Predicting Future Migration Destinations from Natural Disasters: the Great East Japan Earthquake

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Keywords: Great East Japan Earthquake, Migration systems, Fukushima, Hurricane Katrina, Destination

Abstract:

Environmentally induced migration has a long history within the demographic literature but only recently have there been calls to better understand the geographic implications in the origin and destinations of these migrants. To date, very few empirical studies examine the "where" questions in environmental migration with explanations that range from the vague such as 'rural to urban' or 'to nearby cities' to simple estimates of displacement to origin but not destination. Here we show that migration systems before and after the Great East Japan Earthquake are almost identical. Post-disaster migration – expressed as both proportions of total flows and destinations – is largely identical to pre-disaster migration. While the magnitude of flows increased, the proportions and destinations of migrants remain largely intact. Our results demonstrate that past migration systems can potentially be used to predict future emigrations from environmental stressors, an increasingly important finding given the anticipated population displacements due to climate change.

Introduction

On March 11, 2011, a magnitude 9.0 earthquake occurred off the east coast of Japan – making it the most powerful earthquakes on record in Japan and the fourth most powerful earthquake in the world since record keeping began in 1900 (USGS 2014). This event is now known as the Great East Japan Earthquake. The earthquake triggered a tsunami that was on average 10m high and up to 40m in height in some places (Sawa, Osaki and Koishikawa 2013), causing 15,871 people to lose their lives, injuring 6,114 people, and 2,778 people are still missing and presumed dead (Hasegawa 2013). Financial damages are estimated near $160 billion with over 300,000 residential buildings damaged (Sheet 2011, Takano 2011). The disaster culminated with the accident at the Fukushima-Daiichi nuclear plant where, as of this writing, the long term implications of the plant's failure are still unknown. Japan's Prime Minister, Naoto Kan, called it "Japan's worst crisis since the second world war" (Branigan 2011) and the damages make it the second largest natural disaster in Japan's modern history. In total, the disaster displaced some 460,000 people. Where did these people go and why? Who has permanently resettled and where? What can this displacement tell us about the broader scope of environmentally induced migration?

The earthquake and ensuing tsunami occurred just off the Sanriku Coast, with most of the coast hit by the largest part of the tsunami, upwards of 10m or more in height, with the worst inundation of up to 3km from the shore (Takano 2012). Three prefectures in particular were most adversely impacted by the earthquake and tsunami. Iwate and Miyagi prefectures account for the majority of the Sanriku Coast, and were impacted the most by the tsunami. Fukushima Prefecture is just to the south of Miyagi Prefecture and is home to the Fukushima-Daiichi Nuclear Plant where the cooling functions of the reactors failed resulting in a meltdown of the nuclear fuels and leakage of radioactive materials into the local environment (Takano 2011). These three prefectures accounted for nearly 82% of the damaged fishing ports, nearly 91% of the damaged fishing boats, and 84% of the lost aquaculture due to the earthquake and tsunami (Takano 2012). The majority of the casualties and evacuees were also concentrated in these three prefectures (Isoda 2011).

The disaster caused a Japan-wide wide diaspora of residents most affected by the Tsunami and nuclear fallout. Residents of Fukushima Prefecture – home of the Fukushima-Daiichi Nuclear Plant – were affected the most. All residents in Fukushima Prefecture within 20km of the plant and most residents within 30km were forced to evacuate. Within three days of the earthquake, over 468,000 people sought refuge in nearby prefectures. Many of these refugees were displaced from the three prefectures affected the most: Iwate, Miyagi, and Fukushima (Ishikawa 2012).

Diaspora becomes the only word to describe the population displacement. While many of the effects of the diaspora have been temporary, the permanent changes to Fukushima's migration were felt almost immediately – changes to a prefecture that has already been reeling from de-population (Matanle 2013). Out migration from Fukushima increased by 70% between 2010 and 2011 while in-migration fell by 15%. This caused a change in the total net migration from -5,752 persons in 2010 to -31,381 in 2011 – over a fivefold increase in net out migration over a single year's time (Bureau 2011). As of December of 2011, just eight months after the incident, the number of evacuees from Fukushima Prefecture stood at 92,712 with 33,943 still

living inside the prefecture, according to the International Medical Corps' Fukushima Prefecture Data Sheet (2011).

These evacuees are captured in a separate data collection system and are not a part of the official migration statistics. By law, all Japanese nationals are required to register their residency. However, many evacuees are unwilling to report their relocation, hoping to return home. The Japanese Ministry of Home Affairs set up a new system following the tsunami and nuclear reactor disaster for evacuees allowing a resident to maintain their residency in their home prefecture while presently living in a different prefecture. Thus, evacuees from Fukushima Prefecture living in a nearby prefecture are still counted as residing in Fukushima in the official population estimates of the Ministry of Home Affairs while appearing in a nationwide evacuee database at their present prefecture.

