant changes in the Lake Powell ecosystem; (8) recreational carrying capacity and utilization of the Glen Canyon National Recreational Area; (9) impact of energy development around Lake Powell; and (10) consequences of variability in the lake level of Lake Powell.

One of the major missions of RANN projects is to communicate research results directly to user groups of the region, which include government agencies, Native American Tribes, legislative bodies, and interested civic groups. The Lake Powell Research Project Bulletins are intended to make timely research results readily accessible to user Groups. The Bulletins supplement technical articles published by Project members in scholarly journals.

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ABSTRACT

Part I of this bulletin briefly reviews changes in American Indian mortality and fertility as a means of illustrating the passage of this population through a transition process much like that experienced by populations of developing nations. Part II is an analysis of variations in economic and social organization in different parts of the Navajo Reservation. Part III uses data from the Indian Health Service to show how mortality and fertility rates vary across the reservation in response to the economic variations described in Part II.

We suggest that the eastern end of the reservation is more highly developed economically than is the western end. This difference is reflected in (1) higher mortality and fertility rates in the west; (2) higher male death rates in the east; and (3) a tendency for causes of death in the west to be infectious rather than man-made in origin. We also suggest that the most important cause of death among Navajos at present--accidents--appears not to be susceptible to the kind of curative medicine that has been practiced so successfully in the past. Other modalities aimed at the understanding and prevention of this phenomenon need to be developed. In the absence of significant economic development in the western part of the reservation, we expect that this population will continue to lag behind the eastern population in the rate at which its' fertility rates decline.

THE RELATIONSHIP OF ECONOMIC VARIATIONS TO MORTALITY AND FERTILITY PATTERNS ON THE NAVAJO RESERVATION

I. INTRODUCTION

Though there is evidence that many pre-industrial societies have made more or less successful attempts to regulate their numbers, it appears to be generally agreed that during the process of transformation of these societies to industrial or colonial status, a series of characteristic changes, usually designated the demographic transition, occur. Mortality rates first increase and then decline. The chief causes of mortality and morbidity shift from infectious and epidemic diseases to degenerative diseases and factors of manmade origin (Omran 1970). Host factors of a psycho-social nature assume relatively greater significance in the etiology of disease (Cassel 1970), and fertility becomes of more importance than mortality in determining population growth (Omran 1970). Also, the concern of health-care providers and of the population shifts from those diseases that are rapidly fatal to the sequelae of morbidity. These changes have more impact on infant and adult female mortality than on adult male mortality. Hence, life expectancy of females increases more rapidly than that of males and the age-sex pyramid shifts (Coale 1956). One notable change is that the sex ratio (number of males per 100 females) tends to decrease for all ages beyond childhood.

Although the precise causal relationships between modernization and the decline in mortality and fertility are not well understood, it is generally agreed that such a relationship exists in the sense that increased modernization causes decreases in mortality and fertility. The notion of modernization, however, is in itself problematic. It generally refers to a cluster of factors, including increasing literacy; industrial development; an economy based upon cash rather than barter; and increasing per capita consumption of energy. Indeed, this last factor has been used as an indicator of modernization in some cross-national studies (Irwin 1975).

Not only is the notion of modernization problematic, but, as implied above, it is not entirely clear how modernization leads to changes in vital rates. Certainly declining mortality rates resulting from improved nutrition, hygiene, and health care are important factors; but once mortality is reduced, why do some populations continue to have higher fertility than others? Several factors have been implicated, including differential educational attainment, religious values, the structure of the economy (Szymanski 1974), the kinship network, and conjugal relationships.

We cannot specify here all the causal connections between economic change and birth and death rates. We assert, however, that as the degree of literacy and industrialization increases, and as a cash economy replaces subsistence in a society, first mortality and then fertility rates begin to decline. Although this is a description of the situation rather than an explanatory theory (Teitelbaum 1975), it is a description of a process that has been generally found to occur in the course of modernization. This bulletin describes the general aspects of some of these relationships that are presently

observed on the Navajo Reservation. We attempt to show first, that the reservation can be divided into regions in which the population is engaged in different types of economic pursuits, and second, that these economic differences are related to differences in mortality and fertility.

The history of the American Indian population is in many respects comparable to that of populations in developing nations. Though estimates of the aboriginal (pre-contact) population of North America differ (Mooney 1928; Kroeber 1934; Dobyns 1966), it is generally agreed that contact with Europeans had devastating results. Epidemics appear to have been the final common pathway through which warfare, social disorganization, famine, and contact with new diseases led to the virtual disappearance of entire tribes (Cook 1973; Hadley 1957).

There is some disagreement as to when the American Indian population reached its nadir. Some believe that it was in the late nineteenth century (Hadley 1957:24); others claim that it was in the 1930s (Dobyns 1966). Despite the disagreement as to the date of the population minimum, however, it is agreed that the North American Indian population, after a major decline, has grown remarkably in recent decades.

This very rapid growth is accounted for largely by a decline in death rates and by a continuing high birth rate. Table 1 displays crude birth and death rates for Indians and the general U.S. population. It is clear that mortality since the late 1940s has been about the same for both groups, while fertility has differed considerably. Indeed, in the 1950s, Indian fertility increased and has only recently returned to 1949 levels.

Table 1: Crude Birth and Death Rates in the American Indian and General U.S. Populations (number per 1,000 population)

	American Indians		U.S. All Races	
Year	Deaths	Births	Deaths	Births
1949-1953 annual average	10.3	32.1	9.6	24.5
1955	9.3	36.1	9.3	24.6
1960	9.1	42.2	9.5	23.7
1965	8.8	36.8	9.4	19.4
1970	9.3[a]	32.8	7.3[a]	18.2

[a]age adjusted

Source: U.S. Public Health Service (1957, 1974)

At present, the Indian population is increasing at about 22 per 1,000 each year compared to 11 per 1,000 for the rest of the population.

Unfortunately, adequate comparative mortality and fertility data for the period before World War II are generally unavailable. It does appear, however, that the waning of epidemics has allowed the emergence of new disease patterns among Indians that roughly parallel, but lag behind, changes in the larger society. In Figure 1 mortality rates per 100,000 population are shown for five of the most common causes of death in the general U.S. population (U.S. Public Health Service 1957, 1974).

Mortality rates from tuberculosis and pneumonia/influenza have steadily declined since 1900, with the exception of an increase in 1920. These rates have stabilized in recent years. The rates for heart disease and cancer have actually increased over this same period. Accident rates, meanwhile, have remained constant but therefore have increased in relative importance. This clearly is what is meant when it is said that the U.S. population is now in the era of degenerative and manmade diseases.

In Figure 2 curves are presented for the same causes of death as they occur among American Indians (U.S. Public Health Service 1957, 1974). A decline in tuberculosis and pneumonia/influenza is again evident, and is even more precipitous than in the U.S. population as a whole. There is also an increase in heart disease and cancer mortality in the Indian population. In contrast to the U.S. population, however, accidents have actually increased in absolute as well as relative significance and are the leading cause of death among Indians.

Figure 3 shows the changing pattern of maternal mortality in the American Indian and the general U.S. populations. Again it is clear that rates have declined dramatically in the past generation or two. This pattern also is characteristic of the epidemiologic transition (Slocumb and Kunitz, in press).

These changes in mortality patterns generally favor females and infants rather than adult males. Thus, one consequence of the transition process is that the sex ratio tends to shift from an excess number of males to an excess number of females. Such a shift has in fact occurred in the U.S. population, among all American Indians, and among the Navajos in particular. Interestingly, the shift took place for all three populations at about the same time, in the 1940s and 1950s. Some of the consequences of this shift will be discussed elsewhere and will not be treated here (Kunitz and Slocumb, in press).

In summary, the epidemiologic and demographic transitions appear to have influenced American Indians as they have other developing or modernizing populations. This bulletin is primarily concerned with reservation Navajos. We show first that different parts of the Navajo Reservation have different patterns of economic development, and second, that these patterns are correlated with differences in mortality and fertility. We suggest that the result of these economic variations is that local populations are

