

THE IMPACT OF HURRICANES ON CRIME IN THE CITY OF HOUSTON, TX: A SPATIO-TEMPORAL ANALYSIS

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ABSTRACT:

The impact that natural disasters have on crime is still little known. In general, it is assumed that crime declines shortly after the disaster and slowly increases to pre-disaster levels over time. However, this assumption is not always confirmed by the few empirical studies that have been conducted to date. In this paper we analyze the impacts that Hurricanes Katrina and Rita had on the temporal and spatial distribution of reported crimes in the city of Houston, TX. Crime data were collected before, during, and after the landfall of both hurricanes. The modeling part of this paper focused on spatial, temporal, and spatio-temporal models, at both global and local scales. The results show that while Hurricane Katrina did not have any apparent impact on crime, Hurricane Rita led to a significant short-term increase in burglaries and auto thefts. Spatial analysis indicated that the increase in burglaries was mostly concentrated in African American and, to a lesser degree, in Hispanic neighborhoods. There is some indication that the mandatory evacuation order that was issued prior to the arrival of Hurricane Rita motivated crime “prone” individuals, who did not follow the evacuation order, to burglarize unprotected residences of individuals, who evacuated. No mandatory evacuation order was issued for Hurricane Katrina.

1. INTRODUCTION

The city of Houston, TX has a high number of crimes. Between 1999 and 2005, the yearly totals ranged between 130,000 and 150,000, with crimes moderately increasing during this time period. This paper investigates the impact that natural disasters, specifically hurricanes have on the spatial and temporal distributions of crimes. In general, it is believed that crime generally trends downward during the recovery stage, with the exception of domestic violence (Tucker, 2001; Enarson, 1999), and gradually returns to pre-disaster levels during the reconstruction stage (Leitner et al., 2011). The downward trend during the recovery stage is due in part to emergent pro-social behaviors which create an atmosphere of altruism among the members of the community (Drabek and McEntire, 2003; Quarantelli, 1970). Cromwell et al. (1995) refers to this behavior as informal guardianship. It is speculated that in the case of post-Katrina New Orleans, the presence of a large number of National Guard troops and the influx of billions of dollars in governmental aid have contributed to the reduction in crime rates, as well (Roman, Irazola, and Osborne, 2007). After some time, the altruism of the community fades away and crime returns to pre-disaster levels (Bailey, 2009). One phenomenon that has attracted much attention in the literature is whether (extensive) looting occurs during the emergency stage of a disaster. Some researchers argue that the belief that citizens will begin looting simply because the opportunity presents itself in the wake of a disaster is a myth and largely promulgated by media reports (Sunseri, 2005; Quarantelli, 1970; Wenger and Friedman, 1986). In contrast, other researchers believe that looting following a domestic disaster is not a myth (Frailing and Harper, 2007) or found support both for and against the “looting myth” (Manusinghe, 2007).

Until today, just a handful of empirical studies exist that have tested whether the different theories expressing the relationship between crime and natural disaster can be supported. Of those quite a few have investigated the impact of Hurricanes Katrina and Rita on crime in New Orleans, or other major cities directly “hit” by either one or both hurricanes (e.g., Houston) and/or receiving large numbers of New Orleans evacuees (e.g., Atlanta, Baton Rouge, Houston, etc.) (Leitner et al., 2011). Of all studies, most of them are small-scale, time-series analysis, usually covering a multi-year time period, focusing exclusively on a single urban neighborhood. One exception is the study by Bass (2008) which compared crime trends in New Orleans with crime trends in ten major evacuation cities and ten other cities of similar size that did not receive large numbers of evacuees from New Orleans after Hurricane Katrina. In addition, the focus of empirical studies is on one crime type, only (VanLandingham, 2007, 2008; Frailing and Harper, 2007) or on several different crime types (Leitner and Helbich, 2009; Lawton and Schulenburg, 2007; Cromwell et al., 1995; Bailey, 2009; Wenger and Friedman, 1986; Munasinghe, 2007; Suar and Kar, 2005). Most studies discuss changes in crime during the emergency and reconstruction stages with the length of both stages depending on the severity of the disaster. According to Kates et al. (2006) the emergency stage for New Orleans after Katrina is the longest on record at six weeks, while the reconstruction stage is predicted to last for about eight to eleven years. The empirical study by Leitner et al. (2011) is the only large-scale study to date that investigates the relationship between one specific natural disaster (Hurricane Katrina) and crime in both urban and rural parishes (of Louisiana). The same study also discusses violent and non-violent crime trends (temporally and spatially) during the four stages of a disaster in both the hardest hit areas (Orleans Parish

and neighboring parishes) and areas outside this disaster zone receiving (large numbers of) evacuees.

