Abstract

Despite near universal recognition of the importance of climate change impacts on future generations, to date there has been no dedicated research on the effects of climate change on the population distribution in Aotearoa New Zealand. This paper reports on a review of international literature on the demographic impacts of climate change, with a particular focus on the likely implications for Aotearoa New Zealand. The paper argues that the greatest impacts are likely to be felt in terms of internal migration changes, with smaller but still significant effects on international migration and mortality rates.

Introduction

We are facing a global climate crisis. It is deepening. We are entering a period of consequences (Al Gore, speech at National Sierra Club Convention, 9 September, 2005).

Advocates raising awareness on global climate change almost universally warn of dire consequences for future generations should action not begin now to mitigate the effects of global climate change (see, for example, Stern (2007) and Garnaut (2011)). However, climate change and its population impacts are not a new phenomenon. Climate has affected human population growth and distribution since prehistoric times (Gamble, Davies, Pettitt & Richards, 2004). The key difference is that current patterns of global climate change, that is, those occurring since the industrial revolution, are different from those observed in the past, and are generally accepted as being caused by human activity (Hegerl et al., 2007). For instance, the Fourth Assessment Report of the...
Intergovernmental Panel on Climate Change (IPCC) notes that “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level” (IPCC, 2007, p. 30). The capacity of the earth to deal with such sudden anthropogenic climate change has been questioned (Rockström et al., 2009).

The consequences of global climate change are substantial, and will severely constrain human activity. Several effects have been noted in the Fourth Assessment Report of the IPCC as having “high confidence” or “very high confidence” of occurring (IPCC, 2007). Agricultural productivity is expected to decline on average (Mendelsohn & Dinar, 2009), leading to increasing global food insecurity (Schmidhuber & Tubeillo, 2007; Hanjra & Qureshi, 2010). Freshwater availability is expected to decline, particularly in glacier- or snowmelt-fed river basins (Kundzewicz et al, 2007; Alcamo, Florke, & Marker, 2007; Hanjra & Qureshi, 2010). Desertification and frequency of drought are expected to increase (Burke, Brown, & Christis, 2006; Lioubimtseva & Adams, 2004). At the other extreme, increasing rainfall intensity is expected to lead to more frequent and widespread flood events (Nicholls et al., 2007; Pall et al., 2011), while sea-level rise is expected to inundate low-lying coastal areas and increase coastal erosion (Kundzewicz et al., 2007). Groundwater salinisation is also likely to increase, due to decreasing groundwater recharge and increasing evapotranspiration (Kundzewicz et al., 2007).

Inevitably, these changes will make some areas less suitable for human habitation, while other areas become relatively more suitable, with consequent impacts on demographic change. However, despite the obvious implications for human systems, to date there has been no dedicated research on the effects of climate change on the population distribution in Aotearoa New Zealand. In 2012, the Ministry of Business, Innovation and Employment (MBIE) contracted the National Institute of Water and Atmospheric Research (NIWA) and Landcare Research to undertake a wide-ranging assessment of the impacts of climate change on Aotearoa New Zealand to 2100 (Rutledge & Tait, 2013). As part of that project, a climate-calibrated regional demographic model of Aotearoa New Zealand is under development. There are substantial gaps in our knowledge about the implications of climate change for Aotearoa New Zealand – much more needs to be investigated. The model will specifically address the lack of
systematic analysis of the available evidence on the demographic impacts of climate change in Aotearoa New Zealand.

This paper reports on an initial review of the international literature on the demographic impacts of climate change, undertaken as part of that research project, with a particular focus on the likely implications for Aotearoa New Zealand. The paper begins by briefly reviewing the possible effects of climate change on Aotearoa New Zealand, and how climate affects population processes, before looking in turn at possible impacts on fertility, mortality and migration (internal and international) for Aotearoa New Zealand.

