DEMOGRAPHIC EFFECTS OF NATURAL DISASTERS: A CASE STUDY OF HURRICANE ANDREW*

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Many studies have considered the economic, social, and psychological effects of hurricanes, earthquakes, floods, tornadoes, and other natural disasters, but few have considered their demographic effects. In this paper we describe and evaluate a method for measuring the effects of Hurricane Andrew on the housing stock and population distribution in Dade County, Florida. Using information collected through sample surveys and from other data sources, we investigate the extent of housing damages, the number of people forced out of their homes, where they went, how long they stayed, and whether they returned to their prehurricane residences. We conclude that more than half the housing units in Dade County were damaged by Hurricane Andrew; that more than 353,000 people were forced to leave their homes, at least temporarily; and that almost 40,000 people left the county permanently as a direct result of the hurricane. We believe that this study will provide methodological guidance to analysts studying the demographic effects of other large-scale natural disasters.

Hurricanes, earthquakes, floods, tornadoes, and other natural disasters strike with alarming frequency, often leaving death and destruction in their wake. These events have profound social, economic, and psychological effects on the stricken individuals and communities. Although there is little evidence that the frequency of natural disasters has increased in recent years, their social and economic impact has increased because of population growth and economic development in particularly hazardous areas (e.g., Drabek 1986; Friedman 1984; Haas, Kates, and Bowden 1977; Shah 1983).[1]

There is a substantial social science literature on natural disasters, covering topics as diverse as the effects of disasters on income, employment, tax revenue, and other economic variables (e.g., Chang 1983; Ellson, Milliman, and Roberts 1984; Gillespie 1991; Kimball and Bolton 1994; West and Lenze 1994); institutional and organizational responses to disasters (e.g., Oliver-Smith 1993; Stallings 1987); recovery and restoration following disasters (e.g., Bates and Peacock 1987; Haas et al. 1977); mental, emotional, and behavioral responses to disasters (e.g., Church 1974; Perry and Lindell 1978); and the effects of disasters on crime rates, divorce rates, and other social variables (e.g., Friesema et al. 1979; Geipel 1989).

Very few studies, however, have considered the demographic effects of natural disasters, mainly because of the scarcity of timely, accurate, and comprehensive data. Data on damages from natural disasters are often little more than "a congeries of rumors, clippings from old newspaper stories, and guesses, more or less educated" (Wright and Rossi 1981:156). Estimates of changes in population size and of the underlying mortality, fertility, and migration rates are also incomplete and unreliable (e.g., Adugna 1989; Clarke 1989; Friesema et al. 1979). The literature offers very little guidance for answering even the most basic demographic questions, such as how to measure the extent of housing damages, the number of persons forced out of their homes, where they went, how long they stayed, and whether they returned to their predisaster residences.

In this study we develop a method for answering these questions, and test that method using Hurricane Andrew and its demographic impact on the population of Dade County, Florida as a case study. In the following section we briefly describe Hurricane Andrew and the prehurricane population of Dade County. Next we discuss the strengths and weaknesses of potential sources of data for estimating housing damages and population redistribution following a natural disaster. Then we describe a sample survey designed to collect data not found elsewhere, and analyze the survey results. Finally we offer several conclusions regarding the applicability of this method in other circumstances. The frequency and magnitude of recent earthquakes, hurricanes, and floods in the United States illustrate the importance of finding ways to measure the demographic consequences of natural disasters and developing appropriate plans and policies for dealing with those consequences.

HURRICANE ANDREW

With winds gusting up to 175 miles per hour, Hurricane Andrew ripped through the southern tip of Florida on August 24, 1992. Before crossing the state and exiting into the Gulf of Mexico, the storm took at least 15 lives, destroyed or dam-

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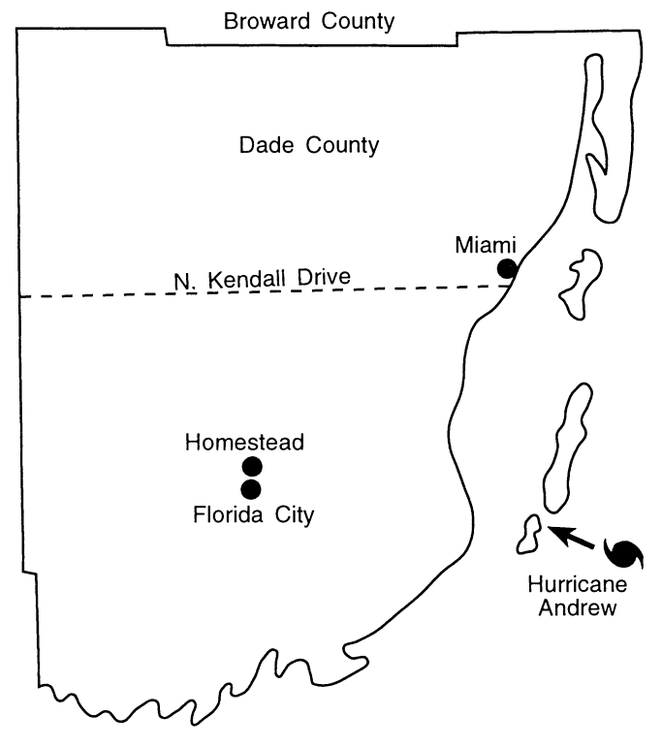
1. We define natural disasters as sudden meteorological or geophysical events that produce high levels of damage and destruction (e.g., hurricanes, earthquakes, and tornadoes). We do not include long-lasting natural events (e.g., droughts) or the effects of human activities (e.g., chemical spills), although the methods described here may be applicable in those circumstances as well.

FIGURE 1. MAP OF DADE COUNTY AND THE HURRICANE AREA



aged many thousands of homes and businesses, and forced hundreds of thousands of people to make other living arrangements. Total damages in Florida were estimated at more than $22 billion, making it the most costly natural disaster in United States history (West and Lenze 1994).

The eye of the storm crossed Dade County about 20 miles south of Miami (Figure 1). Red Cross reports, aerial photographs, and an examination of property appraisal records showed that damages were greatest in the Florida City-Homestead area and became less severe farther north (areas south of Florida City were largely unpopulated). The Metropolitan Dade County Planning Department (1993) designated North Kendall Drive as the northern boundary of the "hurricane area;" we use that boundary to separate North from South Dade in our analysis.