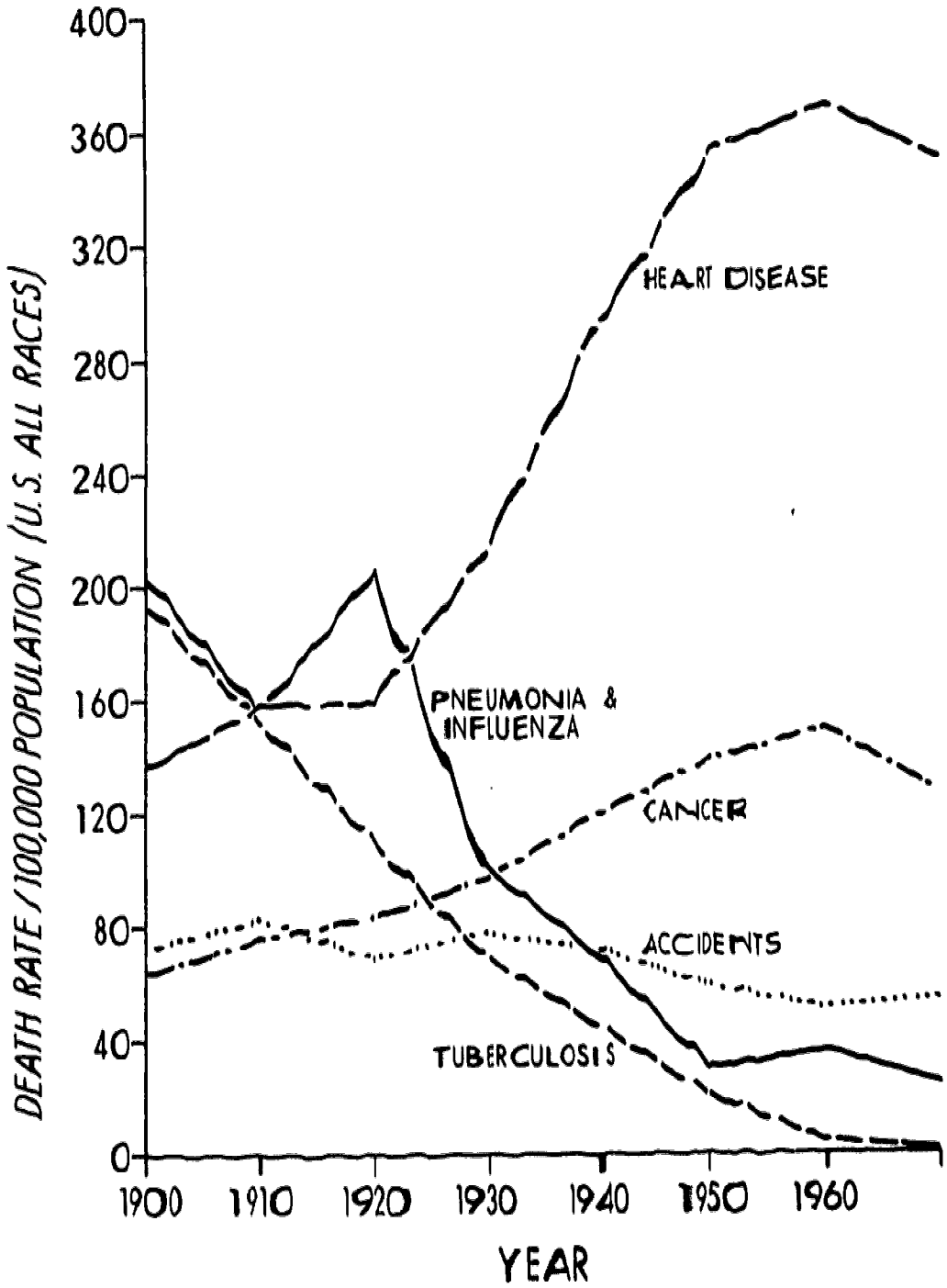

Figure 1: Death Rates Per 100,000 Population: U.S., All Races

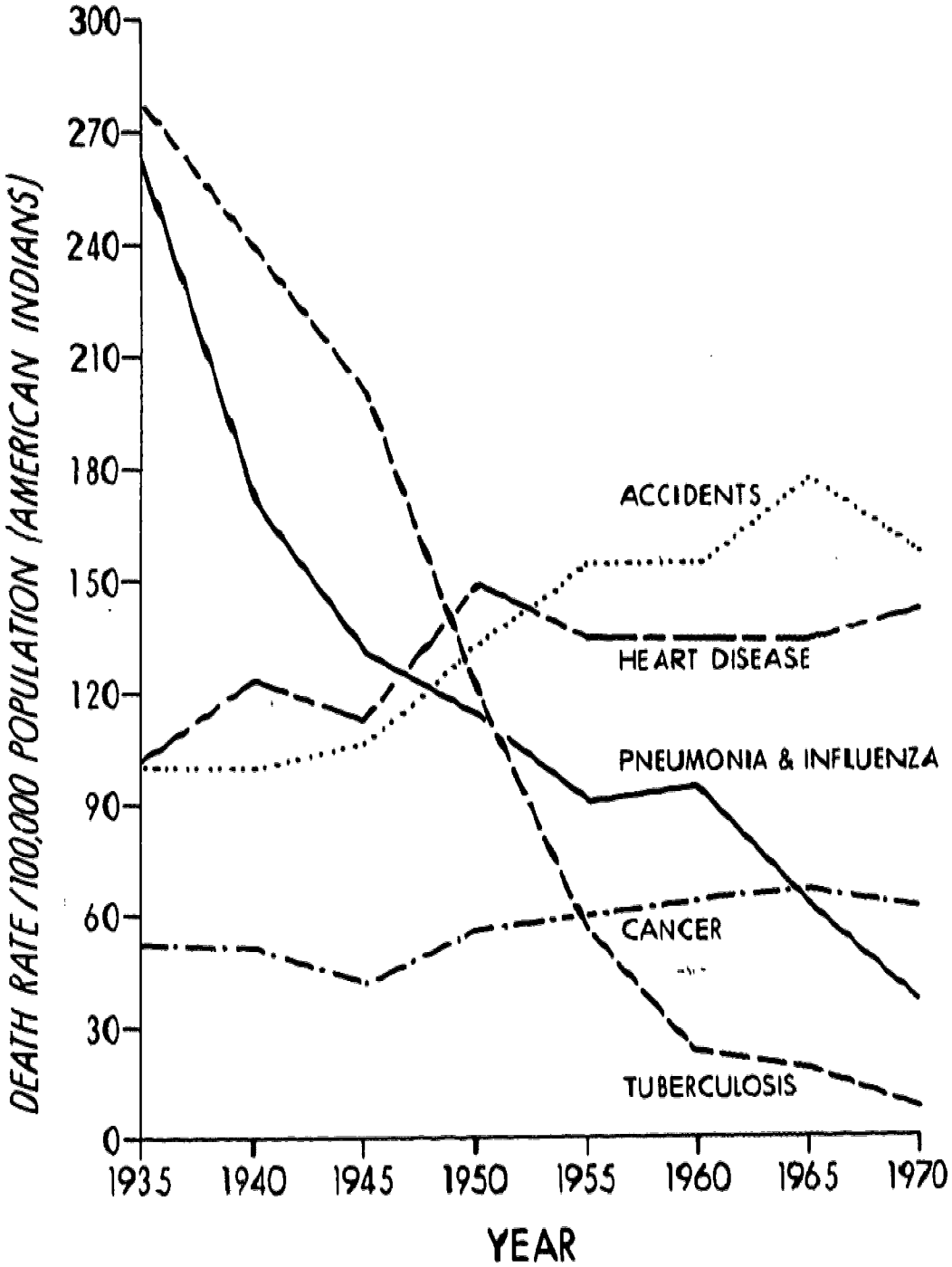

Figure 2: Death Rates Per 100,000 Population: American Indians

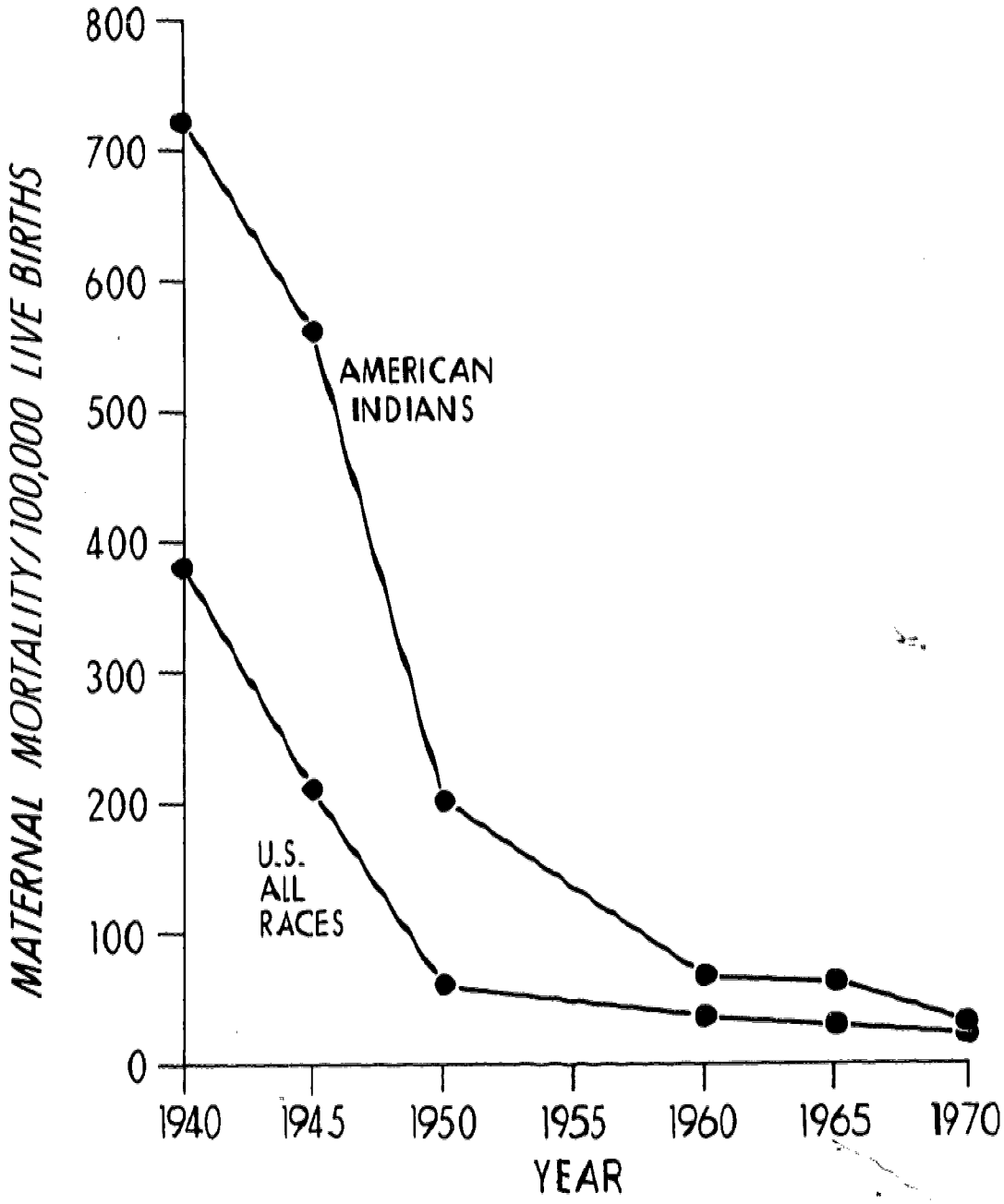

Figure 3: Maternal Mortality: U.S., All Races and American Indians

at different phases of the transition process.

II. A BRIEF OVERVIEW OF THE NAVAJO RESERVATION

In this section we are concerned only with the period since the 1930s, when reservation-wide surveys were made using land management districts as the basic units. We will not discuss the entire history of Navajo occupancy of the area now included in the reservation. The land management districts were established when the federal government first attempted to control the amount of livestock grazed on the range, and the first population surveys were part of that effort. The Human Dependency Survey carried out by the U.S. Soil Conservation Service (1939) in the late 1930s was the first study to give some notion of the differences that existed from one area to another. This study showed that consumption units (households or camps) were largest on the western end of the reservation, and dependence on subsistence livestock raising was greatest and population density lowest there. We have used data from this survey as well as more recent ones to provide a broad picture of differences among areas of the reservation in regard to various types of economic activities.

The land management districts are shown in Figure 4, and the data are provided in Table 2. With the exception of column K, the data for columns A through P are taken from the Human Dependency Survey carried out in 1936-37 by the U.S. Soil Conservation Service (1939). Columns K, R, S, and T are from the Navajo Yearbook (Young 1968). These data were collected as part of a study of Bureau of Indian Affairs (BIA) records pertaining to livestock and range management in 1959.

Column Q, population per square mile in 1971, is based on BIA estimates of population for each land management district. Columns U and V are derived from a 1972 range report of the Navajo Tribe. AUM refers to animal unit months and is a measure of how many animals are pastured in different land management districts.

Column W, proportion on general assistance, is derived from data provided by the BIA for the numbers of individuals receiving BIA welfare support. This is not the only form of welfare available. The states provide categorical types such as aid to the blind, to dependent children, to the aged, and to the disabled; and the tribe provides emergency welfare aid under certain conditions as well. It was not possible, nor particularly desirable, to collate information from all welfare agencies, but it seems to be generally agreed that areas high in general assistance are high in state and tribal services as well.

Column X, from Gilbreath (1973:19), is an attempt to measure the concentration of non-governmental business establishments on the reservation in relation to population distribution.

Columns Y and Z, the proportions of adult males and females engaged in non-traditional occupations, are taken from a reservation-wide survey carried out in 1967 (Navajo Tribe 1968). Unfortunately, the sampling frame of the survey was not land management districts but school districts. To make the data compatible with the land management district data, maps were compared and then estimates made of the proportion of each school district population found in each of several neighboring land management districts. If, for instance, a school district lay about

