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## Migration in the context of vulnerability and adaptation to climate change: insights from analogues

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### Abstract

Migration is one of the variety of ways by which human populations adapt to environmental changes. The study of migration in the context of anthropogenic climate change is often approached using the concept of vulnerability and its key functional elements: exposure, system sensitivity, and adaptive capacity. This article explores the interaction of climate change and vulnerability through review of case studies of dry-season migration in the West African Sahel, hurricane-related population displacements in the Caribbean basin, winter migration of ‘snowbirds’ to the US Sun-belt, and 1930s drought migration on the North American Great Plains. These examples are then used as analogues for identifying general causal, temporal, and spatial dimensions of climate migration, along with potential considerations for policy-making and future research needs.

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With the rise of scientific evidence of anthropogenic climate change, increasingly detailed scientific inquiries have been made into potential future climatic influences on global migration patterns.<sup>1–8</sup> Environmental changes, of which climate variability and change represent one set of examples, have long been recognized as having the potential to influence human migration and settlement patterns. However, migration outcomes rarely emerge in a simple stimulus-response fashion, but are instead modified and shaped by the interaction of environmental changes or events with human social, economic, and cultural processes.<sup>6,9</sup> In the field of climate change research, interactions between climate and migration are increasingly situated within the context of human vulnerability to climate change, which is in turn identified as being a function of exposure to the impacts of climate change, the sensitivity of communities or socioeconomic systems to such impacts, and the capacity of those exposed to adapt.<sup>10</sup> Migration responses to climate change may therefore be treated as one of the range of possible ways by which people may adapt to adverse impacts of climate change or take advantage of resultant opportunities.

Geographical and historical analog case studies are used as learning devices in a variety of fields, including research into the physical and human impacts of climate change.<sup>11–13</sup> In this article, we use well-known examples of climate-related migration patterns from West Africa, the North American Great Plains, the US Sun-belt, and the Caribbean basin, as analogs from which to identify more general causal, temporal, and spatial dimensions associated with climate-related migration. Because migration in this context is closely tied to adaptation processes, we find there to be considerable potential to moderate the impacts of anthropogenic climate change on future population movements through policy-making, especially through proactive building of adaptive capacity in vulnerable populations and

regions. We also observe that greater empirical research into environment–migration relationships is needed to improve our ability to anticipate future climate-related population movements and to formulate policy decisions accordingly.

## MIGRATION IN THE CONTEXT OF VULNERABILITY AND ADAPTATION

### Vulnerability

The concept of vulnerability provides a basis for understanding the spatial and temporal patterns of climate-related migration, as well as its consequences for societal well-being. In the climate change research community, vulnerability has been defined as being ‘the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes’ (see Ref 10, p. 883). The nature and characteristics of vulnerability vary considerably across geographic and ecological regions. Vulnerability also differentially characterizes social systems and, indeed, communities and households within particular systems. These differences are shaped by a variety of factors including the particular nature of climate impacts; the degree of exposure to such impacts; the sensitivity of human systems to such changes; and the capacity of the exposed population and its socioeconomic systems to adapt<sup>14,15</sup>.

Migration is but one possible form of adaptation within a broader set of potential adaptive responses that individuals and households make when sensitive systems are exposed to stressed or changing environmental conditions.<sup>6–8</sup> Certain types of socioeconomic systems are inherently more sensitive to climate-related environmental changes and are therefore more likely to engender adaptive migration. These include systems characterized by agricultural and natural resource-dependence and those within low-lying coastal areas, small island states, and other settings where exposure to climate-related risks is high and human livelihood possibilities are limited.<sup>1–9</sup>

Climate-related exposures most commonly associated with migration fall into two general categories: *sudden-onset events* and *slow-onset changes* in environmental conditions. *Sudden-onset events* take place over short periods of time and include such phenomena as tornadoes, hurricanes, floods, wildfires and extreme wind, rain or snow events. Sudden-onset events have the potential to cause considerable damage to infrastructure and property, as well as resulting in loss of life, and are therefore often associated with distress migration. In these cases, exposed populations may attempt to flee before the event occurs or evacuate during or after the event. Conversely, *slow-onset* changes in conditions, such as droughts, land degradation, or oscillations in precipitation patterns, typically do not stimulate permanent relocation as a first-order household adaptation. They may, however, stimulate changes in temporary migration as a short-term adaptation.

