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Population movement after natural disasters: a literature review and assessment of Christchurch data

Tom Love

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Wellington
Level 9, 1 Willeston St
PO Box 587
Wellington 6140
Ph: +64 4 915 7590
Fax: +64 4 915 7596

Auckland
Level 17, 3-5 Albert St
PO Box 2475
Auckland 1140
Ph: +64 9 913 6240
Fax: +64 9 913 6241

Sydney
Level 14, 68 Pitt St
GPO Box 220
NSW 2001
Ph: + 61 2 9234 0200
Fax : + 61 2 9234 0201

Canberra
Level 6, 39 London Circuit
PO Box 266
Canberra City
ACT 2601
Ph: +61 2 6263 5941
Fax: +61 2 6230 5269

Melbourne
Level 2, 65 Southbank Boulevard
GPO Box 3179
Melbourne, VIC 3001
Ph: + 61 3 9626 4333
Fax: + 61 3 9626 4231

For information on this report please contact:

Name: Tom Love

Telephone: +64 4 915 5358

Mobile: +64 21 440 334

Email: tlove@srgexpert.com

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Executive Summary

A commonly quoted estimate of out-migration from Christchurch after the February 2011 earthquake is 70,000 people. This review considers peer reviewed research on natural disasters in developed countries, and available data on the Christchurch population, to arrive at an independent estimate of population change after the earthquake.

The most comparable disasters for which published data are available are Hurricane Andrew in Florida, and the Kobe earthquake in Japan.

New Orleans after Hurricane Katrina cannot be compared to Christchurch in 2011. The level of damage was of a different magnitude, with the entire city being evacuated for over a month. The population of New Orleans is different to Christchurch in important respects, including a history of population decline over decades, with high levels of unemployment and rented accommodation. The reconstruction and recovery process in New Orleans was widely considered to be inadequate, mitigating against population return.

Applying the results of analysis of the Kobe earthquake to data on the levels of residential damage observed across the seven city wards in Christchurch gives a predicted population increase of 1.7% for the year following the earthquake. This reflects high underlying population growth in Kobe, and loss of population in specific areas of the city where damage is greatest. These characteristics are broadly comparable to the situation in Christchurch, although this estimate is likely to represent an upper limit for population change in Christchurch.

Applying the two year out-migration figures for North and South Dade County after Hurricane Andrew to the seven city wards in Christchurch gives a predicted long term departure of 2.4% of the population This result is for gross out-migration, and does not consider any immigration associated with background population change, or with post disaster construction. This estimate is likely to be a lower limit for net population change in Christchurch. This estimate is similar to the gross out-migration documented after the Kobe earthquake.

School re-enrolment data are consistent with the impression derived from the literature that the original out-migration from Canterbury has been less than 10 percent, and that populations are already returning steadily. The North Dade County scenario is broadly consistent with the levels of out-migration observed in Canterbury school children.

On the basis of research on previous experience of natural disasters in developed countries, it is likely that gross out-migration is likely to be less than 2.5% after 12 months. The existing trend of increasing population and strong in-migration in Christchurch City is likely to offset that decrease, meaning that the impact of the earthquake on population may be a one-off shock, rather than a long term decline.

It will be important to continue to monitor the movement of population in and out of Christchurch as new datasets become available, so that updated estimates of trend can be calculated for planning purposes.

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1 Introduction

The seismic event of 22 February 2011 resulted in a number of residents of Christchurch city moving to alternative accommodation. The reasons for moving include damage to a main residence making it uninhabitable; broken support infrastructure (such as water and sewage systems); unavailability of important social services (such as schools); or a desire to avoid the continuing experience of aftershocks.

Shortly after the event, the Mayor announced to a press conference that 70,000 people had left Christchurch, a figure that became widely quoted in the media and fuelled speculation of a long term population boost for provincial centres in the South Island (1).

The likely magnitude and duration of population movement after the disaster is an important piece of information for future health planning, informing decisions about future demand and the recovery of services and facilities. This review considers the evidence from research on previous disasters in developed countries, and places the Christchurch experience in that context. It seeks to estimate the likely magnitude and duration of population movements out of Canterbury after the February 22 earthquake.

2 Data from previous events

Relatively little research has been conducted on population movements after natural disasters in developed countries. A search of literature published in English found direct population data for only three events: Hurricane Andrew, the Kobe earthquake, and Hurricanes Katrina and Rita. A much greater volume of literature considers the economic impact of disasters and the phases of the recovery process, but does not present empirical data on population movements. There is a considerable literature on evacuation in hurricane events, but this is largely directed towards the efforts of persuading a population to leave before an event, and to return on a specifically planned timetable after the event (for example Smith and McCarty 2007: (2))

There appears to be very little literature in English on the experience of earthquakes and population movement in Italy, although that is a developed country which experiences a large number of seismic events. English language research on Italian earthquakes appears to be much more focussed upon the geotechnical aspects than social impact.

2.1 Hurricane Andrew

Hurricane Andrew struck Florida in August 1992, killing at least 15 people, and causing damage to many thousands of homes. At the time it was the most costly natural disaster in the history of the united States (3).

Smith and McCarty conducted a detailed followup survey, using both field and telephone methods, in 1993 and 1994. The survey was carefully designed to be representative of the population of Dade County, where the hurricane had the greatest impact, and used network sampling of neighbours to collect information on people who had not returned to their pre-hurricane homes (4).