2. STUDY AREA AND DATA

The study area comprises of the jurisdiction of the Houston Police Department (HPD), which is located inside Harris County, one of 254 counties in the state of Texas. Crime data for this study area were downloaded from the Houston Police Department (HPD) website (<http://www.houstontx.gov/police/cs/stats2.htm>). The HPD is one of the ten largest police departments in the U.S., serving a population of over two million residents, and covering an area of approximately 600 square miles. Over 5,500 sworn full-time police officers and over 1,500 non-sworn full-time employees work for the HPD (Lawton, 2007).

Crime data were downloaded for the entire months of August, September, and October 2005. This time period covered several weeks before, during, and after the landfall of both Hurricane Katrina (August 29th) and Hurricane Rita (September 24th). The data included the offense date and time, offense type, police beat, and the address of the offense at the street block level. This allowed the geo-coding of crime locations using the TIGER (Topologically Integrated Geographic Encoding and Referencing system) street network data available from the U.S. Census website (<http://www.census.gov/geo/www/tiger/index.html>). Of the total number of crimes (26,746) that occurred during the three-months time period, 25,092 (93.8%) were successfully geo-coded. As expected, the geo-coding rate varies by police district and ranges from a high of 100% to a low of 77%.

When creating a time series of daily crime totals for the three-months time period for all ten crime types reveals an intriguing feature - a significant spike in burglaries contemporaneous with the largest ever mandatory evacuation in Houston's history due to the approaching Hurricane Rita. Recall that Hurricane Rita made landfall on Sept 24. The significant increase in burglary cases lasted four days. It started on September 21 with 251 burglaries, reached a high of 428 burglaries on September 22, decreased to 200 burglaries on September 23, decreased further to 135 burglaries on September 24 and returned to pre-hurricane levels on September 25 with 67 burglaries. A second minor spike is also apparent for auto thefts with a high of 75 cases on September 22. All other crime types show a slight decrease in daily totals during the evacuation period for Hurricane Rita. In contrast, no mandatory evacuation order was issued for Hurricane Katrina; this maybe the main reason that no apparent change in the daily totals for any of the ten crime types can be observed before, during, and after Hurricane Katrina made landfall on August 29 (Leitner and Helbich, 2009). The spatial distribution of the three crime types (burglary, burglary of motor vehicle, and auto theft) for the three-months time period is shown in Figure 1. While the spatial patterns of all three crime types seem to be similar, a visual interpretation and comparison is clearly limited.

3. METHOD

During the past few years, geographic information systems (GIS) and spatial statistical methods, including spatial cluster methods, have become increasingly important in spatial crime analysis (Eck et al., 2005). A variety of explorative and inferential methods exist for the analysis of spatio-temporal crime patterns for spatial point distributions. Such patterns include global statistics (e. g. Knox, 1964, Mantel, 1967, Diggle et al., 1995), which evaluate the point pattern across the entire study area and local methods (e. g. Kulldorff and Nagarwalla, 1995; Kulldorff, 1997; Kulldorff et al., 1998), which allow to detect and quantify individual spatio-temporal cluster. In the following, only local techniques are first introduced and subsequently applied to the crime data set from Houston.