Before the hurricane, South Dade had a population of about 360,000, representing 18% of the county total. As shown in Table 1, the population of South Dade was younger than the population of North Dade, with higher proportions of children and lower proportions of the elderly. Both regions had relatively high proportions of blacks and Hispanics, but the proportions were higher for North than for South Dade, especially for the Hispanic population. Income and education levels and the proportion of owner-occupied housing

TABLE 1. POPULATION AND HOUSING CHARACTERISTICS OF NORTH AND SOUTH DADE COUNTY, 1990

Characteristic	North	South	County
Percent < Age 15	19.6	23.0	20.2
Percent Age 65+	14.7	10.7	14.0
Percent Black	21.3	17.3	20.6
Percent Hispanic	53.6	29.2	49.2
Percent High School Graduates (age 25+)	62.1	78.4	65.0
Percent College Graduates (age 25+)	17.2	26.0	18.8
Per Capita Income (1989) ($)	12,852	17,364	13,686
Percent of Families in Poverty (1989)	15.3	9.3	14.2
Average Household Size	2.74	2.79	2.75
Percent Owner-Occupied Housing Units	46.3	59.5	48.8
Percent Seasonal Housing Units	2.3	3.5	2.5

Source: U.S. Bureau of the Census (1991).

units were much higher in South than in North Dade; average household size and the proportion of seasonal units were also slightly higher in South Dade. Average household size in both regions was considerably higher than the state average (2.46), but the proportion of seasonal units was far lower than in the state as a whole (6.8%).

POTENTIAL DATA SOURCES

A number of data sources potentially provide useful information on the population and housing effects of natural disasters. One such source is a survey conducted by the American Red Cross in the weeks immediately following a disaster. Field workers canvass the disaster area, classifying housing units as destroyed (unrepairable), sustaining major damage (repairable, but uninhabitable until repairs are completed), or sustaining minor damage (inhabitable during repairs). For Hurricane Andrew, the survey of Dade County counted 27,813 destroyed units, 51,850 suffering major damage, and 54,189 suffering minor damage (American Red Cross 1992).

Data from Red Cross surveys typically become available soon after a disaster occurs, but provide no information on occupancy rates or the average number of persons per household (PPH). Consequently they do not provide enough information to produce reliable estimates of population change. Furthermore, several analysts have concluded that Red Cross surveys tend to underestimate the total number of damaged or destroyed housing units, sometimes by a substantial amount (e.g., Gillespie 1991; West and Lenze 1994).

A second source of data is insurance claims paid under homeowner and renter policies. These records often cover many more damaged units than Red Cross surveys, and report the dollar value of losses as well as the number of claims filed. They showed more than 500,000 homeowner and renter claims filed in Florida in the 20 months following Hurricane Andrew (Florida Department of Insurance 1994). Insurance records, however, do not cover uninsured losses and often provide no information on the geographic location of damaged units. Like the Red Cross surveys, insurance records provide no information on occupancy rates, PPH, reconstruction, or population redistribution.

Local administrative records are a third source of data. In Dade County, the planning department used property appraisal files to estimate the number of destroyed housing units (Metropolitan Dade County Planning Department 1993). These files covered the entire county and were updated after the hurricane through field visits and the examination of aerial photographs. Housing units were classified as destroyed if their posthurricane values were less than a specified proportion of prehurricane values (30% for single-family and duplex units; 40% for multifamily units). This analysis showed a loss of 47,100 housing units. Property appraisal data are useful because records refer to individual parcels and can be used to analyze the geographic distribution of damages. They are generally updated over time, and thus provide a basis for monitoring reconstruction and population redistribution. They provide no information, however, on changes in occupancy rates or PPH.

Other types of administrative records also can be used to estimate damages and/or population movements. Examples include change-of-address records from the U.S. Postal Service, annual migration estimates based on Internal Revenue Service tax return data, and lists of addresses for telephone, electric, gas, or water utility customers. The usefulness of these records depends on how quickly they become available after a disaster, the time periods and geographic regions they cover, and how closely they track population movements. These characteristics will vary case by case.

A final source of data is the decennial census, which provides comprehensive housing and population data for all areas of the United States. Although the decennial census can be used to analyze the long-range demographic effects of natural disasters (e.g., Wright et al. 1979), its usefulness for many purposes is limited because it is available only once every 10 years, refers only to place of permanent residence, does not track multiple moves during a decade, and provides no information on reasons for moving.

To be most useful, data sources must cover areas affected both directly and indirectly by a disaster, must provide information for small geographic areas, must reflect both housing damages and population movements, and must provide information for a number of points in time. This last criterion is particularly important because large-scale disasters induce a series of short-term, temporary moves as well as long-term, permanent moves. None of the data sources discussed above—either individually or in combination with other sources—was adequate for estimating the demographic impact of Hurricane Andrew. We concluded that the only way to collect the necessary data was through a series of sample surveys.

SURVEY METHOD

We conducted several field and telephone surveys in 1993 and 1994. The field surveys covered only the South Dade area, but the telephone surveys covered all of Dade and Broward Counties (Broward County is located just north of Dade County). Each survey was designed to collect data related to a specific demographic issue. In this article we focus primarily on a telephone survey conducted in Dade County in the summer of 1994; results from the other surveys have been reported elsewhere (e.g., Smith forthcoming). The surveys excluded all seasonal and part-time residents; consequently the results reported here refer solely to housing damages and population movements for permanent residents of Dade County.[2]

A difficult conceptual problem for postdisaster survey research is choosing the appropriate survey population. Some predisaster residents remain at the same location as before the disaster, but others have moved to a different location in the same general area or have left the area completely. What is the relevant survey population under these circumstances? The answer depends on the intended use of the survey data.

In an earlier study, the objective was simply to develop population estimates for April 1, 1993; therefore it was appropriate to collect data related to the population living in Dade County at that time (Smith forthcoming). In the present study, however, we wanted information on housing damages and population movements for persons living in Dade County at the time of the hurricane, not those living there at the time of the survey. Thus we needed data for persons who had left since the hurricane, as well as those who remained.