An interesting feature of Smith's approach was the ability to distinguish between the harder hit South of Dade County, and the less affected Northern part. This means that data on proportion of population leaving and returning can be interpreted in light of the level of damage to residences.

Table 1 presents data synthesised from a number of different tables within Smith and McCarty (4). The first striking result is the difference in the level of damage, with 46.7 respondents reporting damage in North Dade, and 89.3% reporting damage in South Dade. All of the reported measures vary substantially between North and South Dade, and are likely to be influenced by the varying degree of damage experienced in the two areas.

The main points suggested by the data are:

- The specific impact of a disaster on population movement is locally variable, according to the degree of damage to residences;
- In the less damaged north Dade, where nearly half the population reported some degree of damage to their home, only 10% actually left their residence;
- The majority of people who left their pre-hurricane home returned, although the proportion was somewhat lower in the harder hit south of Dade;
- Of those who came back, more than 90% returned within six months in the les hard hit North, while the return in the South was slower;
- For both the North and South, over 80% of those who moved remained in Dade or the neighbouring Broward County rather than moving further afield; and
- Two years after the event, a tiny proportion (0.2%) of the North Dade population had moved and remained outside Dade/Broward, while a much larger proportion of the South Dade population (6.5%) had moved and stayed outside the area.

Table 1: Smith and McCarty estimates post Hurricane Andrew

	North	South	Total
Total population pre-hurricane	1,622,679	360,222	1,982,901
% reporting damage to home	46.7	89.3	53.6
% Left pre-hurricane home	10.2	51.7	16.9
% of those who left who came back to pre-hurricane home	72.1	61.4	66.8
% of those who came back who were back in 6 months	92.0	61.4	78.1
% of those who came back who were back in 1 year	95.5	87.3	91.8
% of those who moved who stayed in Dade or neighbouring Broward county	89.4	82.5	85.1
% those who moved who left Florida	1.3	8.3	5.7
% of total pop that moved out of Dade and Broward	1.1	9.0	2.5
% that moved out of Dade/Broward who returned to pre-hurricane residence	78.5	28.4	41.1
% total pop that moved out of Dade/Broward and didn't return to pre-hurricane residence	0.2	6.5	1.5

The authors of this study concluded that population movements which persisted after two years were likely to be permanent. They suggest that the overall trajectory of population growth in Dade will be unaffected by the hurricane, but that there was a permanent shift of 40,000 fewer people against that original trajectory.

A later study on recovery after Hurricane Andrew found that recovery was slower for households in apartments than single unit houses, that recovery tended to exacerbate patterns of social inequality in housing status, and that rented housing showed a slower rate of recovery (5).

A further important element of recovery which has been studied in the aftermath of Andrew is the socioeconomic impact of the disaster. There is a considerable literature on this aspect of recovery, and while it is not the main focus of this review it is worth noting the findings of a recent study. This showed that after Hurricane Andrew there occurred both displacement of more vulnerable populations from areas where they do not have the resources to recover, and concentration of vulnerable populations in areas where better resourced families were able to leave. Displacement was a feature of the more urbanised Miami coast, while concentration occurred in the more rural areas of Louisiana (6).

2.2 The Kobe earthquake

There are two pieces of research which present specific population information about the Kobe earthquake. Horwich presents an assessment of the economic implications of the Kobe event, while Chang considers the more general framework for recovery (7,8).

Horwich provides some key information about the 7.2 magnitude earthquake, which struck in January 1995. The quake destroyed the entire underground water system, much of the sewage system, the gas system, the power system, the rail system and the main coastal highway. Many fires burned out of control. In spite of widespread destruction, including to the world's sixth largest container port, manufacturing had returned to 98% of pre-quake levels within 15 months, and 79% of shops had reopened within 18 months, including all department stores.

Horwich reports that approximately 100,000 people left the city permanently, or 2.5% of the total population, and that Kobe took ten years to return to pre-disaster levels of population (7).

Chang's more detailed framework provides specific data on the population trend over time (8). This is summarised in the graph which is reproduced in Figure 1 , showing population trends across different city wards and for Kobe overall. Overall, Chang argued that the earthquake had the effect of accelerating long term patterns of population decline in the inner city and growth in the suburbs.

Chang analyses the relationship between population change in the year following the earthquake and the level of housing damage, showing clearly that at a micro census area level there is a strong correlation between level of housing damage and loss of population. The housing damage index indicates the percentage of housing stock which is destroyed in an area, while the population index measures the size of the population compared to 1994 (1994 population pre-quake = 100). Chang's correlation is presented in Figure 2.