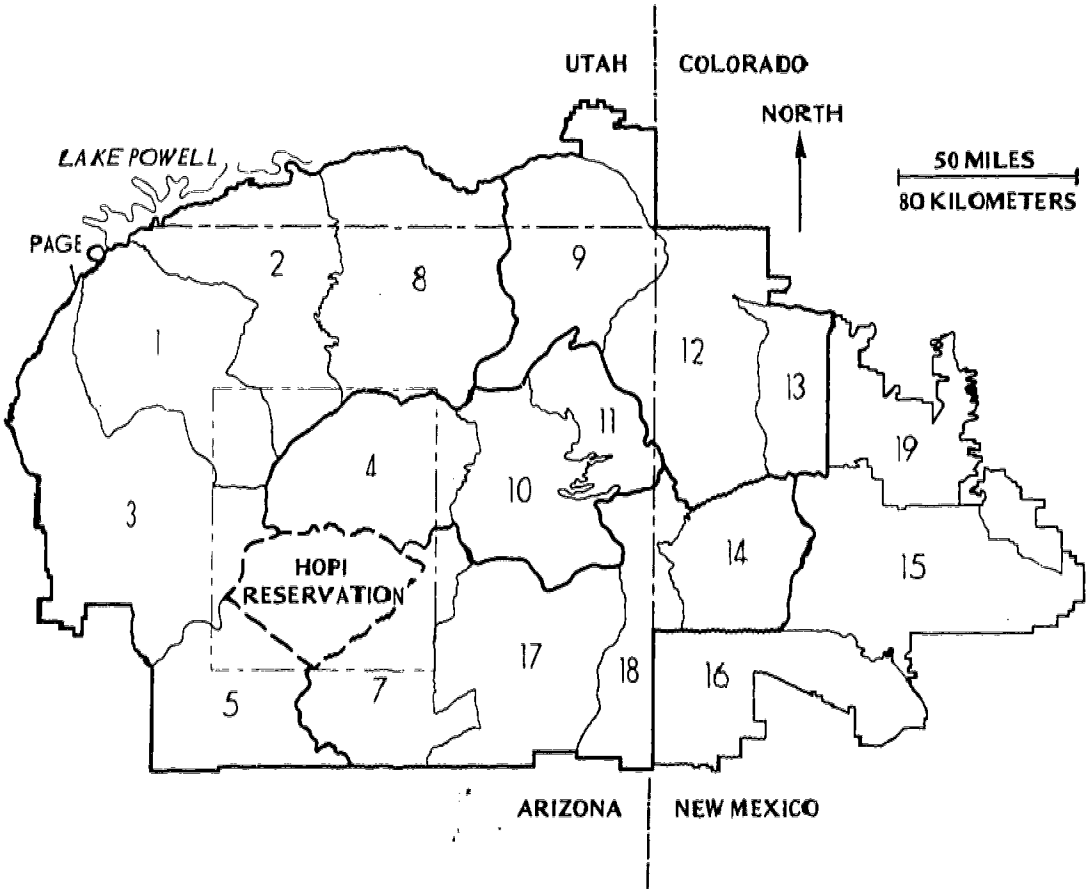

Figure 4: Navajo Reservation and Land Management Districts

Table 2: Land Management District Data

Key

LMD	Land Management District
A	population per square mile 1936 (number of persons)
B	average size of consumption group 1936 (number of persons)
C	commercial per capita income 1936 (1936 dollars)
D	non-commercial per capita income 1936 (1936 dollars)
E	total per capita income 1936 (1936 dollars)
F	income by class: wage income per capita 1936 (1936 dollars)
G	livestock income per capita 1936 (1936 dollars)
H	agricultural per capita income 1936 (1936 dollars)
I	commercial livestock income per capita (1936 dollars)
J	non-commercial livestock income per capita (1936 dollars)
K	largest permit size 1930s (number of sheep units)
L	commercial agricultural income per capita 1936 (1936 dollars)
M	non-commercial agricultural income per capita (1936 dollars)
N	income per sheep unit 1936 (1936 dollars)
O	commercial livestock income per sheep unit 1936 (1936 dollars)
P	sheep units per capita 1936 (number of sheep units)
Q	population per square mile 1971 (number of persons)
R	proportion of permittees 1959 (percent)
S	average size of permit 1959 (number of sheep units)
T	percent over or under carrying capacity 1959 (percent)
U	ratio of grazed to authorized animal unit months 1972 (ratio)
V	ratio of animal unit months to population 1972
W	proportion of population on general assistance 1974 (percent)
X	population per business 1970 (number of persons)
Y	proportion of employed females in non-traditional occupations 1968 (percent)
Z	proportion of employed males in non-traditional occupations 1968 (percent)

Table 2 Continued: Land Management District Data

	A	B	C	D	E	F	G	H	I	J	K	L	M
LMD	pop./ sq. mile 1936	avg. cons. group 1936	comm./ capita income 1936	non-comm./ capita income 1936	total/ capita income 1936	income by class: wages/ capita 1936	live-stock income/ capita 1936	agri-cult./ capita income 1936	comm. live-stock income/ capita 1936	non-comm. live-stock income/ capita 1936	largest permit size 1930s	comm. agric. income/ capita 1936	non-comm. agric. income/ capita 1936
1	.8	7.6	51.50	30.38	81.88	12.07	43.59	13.00	26.09	17.50	225	.12	12.88
2	.5	7.9	65.99	42.10	108.09	28.93	36.97	27.99	22.67	14.30	161	.19	27.80
3	.7	7.5	106.67	53.53	160.20	63.30	46.03	39.07	30.92	15.11	280	.65	38.42
4	1.6	8.5	35.90	34.38	70.28	5.35	34.11	21.58	21.10	13.01	72	.21	21.37
5	1.0	9.1	98.47	32.18	130.65	59.12	51.62	13.17	32.36	19.26	280	.25	12.92
7	1.3	8.0	103.82	30.59	134.41	32.04	67.32	16.87	52.65	14.67	237	.95	15.92
8	.7	7.6	83.33	49.43	132.76	55.11	37.55	30.10	17.45	20.10	154	.77	29.33
9	1.2	8.0	70.94	28.77	99.71	21.95	56.12	11.57	37.87	18.25	83	1.05	10.52
10	2.2	6.9	64.31	57.89	122.20	27.45	26.58	48.26	14.72	11.86	153	2.23	46.03
11	1.9	7.3	53.86	59.92	113.78	25.21	27.93	50.37	15.95	11.98	105	2.43	47.94
12	1.9	6.1	109.84	40.10	149.94	56.17	43.72	38.07	35.29	8.43	104	6.40	31.67
13	1.6	6.1	148.13	39.30	187.43	66.32	68.04	33.90	59.58	8.46	200	3.06	30.84
14	2.6	6.7	125.66	23.87	149.53	60.12	38.22	15.49	28.93	9.29	61	.91	14.58
17	2.1	7.0	92.62	42.88	135.50	34.71	47.45	29.61	32.79	14.66	275	1.39	28.22
18	3.0	6.2	205.69	40.40	246.09	135.25	40.63	33.75	31.94	8.69	238	2.04	31.71

Table 2 Continued: Land Management District Data

LMD	N income/ sheep unit 1936	O comm. livest. income sheep unit 1936	P sheep units/ capita 1936	Q pop./ sq. mile 1971	R prop. permit-tees 1959	S avg. size of permit 1959	T percent over/ under carrying capacity 1959	U ratio grazed to auth. AUM's 1972	V AUM's/ Pop. 1972	W prop. on gen. asst. 1974	X popu-lation business 1970	Y prop. emp. females in non-trade occ. 1968	Z prop. emp. males in non-trade occ. 1968
1	1.34	.80	44.6	2.8	18.16	77.7	+7	1.71	38.27	28.4	841	7.7	21.3
2	1.59	.97	31.2	2.0	17.83	69.5	+36	1.96	33.65	23.2	1641	7.7	21.3
3	2.36	1.58	26.7	2.0	16.93	89.6	-17	1.39	35.94	32.2	476	20.8	25.9
4	2.23	1.38	21.2	5.7	10.09	52.0	+85	1.85	15.60	18.0	2442	10.8	20.3
5	2.95	1.85	25.2	2.6	13.97	95.0	-12	0.88	21.72	27.4	1020	17.4	37.3
7	3.35	2.62	29.5	4.2	19.38	70.4	-15	0.81	12.38	32.9	1149	11.4	23.3
8	2.63	1.22	22.0	2.9	13.27	66.5	+33	1.92	27.10	26.5	243	16.3	25.3
9	3.66	2.47	21.1	4.1	16.16	58.5	+86	2.44	26.16	9.2	964	9.7	21.1
10	2.64	1.46	14.6	7.8	19.55	45.3	-2	1.12	11.94	16.7	303	19.8	28.5
11	2.69	1.54	14.2	4.7	19.64	44.9	-2	1.08	15.74	18.9	334	13.6	16.4
12	3.63	2.93	17.0	8.0	7.99	53.9	+6	1.51	14.42	5.7	404	17.6	30.9
13	3.50	3.06	25.0	5.9	21.05	77.0	-23	0.85	12.31	2.9	1028	29.5	43.6
14	2.58	1.95	19.2	6.3	11.83	49.3	+26	1.46	17.68	16.5	771	14.6	25.0
17	3.24	2.24	20.1	4.6	13.04	73.5	-16	0.66	18.10	22.1	554	13.0	24.0
18	2.71	2.13	20.2	8.5	27.22	59.3	-17	0.61	7.92	13.9	339	28.6	43.3

evenly in two districts, the number and types of respondents were allocated evenly between each land management district. Although the methods used were far from desirable for our purposes, this manpower survey was the most recent and carefully done of its kind we could find, and we regard the survey as worthwhile.

The data are displayed by use of the biplot (Figure 5). (For a discussion of this technique, see Appendix.) The land management districts are the numbered points, the numbers corresponding to those on the map of the districts shown in Figure 4. The lettered arrows correspond to the variables described above.

We have not included districts 15, 16, and 19, the checkerboard area on the eastern end of the reservation for which adequate data do not exist. Nor have we included districts 21 (Canoncito), 22 (Alamo), and 23 (Ramah), which are small reservation enclaves physically separated from the large reservation.

In general, land management districts on the western end of the reservation are on the left side of the biplot and those in the east on the right (Figure 5). The blunt-tipped arrows pointing to the right represent variables that measure commercial income, participation in the wage economy, and agricultural activity (both subsistence and commercial). Those pointing to the left relate to subsistence livestock raising, family size, high ratios of population to business establishments, and dependence on general welfare assistance.

We can be even more specific by dividing the biplot into quadrants. In the upper left are those land management districts (2, 4, 8, and 9) in the northern and central part of the reservation with severe overgrazing (U and T), the lowest proportion of permittees (R), the least involvement in wagework (F, Y, and Z), and the lowest income per unit of livestock (C, N, and O).

In the lower right quadrant are areas to the east (districts 13, 17, and 18) that show patterns just the opposite of those mentioned above. They are much involved in commercial livestock activities and in the wage economy (C, E, F, O, R, Y, and Z).

In the upper right quadrant are districts 10, 11, 12, and 14 in the northeast and east that have high population densities (A and Q), high non-commercial income (D), and high agricultural income (H, L, and M). These are just the reverse of the characteristics of districts 1, 3, 5, and 7 on the western and southwestern portion of the reservation (lower left quadrant). These districts have low involvement in agriculture, high ratios of population per business establishment (X), great dependence on livestock (P, S, G, K, and V), larger than average consumption groups (B), and the greatest dependence on welfare (W).

From this initial analysis, several observations may be made. First, considering that the data have been gathered from a variety of sources, there is a remarkable consistency over the past 35 to 40 years in the economic situation on the different parts of the reservation. In general, if a diagonal line is drawn from the Four Corners area, where the states of Utah, Colorado, New Mexico, and Arizona meet, southwest to the point on the southern reservation boundary where districts 7 and 17 meet, the reservation is thereby divided into two unequal parts with