## CASE EXAMPLES OF ADAPTIVE MIGRATION

### Dry-season migration in the west african sahel

For generations, rural households in the West African Sahel have incorporated a variety of migration strategies to adapt to rainfall’s seasonality and the effects of periodic droughts. A north–south rainfall gradient creates annual variations in rainfall levels and timing, thereby lessening crop predictability and generating considerable uncertainty for rural resource-based livelihoods in the region.<sup>16</sup> In response, the region’s pastoralists undertake an annual north–south movement of their herds in conjunction with the seasonal availability of forage.<sup>17</sup> Sedentary agriculturalist households undertake a range of adaptive migration strategies to reduce the impacts of dry conditions on household well-being in a process sometimes referred to as ‘eating the dry season’.<sup>18</sup> Young men, and in some cultural groups young women as well, will often leave their rural homes during dry periods when there is

less work to be done. Many of these young adults migrate to regional urban centers to seek employment and send remittances from earned income back to their rural homes.<sup>19–21</sup> Other areas within the region may experience high levels of rural-to-rural migration, as households move to other rural villages to adapt to local environmental conditions.<sup>22</sup> During prolonged dry periods, young children may be sent out of the drought-affected area to stay with relatives elsewhere, further reducing pressure on household resources.<sup>23,24</sup> The goal of these various seasonal migrations is similar: to reduce pressure on household food reserves and diversify livelihood opportunities when environmental conditions are unfavorable.

Although temporary migration takes multiple forms, drought conditions within West Africa do not necessarily yield permanent relocation from rural to urban centers.<sup>21</sup> Moreover, while there exists an ongoing movement of migrants from West Africa to Europe, drought does not necessarily lead to sudden increases in levels of migration along these established transnational migrant networks.<sup>24,25</sup> There are logical reasons for these patterns. When household incomes shrink due to severely dry conditions, a lack of financial capital may restrict migration options and result in shorter distance, intraregional temporary relocation. Conversely, after a successful harvest, a household may be better able to afford longer-distance migration of one of its members, but it must be ready and able to forego the absence of that household member's labor when the agricultural season resumes. In each case, the household must assess a range of potential opportunities and losses that may be experienced due to migration. In such contexts, migration in a variety of forms becomes an important adaptation strategy within the broader objective of minimizing household vulnerability to environmental scarcity.

### **Hurricane-related migration in the caribbean region**

Hurricanes have the potential to cause large-scale destruction to property, infrastructure, as well as loss of human life. They are a common phenomenon in the Caribbean basin, with Hurricanes Mitch in 1998 and Katrina in 2005 offering two well-known examples that led to large-scale population displacements and a range of migration responses. They also show how underlying conditions of socioeconomic inequity, institutional neglect of infrastructure, civil conflicts, and other phenomena that exacerbate vulnerability can lead to a variety of migration outcomes with long-term consequences for sending and receiving areas alike.

Hurricane Mitch was a powerful storm that in 1 week delivered almost a year's worth of rainfall to large swathes of Central America, killing as many as 20,000 people and displacing 2 million others.<sup>26–28</sup> Decades of prior civil conflict in Nicaragua, Honduras, and El Salvador had created large populations of highly vulnerable people in the region, leaving many thousands of impoverished households occupying marginal and inherently hazardous lands in both the countryside and urban peripheries. These hazardous lands included steep slopes prone to failure and easily flooded low-lying areas. The vulnerability of these households was further exacerbated by ongoing deforestation and land degradation, and governments' inability to take measures to alleviate the endemic poverty.