Figure 1: Population trends for Kobe and its city wards 1965-2006

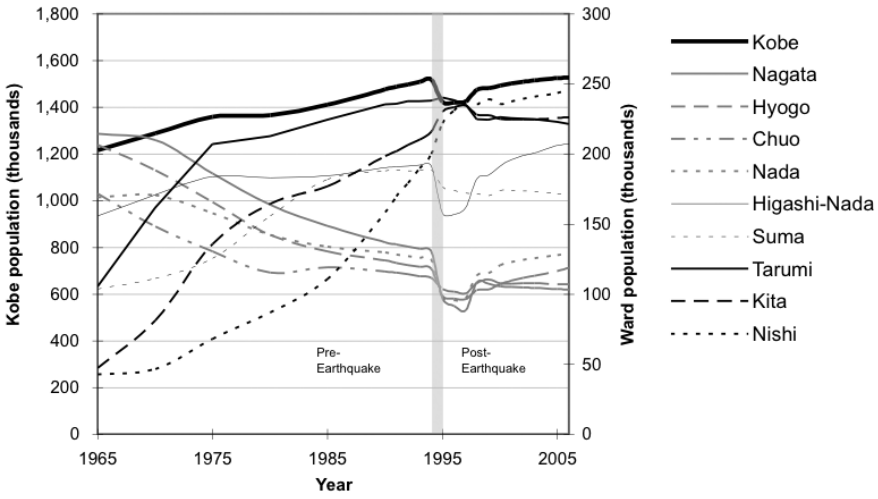
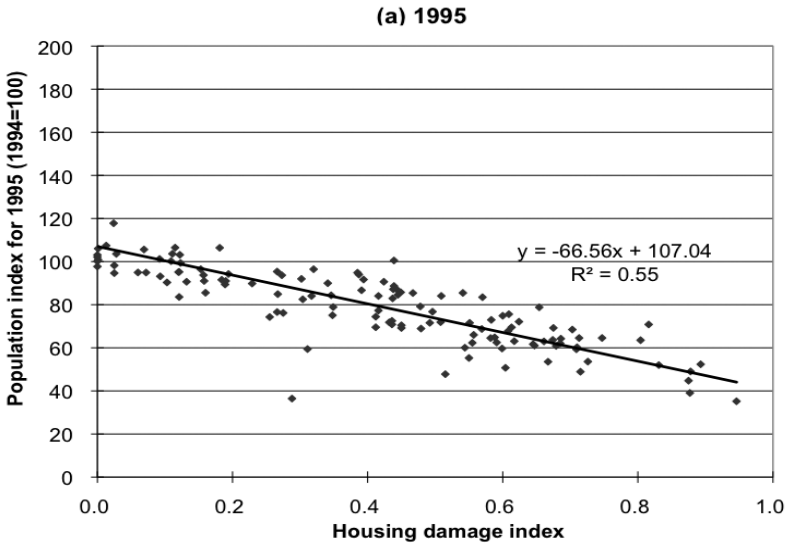


Figure 2: Housing damage and population index 1 year post Kobe



The strength of the association is described in the bivariate regression equation:

Where y is the population index and x is the housing damage index.

The strength of the correlation between housing damage and population index weakens over time, and is effectively nonexistent after 6 years. Chang points out that as recovery proceeds other factors become more important than the sheer extent of the original physical damage.

The main points of the population analysis in this study are:

- The disaster tends to accelerate existing patterns of population change;
- Population drop after the earthquake is very sensitive to housing damage at a small area level;
- Longer term population recovery is not strongly correlated with physical damage at a small area level; and
- Overall estimates of permanent out migration are approximately 2.5% of population.

2.3 Hurricane Katrina

Hurricane Katrina has been relatively well studied, although some of the consequences are still unfolding. Katrina struck Southern Louisiana in August 2005. The storm was estimated to have displaced over 1 million people, with damage in excess of US$200 billion (9).

In New Orleans City, the majority of the damage was caused by flooding in the wake of broken levees and consequent chemical contamination, rather than directly from the hurricane. As a consequence the entire city was evacuated, and residents were not permitted to return until the end of September, initially to non flooded areas, and then increasingly to other areas across the city (10).

New Orleans has had a declining population since at least 1970, and decreased by 6% in the five years before Hurricane Katrina. By the time of the hurricane, the population of the greater New Orleans conurbation was 1,338,000, of which about a third was in the New Orleans Parish (454,863). In 2004 about 23 percent of New Orleans residents lived below the poverty line, and a number of other indicators describe a population with a high level of socioeconomic disadvantage (10).

Three studies provide specific data on population movements in New Orleans after Hurricane Katrina. Hori et al studied detailed population movements in 18 parishes

in Southern Louisiana after Hurricanes Katrina and Rita (11), Fussell et al present the results of the Displaced New Orleans Residents Pilot Survey (12), while Groen and Polivka draw upon the Current Population Survey for a Bureau of Labor Statistics report (13).

Table 2: Hori et al Louisiana population change for 19 parishes

	July 2005	July 2006	Net change	% Change
Louisiana	4,373,422	4,165,301	-208,121	-4.8
Severely damaged				
Cameron	9,546	7,743	-1,803	-18.9
Orleans	434,493	215,399	-219,094	-50.4
Plaquemines	28,190	22,006	-6,184	-21.9
St. Bernard	64,359	15,344	-49,015	-76.2
Receiving				
Ascension	89,801	96,689	6,888	7.7
East Baton rouge	395,127	414,391	19,264	4.9
Livingston	108,374	114,221	5,847	5.4
St. Charles	50,124	52,331	2,207	4.4
St. Helena	10,066	10,687	621	6.2
Washington	42,620	43,093	473	1.1
Tangipahoa	102,911	109,896	6,985	6.8
Buffer				
Calcasieu	179,998	179,814	-184	-0.1
Jefferson	446,803	427,776	-19,027	-4.3
St. Tammany	217,518	228,561	11,043	5.1
Vermilion	54,500	55,254	754	1.4
Other				
Iberia	72,597	73,894	1,297	1.8
Lafourche	90,274	91,918	1,644	1.8
Terrebonne	105,681	107,935	2,254	2.1

Hori used cross sectional survey data taken approximately one year after Hurricanes Katrina and Rita hit Southern Louisiana, in a special exercise known as the Louisiana

Health and Population survey, which used standard US Census Bureau sampling techniques. They were able to describe both immigration and emigration at the parish level, allowing for estimates of actual and net population flows (11).