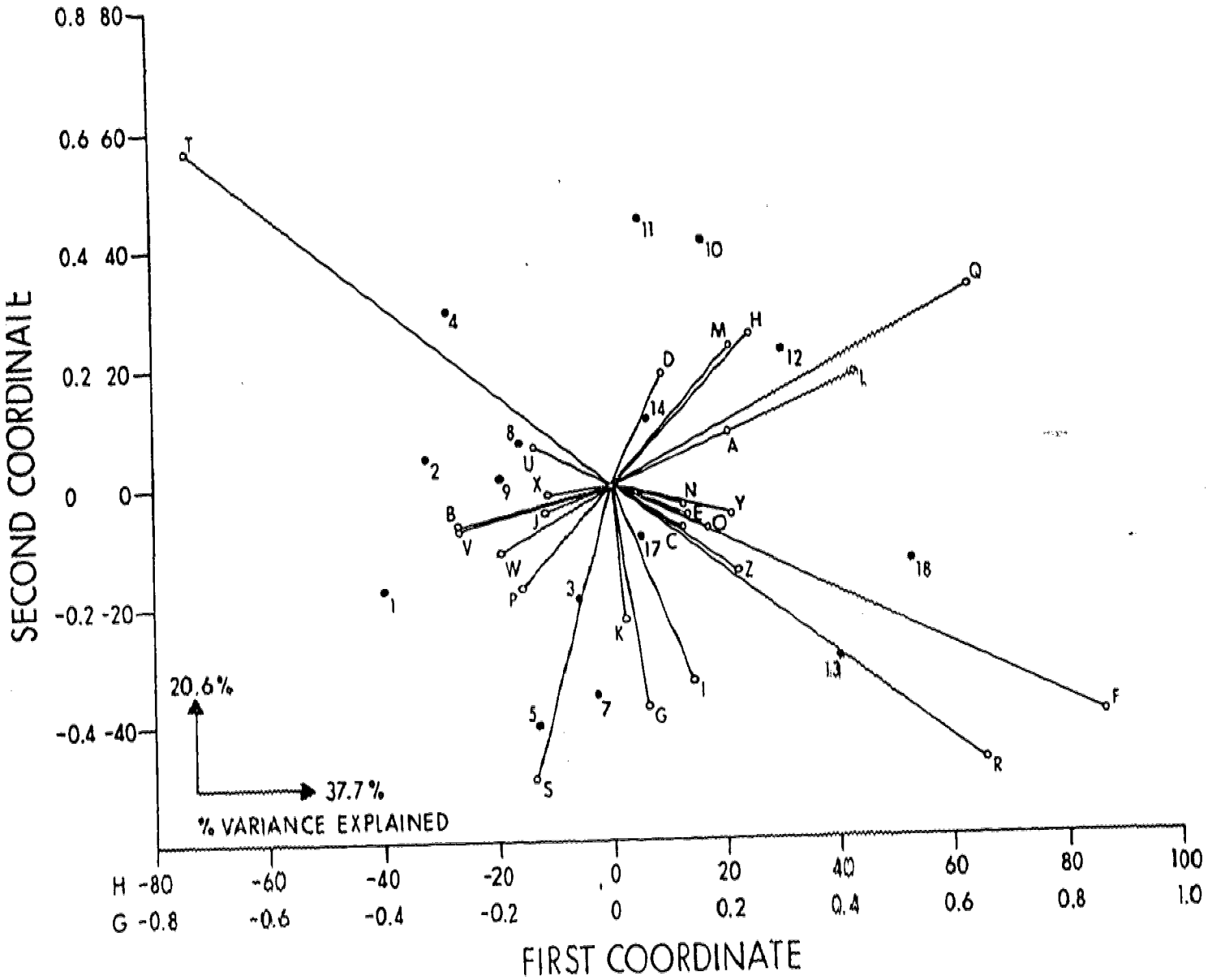

Figure 5: Biplot Display of Economic Variables and Land Management Districts Showing Plane Which Explains 58 Percent of the Variance (Numbers = Land Management Districts; Letters = Variables in Table 2).

somewhat different economic and social characteristics. East of that line is an area where the population has been relatively heavily involved in commercial and wagework activities. West of that line, the population has been relatively more involved in subsistence livestock raising, which has been supplemented by social welfare.

Second, consumption groups were largest on the average in areas with the highest proportion of subsistence livestock activities. It is not clear whether this pattern is related to differential fertility, differential family organization, or both. These data for consumption groups were taken in 1936 and 1937, and the available data on family organization and fertility were obtained a generation or more later. The evidence we do have concerning family organization is presented below. Fertility is discussed in Part III.

Third, those areas in the north central portion of the reservation that are the most overgrazed are the ones where the proportion of people allowed to have livestock is the lowest. In addition, these same areas do not have the largest proportions receiving general assistance. BIA welfare workers have commented that people in this area are less likely than are people elsewhere to request welfare help even though they qualify for it. We cannot explain this observation.

So far we have analyzed the biplot in two dimensions. A measure of goodness of fit indicates that the first plane of the biplot, described above, explains about 58 percent of the variation. It is useful, however, to visualize these relations in three dimensions. The arrows and dots are distributed around a central point like pins stuck into a ball. Therefore, points that appear to be close to one another in a two-dimensional projection may actually be quite far apart when the third dimension is considered. Conversely, points appearing far apart in one projection may appear to be close together in another.

In the projection used in Figure 5, we note that two variables, proportion of permittees (R) and percent of range over or under carrying capacity (T), are almost perfectly negatively correlated and that many of the numbered dots are separated by the axis consisting of the R and T arrows. If we rotate the biplot so that the viewer looks along the R arrow toward the center of the diagram, we obtain the biplot shown in Figure 6.

In Figure 6, the arrows for R and T are greatly foreshortened. Using the third coordinate adds another 15.6 percent to the variation explained and reveals new relationships. Note that in Figure 5, district 8 was widely separated from districts 1, 2, and 3. In Figure 6, it is seen to be much closer to them. All four districts have above-average values for the variables relating to average size of consumption group (B), non-commercial livestock income per capita (J), ratio of grazed to authorized animal unit months (U), animal unit months per population (V), and proportion of the population on general assistance (W). Similarly, we now see that districts 12, 13, 14, and 18 (the eastern end of the reservation) are similar in population density (A and Q), commercial agricultural income per capita (L), proportion of males and females in non-traditional labor (Y and Z), and various measures related to commercial income. This cluster did not stand out so clearly in Figure 5 because the overwhelming

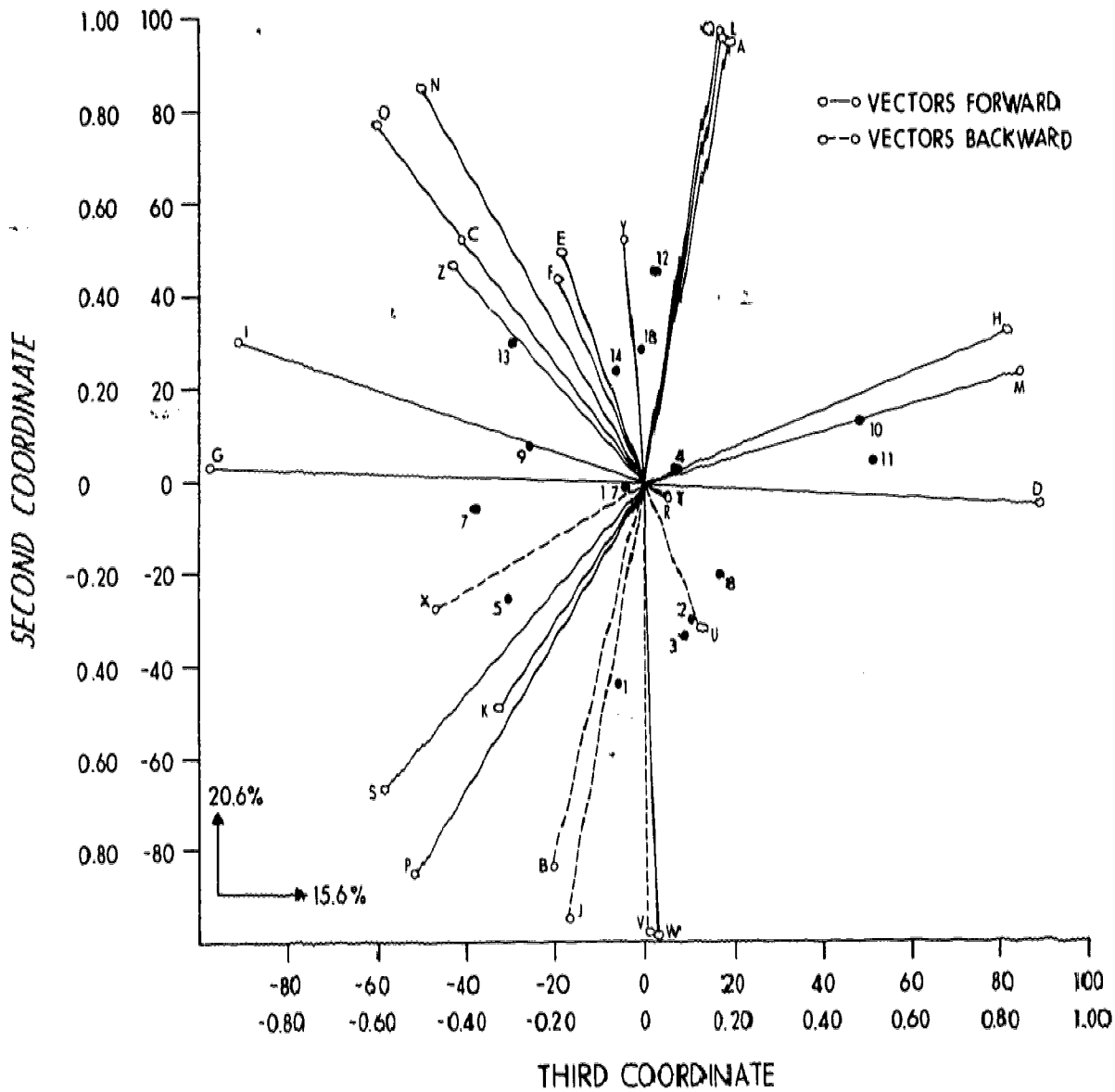

Figure 6: Biplot Display of Economic Variables and Land Management Districts Showing Plane Which Explains an Additional 15.6 Percent of the Variance (Numbers = Land Management Districts; Letters = Variables in Table 2)

influence of variables R and T spreads the districts apart.

In general, it appears that on the eastern end of the reservation, there is greater involvement in wagework, higher income from commercial, agricultural, and livestock activities, a higher proportion of the population with livestock permits, and less overgrazing. In the western part of the reservation, there is more overgrazing, more dependence on welfare, and a smaller proportion of the population that is allowed to have livestock.

The history of stock reduction on the Navajo Reservation in the 1930s and the formula by which permit sizes in different districts were determined have been discussed by Aberle. Briefly, "the maximum permit was set at a level such that if every owner holding more than the maximum permit sold stock until he had only that amount, and if every owner holding only the maximum permit or less retained his stock at his current level, the District's livestock would be equal to its carrying capacity" (Aberle 1966:67). Areas on the western end of the reservation where the largest maximum permits were assigned in 1936 were those that were the least densely settled. In these areas, permit sizes could be larger than in the east, where there was relatively more crowding by both the human and livestock populations.

Thus, from the start there seems to have been a greater potential for disparities in livestock holdings on the western than on the eastern end of the reservation. Twenty-three years after stock reduction, in 1959, permits on the western end of the reservation area were still larger than in the east. Moreover, the proportion of people allowed to have permits was smaller in the west and the overgrazing was greatest there. The same disparity existed in 1972, when more animals than were permitted were grazed in the western districts, while there were fewer animals grazed than were permitted in the east.

There are at least two possible--and not mutually exclusive--explanations for the livestock-holding patterns described above. The first is that individuals on the western end of the reservation may have livestock that is listed under someone else's permit. For instance, a child may own sheep that are listed on the tribal permit as belonging to one of the parents. This is known to occur in various areas on the reservation.

The other possible explanation is that the larger maximum permit sizes in the west and the smaller proportion of permittees reflect the presence of a substantial proportion of individuals who in fact have no livestock at all, either in their own or in anyone else's name. This seems to have been true in the pre-reservation period (Vogt 1961). Preliminary analysis of unpublished data gathered by Jerrold Levy and his colleagues on the Lake Powell Research Project suggests that this may largely explain the situation at present (J.E. Levy, personal communication).

Satisfactory explanation of the livestock-holding patterns must await more detailed analysis of survey data. Nonetheless, if we accept for the present that there are considerable discrepancies in livestock holdings among families in the same areas as well as between areas in the east and west, we may speculate as to how these patterns came about. We have already suggested that population and livestock densities differed across the

reservation in the 1930s and that these densities are related to differences in the permit sizes that were issued. We have not explained, however, why there is overgrazing in the west and undergrazing (or, perhaps, simply less overgrazing) in the east at present, nor why average flock size and proportion of permittees differ from east to west.