Climate Change in Aotearoa New Zealand

Mullan et al. (2008) identified and mapped the likely future effects of climate change across New Zealand. Their results were based on results from General Circulation Model simulations prepared for the IPCC Fourth Assessment (Meehl et al., 2007). Specifically, the results from 12 global climate models were statistically downscaled (Mullan, Wratt, & Renwick, 2001) to provide local spatial detail for New Zealand, along with initial analyses from NIWA’s regional climate models. The results demonstrate that New Zealand temperatures, on average, are expected to increase by about 1°C by 2040, and by about 2°C by 2090. However, these average changes mask significant differences in temperature change at the local level. The greatest increases in average summer temperatures are expected to occur in the North Island (and in particular in the central and west of the North Island), while the greatest increases in average winter temperatures are expected to occur in the central South Island (Mullan et al., 2008).

The models demonstrate a marked increase in the seasonality of rainfall and wind patterns, with increased frequency of westerlies in winter and spring, but decreased frequency of westerlies in summer and autumn. Rainfall is expected to increase during winter and spring in the west of both the North and the South Islands, with lower rainfall expected in the east and north. Conversely, in summer and autumn, drier conditions in the west of the North Island and increased rainfall in the east are expected (Mullan et al., 2008). They also projected increases in the incidence of extreme weather including high temperatures, extreme
rainfall and strong winds, but decreases in frost incidence and snow cover. However, it isn’t clear whether these projected climate changes are reversible in the future through human intervention, or whether they represent part of a hysteretic transition to a new more-or-less permanent climate regime.

**Climate Change and Population Processes**

The changes in local climate outlined in the previous section, as well as the wider changes in global climate, are expected to have an impact on the demographic future for New Zealand. If we want to understand the impacts of climate change on the size and distribution of the future population, we need to recognise the effects climate change will have on population processes. Simply, the future population size and distribution relies on three key interacting factors: (1) fertility rates, (2) mortality rates, and (3) migration (international and internal). Thus, to understand the impact of climate change on the future population size and distribution, we must first understand its likely impact on each of these three factors.

However, before we consider directly the potential impacts of climate change on the factors that determine future population, we must first consider two broader issues. First, climate change is an ongoing and long-run process, which leads to an identification problem. For instance, when considering population data it might not be possible to empirically separate the proportion of changes in fertility, mortality or migration that occurs as a result of changing climate from changes resulting from other long-run processes such as demographic fertility transitions (particularly in developing countries), increases in life expectancy due to improved infant and youth health or life extension at older ages, or migration due to economic or other factors. Thus, while it may be intuitively appealing to attempt to empirically determine the incremental contribution of climate change to future demographic change, there is likely to be a significant amount of statistical error associated with any such estimates based on past data. These errors will then transfer into projections of demographic parameters that are based on past data and used to project future population.
A second related issue is that of uncertainty more generally. Population projections are known to be subject to a great deal of uncertainty (Lutz & Goldstein, 2007), particularly at smaller geographical scales (Cameron & Poot, 2011; Wilson, 2013). Dowd, Blake, and Cairns (2010) identify three sources of uncertainty: (1) model uncertainty, wherein we do not know the true model that underlies the demographic process; (2) parameter uncertainty, wherein we do not know the true parameter values for the model; and (3) forecast uncertainty, which arises from any given model being projected into the future. These sources apply to all demographic parameters, but uncertainty is likely greatest in the case of migration. As a graphic example of the relative uncertainty of migration, Cameron and Poot (2011) demonstrate the relative stability over time of natural increase compared with net migration for New Zealand as a whole.

Added to this, models of climate change are also subject to a great deal of uncertainty. This uncertainty arises because of uncertainty about future greenhouse gas emissions, the extent and intensity of mitigation efforts, and the impact of new technologies, as well as uncertainty about the effects of emissions on future climate (so-called climate sensitivity) (Visser, Folkert, & Hoekstra, 2000; Stainforth et al., 2005). Uncertainty about future population will therefore include uncertainty from both demographic modelling and climate change modelling. Furthermore, it is possible that these sources of uncertainty are correlated, which further increases the complexity of the required modelling.