We decided that the necessary data could be collected through a large telephone survey if the appropriate questions were asked. The telephone company provided a computer tape containing all listed residential telephone numbers for each of the 229 telephone prefixes in Dade County. Using a sample drawn in proportion to the distribution of these numbers by prefix, we surveyed nearly 6,000 households in the summer of 1994. The data presented here were collected from the 5,310 respondents who reported that they had been living in Dade County at the time of the hurricane.

Because unlisted numbers account for a high proportion of total numbers in Dade County (30–40%), we used random digit dialing (RDD) to reach potentially any household with a telephone. We set a target quota for each prefix based on its proportion of the total listed numbers as shown on the

2. Estimates of the number of seasonal and part-time residents of Dade County are not available, but housing data indicate that they account for only a small proportion of the total de facto population. Although the hurricane may have affected some seasonal and part-time residents, that number was most likely quite small.

tape. For example, if a prefix accounted for 1% of the numbers on the tape, we attempted to obtain 1% of the interviews from that prefix. Telephone numbers that were answered by answering machine or were not answered received up to nine calls before we removed them from the sample. Approximately 70% of the telephone calls resulted in completed interviews, a high response rate for surveys of this type.[3]

Used in this manner, the RDD method should generate a sample that is approximately representative of Dade County households. We were forced to adjust the data, however, in order to reduce the contributions of several prefixes that were inadvertently oversampled. Rather than discarding data from completed interviews, we developed a set of weights by dividing the target sample size by the actual sample size for each prefix. For example, if a prefix had been targeted to receive 25 interviews but actually received 50, we applied a weight of .5 to each interview with that prefix.

In our initial examination of survey results, we noticed that the sample contained a higher proportion of single-family units than we had expected on the basis of the distribution of housing units by type in Dade County. This discrepancy probably existed because single-family units often have a larger PPH than multifamily units; thus it is more likely that someone living in a single-family unit will be at home when called by the interviewer. Because the distribution of housing units by type varies throughout the county and because different types of units may have been affected differently by the hurricane, the survey results could be biased. To deal with this problem, we weighted responses according to the distribution of housing units by type in Dade County (single-family, multifamily, mobile home). We calculated weights for each housing type by dividing the proportion found in the 1990 census by the proportion found in the survey. The resulting weights were .826 for single-family units, 1.329 for multifamily units, and 1.375 for mobile homes.[4]

As a final step, we multiplied together these two weights (one correcting for prefix oversampling and the other correcting for the overrepresentation of single-family units) to create a single weight for each respondent. All the results presented here reflect the application of these weights to the survey data.

The survey described above was sufficient for reaching persons currently living in Dade County, but could not reach those who had left the county after the hurricane and had not returned. Given the tremendous destruction caused by the hurricane, many previous residents might have moved to other parts of Florida or left the state completely. A survey of the entire United States population was not feasible. How could information on these individuals be obtained?

One way to collect this information is through network (or multiplicity) sampling (e.g., Kalton and Anderson 1986; Sirken 1970). With this approach, information on persons outside the sample is collected from survey respondents who have some personal connection to them (i.e., "network members"). Network sampling has often been used in studies of social support among network members (e.g., Fischer 1982; Laumann 1973; Wellman 1979). More recently it has been used to estimate the number of earthquake victims in Mexico City (Bernard et al. 1991), emigrants from the United States (Woodrow-Lafield 1990), and HIV-positive residents of the United States (Killworth et al. 1994).

Some researchers have questioned respondents' ability to recall events associated with network members (e.g., Bernard et al. 1984). Others, however, attest to their ability to recall certain events accurately, as long as those events are not trivial and are associated with persons they know fairly well (e.g., Freeman, Romney, and Freeman 1987).

We were confident that respondents could accurately recall events related to the hurricane because it had had such an impact on their lives. Defining network members was a more difficult problem. We first considered using friends and relatives of survey respondents, on the assumption that respondents would know how their friends and relatives had been affected by the hurricane. We ruled out this approach, however, because we could not control the geographic distribution of friends and relatives in the same way we controlled the distribution of the respondents themselves. In addition, some respondents might have had friends and relatives in common, which would have created the possibility of double-counting.

Instead, we decided to focus on close neighbors, defined as persons living to the immediate right or left of the respondent at the time of the hurricane. We believed that most respondents would know something about the effect of the hurricane on their neighbors and that the probability of two respondents having the same neighbor was very low. More important, this approach distributes network members in a manner geographically equivalent to the distribution of survey respondents. Thus the weights we used for the respondents themselves could also be used for their neighbors.

SURVEY RESULTS[5]

Damage to Housing Units

About 90% of the survey respondents reported that they had been living in Dade County when the hurricane struck. Of those, almost 54% sustained some damage to their homes (Table 2). Those living in South Dade were affected most heavily: 89% reported damages, compared with 47% for

3. A sample based on the distribution of listed numbers may produce biased estimates if the proportion of unlisted numbers varies by prefix. An examination of the survey data found some variation of this type, but it was not related to the geographic distribution of prefixes throughout the county. We do not believe that the use of listed numbers for target quotas creates any bias in the estimates of housing damages and population redistribution.

4. Postcensal estimates of housing units by type were not available. Because the mix of housing units in large places generally changes slowly over time, we believe that 1990 data provide a reasonable proxy for the distribution of housing units in 1992. The weights refer to the housing stock just before the hurricane (1992), not the housing stock at the time of the survey (1994).

5. Most of the survey results reported here have a margin of error of less than 3%, at a 95% level of confidence.

TABLE 2. PERCENTAGES OF RESPONDENTS REPORTING HURRICANE DAMAGE, BY SEVERITY

	Residence in August 1992		
Severity of damage	North	South	Total
Destroyed	0.6	14.1	2.8
Major Damage	8.8	46.9	14.9
Minor Damage	37.3	28.3	35.9
Subtotal (Damages)	46.7	89.3	53.6
No Damage	53.3	10.7	46.4
Total	100.0	100.0	100.0
Number of Respondents	4,075	1,235	5,310

those living in North Dade. Damages also were more severe in South than in North Dade; much higher proportions reported major damage or complete destruction of their homes. (The classification of damages by severity was based on the Red Cross guidelines described above.)