A reasonable but tentative hypothesis, unsupported as yet by direct evidence, is that the availability of relatively more wagework opportunities in the east than in the west has led to a greater likelihood that livestock inheritance will be divided about equally among children. Conversely, in the west, where wagework is not available, survival on livestock is possible only if flocks are kept large and hence are inherited unequally. Alternatively, inheritance may be equal among siblings but differential outmigration may result ultimately in an unequal distribution of stock.

As we have shown elsewhere, net outmigration is greater from the western end than from the eastern end of the reservation (Kunitz 1973). People in the west seem to be at a double disadvantage. Not only do they not have access to adequate livestock to maintain themselves at a subsistence level, but they also do not have access to jobs. The shortage of available jobs may have enhanced the unequal livestock distribution observed in the 1930s. Therefore the people who do not migrate from the western end may be especially likely to become dependent on welfare. Moreover, the unequal distribution of livestock and the low availability of jobs in the west are related to (1) animals exceeding permit allowances being grazed in the west; (2) greater destruction of the range in the west than in the east as a result of this overgrazing; (3) a greater persistence of the extended household in the west than in the east; and (4) differences in fertility rates and mortality patterns from west to east.

It is extremely difficult to compare the results of the many community studies done on the Navajo Reservation over the past generation or two. Nonetheless, there is some evidence that social organization does differ from east to west (Henderson and Levy 1975). In Table 3 are shown data on the proportion of neolocal households found in community surveys done in the late 1950s and early 1960s in districts 1, 2, 3, 12, and 13. Notice that the western districts had a smaller proportion of neolocally organized camps than the eastern districts. It appears that in the areas where wagework is most prevalent, families are organized in a different fashion than where welfare and subsistence livestock activities are the most common sources of support. This pattern is perhaps not surprising and suggests that in the western districts the extended family is used as a means of maximizing support when the sources of income are fluctuating and uncertain (Aberle 1963). This may also help explain the varying size of consumption groups reported from 1936 though, as we shall show in Part III, fertility may also contribute significantly to these differences.

Aberle (1961:199f) has observed that:

> Roughly speaking, a high percentage of extended family units is found in the western half of the reservation, in more thinly populated and less agricultural units. Agriculture and density tend to coincide, so that the effects of these two variables cannot be easily disentangled.

He has also noted that, in the 1930s, the proportion of polygynous marriages tended

Table 3: Camp Organization on the Navajo Reservation

Area	Total Camps	Neolocal	
	Number	Number	Percent
Western Rural 1960s (Land Management Districts 1,2,3)	62	14	23
Eastern Rural			
Sheep Springs	74	33	45
Fruitland 1950s (Land Management District 13)	156	101	65

Source: Henderson and Levy (1975)

to increase from east to west, which also presumably reflects the relative intensity of contact with the dominant society as well as differences in subsistence patterns (Aberle 1961).

Finally, we wish to suggest that two cycles, one vicious, the other relatively virtuous, may be at work. The vicious cycle has already been described in part. The virtuous cycle in the east is created by the fact that new jobs seem to be most common there, thus allowing for more equitable distribution of livestock; relatively less dependence on available livestock; and therefore less destruction of the range. Moreover, it is unlikely that job opportunities will be either massively increased or more evenly distributed around the reservation, primarily because the reservation resembles a colony from which natural resources are extracted but where relatively few production jobs are created. The jobs that do arise--apart from those in the service sector provided by federal and tribal agencies--are in extractive industries. These jobs, by their very nature, are located near the natural resources being extracted, namely, coal, oil, natural gas, and uranium, which are found primarily in the eastern part of the reservation (Navajo Tribe 1974:57).

We described the second cycle as only relatively virtuous because, even on the eastern end of the reservation, the standard of living seems to be well below that of the general U.S. population. Moreover, the data in Table 2 suggest that people on the western end are in even worse economic circumstances than Navajos elsewhere. It is in this context that the developments in the Lake Powell region have special significance, for they are taking place in an area that has been the most isolated from employment opportunities in the past. The impact of these developments on patterns of mortality and fertility is of particular concern in the present study.

III. MORTALITY, MORBIDITY, AND FERTILITY PATTERNS ON THE NAVAJO RESERVATION

Background

During the 3-year period 1965 through 1967, the proportionate contribution to

mortality in the Navajo area from the five leading causes of death was that shown in Table 4. Infant mortality and infectious diseases are still higher among Navajos than in the general U.S. population, although the pattern is changing rapidly (Part I).

Accidents. In spite of their importance as the leading cause of death among Indians, relatively little has been written about accidents. In fact more articles have been written on heart disease and cancer than on accidents among Indians, presumably reflecting the major concerns of the larger society. The available data do not allow us to document with any certainty the change in accident rates among the Navajos, but it seems safe to say that it has probably followed the same pattern as that demonstrated for all Indians, with an absolute increase over the past generation and a very large increase in relative importance as compared to other causes of death.

Table 4: Leading Causes of Death, Navajo Area, 1965-67 (in percent)

	Navajo Area	U.S. All Races
Accidents	22.9	6.1
Diseases of the heart	6.5	39.0
Malignant neoplasms	7.4	16.3
Influenza and pneumonia (excluding newborns)	8.1	3.4
Certain diseases of early infancy	7.4	2.8

Source: U.S. Public Health Service (1971:27)

Two studies of accidents have been done on the Navajo Reservation, and their results may be summarized briefly. In 1966 and 1967, the Navajo accidental death rate was 104.2 per 100,000 population, 1.8 times greater than the rate for the U.S. population (58.0). The death rate for Navajo males was 160.6 as opposed to 48.9 for females (relative risk for males is 3.3 times that for females). Navajo males 25 through 34 years of age had the highest incidence of accidents, but males above the age of 65 had the highest death rate from accidents. Motor vehicle accidents were responsible for almost half (48.2 percent) of the accidental deaths, but represented only about 20 percent of the total number of accidents recorded (Brown et al. 1970).

Using data collected somewhat earlier than those cited above, Omran and Loughlin (1972) analyzed the pattern of accidents affecting the residents of one rather isolated and traditional Navajo community in the years 1957 through 1962. Accidental deaths (10 in all) were responsible for 15.4 percent of all deaths. "The leading cause of accidents were domestic injuries followed by injuries due to sharp instruments that the average Navajo uses in every day life" (Omran and Loughlin 1972: 17). In addition to environmental hazards, however, the authors emphasize that psychosocial factors were also significant.

> As a people in transition, the Navajos exhibit many insecurities and inabilities to cope with their changing way of life. This has resulted in a great deal of stress, violence, alcoholism, undisciplined children and social maladjustment. It is generally assumed that the relatively high rate of accidents associated with alcohol and violence is symptomatic of deeper seated social disorders among the Navajos. Drinking was associated with at least five of the fatal accidents, and with

the more serious injuries especially those inflicted by others, as well as a number of motor vehicle accidents (Omran and Loughlin 1972:18).

More recent data published by the Indian Health Service (IHS) (U.S. Public Health Service 1973) indicate that alcohol use is associated with some categories of accidents, but it is less clear whether the accidents are caused by alcohol. Table 5 shows the proportion of accidents of different types that were, in the estimation of the attending professional, alcohol-related.

A major problem faced by all investigators of the accident phenomenon is the determination of risk factors and the assessment of their relative importance. We have already suggested that the implements that Navajos use are of major importance in the accident pattern. In addition, the quality of vehicles, roads, and drivers and the number of miles driven per person are significant (Boyd et al. 1968).

Table 5: Alcohol-Related Accidents as a Percentage of Total Accidents, Navajo Area, 1972

Type of Accident	Percent Alcohol-Related
Motor vehicle	19.5
All other accidents	2.3
Falls	2.1
Cutting, piercing objects	3.2
Suicide attempts	17.9
Injuries purposely inflicted by others	28.7

Source: U.S. Public Health Service (1973)

Based upon interview data, Levy (personal communication, 1975) has estimated that on the average a pick-up truck on the reservation is driven 25,000 miles per year, mostly on very bad roads. Finally, personality factors and various demographic characteristics have been shown to be of major significance. For instance, in the general U.S. population, males have higher motor-vehicle-accident death rates than females; non-white males higher than white males; divorced individuals higher than widowed; widowed higher than single; and single higher than married (National Center for Health Statistics 1970).

Iskrant and Joliet (1968:46) list the following personality characteristics as significant among accident repeaters: youthfulness, low intelligence, egocentricity, aggressiveness, anti-social feelings, social irresponsibility, and unconventionality. The accident repeater is "dissatisfied with everyday life; lacks clearly defined goals; is unable to control hostility; tends towards 'acting out' behavior either physically or verbally; shows poor judgment;" (Iskrant and Joliet, 1968:46). These authors continue: "this study portrays the accident-repeater as a person who is unable to adjust to stress, whose attempts towards mobility are generally thwarted, and who has feelings of insecurity." In addition, several studies agree "that conflict with authority bears a definite relation to accident causation" (Iskrant and Joliet 1968:47).

There are differences in the accident rates not only among Indian tribes but also within a single tribe. Hackenberg (1972) has shown that accident rates are higher in "modern" than in "traditional" communities on the Papago Reservation. A companion study by Stull (1972) shows that individuals judged to be "modern" and

living in "modern" communities have higher accident rates than "traditional" individuals in those same communities. The latter in turn have higher rates than either "modern" or "traditional" individuals living in "traditional" communities. In "traditional" communities, "modern" and "traditional" individuals cannot be distinguished in terms of their accident rates.

Thus, personality structure, degree of acculturation to the dominant society, community of residence, and, presumably, environmental risk factors all seem to be related to the patterns that have been reported, but the relative importance of these various factors is by no means obvious.

Heart disease. We have shown in Table 4 that heart disease is much less significant at present as a cause of mortality among Navajos than are accidents. The figures are somewhat misleading, because deaths from rheumatic (infectious) and ischemic processes (such as coronary artery disease) have been included in the heart disease category. Numerous investigators have attempted to explain the low rates of ischemic heart disease among American Indians in general and among Navajos in particular (Hesse 1964; Maynard et al. 1967; Sievers 1967). Usually, these studies have been concerned with exploring the exposure of populations to a variety of factors said to be associated with the risk of developing coronary artery disease in the general U.S. population. Such risk factors as hypercholesterolemia, hypertension, cigarette smoking, physical activity, dietary patterns, acculturation, and social mobility have all been considered.

Navajos and other Indians have been found to have low serum cholesterol, even though some investigators are of the opinion that their diet is high in saturated fats (Abraham and Miller 1959; Page et al. 1956; Fulmer and Roberts 1963; Comess et al. 1967). It has been suggested that perhaps they metabolize cholesterol in such a fashion that it is excreted in the bile, which would explain the high prevalence of cholesterol gall stones observed by Small and Rapo (1970). Hypertension is infrequent among reservation residents but increases among migrants in urban areas and may be increasing among reservation populations as well (Alfred 1965; Cohen 1953; Clifford et al. 1963; Reisinser et al. undated:75; Strotz and Shorr 1973). Cigarette smoking is not common (Sievers 1968). Most Navajos engage in physical activity, at least to a moderate extent. The low rate of ischemic heart disease has also been attributed in part to low levels of psycho-social stress (Sievers 1967; Fulmer and Roberts 1963; Streeper et al. 1960).

It is puzzling that, for the same population, high accident rates have been attributed to high levels of stress and low coronary heart disease rates to low levels of stress. This paradox should make one wary of invoking "stress" as a causative factor when other explanations fail. One possible explanation may be that factors of a psycho-social nature are important in the etiology of both accidents and ischemic heart disease. However, in the case of heart disease, such factors may interact with a variety of physiological characteristics that take a long time to manifest themselves and that are of no importance in the etiology of accidents. In other words, psycho-social factors may be necessary

conditions in the etiology of both accidents and ischemic heart disease but in the case of accidents they may be more nearly sufficient as well.