Kulldorff's scan statistic is a state-of-the-art method for the detection and evaluation of spatial, temporal, and spatio-temporal clusters (Kulldorff, 1997; Kulldorff et al., 1998). Many applications can be found in the medical profession, especially epidemiology, with the focus on the identification of purely spatial clusters. Fewer applications have used the spatio-temporal scan statistic (Kulldorff et al., 1998). Examples are Kulldorff et al. (1998), Elias et al. (2006), and Gaudart et al. (2006). While few applications of the scan statistic to model spatial clusters in criminology exist (e.g. Jefferis, 1998; Ceccato & Haining, 2004; Ceccato, 2005), we do not know of any examples in the criminology literature using the spatio-temporal scan statistic to identify spatio-temporal crime clusters. In general, Kulldorff's statistics are popular because they can be adapted to different data types and distributions (Kulldorff, 1997). The following discussion focuses on the scan statistic with a spatio-temporal permutation model (Kulldorff et al., 1998; Kulldorff et al., 2005).

The input data for this model are the coordinates of the crime locations and their time stamps. The scan window is a three-dimensional cylinder with the base area representing the spatial dimension and the height the temporal dimension. During the analysis, the cylinder moves from one crime location to the next and continuously changes the radius of the base area and its height. This results in a large number of differently-sized overlapping cylinders, for which the observed number of crime locations are compared with the expected number of crime locations using a spatio-temporal permutation model. The number of expected crime locations is estimated with a Poisson distribution. A spatio-temporal cluster is identified by a cylinder that includes a significantly larger number of observed crime locations than would be expected by chance for a certain time period. The statistical significance of each cluster is determined by a Monte Carlo simulation. One point of criticism comes from Tango und Takahashi (2005), who argue that most geographic clusters are not circular. This resulted in the extension of the method to an elliptical scan window (Kulldorff et al., 2006) and the implementation of alternative statistics (Tango & Takahashi, 2005). Further details about this method can be found in Kulldorff and Nagarwalla (1995), Song & Kulldorff (2003), or Kulldorff et al. (2004).

4. RESULTS

In this study a cylinder with circular base area was used as the scan window. The temporal unit was one day, although a more precise time stamp (minutes and hours) was provided in the original crime data. The coarser temporal unit (day) was chosen because the computing time with a finer temporal unit would have been too long. For example, the computing time was 94 hours for burglaries using a Dell Optiplex 745 Computer with Intel Core 2 CPU 6400, 2.13 GHz, 2 GB DDR2 RAM. The maximum size of the circular base area of the cylinder was set to 50% of the expected crime locations. Similar, the maximum time length was set to 50% of the entire observed time period from August 1 to October 31. All levels of significance are based on 999 Monte Carlo simulations.

In general results show that all crime patterns exhibit a different and heterogeneous spatio-temporal behavior. For burglaries and burglaries of a motor vehicle the highest number of significant spatio-temporal clusters was found. For this reason the focus of the following interpretation is on these two crime types. Of the 24 spatio-temporal clusters found for burglaries, four had a level of significance of $p < 0.1$ (Figure 2 and Table 1). All clusters are dominated by the large Cluster C1 ($p = 0,001$) located in the (north) eastern part of the study area. In contrast, the other three significant clusters, C2-C4, are much smaller and located in the center and western part of Houston. Cluster C1 lasts from September 21 to 27, which covers exactly the time-period from one day before and several days after Hurricane Rita hit the city of Houston on September 22 2005. The neighborhoods falling inside this cluster can be described as mostly African-American (northern part) and Hispanic (southern part) (Leitner and Helbich, 2009).

Spatio-temporal clusters for the theft of motor vehicle shows a pattern that is quite different from burglaries. While more spatio-temporal clusters (45) and clusters that are significant (8 with $p < 0.1$) were found, none was as large and dominant as burglary cluster C1. Most of the significant clusters for the theft of motor vehicle are located in the center of the study area, where the percentage of the white population is high (80% of higher) (Leitner and Helbich 2009). The primary cluster C1 and secondary clusters C3-C5 can mostly be found along the Southwest Freeway and Highway 59. Hurricane Katrina that hit Houston on August 29 2005 did not have any effect on cluster creation. All significant clusters lasted just a few days and were formed almost two weeks before or more than one week after Hurricane Katrina (Table 1). The only significant cluster during the mandatory evacuation of Houston due to the approaching Hurricane Rita was cluster C4. This cluster is located almost in the center of the study area and lasted from September 22 to 25. A more detail study needs to be conducted to find out whether or not this cluster was directly related to the mandatory evacuation. An analysis of auto thefts revealed that while there was an overall increase in the total number of auto thefts when Hurricane Rita hit Houston, no significant spatio-temporal clusters were found for that same time period (Table 1). To sum up, the different crime types show a clear and distinct spatio-temporal pattern of clusters with little spatial overlap. This raises the question of the existence of spatio-temporal "crime niches" in Houston.