The estimated housing stock in August 1992 was 663,100 in North Dade and 133,700 in South Dade (Bureau of Economic and Business Research 1995). Survey damage rates, when applied to these numbers, imply 309,700 damaged or destroyed units in North Dade and 119,400 in South Dade, a total of 429,100 for the county as a whole. Of these, 23,200 units were destroyed, 120,900 sustained major damage, and 285,000 sustained minor damage.[6]

This estimate of damaged units can be evaluated by comparing it with estimates from other sources. The American Red Cross (1992) reported 133,582 damaged or destroyed units in Dade County, far below our estimate of 429,100. The major reason for this difference is that the Red Cross survey focused primarily on the southern part of the county, whereas our survey covered the entire county. We learned through personal communication with Red Cross staff members that 90 to 95% of the damaged or destroyed units in their survey were located south of North Kendall Drive. When the midpoint of this range (92.5%) is applied to the Red Cross estimate, 123,563 damaged or destroyed units in South Dade are implied, very close to our estimate of 119,400. More research is needed, but this focus on the most heavily affected areas may have caused Red Cross estimates to understate total housing damages following some natural disasters (e.g., Gillespie 1991; West and Lenze 1994).

The Florida Department of Insurance (1994) reported 514,430 homeowner and renter claims related to Hurricane Andrew damages. The geographic distribution of those claims was not available, but Property Claim Services reported that 82% of the dollar value of Florida's damages occurred in Dade County (West and Lenze 1994). Given that damages were heaviest in Dade County, it is likely that the proportion of dollar damages in Dade County was higher than the proportion of damaged units. Assuming that 75% of Florida's damaged units were located in Dade County implies 385,823 claims. According to our survey, 78.2% of the respondents had property insurance. When the reciprocal of this percentage is applied to the 385,823 claims, 493,379 damaged or destroyed units in Dade County are implied, about 15% higher than our estimate of 429,100.

Another estimate of damaged or destroyed units comes from a study of the economic impact of Hurricane Andrew (West and Lenze 1994). Using an analysis of hurricane damages over a number of years in the United States (Friedman 1984), West and Lenze calculated average damage rates by housing type, adjusted for wind speed and county size. Applying these rates to the 1990 census count of housing units implies 351,995 damaged or destroyed units in Dade County. When this estimate is adjusted for housing growth between 1990 and 1992, the result is an estimate of 363,611 damaged or destroyed units, about 15% lower than our estimate.

The Red Cross estimate was based on a comprehensive block-by-block survey and was very close to our estimate for South Dade. The other two estimates were based on reasonable but largely unsubstantiated assumptions; they bracket more or less symmetrically our estimate of damaged or destroyed housing units for the county as a whole. We believe that these estimates provide strong external validation for the damage estimates derived from the survey.

Value of Residential Damages

According to the survey, 78.2% of households with hurricane damage had property insurance; this proportion is similar to those reported in several other studies (e.g., Drabek 1986; Rossi et al. 1983). About 6% of those with insurance received no settlements, most likely because the value of damages did not exceed the deductible level set in their insurance policies. For those who received insurance settlements, we found large differences between North and South Dade (Table 3). More than half the settlements in North Dade were for less than $5,000; only 4% were for more than $40,000. In contrast, only 11% of the settlements in South Dade were for less than $5,000, and more than half were for more than $40,000. Again, these numbers reflect the heavy damages suffered in the southern part of the county. For the county as a whole, the average settlement was just under $32,000.

To make an external check of these estimates, one can compare them with estimates developed by West and Lenze (1994). Using data from the insurance industry and several other sources, West and Lenze estimated $11.7 billion of insured residential damages in Florida. Property Claim Services estimated that 82% of the value of Florida's damages occurred in Dade County; applying this to the West and Lenze estimate implies $9.6 billion of insured damages in Dade County. Using an estimate of 797,000 housing units

6. This estimate was based on the assumption that damage rates were the same for persons who left Dade County between 1992 and 1994 as for those still living there in 1994. Although damage rates may have been different for those who left, this difference would have had little effect on the overall estimate of damaged units because persons who left and did not return accounted for a very small proportion of the total population.

TABLE 3. VALUE OF INSURANCE SETTLEMENTS (PERCENTAGE DISTRIBUTION)

	Residence in August 1992		
Value of Settlement	North	South	Total
≤ $5,000	55.7	10.6	43.7
$5,001–10,000	18.8	7.8	15.9
$10,001–20,000	13.3	12.2	13.0
$20,001–40,000	8.0	18.6	10.8
$40,001–60,000	2.1	14.5	5.4
$60,001–100,000	1.1	17.9	5.6
> $100,000	1.0	18.4	5.6
Total	100.0	100.0	100.0
Number of Respondents	907	474	1,381

and survey data that showed 53.6% of households suffering damages, 78.2% with insurance coverage, 94.2% receiving a settlement, and an average settlement of $31,936, we estimated $10.0 billion of insured damages. Again, estimates based on the survey are consistent with those from other sources.

Population Redistribution

About one-sixth of the survey respondents living in Dade County in August 1992 were driven from their homes by the hurricane (Table 4). More than half the respondents living in South Dade left their homes, compared with only one-tenth of the respondents living in North Dade. Most of those who moved out in South Dade did so because of structural damage to their homes. In North Dade, however, the majority moved out because of the loss of electricity, telephone, water, and/or gas services or for other hurricane-related reasons; fewer than half the respondents in North Dade moved because of direct structural damage to their homes.