Cancer. Death rates from cancers of all types have generally increased among American Indians but are still lower than in the general U.S. population (Creagan and Fraumeni 1972; Smith 1957; Smith et al. 1956). Certain specific cancers do occur more frequently among Indians, however. For example, death rates from cancer of the gall bladder and bile duct are higher among Indians, presumably as a result of the higher prevalence of gall stones.

There is some question concerning the relative importance of carcinoma of the cervix among Indians and non-Indians. Some studies find the rates to be lower than, or the same as, rates in the general population (Jordan et al. 1972; Bivens and Fleetwood 1968), while other studies find the rates to be higher (Creagan and Fraumeni 1967; Dunham et al. 1973). The differences may primarily be due to the different methods used in calculating the rates. The lower rates were calculated from hospital statistics on the proportion of positive Pap smears among Indian and non-Indian patients. The higher rates were calculated from mortality data. The differences might be explained if Indians, for whatever reason, were less thoroughly screened and therefore were more likely to die from this cancer. Since Indian women tend to engage in sexual relations at a relatively early age, one of the risk factors in carcinoma of the cervix is present to a considerable degree. It would not be surprising, therefore, if the rates were found to be at least as high as in the general U.S. population.

Lung cancer is lower among Indians than non-Indians (Sievers and Cohen 1961; Creagan and Fraumeni 1967). The lower rate is probably due to the fact that Indians smoke less than do non-Indians, live in rural settings with clean air, and do not engage in occupations that expose them to carcinogens. The only documented cases of lung cancer among Navajos are said to have been found among former uranium miners (A. Vall-Spinosa, personal communication, 1974). More generally, it appears likely that Navajos and other Indians will show an increase in carcinomas to the extent that they are allowed to participate more actively in the polluted mainstream of American economic life.

Infant mortality. Navajo infant mortality has in general declined over the past generation or two (Table 6). Hadley's (1953) estimate of 139 infant deaths per 1,000 live births in the early 1950s in itself probably represents a considerable reduction since the pre-World War II era when the rate may have been more than 200 per 1,000 live births, as it was among the Hopis at that time (Kunitz 1974a).

Though Navajo infant mortality has been reduced dramatically in recent years, it is still higher than in the general U.S. population. Moreover, as is shown below, the rate is quite variable from one part of the reservation to another. Nonetheless, there has been a profound change in disease patterns. This is reflected on the part of health care providers by a change in concern from mortality to the

Table 6: Navajo Infant Mortality

Date	Infant Mortality per 1,000 Live Births	Area	Source
1949-51	139.4	Reservation-wide	Hadley (1955)
Late 1950s	70.0	Many Farms	McDermott et al. (1972)
Early 1970s	37.0	Fort Defiance	Brenner et al. (1974)
1970	31.5	Reservation-wide	USPHS (1971)

more subtle developmental effects of the sequelae of morbidity. This is also reflected in a growing concern with problems of mental health (Kunitz and Levy 1974).

Excessively high infant mortality is still a major problem among Navajos and other tribes, however. Factors such as prenatal care (Iba et al. 1973; Brenner et al. 1974); birth weight (Rosa and Resnick 1965); feeding patterns and nutritional status (French 1967; Van Duzen et al. 1969; Darby et al. 1956; Reisenger et al. undated; Maynard and Hammes 1970); and complicated pregnancies (Brenner et al. 1974) have all been implicated. Attempts made to mitigate the effects of some of these factors have not been notably successful (Rogers et al. 1974). Most improvements in the future are likely to result from improved living conditions usually associated with improved economic status rather than from improved medical care (Oakland and Kane 1973).

Nutritional deficiencies in children are still significant on the Navajo Reservation. Overt protein-calorie malnutrition was reported from the western end of the reservation as late as the mid-1960s, but is virtually unknown on the eastern end (Van Duzen et al. 1969: 1398). Throughout the reservation, however, Navajo youngsters are found to be smaller and lighter than expected when compared to non-Indian age mates (Van Duzen et al. 1969; Reisenger et al. undated). Even border line malnutrition may have a measurable influence on ability to learn necessary skills in school and elsewhere (Moore et al. undated).

Compounding the nutritional deficiencies are problems related to chronic otitis media (middle ear disease). An enormous literature has developed on this condition as it is related to learning disorders among American Indians and Alaskan natives (Ling et al. 1969; Zonis 1968; Johnson 1967; Brody et al. 1965; Reed et al. 1967; Brody 1964; Gregg et al. 1970; Maynard 1969; Reed and Dunn 1970; Maynard et al. 1972; Rossi 1972; Jaffe 1969). It is not our purpose here to add to this literature, but only to note that such growing interest in this ear disease is an additional index of the passage of the Navajo population into the later stages of the epidemiologic transition where concern for problems related to morbidity rather than mortality becomes increasingly important.

This necessarily cursory review of some of the previous work relating to major health problems of American Indians is intended to show that the disease patterns among the Navajos are a reflection of their situation as a modernizing population. These changes associated with modernization will have a profound influence on many aspects of Navajo life. At the same time, as indicated above, changes are not proceeding uniformly across the reservation. In the remainder of this discussion, we will examine some of the different patterns of mortality and fertility that exist across the Navajo Reservation.

Methods

We have estimated that the resident Navajo population in 1968 and 1969 was 110,000, and have used this figure to calculate population distributions and vital rates.

Because the Navajo Reservation is so large, it has been divided by the IHS into eight service units. The problems of estimating IHS service unit populations are discussed below. Unfortunately, the boundaries of these service units are not contiguous with those of the land management districts (Figure 4) described in the previous section. On the western end of the reservation, the Tuba City Service Unit encompasses land management districts 1 and 3; Kayenta, districts 2 and 8; and Winslow, 5 and 7. On the eastern end of the reservation, the discrepancies are greater. The Fort Defiance Service Unit includes districts 17, 18, and part of 14; Chinle, 4, 10, 11, and part of 9; Gallup-Tohatchi, 16 and part of 14; Shiprock, part of 9 and all of 12, 13, and 19; and Crownpoint, district 15. Another impediment to our analysis is that adequate economic data from districts 15, 16, and 19 are lacking; they do not appear in the biplot (Figures 5 and 6).

Data for the variables related to mortality and fertility are obtained from IHS publications (U.S. Public Health Service 1970a, 1970b) and are derived from birth and death certificates of Indians residing in the service units in calendar years 1968 and 1969. The vast majority of these Indians are Navajos, but undoubtedly members of other tribes are represented from time to time. There is no way to exclude non-Navajos from the calculation. Fortunately for our analysis, the number of non-Navajos is very small compared to the Navajos, so that their inclusion in the data represents no problem.

The variables listed in Table 7 are for the most part self-explanatory. Median birth weight is that birth weight (in grams) which 50 percent of the newborns are above and 50 percent below. Birth order refers to the number of births a woman has had, including as the last the child whose certificate is inspected. The median birth order, then, is the number of previous births to women delivering in 1968 and 1969 which divides the population of newborns in half. High median birth order means that the women in that particular area have already had many children.

Median age of mother and father is the age which divides the groups into equal halves by age. Median age at death is the same way of dividing the group of the people who died. Low median age at death reflects a high infant mortality rate. The category "proportion of fathers unknown" refers to the many birth certificates on which the name of the father is not recorded. Infant mortality is calculated as the number of children dying

Table 7: Vital Rates of Navajo Service Unit Populations, 1968-69

Service Unit	Median Birth Weight (grams)	Median Birth Order	Median Age of Mother	Median Age of Father	Median Age of Death	Percent of Fathers Unknown	Percent of Males Among Those Who Died	Infant Mortality	Percent on Welfare	Death Rate/1,000 Population: Accident	Death Rate/1,000 Population: Crude	Death Rate/1,000 Population: Infectious	Crude Birth Rate
Chinle	3224	4.3	26.8	30.7	32.9	16.2	60.8	44.0	17.6	1.7	6.9	0.9	38.5
Crownpoint	3127	3.4	26.3	29.3	41.4	17.4	59.1	57.0	15.3	2.0	7.2	0.6	29.3
Fort Defiance	3185	3.5	25.6	29.2	40.5	17.0	67.0	35.6	17.5	1.9	7.0	0.3	37.2
Gallup	3133	3.4	25.6	29.1	42.9	28.3	56.5	39.4	19.3	1.8	5.8	0.3	27.9
Kayenta	3204	6.0	28.7	32.3	5.0	3.6	54.0	74.9	25.3	1.4	7.0	1.0	42.3
Shiprock	3276	4.1	26.5	30.6	28.0	24.4	63.0	65.5	8.4	1.5	5.6	0.6	26.4
Tuba City	3257	4.7	27.9	30.7	16.0	17.3	51.5	53.2	30.5	1.9	8.2	1.2	57.3
Winslow	3265	4.2	26.7	31.6	49.0	18.8	60.4	33.1	30.9	1.0	5.1	0.4	28.2
Coordinates multiplied by factor of: (for biplot)	1	50	50	50	2	5	10	2	10	100	50	100	5

below the age of one year per 1,000 live births in that year.

It is important to note that none of the variables listed so far require knowledge of the size or composition of the population of the service units. They are all calculated by reference only to birth and death certificates. As reporting of these vital events is as valid as in most rural parts of the United States, we may have some confidence in their completeness. The variables to be discussed below are all rates that can only be calculated if the population of the service unit is known, which makes them somewhat more problematic.

The proportion of Navajos on welfare was calculated by (1) ascertaining how many individuals in each reservation chapter received BIA welfare support (as in Part II); (2) aggregating chapters into IHS service units; and (3) determining the proportion of the total service unit population receiving this form of support.

Similarly, estimates of the service unit populations are needed for the computation of death rates per 1,000 population. Crude death rate is the number of deaths per 1,000 population, and as the fact of death is relatively well reported, this rate represents less of a problem than the other two rates. The degree of accuracy of death rates due to infectious diseases and accidents depends on reports of not only the fact of death, but the cause as well. Determining cause is always a problem, even if broad categories such as these are chosen. Hence a greater amount of uncertainty is involved in the death rates due to infectious diseases and accidents. Crude birth rates, like crude death rates, depend on knowing simply the fact of birth and calculating a rate per 1,000 population. The reporting of births on the Navajo Reservation is as good as it is in most rural areas.

As discussed above, the population data present serious problems. BIA estimates of resident population of the Navajo Reservation do not agree at all with the figures reported by the U.S. Census Bureau. We have chosen to rely more heavily on the BIA information, but the IHS is required to base its population estimates on data provided by the Census Bureau. Moreover, the BIA population figures are provided for BIA designated areas (land management districts and agencies) and not for IHS service units.

Analysts in the IHS have used the U.S. census data for the reservation to estimate the size of each service unit population. (The IHS estimates were kindly provided to us by Mr. Mozart Spector.) We have already noted that the count seems to be too low, but it is probable that the errors in the enumeration procedures were about the same throughout the reservation, and therefore the proportionate distribution is probably more accurate than the absolute number provided.

The procedure we have followed is to use the proportionate distribution of population as estimated by the IHS and to apply the percentage figures to the number for the total resident population as we have extrapolated it from the BIA estimates. As we are interested in relative differences between areas, the over- and under-estimation of the denominators (i.e., the total population) is not quite as significant as it would be were we seeking to calculate absolutely accurate rates. We must assume, however, that the errors that did occur in the enumeration were equally large in all service units.

One way to check the accuracy of our estimates of population is to compare the population distribution as estimated by the IHS with that calculated by aggregating land management district populations into IHS service units. It appears that the estimates agree fairly well (Table 8). Given the inadequacies of the data collection systems, the ad hoc nature of the estimations, and the fluidity of the population, the fact that the proportions are so close to one another is very encouraging.

One major source of disagreement between the BIA and IHS estimates is that the latter includes a number of off-reservation communities within its service unit boundaries. The most important of these are the Gallup and Winslow service units, which include within their service populations a significant number of Indians residing in the border towns of Gallup, New Mexico, and Winslow, Arizona, respectively. For instance, the IHS estimate of the Gallup Service Unit population includes a higher proportional representation than is derived from the BIA estimates (Table 8). For this reason, we have used the IHS estimates of population distribution when computing birth and death rates.