The raw findings from Hori et al for 18 Parishes are reproduced in Table 2, with parishes categorised according to whether they were severely damaged, tended to receive population, or were buffer parishes.

The net loss of population for all 18 Parishes in the year after Katrina and Rita was 236,030, a drop of 9.4% from the 2005 population. At the Parish level, the decrease in population for individual Parishes was 295,307, implying that 59,227 people moved from one of the 19 Parishes to another. The majority of net population flow was therefore right out of the disaster area.

Fussell et al also relied upon survey data taken approximately one year after Katrina (12). The focus of the paper is largely upon racial and socioeconomic disparities in the return rate, but they also present useful information relating the return rate at one year to the damage sustained by an individual's house, summarised in Table 3.

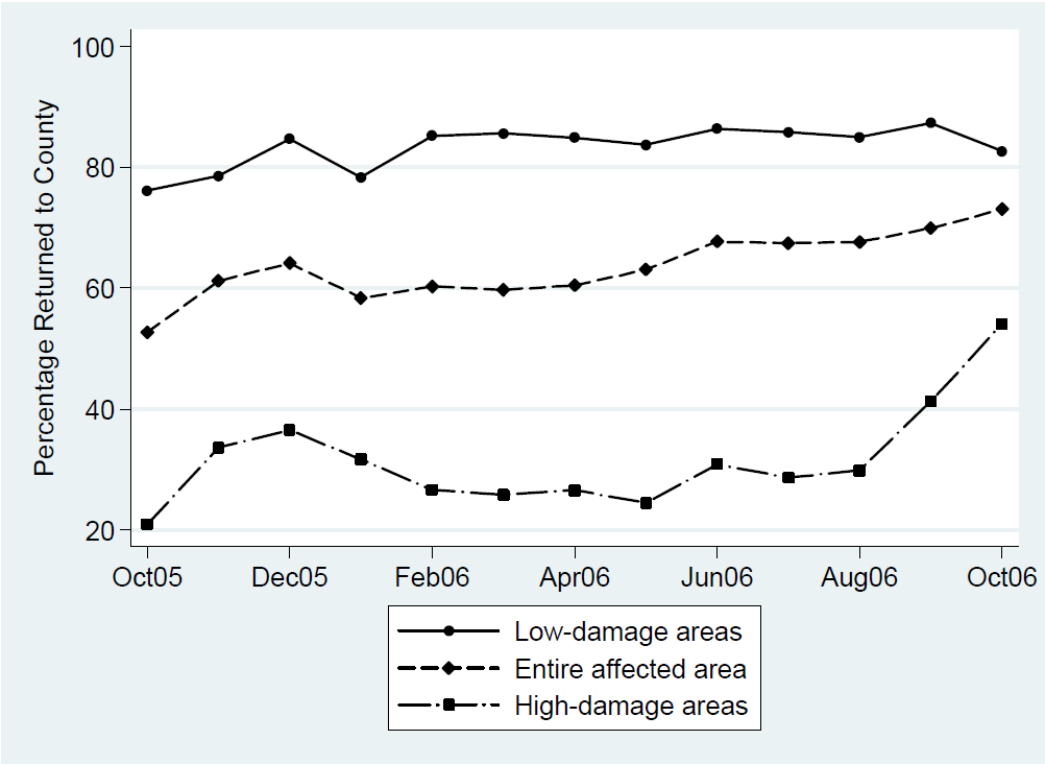
Table 3: Fussell et al one year return rate

Housing status	One year return percentage
Undamaged	96
Damaged but habitable	81
Uninhabitable	54
Destroyed	30

Groen and Polivka used a further survey approach to monitor returnees to New Orleans over the year following Katrina (13). Analysing the high damage areas of New Orleans, Plaqumines and St Bernard Parishes in Louisiana, and Hancock County in Mississippi, they found that age (greater age increases probability of returning), extent of damage and home ownership were important factors for individuals in deciding whether to return to New Orleans.[1] Again, they clearly showed different effects for high and low damage areas, reproduced in Figure 3. The distinction between high and low damage areas becomes less pronounced over the year, but remains stark. While the overall return rate is not much over 70%, the rate in Low-damage areas exceeds 80%.

[1] They also analysed low damage parishes: Jefferson, Lafourche, St Charles, St john, St Tammany, and Harrison Pearl River and Stone Counties in Mississippi.

Figure 3: Groen et al return to New Orleans



2.4 Other events

Some relevant information is available from other disaster events. Kamel and Loukaitou-Sideris discuss aspects of recovery after the 1994 Northridge earthquake in California (14). In that event, 6 percent of the 66,546 inspected buildings were red-tagged, and a further 17 percent yellow tagged. Estimates of the number of people temporarily or permanently displaced because of damage to their residences ranged from 80,000 to 125,000.