While these two issues (identification and uncertainty) might give cause for concern about developing population projections, I argue that neither issue is particularly problematic for demographers. In terms of the identification issue, traditional modelling of future fertility, mortality, and migration based on past trends is likely to be sufficient to account for most of the climate-related variation in the near future, since climate change is a gradual process that is already impacting on population change. While this doesn't solve the identification problem, a distinction between climate and other effects on population parameters is largely unnecessary over short time frames. In contrast, longer-term projections can mitigate the identification issue by using projections of demographic parameters that are calibrated to climatic conditions, particularly for sub-national projections. The second issue is also not problematic. The uncertainties in
climate projections and population projections can be quantified. The combined uncertainty can be incorporated into population projections in the same way as demographic uncertainty is – by using probabilistic or stochastic projection techniques (Tuljapurkar, 1992; Cameron & Poot, 2011). The extent of uncertainty can then be shown by presenting the range of outcomes (or a suitable projection interval) (Cameron & Poot, 2011).

Fertility and Mortality

The international literature reveals little about changes in fertility as a result of climate change, though a changing climate is likely to result in biological changes that affect fertility in both humans and other animals. While global fertility clearly has large implications for future population growth and therefore flow-on effects on carbon emissions and climate change, there is to date no evidence of effects of climate change on the total fertility rate, or the timing or spacing of births in developed countries. Philibert, Tourigny, Coulibaly, and Fournier (2013) found that climate change influenced conception/birth seasonality in the Kayes region of Mali through affecting rates of foetal loss (due to changes in malaria incidence) and changes in agricultural cycles that affect energy balance and sexual behaviour. In a developed country like New Zealand, where food security for the majority of the population is not associated with agricultural cycles, it seems unlikely that fertility will be affected through these mechanisms. Thus, we can be fairly certain that fertility rates will not be directly affected by climate change. However, there may be indirect effects. If climate change affects labour productivity, which in turn affects the incentives for women to engage in labour market activity, fertility (or more likely the timing of births) is likely to be affected. If international migration changes the ethnic mix of the population, in-migration of ethnic groups of traditionally higher (or lower) fertility than the current population on average may cause changes in average age-specific fertility rates. However, it is worth noting that despite dramatic structural and compositional changes in the New Zealand population over recent decades, the total fertility rate has remained fairly stable around replacement levels.

There are a number of mechanisms through which climate change is likely to affect mortality globally, including cardiovascular and
respiratory problems associated with extreme heat (Kalkstein & Greene, 1997), altered transmission of (particularly tropical) infectious diseases (Semenza & Menne, 2009; de Souza, Owusu, & Wilson, 2012), and malnutrition associated with changes in agricultural cycles and food insecurity (Battisti & Naylor, 2009).

Heat-related mortality has been shown to follow a J-curve (McMichael, Haines, Sloof, & Kovats, 1996), with temperatures at both extremes (hot and cold) associated with increased morbidity and mortality (Curriero, Heiner, Zeger, Samet, & Patz, 2002), but with mortality at its highest at high temperatures. The European summer of 2003 provides a recent example that demonstrates the potent effect of extreme heat, as temperatures were approximately 3.5°C higher than average. The extreme heat resulted in as many as 70,000 heat-related deaths (Robine et al., 2008). Notwithstanding the large absolute number of deaths associated with the heatwave, the crude excess mortality was less than 1.6 deaths per 10,000 population, compared with an underlying crude death rate of about 99 per 10,000 population in 2002 (Eurostat, 2005). This equates to an increase in death rates of about 2 percent. As noted earlier in this paper, the average temperature in New Zealand is expected to rise by about 2°C by 2090. It is likely that there will be many years in the future where the increase in temperature above the current average will be similar or greater in magnitude to that of the European heatwave in 2003, and so modestly increased summer mortality rates are likely in those years. However, there also is evidence to suggest that the positive relationship between heat and mortality is declining over time due to adaptation and through the use of technology such as air conditioning (Barreca, Clay, Deschenes, Greenstone & Shapiro, 2012). Thus, we can probably expect a small increase in summer heat-related deaths associated with climate change in New Zealand (see also Woodward, Hales, & de Wet, 2001), but the effect on the overall mortality rate is likely to be small.