Table 8: Estimated Population Distribution in Percent

Service Unit	Indian Health Service	Bureau of Indian Affairs
Chinle	13.4	17.7
Crownpoint	9.5	5.8
Fort Defiance	12.2	15.9
Gallup	19.5	13.3
Kayenta	5.8	7.8
Shiprock	24.2	23.5
Tuba City	6.6	7.9
Winslow	8.8	7.2
TOTAL	100.0	99.1

Results

The rates calculated for the various IHS service units are presented above in Table 7 and, as in Part II, the data are graphically displayed in two views of the biplot (Figures 7 and 8). Because of the lack of variation in certain variables, some arrows are very short; in such cases we have multiplied the coordinates by the factors listed at the bottom of Table 7. Figure 7 displays the projection which explains most (about 94 percent) of the variance in the data.

Close inspection reveals, however, that the Tuba City population appears in this projection to have a lower-than-average death rate from accidents, whereas reference to Table 7 indicates that the rate is actually quite high. Figure 7 is instructive nonetheless. For instance, it seems clear that Tuba City and Kayenta differ from the other areas by having in general above-average values for variables related to fertility and mortality. Winslow, on the other hand, seems to be at the other extreme with much lower rates. Crownpoint has an unusually high death rate from accidents.

One useful way to begin to visualize the distribution of the biplot arrows and dots in three dimensions is to imagine that one is standing at the end of the vector which represents median birth weight and is looking along it to the point of origin of the arrows. The view would be

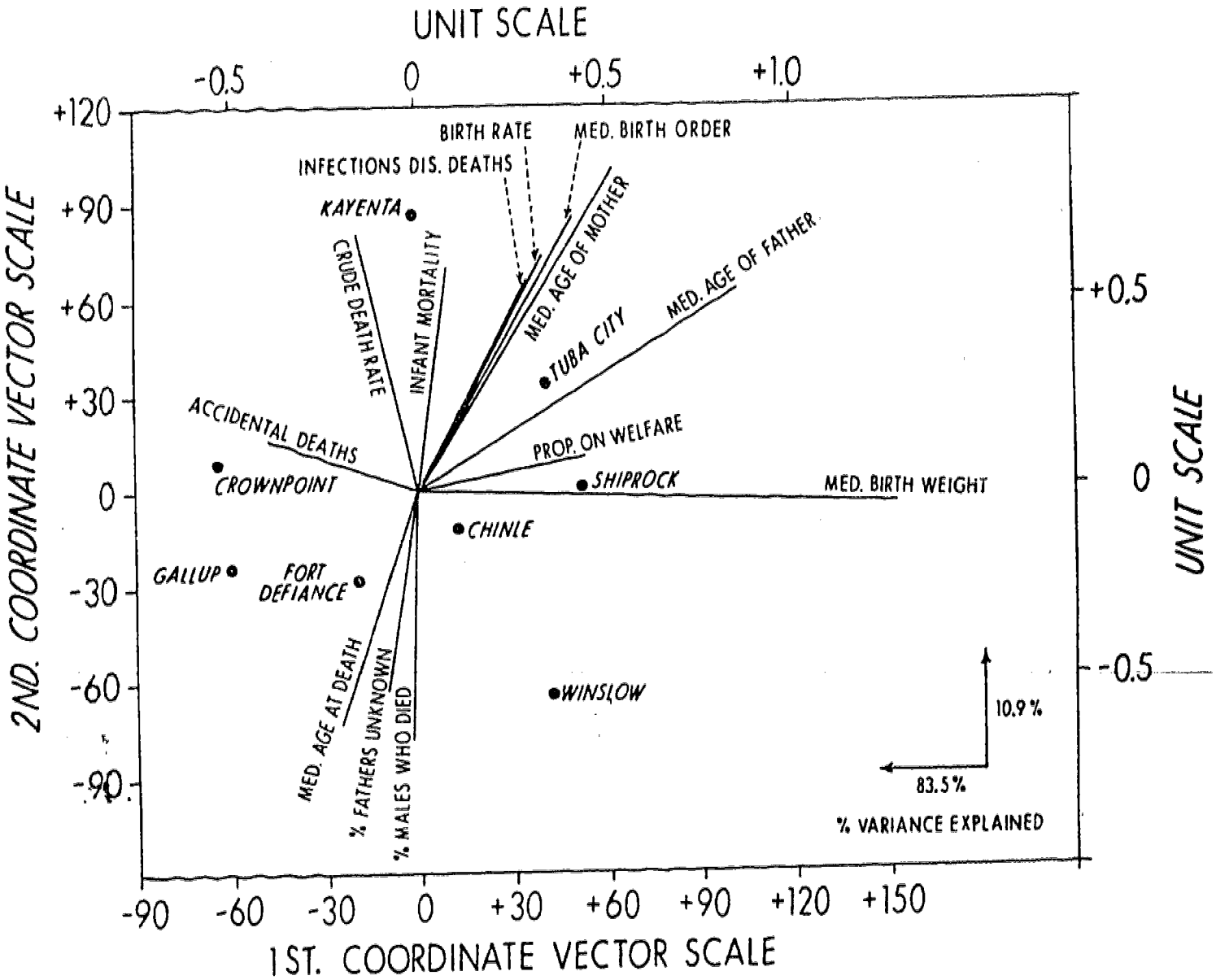

Figure 7: Biplot Display of Vital Rates and Service Units Showing Plane Which Explains 94 Percent of the Variance

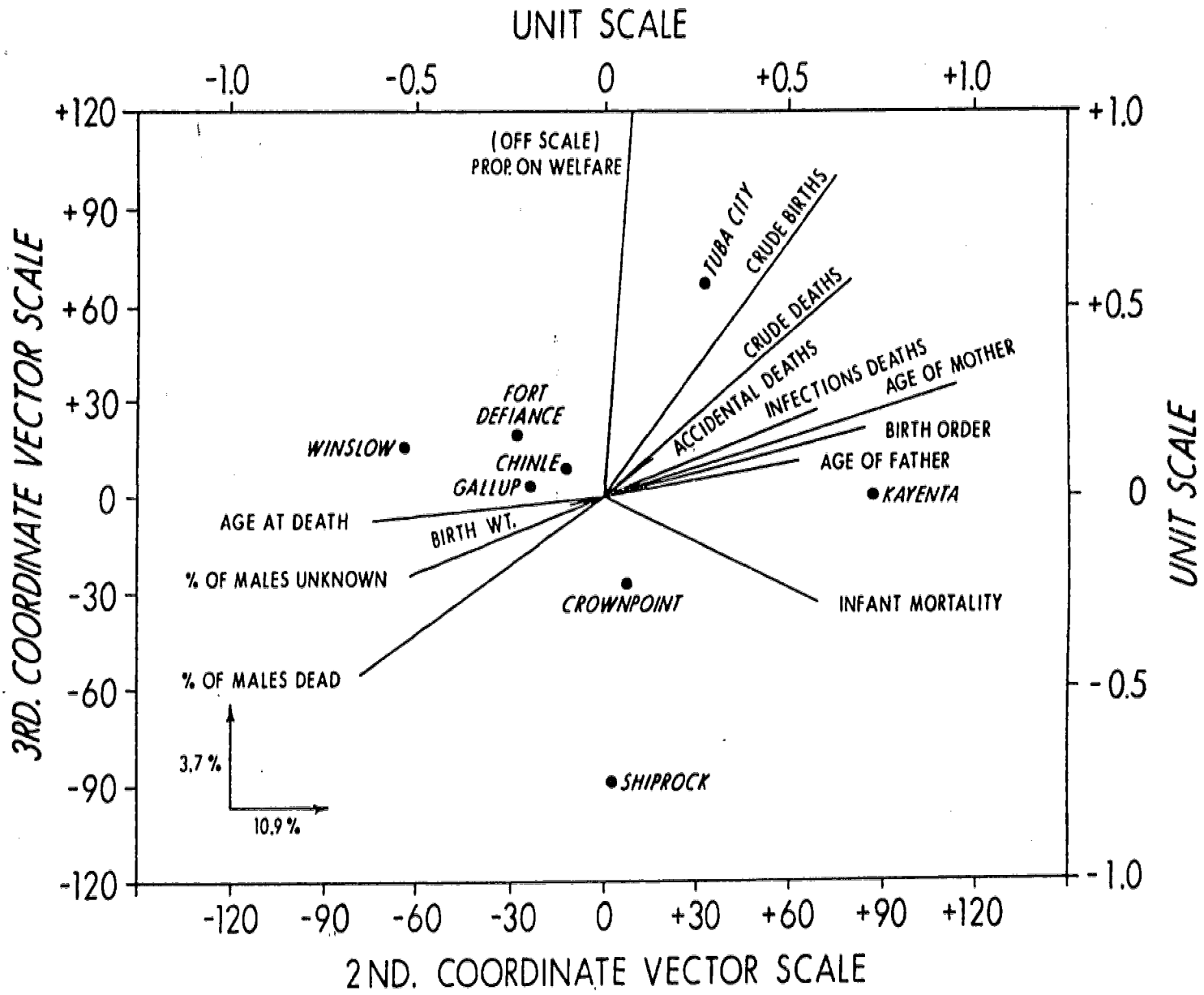

Figure 8: Biplot Display of Vital Rates and Service Units Showing Plane Which Explains an Additional 3.7 Percent of the Variance

that shown in Figure 8. The vector representing birth weight is now very much foreshortened because it is pointing almost directly towards the viewer. Likewise, the vector for accidental death rates is also foreshortened because it points almost directly away from the viewer. All the other points and vectors are fanned out around the origin. We notice that in general those variables related to fertility and crude death rate that were highly correlated in Figure 7 are still highly correlated here. The exception is infant mortality, which now projects below the plane represented by Figure 7.

In Figure 8, Tuba City and Kayenta are still above-average for the variables related to crude death rate and high fertility. It is also true, however, that Shiprock and Tuba City, which in Figure 7 were rather close together, are now widely separated, primarily as a result of the differences in their receipt of general welfare assistance. This variable was included because it was the only economic one for which values could be readily calculated for all service units.

While the different patterns of fertility are relatively clear cut (e.g., high fertility rates in Tuba City and Kayenta), those for mortality are less so. For example, Tuba City has a higher crude death rate and lower infant mortality rate than Kayenta. Moreover, other areas, specifically Crownpoint, Chinle, and Fort Defiance, have crude mortality rates almost the same as that of Kayenta, but lower fertility and infant mortality.

It is also clear that Chinle and Fort Defiance generally resemble one another except for higher infant mortality in the former area. Gallup and Crownpoint plot close to one another in Figure 7 and are more widely separated in Figure 8; the difference is accounted for largely by the higher infant mortality rate at Crownpoint, which may reflect harsher rural living conditions there than in the rest of the Gallup Service Unit.

Accidents are problematic. They are the single most important cause of mortality, manmade or otherwise, on the reservation. We would have expected them to correlate negatively with infectious diseases. That expectation was based on the hypothesis that areas high in infectious disease are at an earlier phase in the demographic and epidemiologic transitions and therefore have lower rates of manmade and degenerative diseases. Our expectation is partially borne out inasmuch as, with one exception, the highest accidental death rates are found in Crownpoint, Fort Defiance, and Gallup, all of which are near the city of Gallup. Tuba City is the exception. It is in a remote area where we would not have expected high rates. In Tuba City, there is a major north-south highway with numerous bars and liquor stores at the points where it crosses the reservation boundary. The Tuba City data suggest that when exposure to the risk of accidents increases in areas relatively unpenetrated by the larger society, the accident rate may increase independently of other changes in the causes of mortality.