An exception to this regional vulnerability can be found in Belize, which had not experienced civil conflict and where environmental degradation was less pronounced. Although Belize, too, felt impacts of the storm, the nation's government was able to organize a systematic evacuation of one-third of its population from highly exposed areas before the hurricane struck, and no deaths were reported.<sup>27</sup> By contrast, in Honduras, where such capacity was lacking, an estimated 18,000 people were killed, hundreds of thousands of homes were damaged or destroyed, agricultural crops were wiped out, and drinking water supplies were contaminated in many areas. More than a year after the storm, tens of thousands of displaced persons continued to live in makeshift camps around urban centers.<sup>29</sup> Migration out of Honduras tripled after the hurricane and increased by 40% from

Nicaragua.<sup>26</sup> Apprehensions of illegal migrants from Central American countries other than Mexico at the US border grew by more than 60% in the months immediately following Mitch; by 2003 US Immigration and Naturalization Services had granted temporary protection status to almost 150,000 migrants of Nicaraguan or Honduran origin under a special program.<sup>30</sup>

Hurricane Katrina in 2005 had significant effects on population patterns in New Orleans and surrounding areas. Classified as a Category 3 storm when it reached the US coast, Katrina was accompanied by a large storm surge that flooded low-lying coastal areas and overwhelmed the flood defenses protecting New Orleans. As a rough indication of the number of lives directly affected, over 1.3 million people requested disaster relief assistance from US government programs as a result of the hurricane.<sup>31</sup> Large parts of the exposed population evacuated before the storm hit, seeking shelter outside the region; many others left as soon as possible after the storm had passed. The city of Houston, Texas, is believed to have been one of the major recipients of Katrina displacees, receiving an estimated 150,000 people from storm-affected areas in the year immediately following the hurricane.<sup>30</sup> While many of those who evacuated returned to their homes, Figure 1 suggests that many others have not returned but relocated elsewhere. Stringfield finds African-Americans were less likely to return, with Fussell et al.<sup>33</sup> observing that these return rates have been affected by the extent of flood-related housing damage. Elliott and Pais<sup>31</sup> found that likelihood of return to New Orleans was positively correlated with home ownership and household income. Consistent with this, McIntosh<sup>30</sup> found that those who resettled in the Houston area tended to be young and unmarried, characteristics often negatively associated with homeownership and income.

The overall picture that emerges from Katrina is that while the regional population suffered hardship and substantial temporary displacement, the migration outcomes that emerged were not random.<sup>32,33</sup> Rather, particular socioeconomic and demographic groups that were economically disadvantaged or marginalized were more likely to permanently relocate elsewhere. Although the causes of this marginalization do not include civil conflict, as was the case with Central America's Mitch displacees, both hurricane examples highlight the important influence of underlying socioeconomic conditions on migration outcomes following extreme events. That said, it may also be observed that not all members of marginalized groups migrated permanently. An interesting outcome of Katrina reported by Airriess et al. (2007) concerned the ability of the New Orleans Vietnamese community to successfully reestablish its presence in the city by drawing upon the resources of a geographically extensive network of social capital within America's large population of Vietnamese origins.<sup>34</sup> This identification of the importance of extended social networks is consistent with a larger body of scholarship that highlights the role of social capital more generally in both climate adaptation and migration decision-making.<sup>35,36</sup>

### **1930s drought migration on the north american great plains**

In the mid-1930s, the combined impacts of economic recession, falling commodity prices, and prolonged droughts stimulated large-scale migrations in many areas of North America's Great Plains. One of these, colloquially referred to as the 'Dust Bowl Migration', saw the movement of hundreds of thousands of residents of Arkansas, Kansas, Oklahoma, north Texas, and parts of Colorado and Missouri to California and other Pacific coast states; hundreds of thousands more relocated within the Great Plains, often moving from rural to urban areas.<sup>37-39</sup> A number of lessons have been gained about environmentally related migration behavior during that period.