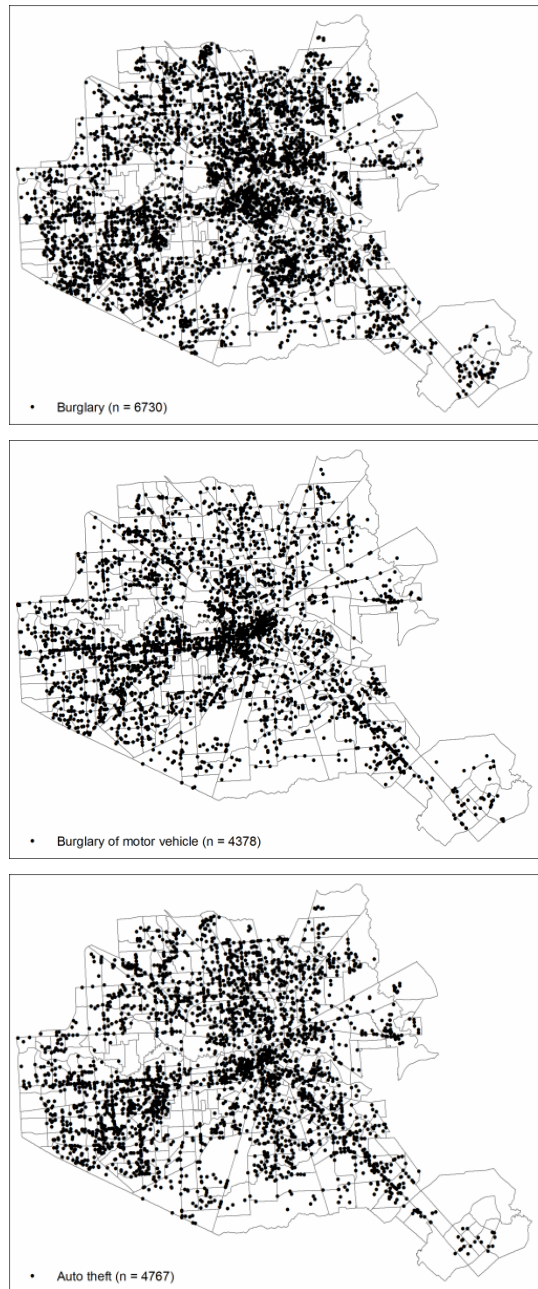


Figure 1. Spatial distribution of three selected crime types from August 1 2005 and October 31 2005 (adapted from Helbich and Leitner, 2010)