Increased summer deaths may even be offset by a reduction in winter deaths. New Zealand currently experiences excess winter deaths, particularly among the oldest and youngest (Davie, Baker, Hales, & Carlin, 2007). In part, this increased risk of death is due to low quality housing stock, resulting in cold, damp conditions in many homes during winter (Ministry for the Environment, 2005). Increased winter temperatures may mediate the mortality effects of the low quality of the housing stock,
resulting in fewer winter deaths. In both cases (increased summer deaths and decreased winter deaths), age-specific mortality rates will be differentially affected, with increased summer deaths and decreased winter deaths both likely to be concentrated among older New Zealanders, particularly older women (Stafoggia et al., 2006; Davie et al., 2007). The change in age-specific mortality rates is likely to be small, but given structural changes in the population with greater numbers of older people, the absolute number of deaths may increase.

Increased temperatures and rainfall (particularly in spring and summer) are associated with increased reproduction and survival rates of protozoa, bacteria, viruses, and their associated vectors such as mosquitoes (Gubler, Reiter, Ebi, Yap, Nasci, & Patz, 2001). The incidence of vector-borne diseases, such as malaria (Parham & Michael, 2010), dengue fever (Hopp & Foley, 2003), and Ross River virus (Woodruff, Guest, Garner, Becker, & Lindsay, 2003), have been shown to be related to changes in climate. These diseases are likely to further spread and increase in incidence through the Pacific due to climate change (Potter, 2008). Furthermore, there is evidence to suggest that food-borne infectious diseases such as salmonellosis (Kovats et al., 2004) and campylobacteriosis (Kovats et al., 2005) are related to temperature. Thus, incidence of these diseases may also alter with changes in climate. New Zealand is projected to get both hotter and wetter in parts. This is likely to increase the suitability of the climate for vector-borne and other infectious diseases (Woodward et al., 2001). For instance, the Foundation for Research, Science and Technology-funded Health Analysis and Information for Action (HAIFA) project found that under the IPCC’s A2 high emissions scenario for 2090, campylobacteriosis would increase by a maximum annual average percentage change of 23 percent, and seasonal influenza (with vaccination) would decrease by 27 percent (Baker, Winstanley, & Slaney, 2013). Despite relatively large increases in rates of incidence of infectious diseases, actual mortality from these diseases is likely to remain low (see for example Harley, Sleigh, & Ritchie (2001) on Ross River Virus). Moreover, it is unclear what effects, if any, climate change may have on important and useful microbiota. Overall, despite the large relative changes in the diseases noted above, the absolute numbers are likely to remain small. Given the availability of modern medicine, New Zealand is likely to experience some increases in morbidity, but little change in
mortality from climate-induced increases in infectious diseases. A better understanding of the interactions between infectious disease morbidity and later mortality in New Zealand is clearly needed, perhaps as an extension to recent work on functional limitation and health expectancy such as that by Graham, Blakely, Davis, Sporle, and Pearce (2004).

Finally, climate change is likely to affect agricultural productivity, and aggregate global agricultural output is expected to fall. While New Zealand is currently a large net exporter of agricultural products, and this is expected not to change under even the most extreme climate scenarios (Tait, Baisden, Wratt, Mullan, & Strooombergen, 2008), reductions in availability of food and the growing global population are likely to significantly raise the price of food. The combination of rising food prices and decreasing food availability is likely to lead to increased food insecurity and malnutrition among the poorest in society, partially offset by a reduction in food waste (Godfray et al., 2010). In turn, food insecurity is likely to lead to nutritional deficits and worsening maternal and infant health (Olson, 1999; Cook et al., 2004). Food insecurity in New Zealand may already be higher than in other developed countries (Parnell, Reid, Wilson, McKenzie, & Russell, 2001), and the extent of future food insecurity in New Zealand arising from climate change is difficult to determine and may be another fruitful area of future research. However, despite the inevitable effects on morbidity, the effects on mortality are likely to be slight, as projections for the global burden of malnutrition due to climate change show no sizeable impact at all on developed countries (Campbell-Lendrum, Corvalan, & Pruss-Ustun, 2003).