Applying these proportions to estimates of the population of Dade County in August 1992 (approximately 1,990,500), we estimated that 353,300 permanent residents were driven from their homes by the hurricane: 166,100 in North Dade and 187,200 in South Dade. Although data from other natural disasters are sketchy, this estimate represents one of the largest population displacements—if not the largest—ever caused by a natural disaster in the United States.[7]

This estimate was based on the assumption that the proportion of residents moving out of their homes because of hurricane damage was the same for persons who left Dade County between 1992 and 1994 as for those still living there

TABLE 4. PERCENTAGES OF RESPONDENTS WHO MOVED OUT OF THEIR HOMES BECAUSE OF HURRICANE DAMAGE; PRIMARY REASONS FOR MOVING

	Residence in August 1992		
	North	South	Total
MOVING STATUS			
Moved Out	10.2	51.7	16.9
Did Not Move Out	89.8	48.3	83.1
Total	100.0	100.0	100.0
Number of Respondents	4,075	1,235	5,310
PRIMARY REASON FOR MOVING			
Structural Damage	43.1	87.0	64.9
Loss of Utilities	41.4	8.3	25.0
Other	15.5	4.7	10.2
Total	100.0	100.0	100.0
Number of Respondents	439	645	1,084

in 1994. We cannot directly test the validity of this assumption, but we will discuss some indirect tests below. Although the proportion moving out because of hurricane damage may have been higher for persons who left the county than for those who remained, the overall estimate of displaced residents would not have been affected much because persons who left and did not return accounted for only a small proportion of the total population.

Displaced residents entered a wide variety of posthurricane living arrangements (Table 5). More than half moved in with friends or relatives, a finding consistent with other studies of evacuations from disaster areas (e.g., Drabek 1986). Eighteen percent rented or bought a house or apartment; 13% moved into a hotel or motel; 8% stayed at their prehurricane location in a tent, mobile home, or recreational vehicle; and 6% made some other type of living arrangement. Residents of North Dade had a somewhat greater tendency to move in with friends or relatives and into hotels or motels, whereas residents of South Dade had a somewhat greater tendency to move into a different house or apartment and to stay at their prehurricane location.

Almost 71% of displaced residents moved only once after their initial moves, into their current house or apartment (not shown here). Seven percent moved in with friends or relatives for their second move, 7% moved to a different house or apartment, and 9% made other arrangements. Two years after the hurricane, fewer than 6% of displaced residents in Dade County remained at the same location as in their initial move.

Many of the hurricane-induced moves were fairly short-lived, especially for residents of North Dade (Table 6). Two-thirds of current Dade County residents who left their homes as a result of the hurricane had returned by summer 1994. Of

7. The San Francisco earthquake of 1906 may have had a comparable demographic impact. Haas et al. (1977) estimated that half the housing units in San Francisco were destroyed by the earthquake, so that some 300,000 people left the area at least temporarily. Even larger numbers have been reported for natural disasters in other countries, such as 105,000 deaths and 702,000 housing units destroyed by a 1923 earthquake in Japan (Mizutani and Nakano 1989) and more than 200,000 deaths from a 1970 cyclone and flooding in Bangladesh (Shah 1983).

TABLE 5. INITIAL LIVING ARRANGEMENTS OF PERSONS MOVING OUT OF HOMES BECAUSE OF HURRICANE DAMAGE (PERCENTAGE DISTRIBUTION)

	Residence in August 1992		
Living Arrangements	North	South	Total
Temporary Quarters, Same Property	4.3	11.7	7.9
Friends/Relatives	57.5	52.1	54.8
Hotel/Motel	16.1	9.9	13.1
House/Apartment	14.7	21.3	18.0
Community Shelter	2.1	0.7	1.4
Other	5.3	4.3	4.8
Total	100.0	100.0	100.0
Number of Respondents	439	645	1,084

those in North Dade who returned, 45% did so within a week and 80% within a month. In South Dade the absences were much longer: only 23% returned in less than one month, and 39% were away from home for more than six months.

Geographic Distribution of Movers

Where did these 353,300 displaced residents go? Using the network approach, we asked survey respondents several questions about their neighbors' moves. More than 91% of the survey respondents living in Dade County in August 1992 reported that they knew whether their neighbors had moved out of their homes because of the hurricane; 52% reported that they knew where their neighbors had gone; and 85% reported that they knew whether they had returned. On the basis of these responses, we were able to estimate the geographic distribution of hurricane-related movers.[8]

According to the survey respondents, 13% of neighbors moved out of their homes because of conditions created by the hurricane: 7% for residents of North Dade and 47% for residents of South Dade (Table 7). These proportions are somewhat lower than those shown in Table 4 for the respondents themselves. The discrepancies may be due partly to survey respondents who did not know whether their neighbors had moved out after the hurricane. They also may reflect the fact that many moves lasted only a short time, especially in North Dade; therefore some neighbors may have moved out and returned without the survey respondents' awareness of the moves. For these reasons we believe that the data shown in Table 4 provide a more realistic estimate of the proportion of movers than do the data shown in Table 7.

8. Tables 7 through 9 refer to the number of responses (i.e., neighbors) rather than the number of respondents. There was some variation in the number of neighbors on whom respondents were able to report, particularly when asked where their neighbors had moved. Consequently the observations are not completely independent of each other. We believe that this creates little potential for bias, however, because the maximum difference in the number of neighbors per respondent was only 2 and the proportion of respondents reporting on these questions was relatively high.

TABLE 6. RETURN STATUS AND WEEKS AWAY FROM HOME, PERSONS WHO MOVED OUT BECAUSE OF HURRICANE DAMAGE (PERCENTAGE DISTRIBUTION)

	Residence in August 1992		
	North	South	Total
RETURN STATUS			
Returned to Prehurricane Residence	72.1	61.4	66.8
Did Not Return	27.9	38.6	33.2
Total	100.0	100.0	100.0
Number of Respondents	439	645	1,084
WEEKS DISPLACED			
< 1	44.7	6.0	27.1
1–2	18.6	7.8	13.7
3–4	16.6	9.6	13.4
5–12	8.0	19.3	13.2
13–26	4.0	18.7	10.7
27–52	3.5	25.9	13.7
53+	4.5	12.7	8.2
Total	100.0	100.0	100.0
Number of Respondents	318	453	771

Table 8 shows the destinations of neighbors who moved. For North Dade, 80% of neighbors who moved remained in Dade County, compared with 74% for South Dade. For both North and South Dade, 9% of neighbors moved to Broward County and 9% moved to other parts of Florida. The biggest difference was for long-distance moves: only 1% of neighbors in North Dade moved out of Florida, but 8% in South Dade left the state. This difference most likely reflects the severity of damages in South Dade: those with the heaviest damages are most likely to leave the state completely (and perhaps permanently).