One such lesson relates to the different demographic characteristics associated with particular migrant groups and destinations. For example, those who left rural Oklahoma and

neighboring states for southern California tended to be young, married couples with children. These migrants often joined friends or relatives who had gone before and had already established a presence in the southern California labor market.<sup>37,39</sup> Other rural displacees remained within the drought-affected region, a disproportionate number of whom were poor, landless agricultural laborers, often from broken households. Many thousands congregated in informal squatter settlements with few basic services.<sup>39</sup> The sociodemographic distinctions between migrant and nonmigrant groups highlight the importance of access to social capital and to basic social services such as education and health care in terms of adaptive capacity-building and migration outcomes during times of pronounced climate-related stress.<sup>40</sup>

The Dust Bowl example also provides evidence of how government policies and programs, and the context in which they are formed, influence vulnerability and shape migration outcomes both intentionally and unintentionally.<sup>41</sup> Many key US federal government 'New Deal' policies that had important effects on rural well-being in drought-stricken areas were not specifically devised as drought-relief measures. Instead, they were aimed at addressing underlying causes of rural vulnerability, such as commodity price instability and endemic rural poverty. For example, the Agricultural Adjustment Act (AAA) provided farmers financial incentives to reduce production of key commodities in order to stabilize market prices. However, because the financial incentives to take land out of production were paid to land owners, the legislation may have also encouraged evictions and out-migration from drought-stricken areas where farm tenancy rates were high (see Lange and Taylor 1939 for one account<sup>42</sup>). In effect, the AAA provided livelihood stability for one segment of the rural population while potentially increasing the insecurity of another. Another key set of New Deal programs consisted of infrastructure projects funded by the Works Progress Administration (WPA) that provided wage employment to many impoverished families across the drought-stricken area. Although demand for such work greatly outstripped the supply, the supplemental incomes obtained from WPA jobs often made the difference between a family staying or migrating elsewhere. Over the long run, by addressing root causes of rural vulnerability, such programs likely reduced the scale of population displacements that might otherwise have occurred.<sup>40</sup>

Some federal programs were specifically targeted at assisting drought migrants, such as the construction of migrant worker camps in southern California by the federal Farm Security Administration (FSA) to provide safe temporary housing for newcomers from the Great Plains. This initiative counteracted the efforts of state and county governments in California to actively discourage migrants and obstruct access to publicly funded services such as schools and medical clinics.<sup>37,43</sup> The FSA camps provided migrants with a springboard from which to gain entry to the California labor force and subsequently establish strong local social networks that in turn attracted additional migrants. Despite the unwelcome reception given to them by local authorities, few Dust Bowl migrants returned to their home states, and the migrants and their children in subsequent decades became important players in the society and economy of the counties in which they settled.<sup>37,39</sup> This underscores an important point, in that environmental migration does not necessarily have negative long-term impacts on receiving areas, so long as newcomers are assisted in their integration—an observation Black (1994) made in studies of environmental migration in the very different social and ecological contexts of the Senegal valley.<sup>44</sup>

### **Snowbird migration to the US sun-belt**

A quite different example of the natural environment shaping population movements can be seen in the contemporary US, where the 'sun-belt' states of the southeast and southwest regions experience high rates of seasonal in-migration during the winter months. Often referred to as the 'snowbird' phenomenon, hundreds of thousands of older North Americans



temporarily move south to avoid harsh winter conditions in their more northern home regions. For some snowbirds, the seasonal migration is a precursor to a permanent move to the south, but most repeat the seasonal north–south migration annually. These groups consist predominantly of healthy, retired individuals of above-average education and income, whose primary residence is in the northeastern or midwestern states or Canada.<sup>45</sup> An estimated 800,000 or more snowbirds temporarily migrate to Florida for a stay of more than 1 month, with several hundred thousand more moving each to Texas and Arizona.<sup>45,46</sup> Coates et al.<sup>47</sup> estimated using 1999 data that 300–375,000 Canadians participated in annual winter trips to southern US destinations in excess of 3 weeks in length, a figure roughly equivalent to 1% of the total population of Canada. Smith and House<sup>45</sup> also identified an opposite pattern, whereby over 300,000 permanent residents of Florida over the age of 55 leave each summer for more northerly climes to escape their home state's intense heat and humidity.