These authors found that the long term effects on the earthquake were related to the levels of assistance provided relative to damage, with proportionately less assistance going to the those who sustained the greatest damage, who were also more socioeconomically vulnerable. Those more vulnerable communities sustained a 7.6% drop in population over the decade from 1990 – 2000, whereas the communities in the top quartile of receipt of assistance, which were less vulnerable, saw a 2.2% increase in population over the same period. Even though the distribution of damage was not associated with particular housing or demographic characteristics, the distribution of assistance was, and the consequent patterns of recovery were disproportionately severe for vulnerable populations.

3 Applying findings to Christchurch

Assessing the implications of the literature for the present events in Christchurch poses three questions:

- To what extent is the nature of the disaster in Christchurch likely to have similar displacement effects to disasters studied in the literature?
- To what extent is the population in Christchurch likely to respond in a similar fashion to populations described in the literature?
- Is relevant information available about Christchurch to make a prediction on the basis of other disasters?

The first two points address the issue of generalisability, while the third requires suitable local information from the present event.

3.1 Relevant themes from the literature

A number of points which arise from the literature review, and are likely to be relevant to the Christchurch situation:

- In all situations, the degree of out-migration and return appears to be very strongly correlated with the damage sustained to homes, at quite a localised geographical level.
    - This pattern was observed in Andrew, Kobe and Katrina.
    - This patterns was observed a number of different levels, from individuals to large geographic areas.

- There is little long term follow up on populations, but it appears that population changes are fairly stable within two years of the disaster, and possibly less.
    - The Andrew experience was that a high proportion of people returned to Dade within six months.
    - Returnees to more damaged areas appear to come back more slowly.

- Most displaced people seem to move smaller rather than larger distances.
    - In the case of Katrina many people appear to have moved out of the state. But New Orleans is right next to a state border, so interstate out-migration is more difficult to interpret as a sign of moving a great distance.

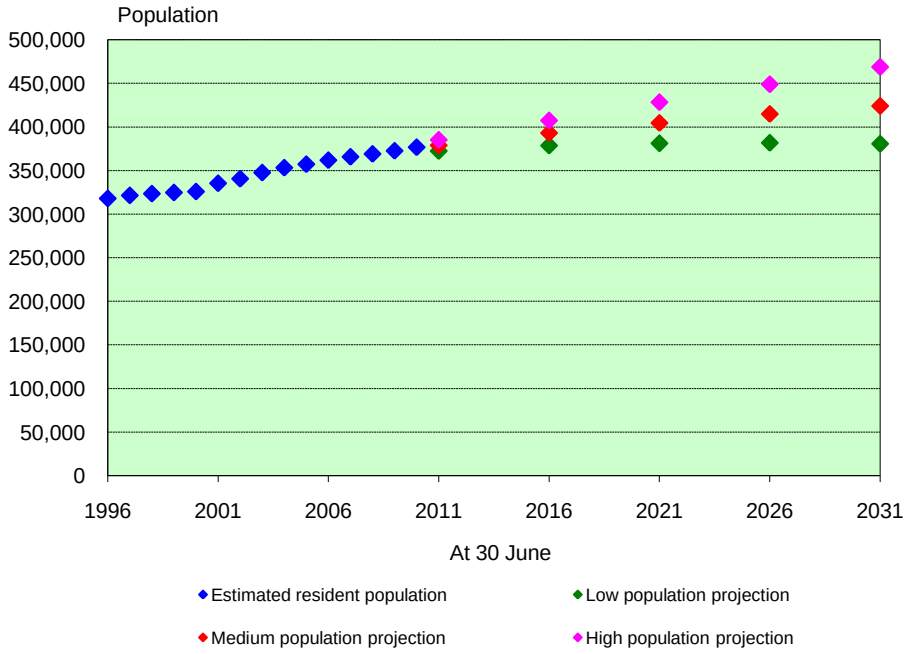
- More socioeconomically vulnerable populations are generally more likely to bear the burden of a natural disaster, and more likely to be displaced, and for longer.
    - Clearly the pattern seen in Andrew and Katrina.
    - Strong evidence from Northridge.

- Disasters can accelerate existing patterns of population change
    - Concluded by researchers of Kobe and Katrina

3.2 Christchurch demographic profile and trends

Before the earthquakes of 2010 and 2011 Christchurch had experienced a trend of growing population, which had been predicted to continue to increase. Statistics New Zealand projected continuous growth to 2031, the limit of existing subnational projections (Figure 4). The rate of increase is likely to be somewhat lower than the high growth experienced in the period 2001 – 2006.

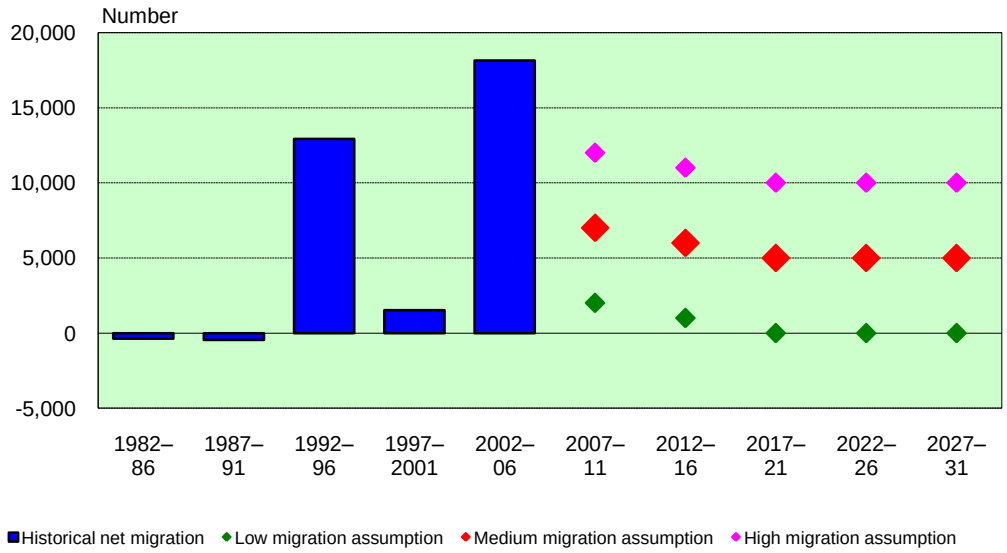
Figure 4: Estimated and projected population for Christchurch City - Statistics New Zealand