Using the estimate of 353,300 displaced residents and the proportions shown in Table 8, we estimated that 271,000 displaced residents remained in Dade County, 31,900 moved to Broward County, 32,700 moved to other parts of Florida, and 17,700 left the state. Adding the last three figures together implies that 82,300 persons left Dade County—at least temporarily—as a result of the hurricane. This represents a 4% loss to the county's prehurricane population.

Survey respondents in North Dade reported that 77% of their neighbors had returned to their prehurricane residences by mid-1994, compared with 63% in South Dade (Table 9). Overall, 68% of neighbors had returned to their prehurricane residences, very close to the 67% reported for the respondents themselves (Table 6). For North Dade we found no clear relationship between the destination of the move and the proportion returning, but the relationship for South Dade was strong: the longer the distance of the move, the lower the proportion returning. For South Dade the proportions re-

TABLE 7. PERCENTAGE OF NEIGHBORS WHO MOVED OUT OF THEIR HOMES BECAUSE OF HURRICANE DAMAGE

	Residence in August 1992		
Moving Status	North	South	Total
Moved Out	6.9	47.4	13.2
Did Not Move Out	93.1	52.6	86.8
Total	100.0	100.0	100.0
Number of Responses	7,543	2,204	9,747

TABLE 8. GEOGRAPHIC DESTINATIONS OF NEIGHBORS WHO MOVED OUT (PERCENTAGE DISTRIBUTION)

	Residence in August 1992		
Destination	North	South	Total
Dade	80.1	73.7	76.1
Broward	9.3	8.8	9.0
Other Florida	9.3	9.2	9.2
Outside Florida	1.3	8.3	5.7
Total	100.0	100.0	100.0
Number of Responses	245	587	832

turning were 72% for those who moved to other parts of Dade County, 56% for those who moved to Broward County, 45% for those who moved to other parts of Florida, and only 10% for those who left the state. Overall, slightly more than half the neighbors who left the county had returned to their prehurricane residences by mid-1994: 75% for North Dade and 38% for South Dade.

Using the proportions shown in Table 9, we estimated that 43,100 of the 82,300 persons who left Dade County because of hurricane damages had returned to their prehurricane residences within two years. Of the 39,200 who did not return, some may have returned to a different residence in Dade County, but we believe this is unlikely for reasons explained below.

These estimates are subject to sampling variability and to errors in the survey respondents' knowledge and memory of their neighbors' activities following the hurricane. How accurate are they? There are no similar estimates against which they can be compared directly, but several consistency checks can be made. One check is to compare the estimate of movers to Broward County derived from the Dade County survey with an estimate based on a survey of Broward County itself. As described above, we estimated that 31,921 persons moved to Broward County as a result of Hurricane Andrew. Using the proportions shown in Table 9, we estimated that 20,022 had returned to their prehurricane residences by summer 1994, leaving 11,899 who had not returned. In the 1994 survey of Broward County, we found that 1.01% of the respondents had moved from Dade County because of hurricane damage. Applying this proportion to Broward's 1994 population estimate (1,340,220) implies that 13,550 former Dade County residents were living in Broward County as a result of the hurricane.

This figure is close to our estimate of 11,899, and supports the validity of the network approach. In addition, the estimate from the Broward survey is higher than the estimate from the Dade survey; this finding implies that most persons who had left the county and had not returned to their prehurricane residences had not returned to Dade County at all.

For another consistency check, we can examine overall population change in Dade County during the 1990s. In the short run, annual population growth rates tend to remain fairly stable in large counties: in the absence of major disruptive events, growth for one year is usually similar to growth for the previous year. In the absence of Hurricane Andrew, Dade County's population growth from 1992 to 1994 most likely would have been about the same as from 1990 to 1992. Because of the hurricane, however, we would expect that 1992–1994 growth would be lower than 1990–1992 growth by an amount roughly equal to the number of persons who had left the county because of the hurricane and had not returned within two years. That is exactly what we found.

Postcensal population estimates are made each year for all cities and counties in Florida, based on building permit and electric customer records and on data from the most recent census (e.g., Bureau of Economic and Business Research 1995). In Dade County these data were supplemented with information collected in posthurricane sample surveys (Smith forthcoming). These estimates showed that the county grew by 45,807 between 1990 and 1992, but by only 7,544 between 1992 and 1994 (Table 10). Growth thus was 38,263 greater in the two years before the hurricane than the two years after. This finding is very close to our estimate that 39,200 persons had left the county because of Hurricane Andrew and had not returned within two years. Although this finding does not prove that the migration estimates derived from the survey are correct, at least it shows that they are consistent with population estimates based on other data sources and estimation techniques.

Temporary and Long-Range Effects

The population of South Dade declined by almost 60,000 between 1992 and 1993 (Table 10). North Dade absorbed a substantial proportion of this outflow, growing by almost 28,000 residents. South Dade's population rebounded sharply between 1993 and 1994, growing by almost 34,000; by contrast, North Dade's population grew by only 5,700. The 1994 population of South Dade was still some 26,000 lower than before the hurricane, but in North Dade it was about 33,000 higher. The county's population as a whole fell by almost 32,000 between 1992 and 1993 but grew by more than 39,000 between 1993 and 1994.

A great deal of cleaning up, repairing, and rebuilding took place in the two years following the hurricane. Survey

TABLE 9. PERCENTAGE OF NEIGHBORS WHO RETURNED TO PREHURRICANE RESIDENCES, BY DESTINATION OF MOVE

	Residence in August 1992		
Destination	North	South	Total
Dade	77.8	72.1	74.4
Broward	70.0	55.9	61.6
Other Florida	78.4	44.7	57.2
Outside Florida	79.5	10.3	15.2
Total	77.1	63.0	68.4
Number of Responses	239	578	817

data showed that about two-thirds of the displaced residents had returned to their prehurricane residences by August 1994. They also showed that more than 90% of the survey respondents living in Dade County who had not returned to their prehurricane residences were not planning to do so. It appears that most of the temporary population shifts caused by the hurricane had come to an end within two years.