In this article we take a migration systems approach to understand the impact of the Great East Japan Earthquake on Japan's migration system. We ask two fundamental questions about the migration system: Do evacuees and migrants share a similar migration system? and how stable is a migration system in the wake of catastrophic environmental perturbations? The unique parsing of evacuees from migrants in the Japanese data collection system allows for a novel approach in understanding post-disaster migration systems in two ways. First, we focus on the spatial and temporal stability of a migration system before, during, and after an environmental disaster, complementing the many temporal approaches on other natural events (Fussell, Curtis and DeWaard 2014, Curtis 2013, Gray and Bilsborrow 2013). Second, we distinguish and compare and contrast the migration systems of evacuees and migrants in response to an acute natural disaster – a distinction absent from previous works (Hassani-Mahmooei and Parris 2012, Kayastha and Yadava 1985, Stone et al. 2012, Hori, Schafer and Bowman 2009). These questions allow us to discern how migration systems might shift after a disaster. Our results show (1) the structure of evacuees' movement systems is quite different from long-term migration systems, even those of the latter that are clearly influenced by environmental change and (2) the stability of the migration system, both spatially and temporally in the face of strong environmental perturbation.

Environmental Migration and Migration Systems Theory

Environmentally induced migration has a long history within the demographic literature (Adamo 2009, Easterli 1971, Hugo 2011b, Svart 1976) but only recently have there been calls to better understand the geographic implications in the origin and destinations of these migrants (Curtis and Schneider 2011, Findlay 2011b, Gray and Bilsborrow 2013, Hassani-Mahmooei and Parris 2012, Hugo 2011a, Smith et al. 2011). To date, very few empirical studies examine the "where" questions in environmental migration with explanations that range from the vague such as 'rural to urban' (Gray and Bilsborrow 2013) or 'to nearby cities' (Mallick and Vogt 2013) to simple estimates of displacement (Oda 2011) to origin but not destination (Council 2011). In spite of this, Findlay (Findlay 2011b) outlines several principles governing destinations based on this scant literature on the drivers of environmental migration. Of interest here are his principles of short-distance migration and the preference to move to locations with already established ties and networks. Recent alarmist claims of climate change's impacts on the global migration system posit increasing flows from the global south to the global north (Adamo 2010, Hugo 2011a, Reuveny 2008) — ties that are already established in the current migration paradigm.

This paper aims to build upon Findlay's work by examining the migration systems of a post-disaster area to the pre-disaster footprints for the Great East Japan Earthquake that caused mass emigration in 2011.

Previous research investigating environmental migration uses largely non-geographic approaches dominated by "who?" and "what?" questions. The omission of important "where?" questions has led to a gross lack of knowledge about changes in migration systems in post-disaster migration networks; far too little is known about the differences between pre- and post-disaster migration patterns. Much more is known about who moves (Rivera and Miller 2007, Hori et al. 2009) and who returns (Stringfield 2010, Groen and Polivka 2010, Thiede and Brown 2013). The International Organization for Migration's document *Improving Methodologies to Estimate Flows* (Kniveton 2008) identifies drought as where the bulk of environmental migration literature has previously investigated. That IOM report also notes the lack of studies on hurricanes and migration, a gap that is already rapidly being filled (Curtis 2013).

Gutman and Field (2010) developed a useful framework to help us understand environmental effects on migration and have identified four types of environmental factors that influence migration: (1) environmental calamities such as floods, hurricanes, and earthquakes, (2) environmental hardships such as drought or short periods of favorable weather, (3) environmental amenities such as warmth, sun, or proximity to mountains and water, and (4) environmental barriers such as heat, air conditioning, irrigation, etc. This framework for environmental migration allows for a useful way to place historically significant environmental events of the 20th century into analytically useful categories. The list of environmental events or impacts is both long and wide and include the American dust bowl of the 1930s (Adamo 2009), air conditioning (Glaeser and Tobio 2007), and Hurricane Katrina (Fussell and Elliott 2009), for instance. These typologies – combined with Findlay's six principles – provide a robust framework for organizing research on environmental migration; a framework that has begun to be deployed with increasing frequency to questions of climate change. Naturally, the vast majority of climate change and migration research tends to focus on a few key questions that revolve around these four typologies that have been identified through the 20th century. These tend to be questions such as "Is Migration a response to climate change?" (Tacoli 2009, Gray and Bilsborrow 2013) where the answers tend to be conflicting; "Who is vulnerable to climate change?" (Meze-Hausek 2000, McLeman 2010, McLeman and Hunter 2010); "What are the repercussions for 'refugees'?" (Barnett and Adger 2007, Reuveny 2007, Reuveny 2008); "Who moves because of the environment?" (Rivera and Miller 2007, Hori et al. 2009); and with the increasing focus on Hurricane Katrina, "Who returns?" (Stringfield 2010, Groen and Polivka 2010, Thiede and Brown 2013).