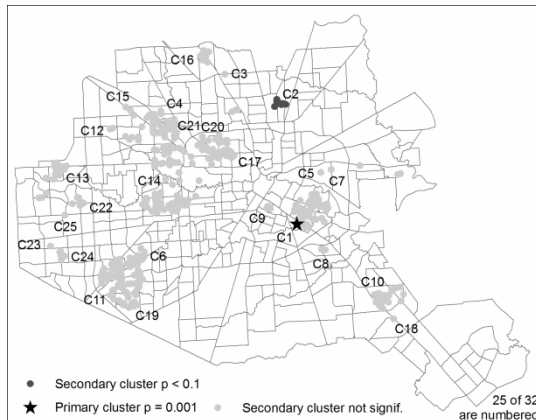
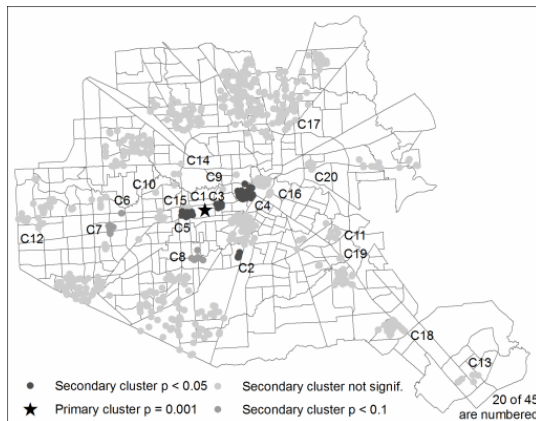
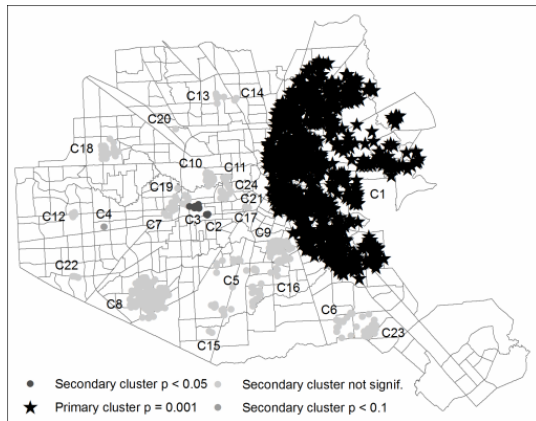


Figure 2. Spatio-temporal crime clusters of three selected crime types from August 1 2005 and October 31 2005 (Top: Burglary; Middle: Burglary of a motor vehicle; Bottom: Auto theft) (adapted from Helbich and Leitner, 2010)

Crime Type	Cluster ID	Time Period	p
Burglary (n = 6,730)	C1	9. 21. - 9. 27.	0.001
	C2	10. 10.	0.012
	C3	9. 9.	0.018
	C4	8. 15.	0.051
Burgl. of motor vehicle (n = 4,378)	C1	8. 13. - 8. 14.	0.001
	C2	9. 20. - 9. 21.	0.001
	C3	9. 12. - 9. 13.	0.002
	C4	9. 22. - 9. 25.	0.002
	C5	9. 26. - 9. 28.	0.048
	C6	9. 29. - 9. 30.	0.061
	C7	10. 16. - 10. 19.	0.070
	C8	9. 8. - 9. 13.	0.099
Auto theft (n = 4,767)	C1	8.1.	0.001
	C2	9.12. - 9.13.	0.007

Table 1. Selected results from spatio-temporal scan statistic

5. SUMMARY

This paper investigates the influence that Hurricanes Katrina and Rita had on the spatio-temporal distribution of crime clusters in the city of Houston, TX. The results show that the distribution of all crime types possesses a spatio-temporal heterogeneous behavior. The most spatio-temporal clusters were found with burglaries and burglaries of motor vehicles. The most dominant cluster for burglaries lasted from September 21 to 27, which covers the time-span just a few days before and after Hurricane Rita. This cluster is located in the (north) eastern part of Houston, which is predominantly African American and Hispanic. One explanation for the creation of this cluster is that despite the issue of a mandatory evacuation before the landfall of Hurricane Rita, few inhabitants did not evacuate. Instead, crime prone individuals, who did not follow the evacuation order, burglarized the temporarily “unprotected” homes of evacuees. This assumption is supported by an important concept from environmental criminology (Brantingham and Brantingham, 1981) which states that the number of crimes decreases with increased distance from the offender’s anchor point (i.e., the offender’s residence). This relationship can be shown with a distance-decay curve and it has been empirically proven many times. Not a single significant spatio-temporal crime cluster is found for Hurricane Katrina. This may have to do with the fact that no mandatory evacuation order was issued before the landfall of Hurricane Katrina. The results of this empirical study are important for law enforcement for proactive planning and resource distribution in the preparation for a natural disaster.

REFERENCES

Bailey, K. L., 2009. An evaluation of the impact of Hurricane Katrina on crime in New Orleans, Louisiana. Unpublished Applied Research Project for a Masters of Public Administration, Department of Political Science, Texas State University, San Marcos, TX.