The long-range effects of the hurricane on population growth in Dade County are more difficult to determine. Several studies have concluded that natural disasters have no significant long-range effects on local population growth (e.g., Friesema et al. 1979; Wright et al. 1979). Yezer and Rubin (1987), however, suggest that the effects of natural disasters depend on prior expectations regarding disaster rates. If disasters occur at anticipated rates, they will not affect the allocation of resources (including labor); if they occur at higher than anticipated rates, they will reduce productivity and utility, spurring the out-migration of both capital and labor. Although hurricanes certainly are anticipated in Florida, it is likely that the magnitude and intensity of Hurricane Andrew were largely unexpected. Therefore it is possible that the hurricane had a significant long-range impact on population growth in Dade County.

The 1994 survey of Broward County showed that among the respondents who had moved from Dade County because of hurricane damage and had not yet returned, none were planning to do so. We have no direct information from persons who moved to other parts of Florida or left the state completely, but we assume that they would be no more likely to return. This assumption is supported by data from the network questions: survey respondents believed that almost 90% of the neighbors who had left Dade County and had not yet returned were not planning to do so. We believe it is safe to conclude that virtually all of the 39,200 persons who left Dade County as a result of the hurricane and had not returned within two years did not intend to do so.

The data needed to evaluate fully the long-range demographic impact of Hurricane Andrew are not yet available, but some preliminary conclusions can be drawn. We do not believe that the birth and death rates in Dade County will be affected significantly because the age distribution apparently was not affected by the hurricane.[9] Future in-migration flows might be lower than they would have been without the hurricane, or future out-migration flows might be higher, but we doubt that either of these scenarios will occur. Rather, we believe that Dade County's future population growth will follow a trajectory largely unaffected by the hurricane. Yet because of persons who left and did not return, the county's population will remain some 40,000 lower than it would have been if the hurricane had not struck. In addition, the geographic distribution of the population within the county will be altered for years to come. These will be the lingering demographic effects of Hurricane Andrew.[10]

TABLE 10. DADE COUNTY POPULATION: APRIL 1, 1990, 1992, 1993, 1994

Region	1990	1992	1993	1994
North	1,588,042	1,622,679	1,650,427	1,656,110
South	349,052	360,222	300,396	334,335
County	1,937,094	1,982,901	1,951,116	1,990,445

Source: Bureau of Economic and Business Research (1995).

CONCLUSION

The lack of reliable data will almost always pose a problem in measuring and evaluating the demographic effects of natural disasters. Red Cross reports, insurance records, property appraisal files, postal change-of-address data, utility company records, and Census Bureau data all provide valuable information, but none of these sources provides timely and comprehensive data on housing damages and population movements, for small geographic areas, or for multiple points in time. We believe that sample surveys are generally the only way to collect the necessary data.

We conducted a large sample survey in Dade County, Florida two years after Hurricane Andrew. We collected data from almost 6,000 residents of the county and used the network approach to collect information on persons who had left the county after the hurricane and had not returned. In this article we have described how this survey was conducted and how survey data can be used to create estimates of housing damages and population redistribution following a natural disaster. On the basis of internal consistency checks and comparisons with estimates from other sources—as well as our assessment of the survey methods themselves—we have concluded that a combination of direct sampling and network sampling can produce reasonably accurate estimates. Al-

9. We investigated potential differences in housing damage and residential dislocation by the survey respondent's age, but found no clear patterns. All differences in damage and dislocation by age were small and statistically insignificant.

10. Recent estimates show that Dade County's population grew by a little more than 23,000 between 1994 and 1995 (Bureau of Economic and Business Research 1995). This is about the same as the average annual increase between 1990 and 1992, an indication that population growth may have returned to its prehurricane levels.

though some adjustments may be needed to account for differing circumstances, we believe that this general approach can be used in virtually any area suffering a natural disaster.

The research described here was funded by the Florida Legislature to raise the quality of the population estimates used for distributing state revenue-sharing funds in Florida. Because the revenue-sharing formula refers only to estimates of the total number of permanent residents, the surveys focused on that aspect of population change. Except for the respondent's age, no data on demographic or socioeconomic characteristics were collected. Other studies of natural disasters may have a considerably broader focus, addressing questions about who leaves, who stays, who returns, and—perhaps more important—why they leave, stay, or return. For such studies, data on demographic or socioeconomic characteristics will be essential. We believe that the survey techniques described here generally will be applicable for those purposes as well.

Many of the moves caused by Hurricane Andrew were short-lived, others lasted for many months, and some were permanent. We believe that the same will be true for most other large-scale natural disasters. Although temporary effects can be measured soon after a disaster occurs, accurate assessments of permanent effects will generally require data covering several years; focusing on a single point in time or on too short a time interval is likely to produce incomplete or even misleading information. Comprehensive studies of the demographic consequences of natural disasters must take a long-range perspective.

REFERENCES

Adugna, A. 1989. "The 1984 Drought and Settler Migration in Ethiopia." Pp. 114–27 in *Population and Disaster*, edited by J.I. Clarke, P. Curson, S.L. Kayastha, and P. Nag. Oxford: Basil Blackwell.

American Red Cross. 1992. "DR831-Hurricane Andrew." Unpublished tables, American Red Cross Form 5233, COB 9/15/92.

Bates, F.L. and W.G. Peacock. 1987. "Disaster and Social Change." Pp. 291–330 in *Sociology of Disasters: Contribution of Sociology to Disaster Research*, edited by R.R. Dynes, B. de Marchi and C. Pelanda. Milan: Franco Angeli.

Bernard, H.R., P.D. Killworth, E.C. Johnson, and S. Robinson. 1991. "Estimating the Size of an Average Personal Network and of an Event Subpopulation: Some Empirical Results." *Social Science Research* 20:109–21.

Bernard, H.R., P.D. Killworth, D. Kronenfeld, and L. Sailer. 1984. "On the Validity of Retrospective Data: The Problem of Informant Accuracy." *Annual Review of Anthropology* 13:495–517.