Additionally, the nature of environmental migration is largely dependent upon the type of environmental pressure. While there are overarching similarities across perturbations in any given system by any given stimuli, droughts, tropical cyclones, and tsunamis all exhibit different effects on a migration system due to the different nature of each event (Hunter, Murray and Riosmena 2013, Thiede and Brown 2013, Gutmann and Field 2010). For instance, droughts generally do not generate evacuees while tropical cyclones and tsunamis will. Similar studies on the displacement of populations from flooding in India found that displacements tended to be localized with migration along short-distances in search for safer areas (Kayastha and Yadava 1985) and studies on Hurricane Katrina's impact on the Gulf Coast of the United States found

similarly large out-flows to nearby areas (Stone et al. 2012, Hori et al. 2009, Frey, Singer and Park 2007). While these studies examine the geography of displacement, there is little or no temporal comparison to the unaltered, previous migration system nor is there a distinction between evacuees and migrants.

Due to data limitations, many of these studies analyze evacuees and migrants together or simply neglect to acknowledge a distinction between an evacuee and a migrant. Findlay's (2011a) six principles governing migration provide key insights for understanding both evacuees and migrants. These principles are 1) Potential migrants prefer to stay in their current residence, often called the 'immobility paradox,' 2) Once people move, they tend to make shorter rather than longer moves, 3) once people move, they tend to live or work in nearer rather than distant places, 4) the relative attraction of a location is interpreted as returns to human capital, 5) destination selections are to some extent shaped by pre-existing socio-cultural connections, and 6) places are viewed as attractive because of the social and cultural capital they offer. These six principles can be boiled down to A) People don't really want to move, B) If they do move, they tend to move short distances, and C) human capital and existing ties play a large role in determining destinations.

While previous studies have shown displacement to short-distance locations, these studies also document some populations choosing to migrate to long-distance locations as well, perhaps due to the comingling of both evacuees and migrants within their data. For instance, Curtis et al (2013) find a concentration of the migration system after Hurricanes Katrina and Rita but still note the presence of long-distance migrant origins and destinations. It is our contention that the concentration of the system is the result of two distinct migration systems being captured within one datum: an evacuee system and a permanent migrant system. The migration data available in the United States does not distinguish between types of movers and thus limits researchers to just one single analysis of both migrants and evacuees together. The unique nature of the Japanese data collection system, however, allows us to parse out permanent migrants from evacuees allowing for an analysis of both permanent *and* impermanent migrations (Oda 2012) and a broader understanding of the impacts on migration systems of both migrants and evacuees.

With a separation between migrants and evacuees we seek to answer our first question: Do evacuees and migrants share a similar migration system? It is our hypothesis that evacuee's migration pattern will follow the 2nd and 3rd of Findlay's principles – that of nearer rather than farther moves – while the permanent migration system follows the 4th through 6th principles. Here we will examine the similarities between both the permanent migration system, as captured in the official statistics of Japan, and the evacuee system, reflecting the number and locations of evacuees from Fukushima prefecture from February 2012 taken from Takashi Oda's *A Snapshot of the Displacement of Fukushima Residents* (2012), compared with the 2010 permanent migration data from the Statistics Bureau of Japan.

Migration Systems Theory (MST) is a branch of migration research that uses all origin-destination combinations as the object of study as opposed to any single origin-destination (Fawcett 1989, Massey et al. 1994, DeWaard, Kim and Raymer 2012). What underlies a systems approach is that when one place experiences a change, the effect is manifested throughout the system. Migration decisions – not just decisions to migrate, but also location decisions – are often driven by the presence or absence of human capital; decisions based on labor forces,

economic vitality, anticipated increases in living standards, amenities, both natural and economic, etc. (Lee 1966, Pandit 1997, Fawcett 1989, Haug 2008, Thiede and Brown 2013). It is this network of human capital embedded within the migration system that tends to drive locational decision making in the aftermath of environmental events (Hugo 2008, Hugo 2011a, Findlay 2011a, Schultz and Elliott 2013, Gray and Bilsborrow 2013, McLeman 2013, Findlay 2011b).