The medium projection predicts an increase from an estimated population of 372,600 in 2009, to 404,500 in 2021, an average rate of 2,900 per annum or 0.8% per annum from a 2009 base.

Across the wider area of the Canterbury Regional Council the drivers of population increase are markedly slanted towards in-migration, with 51% of estimated increase in the year to 30 June 2010 being attributed to migration, compared with 32% for New Zealand as a whole.[2] Net migration for Christchurch City has been high in recent years, but is currently predicted to fall over the next decade, stabilising from 2017 (Figure 5).

Figure 5: Net migration for Christchurch City - Statistics New Zealand Projections

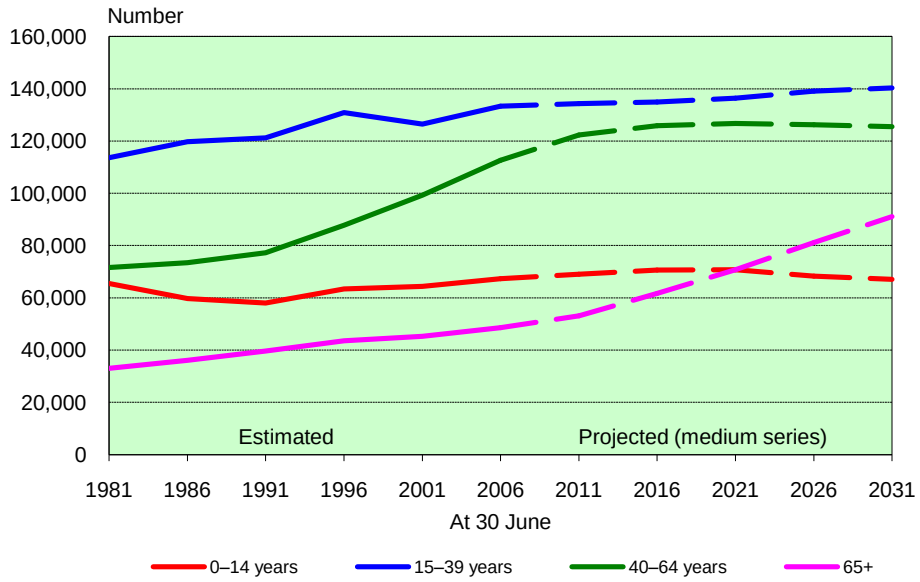


These predictions suggest that, in the absence of the earthquakes, migration would play a decreasing role in the population growth of the city, but would still be important.

Broken down by broad age bands, the population of Christchurch City has been ageing, with a marked increase in those aged 40-64 years. From 2011 the increase in people aged over 64 is expected to accelerate markedly, shown in Figure 6.

[2] Estimates from Statistics New Zealand table builder

Figure 6: Christchurch City population by age: Statistics New Zealand medium projections



The demographic context of the Christchurch earthquakes is therefore one of a population which is both increasing and ageing. In-migration is clearly an important factor in the population increase, and the impact of the earthquake upon inward migration is likely to play a key role in the overall effect upon the previous population trend. Speculatively, it seems likely that while some in-migration is likely to be displaced due to a drop in economic activity in some sectors, other in-migration will be induced by new activity, particularly in the construction sector. Monitoring in-migration as a key indicator of population trend, and comparing it to pre-earthquake predictions, will be an important part of assessing the ongoing pattern of population change in Christchurch.

3.3 Comparable damage

The Christchurch earthquake of 22 February 2011, while undoubtedly severe in world terms, was a less damaging event than any of the three major disasters described in the literature.

Of the 59,543 residential buildings so far inspected 1,756 (2.9%) have been red stickered, meaning that they have been deemed unsafe (15). Less recent data indicates that as at 26 March, across the city 2.9% of buildings had been red-stickered and 7.1% yellow stickered, indicating that limited access is possible, but that further structural assessment is necessary (16). This compares with the 23 percent of

buildings which were red or yellow tagged after assessment following the Northridge earthquake. While red and yellow stickering is a crude way of assessing the total population who have sustained damage to their homes, it is the best proxy information which is readily available.