Migration (International and Internal)

One of the most widely cited estimates of global climate-induced migration is the 200 million environmental refugees claimed by Myers (2002). Myers’s paper itself provides little in the way of empirical support for this claim, and uses an extremely broad definition of environmental refugees, being “people who could no longer gain a secure livelihood in their homelands because of drought, soil erosion, desertification, deforestation and other environmental problems, together with the associated problems of population pressures and profound poverty” (Myers, 2002, p. 609). Leaving aside for a moment the problems associated with use of the term “refugee”, this definition draws no distinction between internally displaced
people and those that migrate internationally, and neither does it distinguish between those who are permanently displaced and those who are temporarily displaced due to extreme weather events such as hurricanes or floods. However, a similar estimate on climate refugee numbers was recently obtained by Biermann and Boas (2010). Both estimates appear to be largely based on estimates of the population exposed to risk, rather than considering the number of people who would actually migrate (Kniveton, Schmidt-Verkerk, Smith, & Black, 2008). Myers’s estimates in particular have been widely criticised (see for example, Castles, 2002, and Kolmannskog, 2008) and debated in the media and elsewhere, but the fact that they are often accepted at face value (see, for example, Stern, 2007, and Brown, 2008) simply reveals a lack of substantive work that focuses on the change in migration patterns that may arise from climate change. This demonstrates the importance of further quantitative research on the migration implications of climate change.

Gemene (2011) reviewed the available estimates of people displaced by environmental change, and noted in particular a number of problems with Myers’s estimates, including: (1) they are a stock, rather than a flow, (2) they do not distinguish between different types of environmental changes as migration drivers and assume that all people displaced in an area affected by environmental changes have been displaced solely because of these changes, and (3) they combine estimates from many other studies, which employ widely varying methods. Gemene (2011, S48) concluded that existing estimates of people displaced by environmental change “lack robust methodological foundations, and are generally grounded in a deterministic perspective, assuming that all people impacted by environmental changes will move away from their homes”. However, these methodological problems are beginning to be addressed in more recent quantitative evaluations (see, for example, Marchiori, Maystadt, & Schumacher, 2012), though a robust theoretical framework with direct relevance to New Zealand remains elusive.

The debate outlined above raises a number of important issues, which must be considered before we can interpret the international literature and its implications for New Zealand. First, there is no commonly accepted definition for a climate-induced migrant, with terms such as “environmental refugees”, “environmentally displaced people” and
“climate migrants” often used interchangeably. The identification of the excess migration that arises due to climate change is complicated by the multi-causal, complex nature of migration, wherein climate change is only one of many drivers of migration (Black, Bennett, Thomas, & Beddington, 2011; Barnett & Chamberlain, 2010; Hugo, 2011a). Piguet (2010, 517) even goes as far as to claim that: “there is truly no such thing as a climate or environmental migrant in the narrow sense of a migrant exclusively moving for environmental reasons”. Despite this assertion, it is likely that climate change will affect the migration decision-making process for a large number of people, both now and in the future, and climate change must therefore be taken into consideration when estimating future migration flows.

The issue of defining who is and who is not a climate-induced migrant is further complicated by the likelihood that climate change will affect existing drivers of migration, such as by changing agricultural profitability and employment opportunities in rural areas (Government Office for Science, 2011). Furthermore, while climate change might make individuals want to migrate, their ability to migrate may be constrained by legal, political or economic reasons (Goldin, 2011). Thus, not all people affected by climate change will migrate and estimates of climate-induced migration based on exposure to climate change may lead to overestimates of future migration flows.