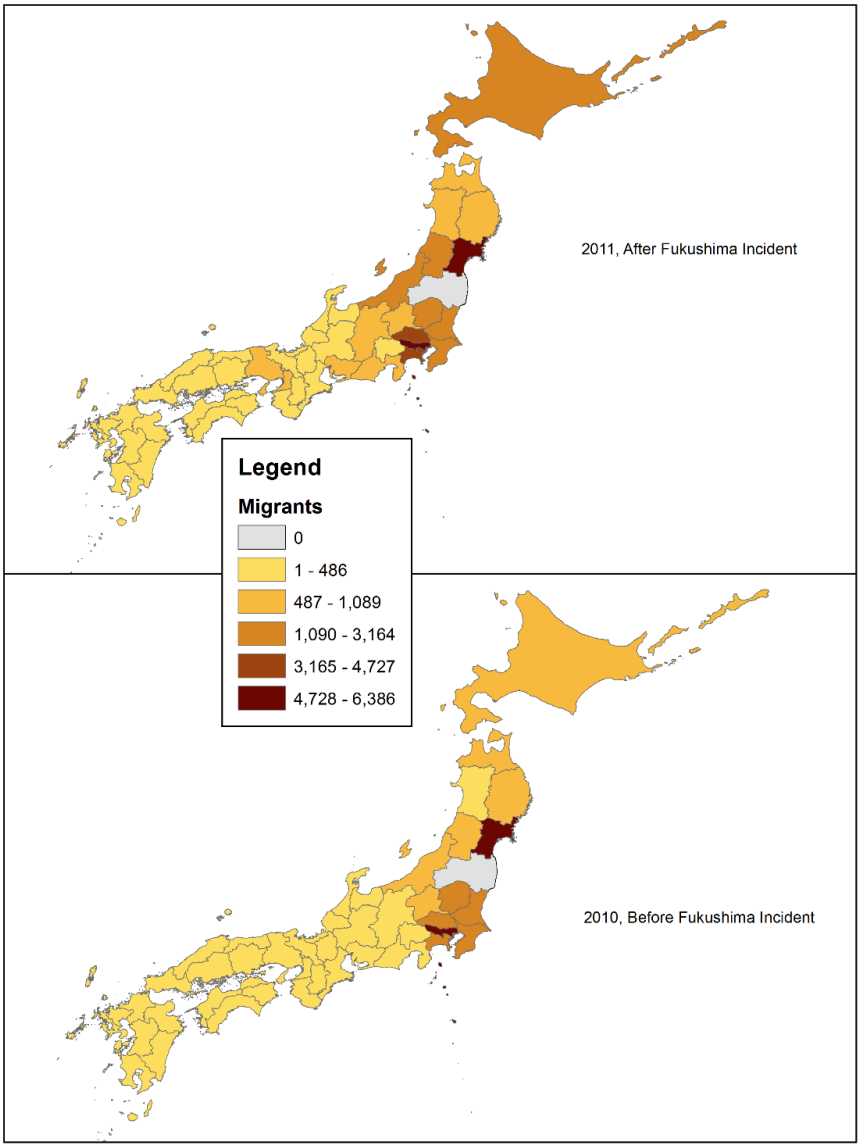
MST has been explicitly tied to environmental migration in recent years (DeWaard et al. 2012, Fawcett 1989, Curtis 2013) with examinations of both the stability of such systems (DeWaard et al. 2012) as well as altered systems (Curtis 2013, Fussell et al. 2014). Here we build on this previous research and employ MST to answer our second main question: how stable is a migration system in the wake of catastrophic environmental perturbations? We anticipate that these networks of human capital are leveraged in the immediate aftermath of an environmental event and that this leveraging of human capital, manifested as the proportions of flows in to and out of the most affected Prefectures in Japan in to and out of all other Prefectures, leads to an essentially unaltered migration system.

What do the resultant migration patterns from the Great East Japan Earthquake tell us about future environmental migration destinations? Here we are not concerned with *who* moved and why, nor *who* returned and why, but rather *where* people moved and whether or not the previous migration patterns are indicative of migration patterns in the aftermath of an environmental event. This paper asks such questions, and evaluates the possible changes in the pre- and post- disaster migration distributions. The results of this comparison are then considered in light of their implications for future migration patterns after an environmentally induced diaspora.

Data and Methods

We describe the migration systems in Japan using the Statistics Bureau of the Ministry of Internal Affairs and Communications of Japan's annual series of Origin-Destination matrices of prefecture-to-prefecture migration. These data only reflect permanent migration and are biased downwards due to the distinction between migrants and evacuees (Oda 2011, Oda 2012). This, however, allows for a unique decomposition of environmental flows between permanent migrants and evacuees. Evacuee data, by its nature, is variable across time and difficult to collect (Hasegawa 2013). Despite these limitations of evacuee data, current estimates from Takashi Oda and Reiko Hasegawa represent the best available data on the evacuees from the earthquake and tsunami from February of 2012.

Figure 1. Fukushima Prefecture Out-Migrants in 2010 and 2011.



In terms of permanent migration, we focus our analysis on the year preceding, the year of, and the immediate years after the earthquake and tsunami. We are interested in the manifestation of the pre-disaster migration system (2010), measured as the immediate year before, the migration system that is leveraged during the immediate aftermath of the disaster (2011), and the post-disaster migration system, measured as the immediate years after (2012 and 2013). In terms of evacuees, we focus our analysis on the comparison between the migration system before (2010) and the diaspora of evacuees in the post-disaster period (2012).