Table 4: Building assessment by city ward

Area	Total	Green		Yellow		Red	
		Number	%	Number	%	Number	%
Riccarton/Wigram	1119	1080	96.5%	30	2.7%	9	0.8%
Banks Peninsula	1531	1264	82.6%	165	10.8%	101	6.6%
Spreydon/Heathcote	11427	10690	93.6%	537	4.7%	197	1.7%
Burwood/Pegasus	18569	16979	91.4%	1297	7.0%	293	1.6%
Fendalton/Waimairi	3408	3159	92.7%	181	5.3%	68	2.0%
Shirley/Papanui	6164	5803	94.1%	296	4.8%	64	1.0%
Hagley/Ferrymead	18841	15930	84.5%	1821	9.7%	1052	5.6%
TOTAL	**61059**	**54905**	**89.9%**	**4327**	**7.1%**	**1784**	**2.9%**

There are two wards in which the level of damage is clearly higher: Hagley/Ferrymead, and Banks Peninsula. Adjusting for the proportion of Christchurch population resident in each ward, the actual proportion of people living in yellow stickered homes can be estimated at 5.8%, and red stickered homes at 2.1%. Anecdotally, the damaged homes are likely to be extremely localised in specific geographical areas within those wards.

The data which are currently available therefore suggest that a total of 7.9% of the Christchurch population are likely to have sustained serious damage to their homes, to the point of being uninhabitable, at least in the short term. This is much lower than the 53.6% of people who reported damage to their home in Dade County after Hurricane Andrew, although those reports are likely to include a large amount of non critical damage which is not comparable to red or yellow stickering. However it is only a little less than the 10.2% of people who left their pre-hurricane home in the less damaged Northern part of Dade County.

After Kobe, the only other earthquake in the literature reported here, it is estimated that there were approximately 300,000 homeless people in the immediate aftermath of the earthquake, or 7.5% (7). This is similar to the estimate of red and yellow stickered homes in Christchurch. The Kobe disaster was on a much greater scale, since the population living in the area was much greater (4 million). But the proportionate level of damage may have been comparable to the recent Christchurch event.

Hurricane Katrina was a very severe event, which had very broad impacts across the population of Southern Louisiana and Mississippi. The event itself was more severe than was experienced in Christchurch, with the entire New Orleans city population of over 450,000 people actively cleared from the city for over one month while chemical and oil decontamination took place. Moreover, the event was followed by a second hurricane later that season.

Overall, the damage sustained by Christchurch in the 2011 earthquake seems not to be comparable with the experience of New Orleans after Hurricane Katrina, but may be more comparable to the experience of the populations after hurricane Andrew or the Kobe earthquake.

3.4 Comparable population

The population of New Orleans was markedly different to that of Christchurch. There was a high level of unemployment (15 percent), and the 2000 census found that nearly half of all proprieties were rental units. New Orleans home owners also had a low level of insurance coverage by New Zealand standards. Among the insured, the mean level of insurance was equal only to the median house price of US$152,000 (10). The US and state governments provided aid to residents after the Northridge earthquake, and the Hurricanes Andrew and Katrina, but not on the comprehensive scale of New Zealand's Earthquake Commission (14).

Another important difference between the population of New Orleans before Katrina and Christchurch is that the New Orleans population had a long term history of contraction, whereas the Christchurch population has been growing, and had been forecast to continue to do so. Several of the studies discussed in this review concluded that disasters tend to accelerate pre-existing population trends. If pre-existing trend is important, then the new Orleans population is even less comparable to the present situation in Christchurch.

The population of Dade County and Kobe are likely to be more comparable to the present Christchurch example, since they were historically growing, and did not experience disruption across the whole city on the scale of Hurricane Katrina. However, Smith and McCarty report that the number of owner-occupied housing units was only 46.3% in North Dade, and 59.5% in South Dade, which would be considered low by New Zealand standards (2).[3]

[3] Statistics New Zealand projections estimate that 67% of New Zealand households are owner-occupied in 2010.

4 Analysis

4.1 School enrolment data

Statistics New Zealand has made data available on the re-enrolment of school students after the Christchurch earthquake (17). Some key results are:

- 9,534 school students who were enrolled in Christchurch, Selwyn and Waimakariri before 22 February 2011 have subsequently re-enrolled in other schools. This constitutes 12.5 percent of all school students enrolled in those three districts.
- 57.5% percent of these students who re-enrolled were at primary schools, 16.2 percent at intermediate schools, and 26.3 percent at secondary schools.
- 2,739, or 28.7 percent of those who re-enrolled did so within the Canterbury District Health Board (CDHB) area. This means that, overall, 6,795 or 8.9% of the total school population re-enrolled outside CDHB boundaries.
- As at 6 April 2011 1,944 students who had re-enrolled outside the CDHB area had returned to their original school.
- As at 6 April 2011, the percentage of the total school population which had moved outside the CDHB area had dropped from 8.9% to 6.4%.

School children are the group for which the most robust data on movement post-earthquake are currently available. School children have limitations as a proxy for the movement of the general population, but are a useful indicator. Groen and Polivka (13) found that after Katrina, older populations were less likely to return – to the extent that this might apply to the Christchurch population, extrapolating from school children is likely to overestimate the true level of migration and speed of return. This seems to be borne out within the school re-enrolment data, since the proportion of primary school aged children seems to be exceptionally high, indicating that families with older children are less likely to move.

It should also be noted that a substantial proportion of the school children who re-enrolled, did so within the CDHB area. Not all out-migration from Christchurch actually removes families from dependence upon the infrastructure and health services of the city.

The total number of children who re-enrolled from their original school (including within the CDHB area) was 12.5 percent, about half as much again than the estimate of 7.9 percent of population who have sustained serious damage to their homes. This seems plausible, given that there are likely to be reasons for moving other than sheer housing damage. These estimates do not seem to be unreasonably inconsistent.