Second, most of the migration flows induced by climate change are likely to be internal (i.e. within national boundaries) rather than international. This follows the fact that most of the world’s current migrants are internal rather than international – according to the International Organization for Migration (IOM) there were 214 million international migrants, compared with 740 million internal migrants in 2010 (IOM, 2011). It is unlikely that there will be a major re-balancing towards international migration in the future.

Different factors affect climate change-induced international migration from the factors that affect internal migration. International migrants generally need greater financial means because of the larger distances involved, and typically require an established social network in the destination country in order to effectively settle (Carrington, Detragiache, & Vishwanath, 1996; Zhao, 2003). Furthermore, the direction and size of migration flows will likely be determined by prior migration ties
between the sending and receiving countries (Adamo & de Sherbinin, 2011). In the New Zealand context, climate-induced international migrants are most likely to originate from low-lying Pacific atolls that are at risk of inundation by sea-level rise, more frequent droughts, and tropical cyclones of greater frequency and intensity (Mimura et al., 2007), or similarly affected areas in the major river deltas of South and South-East Asia such as Bangladesh and Vietnam (Cruz et al., 2007; Ericson, Vörösmarty, Dingman, Ward, & Meybeck, 2006).

For Pacific countries, New Zealand is an obvious destination choice due to its proximity and the dense social networks of foreign-born (and New Zealand-born) Pacific Islanders, particularly in urban centres. However, it is unlikely that all affected Pacific Islanders would migrate to New Zealand. There are similar advantages to resettlement in Australia and the United States, which also boast large Pasifika communities, and Fiji has offered to resettle affected Pacific populations (Bedford & Bedford, 2010). Furthermore, it is likely that climate-induced migration will first be accommodated within the islands rather than by international relocation (Campbell, Goldsmith, & Koshy, 2005; Campbell, 2010). However, the capacity of the islands to accommodate increases in internal migration, particularly to urban centres, has been called into question (Locke, 2009; Hunt, 1996). Given this lack of capacity within the Pacific countries, some increase in international migration seems inevitable.

Currently, permanent and long term migration arrivals into New Zealand from Oceania (excluding Australia) make up about five percent of the total arrivals.¹ A substantial incremental increase in arrivals from the Pacific would be required in order to significantly affect the future population of New Zealand. However, this substantial increase may be possible because to date, most migration to New Zealand has been from smaller Pacific countries such as Samoa and Tonga while the migration flows from populous Melanesian countries such as Papua New Guinea have been much smaller. However, as the impacts of climate change are increasingly felt in these more populous countries, migration flows (both internal and international) can be expected to increase (Moore & Smith, 1995). Thus, the numbers of international migrants from the Pacific to New Zealand in the future is likely to grow as a result of climate change, and may increase as a proportion of total in-migration if migration from Papua New Guinea (in particular) increases.
For non-Pacific-Island countries, distance and the associated cost of travel ensure that only relatively wealthy migrants will have the resources necessary to migrate to New Zealand. This includes large numbers of potentially environmentally displaced people in Asia. Many of these displaced people will prefer other destinations, but at least some will want to migrate to New Zealand, which already attracts migrant flows from countries likely to be greatly affected by climate change such as those areas highlighted in Schneider et al. (2007). Some of these migrants may attempt to enter New Zealand as refugees. Despite the rhetoric that labels climate-induced migrants as environmental refugees (see, for example, Myers, 2002), climate change is not recognised as one of the factors that defines a refugee under international agreements such as the United Nations Convention Relating to the Status of Refugees 1951 (United Nations High Commissioner for Refugees (UNHCR), 2008). Thus, New Zealand is not obliged under these agreements to accept environmental refugees (Burson, 2010). In more general categories of migration, New Zealand currently restricts the conditions under which potential migrants may gain residency (Burson, 2010). Without some relaxation of these regulations, New Zealand is unlikely to experience a large-scale increase in migration. Thus, the impacts of climate change outside of the Pacific Islands are unlikely to induce substantial additional migration flows into New Zealand.