We characterize the migration system of Japan in seven matrices representing the total prefecture-to-prefecture migration as a proportion of total flows in to and out of any given

prefecture. Unlike Fussell, Curtis, and Waard's systems work on New Orleans after Hurricanes Katrina and Rita (2014), we do not control for population size since any change in population in any prefecture will exogenously alter a migration rate, ie the changes in the migration system should be examined independently of other population dynamics such as mortality and fertility. Rather, we use the proportionality of the flows, expressed as $\frac{M_{i,j}}{M_{j,in/out}}$, the ratio of the migrants from prefecture *i* to *j* to the total number of migrants in to or out of prefecture *j* is used to investigate the alterations in the proportionality of flows. We would anticipate changes in the magnitude of migrations after a disaster of this magnitude, but are rather interested in seeing the changes in the structure of the migration system. A set of base matrices from 2010 representing the pre-disaster migration system **Q(0,in/out)**, three matrices for 2011, 2012, and 2013 representing the during and after migration systems **Q(1), Q(2)**, **Q(3)** and one matrix for the evacuees **Q(e)**. These matrices take the following general form:

$$Q(\mathrm{x}, in) = \begin{bmatrix} \frac{M_{i,i}}{M_{i,in}} & \cdots & \frac{M_{i,j}}{M_{j,in}} \\ \vdots & \ddots & \vdots \\ \frac{M_{j,i}}{M_{i,in}} & \cdots & \frac{M_{j,j}}{M_{j,in}} \end{bmatrix}$$

$$Q(x, out) = \begin{bmatrix} \frac{M_{i,i}}{M_{i,\mathrm{out}}} & \cdots & \frac{M_{i,j}}{M_{i,out}} \\ \vdots & \ddots & \vdots \\ \frac{M_{j,i}}{M_{\mathrm{j,out}}} & \cdots & \frac{M_{j,j}}{M_{j,out}} \end{bmatrix}$$

$$Q(e) = \begin{bmatrix} \frac{E_{i,i}}{E_i} & \cdots & \frac{E_{i,j}}{E_i} \\ \vdots & \ddots & \vdots \\ \frac{E_{j,i}}{E_{\mathrm{j}}} & \cdots & \frac{E_{j,j}}{E_j} \end{bmatrix}$$

Such matrices have no "net" migrants and represents the complete picture of prefecture-to-prefecture migration. The sum of any given column and row in the matrix will equal 1.0 representing the total proportionality of flows in to and out of any given prefecture while any given cell inside of the marginal of the matrix represents the proportionality of the whole. With 47 prefectures, the total number of cells in these origin-destination matrices stands at 4,418 representing the complete migration profile for Japan with any given prefecture accounting for 94 cells.

To assess the degree of spatio-temporal structural stability between the distributions of 2010, 2011, 2012, and 2013 migration for the three most severely affected Prefectures – Fukushima, Iwate, and Miyagi – two statistical approaches were employed: a correlation approach and the Index of Dissimilarity. While the magnitudes of the flows can and should be different between pre- and post- disaster, these tests are to determine if the overall structure of the flows to each prefecture have changed in the post-disaster period. We are interested in whether or not the migration systems between the time periods Q(1,2,3,e) are significantly different from Q(0), not necessarily in the absolute changes in both in- and out-flows.

We employ the use of two statistical tests to assess the temporal stability in the migration system. A simple regression analysis is used to determine the extent to which Q(0) explains the variation observed in the subsequent time periods. An altered migration system should be manifested as a low r-squared, ie Q(0) is unable to explain most the variance observed in the subsequent time periods. Here we regress Q(1), Q(2), Q(3), and Q(e) on Q(0) for both in and out-migration, ensuring that the diagonals from the matrices are not included in the analysis; thus with 47 prefectures, we use n=46 pairs.

Additionally, we employ the use of the Index of Dissimilarity (Duncan and Duncan 1955, Sakoda 1981, Holloway, Wright and Ellis 2012) to assess the degree of similarity between the migrant distributions of Q(0) and Q(1,2,3,e). The Index of Dissimilarity or *D* is generally interepeted as the percentage of the population that would need to relocateA large degree of similarity should result in a low Index of Dissimilarity.

$$D = \frac{1}{2}\sum |Q(0) - Q(x)|$$

Results

Table 1 summarizes the results for permanent In- and Out-migration based on the Statistics Bureau of Japan's origin-destination data for the three most adversely affected prefectures – Fukushima, Iwate, and Miyagi—reflecting the during migration system (2011), and immediately after systems (2012 and 2013) regressed against the pre-migration system from 2010 to and from each of the 47 prefectures with the values along the diagonal in each matrix removed. Here we can see very strong similarities between the pre- and post-disaster permanent migration systems. We observe very strong r-square values for the 2011 out-migration (r-squared=0.9763, 0.9941, 0.9841, for Fukushima, Iwate, and Miyagi, respectively), and 2011 in-migration (r-squared=0.9967, 0.9735, and 0.9479). These results indicate that while the overall net migration experienced a fivefold increase, as we would expect them too given the extent of the disaster, the proportions of flows to all origins/destinations remains relatively unchanged.