To the extent that children are a reasonable proxy for the wider population, it therefore appears that 6.4% of the population remain outside the CDHB area, and that this figure will continue to decline in the coming weeks.

4.2 Kobe return equation

Chang's analysis of the Kobe earthquake estimated the relationship between percentage of destroyed housing in an area, and the size of the population one year after the earthquake (8). Applying this equation to the number of red and yellow stickered buildings in the seven wards across Christchurch gives the following result:

Ward	One year population change
Banks Peninsula Ward	-4.5%
Burwood-Pegasus Ward	1.3%
Fendalton-Waimairi Ward	2.2%
Hagley-Ferrymead Ward	-3.1%
Riccarton-Wigram Ward	4.7%
Shirley-Papanui Ward	3.2%
Spreydon-Heathcote Ward	2.8%
Christchurch	**1.7%**

To the extent that the population of Christchurch might behave like that of Kobe after the 1995 earthquake, the overall population may increase somewhat, although with marked losses in the Banks Peninsula and Hagley-Ferrymead wards. Kobe had, before the disaster, been experiencing marked population increase at an even faster rate than Christchurch, so these results are likely to overestimate the level of background increase which would be experienced in Christchurch. Moreover, if the definition of damaged buildings in Kobe is broader than the red/yellow stickered basis used for estimating damage in Christchurch, this approach will also overestimate the resulting population level.

But even if there is a degree of overestimation, it makes the point that the overall population is likely to fall by little, if anything.

4.3 Dade County return rates

Smith and McCarty estimated that 0.2 percent and 6.5 percent moved out of Dade and Broward Counties after Hurricane Andrew, and had not returned after two years from the North and South areas of Dade respectively (4). Of those who had returned, 95.5 percent and 87.3 percent respectively had returned within one year.

To the extent that the Christchurch experience is similar to that of North Dade, it can be expected that almost none of the local population will move permanently to a great distance from the city. To the extent that the experience is more like that of South Dade, it may be the case that 6 to 7 percent of the population might move out of the area.

There are reasons to believe that the South Dade migration estimate is likely to be greater than will be seen in Christchurch. These include the less comprehensive level of insurance in the US, and the lower level of home ownership in Dade than in New Zealand, both representing a weakening of reasons to return to the original site of the disaster.

But the Dade estimates can be applied more selectively to the variability in destruction across Christchurch. If the South Dade return rate of 6.5 percent is applied to the three areas with the greatest destruction (Banks Peninsula, Burwood/Pegasus and Hagley/Ferrymead), and the North Dade return rate is applied to the rest of the city, the overall drop in population at two years would be 2.4 percent.

5 Conclusions

The social science literature provides a limited amount of data which can be used to estimate the impact of a natural disaster upon population flows. Applying Hurricane Andrew and Kobe earthquake estimates to the breakdown of damaged buildings across Christchurch produces estimates of a net population decrease of 2.4% for Hurricane Andrew, and an increase of 1.7% on the basis of the Kobe experience.

These estimates are not as incompatible as they might seem, since the Andrew data are based upon the number of people who leave the area, and do not take account of immigration, or overall trends of population increase. The Kobe data, by contrast, are based upon the net population after both in and out-migration, and are based upon a population which was experiencing marked growth.

It seems likely that the population shift for Christchurch after the 2011 earthquake is likely to be of the order of magnitude described in these studies. After a period of 6 to 12 months, the population is likely to have changed by 1 to 2 percent, either up or down. This conclusion is broadly consistent with the available data on school re-enrolments, which finds that after 6 weeks the out-migration of school children has reduced to 6.4 percent, and is probably going to drop further.

It is important to bear in mind the mixed effects which take place in a population after a disaster. A number of researchers concluded that disasters have the impact

of accelerating pre-existing population trends, which suggests in the case of Christchurch that growth can be expected to at least partly counterbalance any permanent loss of population. In one or two years it is likely that the total population of Christchurch will be slightly smaller than it might have been if there had been no one off out-migration to temporarily interrupt growth. But it is also likely that population growth will continue at, at least, the pre-existing trajectory. Growth may even be enhanced to some extent, if there is an in-migration of construction workers.

The major conclusion to be drawn from the literature review and the available data is that it is highly unlikely that the publicly repeated figure of 70,000 people – 20 percent of the population - leaving the city was ever the case. But even if it was the case that there was such an out-migration in the days following the earthquake, populations tend to return rapidly to the site of a disaster, particularly if drawn by ties of home ownership, family and when supported by an effective recovery and reconstruction process.

It is probable that specific areas of the city which have experienced particularly heavy damage will see considerable numbers of people leaving, but many of these are likely to seek homes in less damaged regions of the city. Effective reconstruction and planning for new residential areas is likely to ameliorate the tendency to move out of Christchurch.

The earthquake of February 2011 will undoubtedly have a longer term impact upon the size and distribution of the Christchurch City population. But that impact is likely to be a small one, in the context of overall population growth.

As further datasets become available, it will be important to monitor the ongoing movement of population after the Christchurch earthquake with as many different methods as possible. School enrolment data has been considered in this review, but it will also be possible to consider information on re-enrolments in general practice, as well as changed patterns of pharmaceutical dispensing. Social Welfare payments may also be able to contribute information on the relocation and return of the population.

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