The snowbird example adds some important, additional nuances to how we understand environmental migration. While the previous three cases describe the migration responses of vulnerable populations to adverse conditions or events, snowbird movements are driven by opportunity. It suggests that migrants may be 'pulled' or drawn to particular destinations because of desirable environmental conditions or attributes, as much as they may be 'pushed' or driven by adverse environmental conditions to leave other regions. The relative desirability between environmental conditions in source areas and potential destinations, as well as the ability to access potential destinations, depends on a variety of demographic, cultural, and socioeconomic factors which in this example entail having the necessary economic means and having reached a particular stage of life.

## DIMENSIONS OF CLIMATE MIGRATION

The above examples are ones where migration patterns are known to have been influenced by phenomena that occur naturally as part of the inherent variability of the Earth's climate. Analogous do have limitations as learning devices.<sup>48</sup> Environments and the human societies that occupy them differ in their characteristics from one region to the next and are in a continual state of change. Consequently, drought-migration patterns in dryland India or China will inevitably exhibit characteristics that differ from those of West Africa. Similarly, migrations of the nature and scale of the 1930s have not accompanied subsequent droughts on the US Great Plains because of the considerable socioeconomic transformations that region underwent in later decades. While the specific details of the case examples may not be fully replicated in other environments or may not capture the full range of possible manifestations of anthropogenic climate change to come, we are nonetheless able to identify from them some general dimensions of environmental migration that are useful when considering how migration decisions and processes unfold in response to conditions and events that may become more common or widespread as a result of anthropogenic climate change in coming decades.

The first of these is the *causal dimension*. Migration stimuli are often described in terms of 'push' and 'pull' factors, such as differentials in educational opportunities or wages between migrant sending and receiving destinations.<sup>49</sup> The above examples illustrate a variety of ways by which climatic conditions or events may act as push or pull stimuli. In the case of the Sahel, the inherent variability of regional climatic conditions is the stimulus pushing households to adapt through particular types of migration, most importantly the temporary seasonal migration of young adult household members to urban centers. Hurricanes in the Caribbean hold the potential to shape large-scale pulses of distress migration, particularly where proactive measures to reduce harm are inadequate (as in New Orleans) or not in place (as in Honduras). The 1930s Dust Bowl migration is one where the coincidence of prolonged, adverse climatic conditions with economic recession helped tip a system into a

situation of distress migration on a scale that may not have occurred had each push factor operated independently. Finally, the potential for favorable climatic conditions to pull or attract population movements is seen in the US Sun-belt example.

The preceding examples also highlight several potential *temporal dimensions* of climate-related migration. They suggest a continuum, from short-term, temporary relocation to permanent migration with no intention of return, to any number of possibilities between these extremes. Both the snowbird and Sahel cases describe regularized, seasonal, cyclical migration patterns; one intended to minimize short-term household exposure to climatic risks, the other to optimize exposure to favorable climatic conditions. The Dust Bowl migration example describes the opposite end of the temporal spectrum. In decades prior to the 1930s, many rural households on the Great Plains had engaged in circular, seasonal labor-migration of the type witnessed more recently in sub-Saharan Africa for similar reasons.<sup>40</sup> The combined effects of prolonged drought and economic hardship of the 1930s so completely eroded the adaptive capacity of many households and communities that temporary relocation became pointless or impossible, and large-scale out-migration from hardest-hit areas ensued. For some jurisdictions on the Great Plains, it would be a generation or more before populations would return to their 1930s levels.<sup>50</sup>

Migration responses to hurricanes in the Caribbean basin fall across the spectrum of temporal possibilities, with multiple migration outcomes arising from the same event. Hurricane-related migrations also highlight the variety of *spatial dimensions* climate-related migration may take, including

- *localized movements* where displacees travel to the nearest safe haven and return to their homes as quickly as is feasible, which for both Mitch and Katrina appear to have been the largest category;
- *intraregional migration* that may consist of both temporary migration with intention to return and permanent resettlement (such as the large influx of Katrina-migrants to Houston, Texas);
- *interregional or international migration* such as the tens of thousands displaced by Hurricane Mitch who followed established international migration routes, legal and otherwise, from Central America to the US.