Figure 2.Relationship between the 2010 percentage of out-migrants and 2011 out-migrants for Fukushima Prefecture.

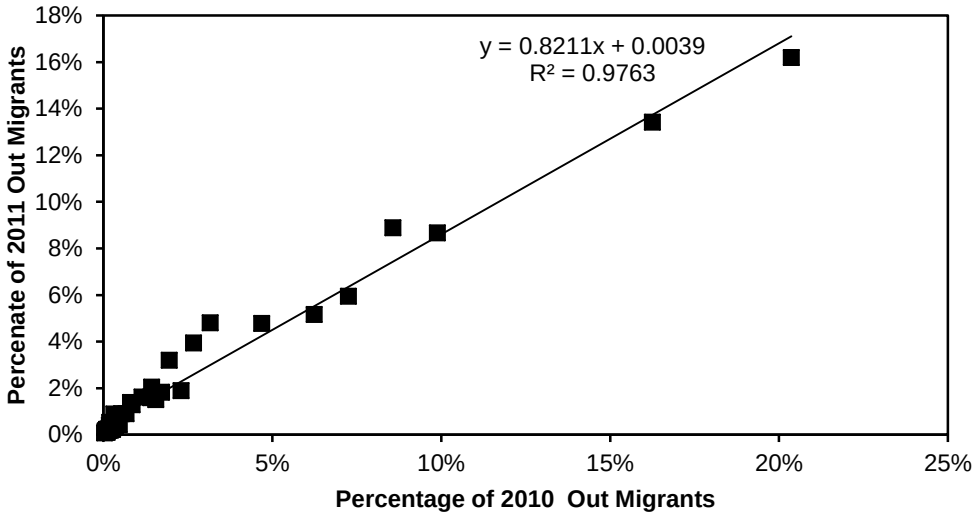


Table 1. 2010 In and Out Migration for each Prefecture regressed on each subsequent year, and 2012 Fukushima evacuee Data.

Prefecture	Type	Independent	Dependent	Observations	R Square	*P-value*	
Fukushima	In-Migration	2010	2011	46	0.9967	0.0000000	***
		2010	2012	46	0.9943	0.0000000	***
		2010	2013	46	0.9957	0.0000000	***
	Out-Migration	2010	2011	46	0.9763	0.0000000	***
		2010	2012	46	0.9904	0.0000000	***
		2010	2013	46	0.9958	0.0000000	***
Iwate	In-Migration	2010	2011	46	0.9735	0.0000000	***
		2010	2012	46	0.9978	0.0000000	***
		2010	2013	46	0.9972	0.0000000	***
	Out-Migration	2010	2011	46	0.9941	0.0000000	***
		2010	2012	46	0.9973	0.0000000	***
		2010	2013	46	0.9948	0.0000000	***
Miyagi	In-Migration	2010	2011	46	0.9479	0.0000000	***
		2010	2012	46	0.9876	0.0000000	***
		2010	2013	46	0.9876	0.0000000	***
	Out-Migration	2010	2011	46	0.9841	0.0000000	***
		2010	2012	46	0.9886	0.0000000	***
		2010	2013	46	0.9942	0.0000000	***
Fukushima	Evacuee	2010 Out-Migration	2012 Evacuees	46	0.2881	0.0000000	***

*significant at the .05 level
**significant at the .01 level
***significant at the .001 lev

Table 1 also summarizes the comparison between 2010 out-migrants from Fukushima prefecture with the 2012 locations of evacuees. Here, the relationship between the 2010 out-migration system and the 2012 evacuee's locations is not nearly as strong (r-squared=0.2881) indicating a marked difference between the in- and out-migration systems and the evacuees systems. These results suggest the presence of two separate migration systems: a system for migrants and a system for evacuees. Here we do not examine the pattern or magnitude of the residuals.

Figure 3 demonstrates the changes in the spatial extent of the migration systems between out-migration and evacuees by looking at the percentage of the out-migration and evacuated to the six prefectures immediately surrounding Fukushima (Gunma, Ibaraki, Miyagi, Niigata, Tochigi, and Yamagata). While the 2010-2013 out-migration data from Fukushima Prefecture hovers between 33.97% and 35.73% of out-migrants going to a nearby prefecture, the percentage of evacuees is markedly different with 46.12% of evacuees being located in nearby prefectures, suggesting that evacuees tended to move to nearer locations in larger numbers than typical out-migrants. Evacuees who suddenly had to give up their home may not be ready for distant relocation. For evacuees who are deeply rooted in their home community, it may be difficult to move far away from their center of social capital.

Figure 3. Percentage of Fukushima out migrants and Evacuees to the six surrounding Prefectures.