Bureau of Economic and Business Research. 1995. *Florida Estimates of Population*. Gainesville: University of Florida, and unpublished tables.

Chang, S. 1983. "Disasters and Fiscal Policy: Hurricane Impact on Municipal Revenue." *Urban Affairs Quarterly* 18:511–23.

Church, J.S. 1974. "The Buffalo Creek Disaster: Extent and Range of Emotional and/or Behavioral Problems." *Omega* 5:61–63.

Clarke, J.I. 1989. "Conclusion." Pp. 273–78 in *Population and Disaster*, edited by J.I. Clarke, P. Curson, S.L. Kayastha, and P. Nag. Oxford: Basil Blackwell.

Drabek, T.E. 1986. *Human System Responses to Disaster: An Inventory of Sociological Findings*. New York: Springer-Verlag.

Ellson, R.W., J.W. Milliman, and R.B. Roberts. 1984. "Measuring the Regional Economic Effects of Earthquakes and Earthquake Predictions." *Journal of Regional Science* 24:559–79.

Fischer, C.S. 1982. *To Dwell Among Friends: Personal Networks in Town and City*. Chicago: University of Chicago Press.

Florida Department of Insurance. 1994. Unpublished tables. Tallahassee: State of Florida.

Freeman, L.C., A.K. Romney, and S.C. Freeman. 1987. "Cognitive Structure and Informant Accuracy." *American Anthropologist* 89:310–25.

Friedman, D.G. 1984. "Natural Hazard Risk Assessment for an Insurance Program." *Geneva Papers on Risk and Insurance* 9:57–128.

Friesema, H.P., J. Caporaso, G. Goldstein, R. Lineberry, and R. McCleary. 1979. *Aftermath: Communities after Natural Disasters*. Beverly Hills: Sage.

Geipel, R. 1989. "Friuli: Ten Years after the Earthquake of 6 May 1976." Pp. 54–70 in *Population and Disaster*, edited by J.I. Clarke, P. Curson, S.L. Kayastha, and P. Nag. Oxford: Basil Blackwell.

Gillespie, W. 1991. "Economic Impact of Hurricane Hugo." Unpublished paper, South Carolina Budget and Control Board, Division of Research and Statistical Services, Office of Economic Research.

Haas, J.E., R.W. Kates, and M.J. Bowden, eds. 1977. *Reconstruction Following Disaster*. Cambridge, MA: MIT Press.

Kalton, G. and D.W. Anderson. 1986. "Sampling Rare Populations." *Journal of the Royal Statistical Society* A 149:65–82.

Killworth, P.D., C. McCarty, E.C. Johnsen, G.A. Shelley, and H.R. Bernard. 1994. "A Social Networks Approach to Estimating Seroprevalence in the United States." Unpublished paper.

Kimball, L.J. and N. Bolton. 1994. "The Impact of the Northridge Earthquake on the Economies of California and Los Angeles." Presented to the Seismic Safety Commission of the State of California, Burbank.

Laumann, E.O. 1973. *Bonds of Pluralism: The Form and Substance of Urban Social Networks*. New York: Wiley.

Metropolitan Dade County Planning Department. 1993. "Population Estimates and Projections Post-Hurricane Andrew: Dade County, Florida, 1993." Unpublished report, Research Division, Miami.

Mizutani, T. and T. Nakano. 1989. "The Impact of Natural Disasters on the Population of Japan." Pp. 24–33 in *Population and Disaster*, edited by J.I. Clarke, P. Curson, S.L. Kayastha, and P. Nag. Oxford: Basil Blackwell.

Oliver-Smith, A. 1993. "Anthropological Perspectives in Disaster Research." Pp. 94–117 in *Proceedings of the US-Former Soviet Union Seminar on Social Science Research on Mitigation and Recovery from Disasters and Large Scale Hazards*, edited by E.L. Quarentelli and K. Popov. Newark, DE: Disaster Research Center.

Perry, R.W. and M.K. Lindell. 1978. "The Psychological Consequences of Natural Disaster: A Review of Research on American Communities." *Mass Emergencies* 3:105–15.

Rossi, P.H., J.D. Wright, E. Weber-Burdin, and J. Pereira. 1983. *Victims of the Environment: Loss from Natural Hazards in the*

United States, 1970–1980. New York: Plenum.

Shah, B.V. 1983. "Is the Environment Becoming More Hazardous? A Global Survey, 1947 to 1980." *Disasters* 7:202–209.

Sirken, M.G. 1970. "Household Surveys with Multiplicity." *Journal of the American Statistical Association* 65:257–66.

Smith, S.K. Forthcoming. "Demography of Disaster: Population Estimates after Hurricane Andrew." *Population Research and Policy Review*.

Stallings, R.A. 1987. "Organizational Change and the Sociology of Disaster." Pp. 239–57 in *Sociology of Disasters: Contribution of Sociology to Disaster Research*, edited by R.R. Dynes, B. de Marchi, and C. Pelanda. Milan: Franco Angeli.

U.S. Bureau of the Census. 1991. *1990 Census of Population and Housing*, STF 3A. Washington, DC: U.S. Bureau of the Census.

Wellman, B. 1979. "The Community Question: The Intimate Networks of East Yorkers." *American Journal of Sociology* 84: 1201–31.

West, C.T. and D.G. Lenze. 1994. "Modeling the Regional Impact of Natural Disaster and Recovery: A General Framework and an Application to Hurricane Andrew." *International Regional Science Review* 17:121–50, and unpublished tables.

Woodrow-Lafield, K.A. 1990. "Emigration from the United States: Multiplicity Survey Evidence." Presented at the annual meetings of the Population Association of America, Toronto.

Wright, J.D. and P.H. Rossi, eds. 1981. *Social Science and Natural Hazards*. Cambridge, MA: Abt Books.

Wright, J.D., P.H. Rossi, S.R. Wright, and E. Weber-Burdin. 1979. *After the Clean-Up: Long-Range Effects of Natural Disasters*. Beverly Hills: Sage.

Yezer, A.M. and C.B. Rubin. 1987. "The Local Economic Effects of Natural Disasters." Boulder: University of Colorado, Institute of Behavioral Science, Working Paper No. 61.