The Sahelian and Dust Bowl case studies also fit within these spatial categories. The Sahelian example illustrates the importance of intraregional migration as an adaptive strategy where households wish to maintain a permanent place of residence in a region repeatedly exposed to climatic stresses. Where that desire to stay in the exposed region is lost or it becomes economically impossible to continue, longer-distance, interregional migration on a permanent basis can ensue, as it did in the US during the Dust Bowl era. The snowbird phenomenon also involves interregional movements of people, but differs from the others in that it is undertaken not out of necessity but to optimize climatic conditions to suit a household's lifestyle.

Another important dimension is *the use of migration relative to other possible adaptations*. In each above example, nonmigrants or return migrants outnumber those individuals who permanently relocated. As an example, although approximately 150,000 people had not returned to New Orleans as of 2009, twice that number have returned. While hundreds of thousands fled drought-stricken areas on the Great Plains during the 1930s, millions did not. Virtually every household in 1930s Oklahoma and 2005 Louisiana was obliged to adapt in some way to their contemporary climate-related events, but only a minority did so via permanent migration. Migration, particularly over long distances, entails significant hardships and costs (direct and indirect) and is therefore not usually an adaptation of first

resort except in the most extreme circumstances. The case studies further emphasize that those who do migrate tend to be drawn from particular socioeconomic or demographic groups rather than a random cross-section of the exposed population. In the Dust Bowl, Sahel and hurricane case studies, climate migrants are, for example, disproportionately young adults. Land tenure and home ownership are also key factors, with lack of home or land ownership being a characteristic of those who left the 1930s Dust Bowl and 2005 New Orleans. In the Sahel, circular migration patterns have emerged as part of broader rural household strategies to minimize the impacts of climatic variability and drought on food security and income. This is consistent with general scholarship that views migration as a household strategy to minimize exposure to economic risks by diversifying livelihoods.<sup>51,52</sup> In the case of snowbirds, the seasonal circular migration is performed at a particular life stage by households whose socioeconomic status enables consumption of preferred climatic conditions throughout the year. In short, the motivational factors for climate migration at the household level and the migration decisions that emerge remain situated within the broader range of forces and factors that shape adaptive capacity and adaptation decision-making more generally and should not be treated exclusive of these.

Understanding these dimensions of climate migration, and their connections to vulnerability, allows for informed consideration of the *potential scale* of future impacts of anthropogenic climate change on migration patterns. The most likely impacts of climate change as identified by the Intergovernmental Panel on Climate Change (IPCC) include increases in the frequency of sudden-onset events and slower-onset changes in environmental conditions known to influence population displacements and migration. Table 1 summarizes the expected future changes in exposure and regions to be affected as identified by the IPCC and their potential linkages to population displacements or migrations. In some areas, the anticipated climatic shifts could create conditions more suitable for economic activity and thereby act as migrant 'pulls'. Such may be the case in the Arctic, where warming conditions already being observed may open shipping passages and create new resource-based economic activity<sup>53</sup> that may in turn be accompanied by economic migration from the south. In many other regions, climate change impacts will likely be unfavorable to human economic activity and well-being, and in the absence of concerted capacity-building efforts, may be expected to stimulate population displacements, distress migration, and potentially the abandonment of some populated areas. On the basis of associations such as those described in Table 1, researchers have suggested a range of estimates of the potential global climate-related migrations anticipated over the course of this century, varying from hundreds of millions to up to 1 billion people.<sup>54-56</sup> Although such estimates are inherently speculative, they provide a general indication of the potential magnitude of climate change-related migration given the current absence of concerted global efforts to mitigate greenhouse gas emissions and build adaptive capacity in especially vulnerable regions.