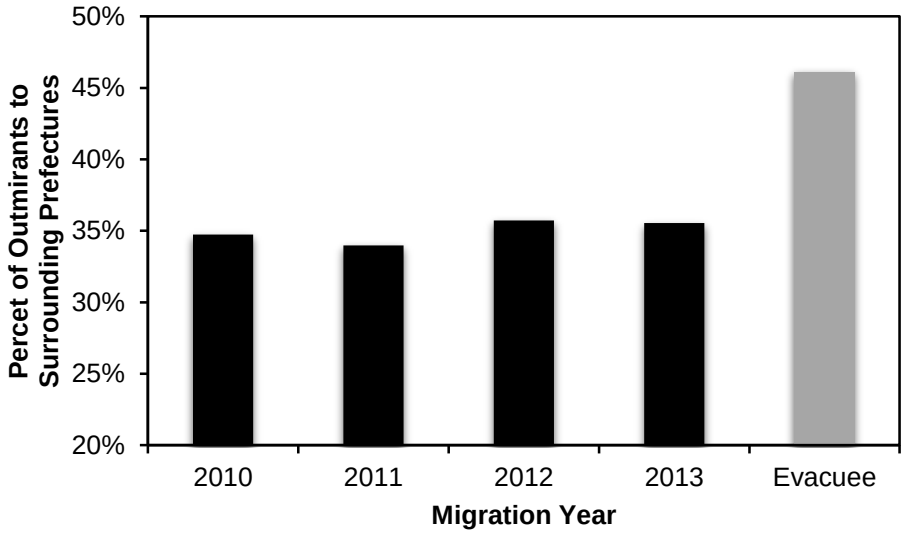


Figure 4 maps the differences between the predicted 2011 evacuees from the results of the regression equations and the actual counts of evacuees. Areas with negative differences represent lower than expected evacuees, given the preexisting migration system while areas with positive differences represent greater than expected evacuees. The concentration of evacuees to nearby prefectures, particularly Niigata and Yamagata prefectures, combined with the lower than expected evacuees into the southern part of Japan show the extent of this geographic concentration of the evacuee system.

Figure 4. The differences between the observed and predicted evacuees from Fukushima Prefecture.

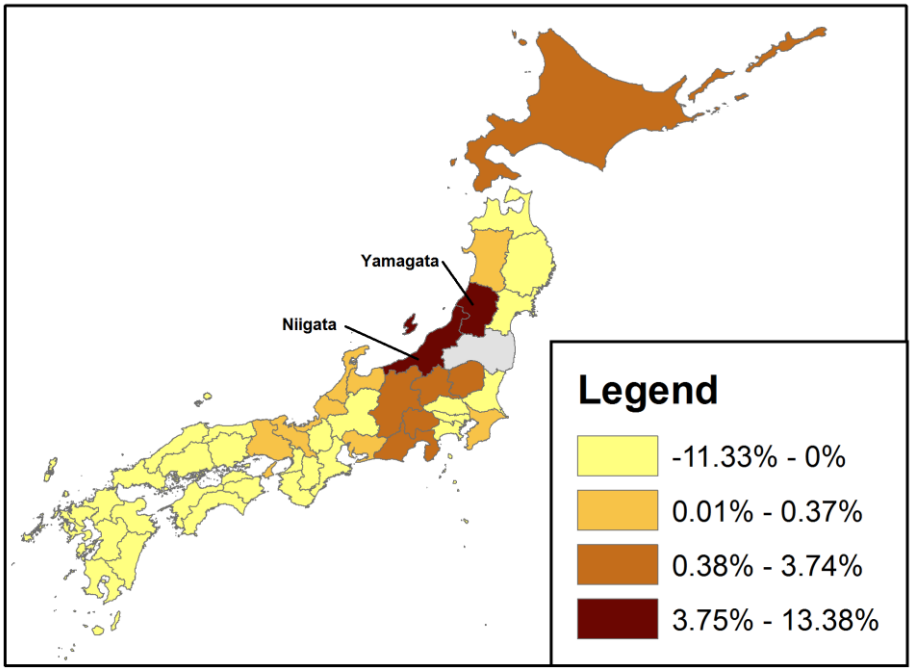


Table 2 summarizes the results of the Index of Dissimilarity for out-migration between the 2010 migration systems and the 2012 and 2013 systems. Fukushima Prefecture sees the largest dissimilarity for 2011 among all 47 prefectures, with 11% of migrants required to change destinations to equal the migration system of 2010. The observed D value for the locations of Evacuees is nearly three times larger where nearly 30% of evacuees would have to change destinations in order to equal the migration system of 2010, further suggesting the existence of two concurrent migration systems: a system for permanent migrants and a system for evacuees. Ultimately many of the D values for out-migration for every prefecture remains relatively stable, and in some years, the three most adversely affected prefectures – Fukushima, Iwate, and Miyagi – do not exhibit the largest D value. Yamanashi Prefecture, located southwest of Tokyo, experienced the largest Index of Dissimilarity in 2012 (7.2) and 2013 (8.5).