- Bass, L., 2008. A pooled time series analysis of Hurricane Katrina evacuees and their effect on crime rates. Paper presented at 66th Midwest Political Science Association Annual National Conference, Chicago, IL, April 3-7 2008 (http://www.allacademic.com/meta/p266793_index.html) (accessed 31 August 2010).
- Brantingham, P. J., and P. L. Brantingham, (Eds.), 1981. *Environmental Criminology*. Sage, Beverly Hills, CA.
- Ceccato, V. and R. Haining, 2004. Crime in border regions: The Scandinavian case of Öresund, 1998-2001. *Annals of the Association of American Geographers*, 94, pp. 807-826.
- Ceccato, V., 2005. Homicide in São Paulo, Brazil: Assessing spatial-temporal and weather variations. *Journal of Environmental Psychology*, 25, pp. 249-360.
- Cromwell, P., Dunham, R., Akers, R., and L. Lanza-Kaduce, 1995. Routine activities and social control in the aftermath of a natural catastrophe. *European Journal of Criminal Policy and Research*, 3, pp. 56-69.
- Diggle, P., Chetwynd, A., Häggkvist, R., and S. Morris, 1995. Second-order analysis of space-time clustering. *Statistical Methods in Medical Research*, 4, pp. 124-136.
- Drabek, T. E., and D. McEntire, 2003. Emergent phenomena and the sociology of disaster: Lessons, trends and opportunities from the research literature. *Disaster Prevention and Management: An International Journal*, 12(2), pp. 97-112.
- Eck, J., Chainey, S.P., Cameron, J., Leitner, M., and R. Wilson (eds.), 2005 *Mapping Crime: Understanding Hotspots*. Washington DC: National Institute of Justice.
- Elias, J., Harmsen, D., Claus, H., Hellenbrand, W., Frosch, M., and U. Vogel, 2006. Spatiotemporal analysis of invasive meningococcal disease, Germany. *Emerging Infectious Diseases*, 12, pp. 1689-1695.
- Enarson, E., 1999. Violence against women in disasters. *Violence Against Women*, 5 (7), pp. 742-68.
- Frailing, K., and D. W. Harper, 2007. Crime and hurricanes in New Orleans. In: *The Sociology of Katrina: Perspectives on a Modern Catastrophe*, ed. D. L. Brunnsma, D. Overfelt, and J. S. Picou, Rowman & Littlefield Publishers, Landham, MD, pp. 51-68.
- Gaudart, J., Poudiougou, B., Dicko, A., Ranque, S., Toure, O., Sagara, I., Diallo, M., Diawara, S., Ouattara, A., Diakite, M. and O. Doumbo. 2006. Space-time clustering of childhood malaria at the household level: A dynamic cohort in a Mali village. *BMC Public Health*, 6, p. 286.
- Helbich, M. and M. Leitner, 2010. Auswirkungen der Hurrikans Katrina und Rita auf raum-zeitliche Kriminalitätscluster in Houston, TX. Ein Scan Statistik Ansatz. In Strobl, J., T. Blaschke & G. Griesebner (eds): *Applied Geographic Information Technology XIV*. Herbert Wichmann, Heidelberg, pp. 50-59.
- Jefferis, E., 1998. A multi-method exploration of crime hot spots: SaTScan results. National Institute of Justice, Crime Mapping Research Center.
- Kates, R. W., Colten, C. E., Laska, S., and S. P. Leatherman, 2006. Reconstruction of New Orleans after Hurricane Katrina: A research perspective. *PNAS*, 103(40), pp. 14653-14660.
- Knox, E., 1964. The detection of space-time interactions. *Applied Statistics*, 13, pp. 25-29.
- Kulldorff, M., 1997. A spatial scan statistic. *Communications in Statistics: Theory and Methods*, 26, pp. 1481-1496.
- Kulldorff, M., and N. Nagarwalla, 1995. Spatial disease clusters: Detection and inference. *Statistics in Medicine*, 14, pp. 799-810.
- Kulldorff, M., Athas, W., Feuer, E., Miller, B., and C. Key, 1998. Evaluating cluster alarms: A space-time scan statistic and brain cancer in Los Alamos. *American Journal of Public Health*, 88, pp. 1377-1380.
- Kulldorff, M., Zhang, Z., Hartman, J., Heffernan, R., Huang, L., and F. Mostashari, 2004. Evaluating disease outbreak detection methods: Benchmark data and power calculations. *Morbidity and Mortality Weekly Report*, 53, pp. 144-151.
- Kulldorff, M., Heffernan, R., Hartman, J., Assunção, R. and F. Mostashari, 2005. A space-time permutation scan statistic for the early detection of disease outbreaks. *PLoS Medicine*, 2, pp. 216-224.
- Kulldorff, M., Huang, L., Pickle, L., and L. Duczmal, 2006. An elliptical spatial scan statistic. *Statistics in Medicine*, 25, pp. 3929-3943.
- Lawton, B. A., and J. Schulenburg, 2007. Assessing the impact of Hurricane Katrina on space-time clusters of crime patterns in Houston. Paper presented at *Ninth Crime Mapping Research Conference*, Pittsburgh, PA, March 28-31 2007.
- Leitner, M., and M. Helbich, 2009. Analyzing, modeling and mapping the impact of Hurricanes Katrina and Rita on the spatial and temporal distribution of crime in Houston, TX. *Proceedings of the Geoinformatics Forum Salzburg*. Herbert Wichmann Verlag, Heidelberg, pp. 110-19.
- Leitner, M., Barnett, M., Kent, J., and T. Barnett, 2011. The impact of Hurricane Katrina on reported crimes in Louisiana – A spatial and temporal analysis. In: LeBeau, J. L., and M. Leitner (eds.) *Spatial Methodologies for Studying Crime*. Special Issue of *The Professional Geographer* (forthcoming).
- Mantel, N., 1967. The detection of disease clustering and a generalized regression approach. *Cancer Research*, 27, pp. 209-220.
- Munasinghe, M., 2007. The importance of social capital: Comparing the impacts of the 2004 Asian Tsunami on Sri Lanka, and Hurricane Katrina 2005 on New Orleans. *Ecological Economics*, 64(1), pp. 9-11.