Whether such estimates actually come to pass will depend considerably on future policy and decision-making processes at international, regional, national, and subnational scales. Currently, matters of agriculture, disaster prevention and response, economic development, environmental management, migration, and similar factors that underlay the formation of vulnerability and adaptation outcomes are often treated at all levels as policy-making silos to be understood and responded to individually.<sup>57</sup> The risk of climate change-related population movements can be expected to create pressure for more cross-cutting approaches to policy-making. For example, international agreements on the movement of people presently take no account of environmental influences on migration. While there is increasing scholarly and popular discussion of the potential emergence of environmental refugees as a result of climate change, involuntary migration of this type is not acknowledged in the *UN Convention on the Protection of Refugees*.<sup>58</sup> It is, however, one of the wide range of potential population displacements accounted for in the *Guiding*



*Principles on Internally Displaced Persons*, a nonbinding UN document often suggested as a model for a more comprehensive approach to international policy on population movements.<sup>59</sup> If in coming decades climate change renders low-lying coastal plains and small island states less suitable for human habitation as is expected, the need to develop relocation programs would inevitably exert significant force on global and regional policy priorities. Indeed, such potentialities are already featuring more frequently in international security discussions.<sup>60–63</sup> Climate-migration considerations may also be expected to particularly influence priority-setting within policy-making domains such as agriculture, gender equity, health, international development, and critical resource management, given their inherent linkages to adaptive capacity and adaptive migration.

## CONCLUSION

As the impacts of anthropogenic climate change become increasingly experienced across a range of human populations and environments, greater attention will be paid to climate-related population redistribution. Existing research on historical and contemporary environment-migration connections provides important insights as to the causal, temporal, and spatial dimensions of this association. On causal connections, analogs suggest climatic conditions and changes represent but one set of ‘push’ and ‘pull’ factors acting upon migration. Ultimately, environmental factors interact with socioeconomic, cultural, and political processes to shape migration decision-making. Temporally, a wide variety of migration patterns are revealed, ranging from short-term, temporary environmentally related migration to permanent relocation resultant of, for example, natural disasters. On the spatial aspects, the analogs described above are consistent with research that suggests the majority of future climate-related movements will likely be internal or intraregional as opposed to geographically extensive movements crossing international boundaries.

In addition, existing research strongly suggests that environmentally influenced migration is closely linked with adaptive capacity. As such, the nature and scale of future climate migration will depend considerably on the extent to which the global community engages in proactive capacity-building in vulnerable populations and regions. The analogs suggest a variety of possible migration outcomes in the absence of greenhouse gas mitigation and capacity-building efforts. Rural-to-urban and peri-urban migration rates may increase, particularly within developing regions where exposure to climate-related risks and dependence on local natural resources are both high. Depending on the nature of climate change and rate of onset, populations inhabiting low-lying coastal regions, small island states, and floodplains will increasingly be at risk of displacement, necessitating international discussion of relocation options.

Patterns of ‘nonmigration’ are also of particular importance in considering future climate-related population movements. In the four case studies presented here, permanent migration is the livelihood option chosen by only a fraction of households affected by environmental change. Because sociodemographic characteristics shape the probability of permanent migration so strongly, targeting efforts to enhance adaptive capacity at particularly vulnerable households may well have the effect of reducing involuntary climate-induced migration in many settings.

Although our knowledge of the interactions between climate change and migration patterns is growing, considerable work still needs to be done. There is a high degree of variability and inconsistency in many of the projections currently being made of future climate-related migration, reflecting challenges in scaling from local examples to global estimates and measures. Additional research is also needed to refine our understanding of the specific ways in which households and their members assess and evaluate migration options in

comparison with other adaptation alternatives and the critical thresholds at which distress migration becomes the predominant adaptation option. To expand upon what may be learned from known migration-event analogs, a much wider range of empirical, longitudinal studies of current and ongoing climate-migration interactions across regions and communities are needed. Research initiatives such as these would greatly enhance the development of adaptation policies and programs in coming years by eliminating much of the still-remaining guess work about how climate change-related migration will unfold.