Table 2. Index of Dissimilarity of out-migrants comparing each year to 2010.

	2011	2012	2013
Fukushima Evacuees	-	29.6	-
Fukushima, Iwate, and Miyagi Prefectures	7.0	3.0	4.0
All other Prefectures	3.1	3.0	3.5

Discussion

Population displacement due to climate change is expected be a growing problem in the 21st century. Within the United States alone, at least 20 million people are expected to be at risk

of sea level rise by 2030 (Curtis and Schneider 2011). Sometimes referred to as 'climate refugees' (Sommers et al. 2006, Gordon 2005, Argos 2010), a great deal of focus on environmental migration has not been on the destinations of migrants but rather on the characteristics of migrants. The implications to understanding *where* climate refugees could migrate is of upmost importance. The 2011 National Research Council's Security Implications for Climate Change Report (2011) suggests that climate change could lead to mass migrations (Black et al. 2011, Feng, Krueger and Oppenheimer 2010). Considering the vast majority of the 20th century's environmentally induced migration contained return migration, this research included, knowing the potential destinations of future climate refugees and environmental migrants is paramount to understanding the total demographic implications of climate change. Simply knowing who and from where someone will migrate is only two-thirds of the migration equation. The research presented here is a good first step to filling in the final third of the migration equation: where.

We find that the migratory responses to environmental effects of the Great East Japan Earthquake are manifested in two separate and distinct systems: those of permanent migrants and those of evacuees. We also find relatively little change in the spatio-temporal structure of the migration system. The proportions and destinations of migrants was relatively unaltered in the aftermath of the earthquake and tsunami. These two systems, evacuation and migrant, each emphasize differing aspects of Alain Findlay's six principles. Evacuees' migration seems to emphasize the 2nd and 3rd principles, concerning short-distance moves, while the permanent migrants seem to emphasize the 4th, 5th, and 6th principles, concerning human-capital. Here we do not explicitly take into consideration any actual measures of human capital, however, based on the stability of the migration system in the face of environmental perturbations, future research questions that further examine the leveraging of human capital in migration and locational decisions would be a fruitful endeavor. These results are not outside the bounds of what should be anticipated. We should expect those who are moving from an environmental impetus to leverage their networks of human-capital, networks that are generally leveraged for all types of migration. In this sense, we should expect the migration systems of permanent migrants from an environmental impetus to reflect the migration system already exhibited before the environmental event, a reflection these results support. Conversely, we would anticipate those who are evacuating to look for shelter nearest the closest, safest locations.

There are still some limitations to this analysis. First, the official numbers of evacuees is in continual flux still three years after the disaster, and has already been shown to be subject to administrative problems (Ishikawa 2012). The extent to which these administrative problems have infected the migration data is unknown. Similar data issues plagued IRS data in the immediate aftermath of Hurricane Katrina (Johnson 2008), and have prompted skepticism around disaster related administrative data (Groen 2014, Curtis 2013). We share their skepticism, but understands that without the limited administrative data, no post-disaster analyses are possible. Data limitations also prevent any sort of analysis of evacuees within Fukushima Prefecture, both how the number of evacuees still residing within the prefecture as well as from where. Finally, while there is nearly a 550% increase in the net negative migration after the disaster from Fukushima Prefecture, the total number of negative net migrants pales in comparison to the known numbers of displaced evacuees. The numerical extent to which these evacuees have been included in the official migration statistics is unknown. The research presented herein reflects only the universe of captured migrants by the Japanese government pre-

and post- disaster. The former can be assumed to be complete or near complete in coverage, the latter's completeness is unknown.

Despite these limitations, the research presented represents the best possible analysis of pre- and post- disaster migration and evacuation systems of the Great East Japan Earthquake, however future research could also consider the distinct possibly of different migratory response patterns of different age groups and gender. For instance, many mothers with small children have evacuated from Fukushima Prefecture while fathers stay within Fukushima or nearby neighboring prefectures. These diffential patterns of evacuees and migrants by more specific demographics could go a long way to informing more concrete how's and why's particular groups evacuate or migrate.

The research here suggests that many of the key theories of migration (Massey et al. 1994, Massey et al. 1993) as well as Findlay's (Findlay 2011b) principle's all ring true. The determinants of previous migration systems' stocks and flows, and origins and destinations are still largely intact after a natural disaster; that these previous systems have the potential to aid in the modeling of future migration systems. The Great East Japan Earthquake provides both a significant enough and timely environmental event to empirically study changes to migration systems from environmental stressors. These findings help inform the broad environmental migration literature and have the potential to leverage these results into the climate change literature.

As the twenty-first century continues to march on, environmental displacement due to climate change will become inevitable. The Great East Japan Earthquake offers a glimpse into the complicated and non-volatile migration systems in the aftermath of a disaster. These results suggest that migration systems continue onward as business-as-usual and offer a glimpse into situations that could arise due to climate change.

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