In contrast, internal migration is not affected by the legal barriers noted above, and is much less costly for potential migrants. The possible effects of climate change differ substantially between the North and South Islands, as noted earlier in this paper. Differences in small-area climate have been shown in international studies to affect internal migration flows (Barrios, Bertinelli, & Strobl, 2006; Barbieri et al., 2010). For example, Poston, Zhang, Gotcher, and Gu (2009) demonstrated that temperature and humidity, but not wind, were related to inter-state migration rates in the United States between 1995 and 2000, and concluded that climate acts more as a pull factor than a push factor for migration. Thus, in addition to present long-term trends in population movement from the South Island to the North Island and from rural areas to urban centres, we can expect to see small but significant climate-induced internal migration effects as changes in local climate affect the relative attractiveness of the different regions. However, the effects are likely to be gradual. Hugo (2011b) notes,
in a recent review of climate change effects on the population of Australia, that “climate change is unlikely to cause massive rapid dislocation of population and population redistribution” (p.65).

In addition to international and internal migration, at the small area level there is likely to be a redistribution of population away from vulnerable coastal and flood plain areas. According to McGranahan, Balk, and Anderson (2007), about 13 percent of the population in New Zealand and Australia currently resides in vulnerable low elevation coastal zones. However, it seems likely that most of the population at risk of sea level rise will either adapt in situ, or migrate within the local area (Hugo, 2011a). Thus the impact of these changes is unlikely to be dramatic except at the localised level in coastal and low-lying areas. However, it is worth noting that most net internal migration in New Zealand is towards coastal cities, similar to the experience of Australia (Hugo, 2011b). This population growth may increase the vulnerability of these areas to further climate effects if the current pattern of internal migration persists, as well as increasing the size of the affected population.

Summary and Future Research Directions

Climate change is likely to have profound impacts, both globally and locally in New Zealand. However, the impacts on population size and distribution are likely to be lessened by humans’ innate ability to adapt to changes in the environment. To date there has been no systematic evaluation of the likely impacts of climate change on demographic change in New Zealand. The review presented in this paper demonstrates that climate change is unlikely to greatly affect fertility rates, and will likely have a small but significant effect on mortality rates. The effect on international migration will largely depend on future government policy with respect to in-migration, but regardless migration from the Pacific will likely increase, both in absolute terms and as a proportion of total migration. Changes in the pattern of internal migration are also likely, as climate change will differentially affect the various regions in New Zealand.

As noted in the introduction, this paper marks the beginning of a four-year MBIE-funded project investigating the impacts and implications of climate change for New Zealand. As part of that project, a climate-
calibrated sub-national demographic model is currently under development. The model will operate at the regional level, and is based on a standard cohort component method, with parameters that are calibrated to account for past and future changes in climate variables, including both average and extreme climate variables (e.g. average daily temperature, and the number of days where temperature exceeds certain values). The relationship between all-cause mortality by region and climate variables is being investigated in order to better incorporate climate-related changes in mortality rates. Gravity models incorporating climate variables at both the inter-regional level (for internal migration) and international level (for international migration) are under development. The inclusion of climate-calibrated parameters in the demographic model addresses the identification issues noted earlier in this paper. The model can also be extended to a stochastic model, following Cameron and Poot (2011), to incorporate both climate and demographic uncertainty. The final model will be integrated into a coupled human-environmental systems model to estimate the future impacts and implications of climate change for New Zealand (Rutledge & Tait, 2013). The model will help to inform decision-making at the national and sub-national level, and provide guidance for future research that can look more deeply into a wider range of demographic and socio-economic impacts of climate change.

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Notes

1 Based on Statistics New Zealand permanent and long-term migration data, there were 87,778 permanent and long term arrivals in the year ended May 2013. Of these, 4207 (4.8 percent) originated from Oceania (excluding Australia). Similarly, arrivals from Oceania (excluding Australia) totalled 4309 of 83,789 (5.1 percent) in the year ended May 2012, and 4299 of 83,781 (5.1 percent) in the year ended May 2011.

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