The pattern of crude death rates shows that they are lowest in the Gallup, Shiprock, and Winslow Service Units, all of which include major off-reservation centers or economically developing reservation communities. There is a tendency for high crude death rates to be negatively correlated with the proportion of

men among those dying. In other words, the lower the death rate, the more likely is it that male deaths outnumber female deaths. In addition, and not surprisingly, the higher the death rate, the lower the median age at death.

Finally, we may take a more conservative position and look only at those variables that do not require knowledge of population size for their estimation. The median age of parents and the median birth order are highly correlated and may be taken as an index of high fertility (high median birth order) caused by continued childbearing to relatively older parents. This cluster is positively correlated with infant mortality and negatively correlated with the cluster representing (1) median age at death (high median age at death suggests low infant mortality); (2) proportion of fathers unknown; and (3) proportion of males among those dying.

Notice that the cluster of dots representing populations with high fertility and low median age at death (i.e., high infant mortality) corresponds to service units on the northern and western part of the reservation: Tuba City, Kayenta, and to a lesser degree Shiprock. Those populations with low fertility, low infant mortality (high median age at death), a high proportion of unknown fathers, and a high proportion of men among those dying are for the most part located in the southern and eastern portion of the reservation: Gallup, Fort Defiance, Winslow and, to a lesser extent, Chinle.

Of particular interest is a calculation using the estimates of crude birth and death rates to compute a rate of natural increase for each service unit population (Table 9). The Tuba City and Kayenta areas clearly have much the highest rates of growth as a result of the generally high fertility of the population compared to relatively low mortality.

Discussion

The patterns of mortality and fertility revealed by this analysis are not as clearly defined as we might have wished. In large measure this is a result of having to work with relatively small numbers representing a short period of time, which produce rates that may fluctuate widely. It is also a reflection of the fact that demographic and epidemiologic changes do not proceed in as orderly a fashion as the investigator might wish. Nonetheless, some patterns do stand out.

The northwestern part of the reservation (Tuba City and Kayenta Service Units) tends to have a population that has above average fertility and mortality. There is

Table 9: Rates of Natural Increase[a] by Service Unit, 1968-69

Service Unit	Rate per 1,000 Population
Chinle	31.6
Crownpoint	22.1
Fort Defiance	30.2
Gallup	22.1
Kayenta	35.3
Shiprock	20.8
Tuba City	49.1
Winslow	23.1

[a]Crude birth rate minus crude death rate

a strong (though not perfect) correlation among infant mortality, crude death rate, crude birth rate, and indicators of childbearing at older ages (high median age of parents and high median birth order). This area, as noted previously, tends to be most involved in subsistence livestock-raising subsidized by welfare support. Moreover, the pattern is not new. Kluckhohn and Leighton (1946:18) observed in the late 1930s and early 1940s that: "the birth rate appears to be appreciably higher in western areas, where livestock economy, plural marriages, and matrilocal residence prevail." This regional pattern of fertility variation on the reservation has also been reported elsewhere (Kunitz 1973, 1974b) using other sources of data.

Crude mortality rates tend to be lowest in service units that include major off-reservation centers of economic activity (Gallup and Winslow) or a developing reservation community (Shiprock). Though there is a tendency for crude mortality to be correlated with accidental death rates, the correlation is not very strong. It may well be that in these areas the major killers of the recent past--the infectious diseases--have waned, and accidents, though important, have not yet achieved the same lethality. It is also true that the area with highest mortality, Tuba City, has simultaneously one of the highest accident death rates and the highest rate of death from infectious diseases--the worst of both possible worlds. In most areas of the reservation, however, a rough pattern appears to be emerging in which infectious diseases are being replaced in importance by accidents. With the notable exception of Tuba City, these patterns are related to prevailing economic conditions in different parts of the reservation.

As noted above, it is significant that in those areas with the lowest crude death rates, men represent a higher proportion of those dying than do women. This is not due to an unequal distribution of males in these areas, but is a reflection of a more general phenomenon occurring during the transition process: higher mortality of males than females.

The proportion of unknown fathers is highest in areas most dependent on wage-work. There are several possible explanations. The most obvious is that those areas are the most disorganized and have the highest proportion of broken or incomplete families. A less obvious explanation is that many young women all over the reservation have children as a result of relatively casual unions. In those areas where childbearing continues longer, women tend to marry and develop stable families. Thus, it is not social disorganization but the termination of childbearing earlier in the reproductive years that may account for the higher proportion of unknown fathers. A third possible explanation is that unmarried mothers on the western side of the reservation are less reluctant to name the father of their child than are unmarried women farther to the east. These explanations of course are not mutually exclusive. Unfortunately, our data are not adequate to resolve this issue.

We notice a high correlation among service units between age of father and median birth weight. A possible explanation is that children born to women living in intact families with older and perhaps more responsible husbands receive better nutrition than women who may not be living in such favorable circumstances. That birth weight does not predict the rate of infant survival, at least at the aggregate

level, suggests that the harsh living conditions in areas dependent primarily upon a subsistence livestock economy have a more significant impact on infant mortality at present than does prenatal care.

We must point out one apparent discrepancy. Districts 5 and 7, which make up much of the Winslow Service Unit, have been shown in Part II to have economic characteristics similar to those of other communities on the western portion of the reservation. Nonetheless, the data relating to mortality and fertility suggest that this population is similar to those further east. Although conclusive evidence is lacking, we believe that this is explained by the inclusion of the border town of Winslow, Arizona, within the service unit boundaries. It is likely that the Indian residents of this community have mortality and fertility patterns much like those of Indians in economically developed areas, which results in a substantial shift in mortality and fertility rates.

In summary, there is some evidence that populations in different areas of the Navajo Reservation are at different phases of the epidemiologic and demographic transition. With some exceptions, there seems to be reasonable evidence that in those areas most involved in the wage economy the causes of mortality have begun to shift from infectious diseases to those that are of manmade etiology. As a result, mortality rates have declined and with them fertility rates as well. In areas where the population is still largely dependent on subsistence livestock raising, mortality is still higher than elsewhere, particularly in the younger age groups. As a result, fertility is also still high, and the evidence suggests that this is a result of continued childbearing later in the reproductive years.

The persistence of continued high fertility rates on the western end of the reservation, while crude mortality rates have fallen somewhat, has caused higher rates of natural increase in the west than the east. Limited economic opportunities combined with population increase have served to further impoverish the population by reducing per capita income.

In conclusion, we make the following observations. Patterns of mortality and morbidity among Indians are changing such that host factors of a psycho-social nature are becoming of increasing significance. This is particularly noteworthy in regard to accidents, which have increased both in absolute and relative importance. The kind of curative medicine practiced so successfully in the past is inadequate to deal with the understanding and prevention of this cause of death and disability. New approaches toward improving health care need to be developed.

The rate of growth of the Indian population is twice that of the non-Indian population. In some counties in the Southwest this has led, or will lead, to an Indian majority which may well control local political offices (Stucki 1971). At the same time, the number of individuals entering the job market each year is greater than the number of new jobs created (Robbins 1975). With fertility now the major determinant of population growth, the issue faced by the Navajo Tribe is much like that faced by other developing nations: to what degree ought population growth be encouraged or discouraged? And what efforts should be made or not made in the area of family planning? Our data suggest that if economic development proceeds

across the reservation, birth rates are likely to drop regardless of policy positions taken by advocates for or against family planning programs. To the degree that some areas remain isolated from such employment possibilities, fertility is likely to remain higher than elsewhere, welfare support will continue to be of major significance, and emigration will be the only means of obtaining a more nearly adequate income.

APPENDIX

READING THE BIPLOT

In Figures 5 and 6 we have displayed the biplot--the land management districts being represented by numbered dots and the variables by lettered blunt-tipped arrows. The configuration of the dots represents the similarities and differences of the land management districts in terms of the variables. Thus, two close dots indicate that the corresponding land management districts are similar on all variables. Dots which are far apart on the biplot indicate that the land management districts concerned must differ considerably on at least one and possibly many of the variables.

The direction of the arrows reflects the correlation of the variables concerned in the following manner. If two arrows have a small angle between them, the two variables they represent are highly correlated; that is, they are both high on the same land management districts and low on the same other land management districts. If, on the other hand, two variables are negatively correlated in that the land management districts on which one is high have low values on the other variable, then the biplot arrows should point in opposite directions or at least subtend on obtuse angle. In the intermediate situation, lack of correlation is represented by a right angle.

It might be added that the lengths of the arrows are proportional to the variables' standard deviations, but this is not very informative in the present context in which different variables are measured in quite different units.

The juxtaposition of the land management districts (dots) and the variables (arrows) reflects the actual values of the original observations. (The joint plotting of districts and variables leads to the name of the technique, the biplot.) To reconstruct a particular district's observation on a given variable (as measured from that variable's mean--the entire biplot is in terms of variation about means), drop a perpendicular from the dot to the straight line through the arrow and measure its distance from the biplot center. Multiply this by the length of the arrow and add a minus sign if the perpendicular falls in the direction opposite to the arrow. This multiplication reproduces the biplot approximation of the original data (as deviations from the mean). This is useful not so much in reproducing the data matrix but in interpreting clusters of dots in the following way.

A cluster of dots is a group of land management districts with similar observations on all variables. It is usually of interest to identify the variables on which this cluster differs from the average or from another cluster. This can be done on the biplot by looking for arrows

which point in the requisite direction (that is, from center to cluster or from one cluster to another). The variables represented by these arrows are the ones which account for the differences between the clusters (K.R. Gabriel, personal communication, 1975).

Percent variance explained is the proportion of the total variability accounted for by any particular two-dimensional biplot display. The planes displayed in this report are the ones that explain most of the variance in the data.

Figures 5 and 6 on the one hand and 7 and 8 on the other have been labelled slightly differently. In Figures 5 and 6 there are two scales, G and H. G refers to the scale used for plotting the units (land management districts). H is the scale for the vectors (arrows) representing the variables. In Figures 7 and 8 the G and H labels were left off and the scales simply labelled as either vector (referring to the variables) or unit (referring to the geographic units, in this case IHS service units). For a more complete discussion of the biplot, see Gabriel (1971, 1973) and Gabriel et al. (1974).

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GLOSSARY

acculturation	modification in one culture resulting from contact with another
age-adjustment	a process of standardization whereby populations with different age structures may be compared in such a way that the effects of age differences are controlled
consumption group	in the Human Dependency Survey, this was the name given to the unit which shared economic resources; most likely a family unit residing under the same roof
correlations	statistical measures of association between variables; a positive correlation means that units (such as land management districts) with high values on one variable (such as proportion of men in non-traditional employment) are also high on another variable (such as proportion of women in non-traditional employment); a negative correlation between variables means that units high on one variable are low on another
degenerative disease	usually applied to diseases characterized by chronicity and deterioration in function; most commonly found among the elderly
DHEW	Department of Health, Education, and Welfare
etiology	all of the causes of a disease or abnormal condition
fertility rate	the number of births per population; crude fertility rate is the number of births per 1,000 population
HSMHA	Health Services and Mental Health Administration
hypercholesterolemia	excessively high levels of serum cholesterol
hypertension	high blood pressure
ischemia	local and temporary anemia due to obstruction of circulation to a part
lethality	capable of causing death
malignant neoplasm	a cancer that is resistant to treatment, tends to grow worse, and is likely to cause death

matrilocal residence	refers to residence pattern in which the household or group of cooperating households contains an older couple, their unmarried children, and their married daughters and their families
modality	a therapeutic agent or technique
morbidity	the relative incidence of disease
mortality	a. the number of deaths in a given time or place b. the proportion of deaths to total population (crude mortality rate is the number of deaths per 1,000 population)
NIH	National Institutes of Health
polygyny	the practice of having more than one wife or female mate at a time
sequelae	plural of sequela; an after-effect of disease or injury
serum cholesterol	the amount of cholesterol per unit (for instance, milliliter) of blood

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