Quarantelli, E., and R. Dynes, 1970. Property norms and looting: Their patterns in community crisis. *Phylon*, 31(2), pp. 168-182.

Roman, C., Irazola, S., and J. W. L. Osborne, 2007. After Katrina: Washed away? Justice in New Orleans. *Urban Institute Research Report*. August: 1-15. (http://www.urban.org/UploadedPDF/411530_washed_away.pdf) (accessed 31 August 2010).

Song, C. and M. Kulldorff, 2003. Power evaluation of disease clustering tests. *International Journal of Health Geographics*, 2.

Suar, D., and S. Kar, 2005. Social and behavioral consequences of the Orissa Supercyclone. *Journal of Health Management*, 7(2), pp. 263-274.

Sunseri, S., 2005. *Review of literature on response behaviors in overseas disaster events*. Opus International Consultants Limited. Gracefield, New Zealand. (<http://www.resilience.org.nz/O2%20M1%20Review%20FINAL.pdf>) (accessed 31 August 2010).

Tango, T. and K. Takahashi, 2005. A flexibly shaped spatial scan statistic for detecting clusters. *International Journal of Health Geographics*, 4.

Tucker, E., 2001. Crime and disaster. *Business Recovery Managers Association Newsletter*, 12, 2.

U.S. Census Bureau, 2007. Population estimates program. Online documentation: <http://www.census.gov/popest/estimates.php>. Washington, DC (accessed 31 August 2010).

VanLandingham, M. J., 2007. Murder rates in New Orleans, LA, 2004-2006. *American Journal of Public Health*, 97(9), pp. 1614-1616.

VanLandingham, M., 2008. 2007 Murder rates in New Orleans, Louisiana. *American Journal of Public Health*, 98(5), 776-777.

Wenger, D., and B. Friedman, 1986. Local and national media coverage of disaster: A content analysis of the print media's treatment of disaster myths. *International Journal of Mass Emergencies and Disasters*, 4(3), pp. 27-50.