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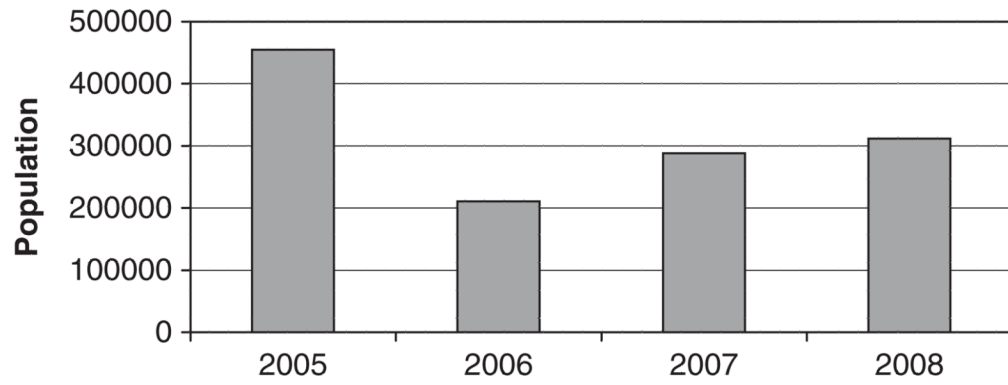
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**FIGURE 1.** Population of New Orleans on July 1, pre- and post-Hurricane Katrina (August 2005).  
Source: US Census Bureau, City population datasets, accessed 30 March 2009  
[http://www.census.gov/popest/counties/files/CO-EST2008-POPCHG2000\\_2008-22.csv](http://www.census.gov/popest/counties/files/CO-EST2008-POPCHG2000_2008-22.csv).

TABLE 1

Expected Impacts of Anthropogenic Climate Change and Potential Associations with Future Population Displacements/Migrations<sup>a</sup>

Expected Change (from IPCC 2007 <sup>10</sup> )	Regions to be Affected (from IPCC 2007 <sup>10</sup> )	Associations with Population Displacement/Migration
Decreased snow and sea ice cover	Arctic	Expansion of shipping and resource extraction economy stimulating influx of economic migrants
Increases in annual average river runoff and water availability	High latitudes and some wet tropical areas	Risk of flood displacements in riverine settlements
Decreases in annual average river runoff and water availability	Midlatitudes and dry tropics	Increased frequency of water scarcity and drought-related population movements; emergence of new areas prone to such events
Increased extent of areas affected by droughts	Regions already susceptible to drought	Increased frequency of water scarcity and drought-related population movements
More intense precipitation events	Will vary by region	Risk of flood displacements in riverine and low-lying coastal settlements
Reduced water availability in regions dependent on mountain snowmelt	South Asia, China, western North America, western South America	Potential for increased influence of agricultural drought and water scarcity on population movements in exposed watersheds
Increasing number of plant and animal species at risk of extinction; increased potential for significant ecosystem disturbances	Globally	Out-migration from settlements dependent on small range of resources
Decreasing crop productivity; more frequent impacts of drought and floods on crop production	Lower latitudes, dry tropics, seasonally dry regions	Potential for increased rural-urban migration in exposed areas
Increased risk of erosion, flooding and extreme storms	Coastal regions, especially those already exposed to such risks	Relocation of populations/settlements from coastal plains, deltas, and small islands

IPCC, Intergovernmental Panel on Climate Change.

<sup>a</sup>The third column in the table describes the general types of population displacements or migrations that may be associated with the types of exposures in the regions given in the first two columns. These associations are derived from analogous cases described in this article, scholarly works cited in the references, and additional sources that have been included in the Further Reading section. These associations are of the type typically relied upon when making future predictions of climate change migration such as those in references.<sup>54–56</sup>