Using Building Permits to Monitor Disaster Recovery:
A spatio-temporal case study of coastal Mississippi following Hurricane Katrina

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ABSTRACT: The pace of disaster recovery can vary considerably from one place to another even when those places suffer impacts from the same event. Unfortunately, most recovery studies lack the spatial and temporal resolution to fully understand the processes of built environment recovery. This paper discusses the use of a spatial scan statistic for the identification of spatial and temporal dimensions of recovery using building permits issued in Mississippi following Hurricane Katrina. Significant space-time and purely spatial clusters are identified using this method. The research suggests that the amount of damage experienced by an area affects the timing and location of building permit clusters and that other factors related to underlying socio-economic and demographic characteristics of a place may also play a role in recovery of the built environment.

KEYWORDS: Building permits, SaTScan, Hurricane Katrina, disaster recovery, rebuilding, Gulf Coast

Introduction

Recovery from a natural disaster is a dynamic and multifaceted process, yet we lack basic information about the recovery process itself, the spatial and temporal variability of recovery from disaster events, and the drivers behind the processes that are taking place. The inability of most methods to provide information about the pace and progression of recovery leads to the problematic conclusion that recovery is spatially uniform and consistent from one time period to another (Cutter et al. 2006; Zottarelli 2008).

One past model (Kates and Pijawka 1977) suggests that long term recovery of the Gulf Coast following Hurricane Katrina could take approximately 11 years. Within that time several billion dollars of aid and countless hours will be spent rebuilding the damaged structures and community institutions impacted by the storm. While many studies following Hurricane Katrina have revealed recovery disparities driven by class and gender, few methods or metrics are capable of capturing trends of recovery throughout the entire spatial extent and over several years of the recovery period (Cutter et al. 2006; Elliott and Pais 2006; Kates 2006; Zottarelli 2008). However, following a disaster with the magnitude of Katrina, it is important to understand how long-term recovery is manifested within an affected landscape and to uncover the physical, social, and political drivers of recovery and how they shift through space and time.

This paper implements a spatial scan statistic, SaTScan, to examine the space-time trends of built environment recovery following a natural disaster. Scan statistics are a common tool used to determine if points are randomly distributed in space and time, or if they are clustered (Kulldorff, 1997). This research specifically investigates the spatial and temporal patterns of building permits issued in three municipalities on Mississippi's Gulf Coast following 2005's Hurricane Katrina. The spatial-temporal relationships between permits issued, damage amounts, and the pre-event number of housing units in the affected area forms the base of this inquiry. We question whether spatial and temporal clusters of building permits, if they exist, are related to certain damage level or pre-event housing categories. Through this method we demonstrate an improvement in our understanding of the uneven progression of recovery following a disaster by outlining a replicable process using publicly available data and statistical analysis tools.

What is Recovery?

A recent review of Hurricane Katrina research focused on human systems (Erikson and Peek 2009) identified 87 articles related to post-disaster recovery since the storm. Of these, 40 were published in 2006, 32 in 2007, and 11 in 2008. This decline shows perhaps a waning interest in understanding recovery trends over time, but more importantly it demonstrates that temporally sensitive data gathering and monitoring, clearly necessary for understanding trends in recovery from disaster, is falling off as well.

Defining what recovery is and means for affected communities is fundamental to finding appropriate ways to measure it. Recovery varies depending on the context of the disaster, the level of impact and extent of the damage, and the pre-event conditions (Bates & Peacock 1989; Quarantelli 1999). Within the literature the term recovery has been used interchangeably with rebuilding, restoration, and redevelopment (Mileti 1999; Quarantelli 1999). These terms, however, are inadequate when trying to generalize about community recovery as a process, one that that includes infrastructure, the environment, institutions, and society.

In addition to physical destruction and disruption, disasters interrupt the highly connected social fabric of communities (Bolin 1976). While some of the literature addresses recovery as a multi-dimensional concept from a theoretical perspective, few researchers approach case studies with the goal of measuring all aspects of recovery. Most case studies of recovery fall into one of five broad themes of recovery: (1) psycho-social; (2) institutional; (3) economic and business; (4) built environment, (5) natural environment. The first, psycho-social recovery, includes studies such as recovery of individuals from stress-disorders caused by the event or the re-establishment of interfamilial roles following a disaster (Kenardy et al. 2000; Gault 2005; Bolin 1976). The second, institutional recovery, addresses the reestablishment and functioning of governmental systems, schools, hospitals, and others that aid communal functionality post-disaster (Rubin and Barbee 1985). The third theme, economic and business recovery, examines specific industries in an affected area, such as Chang's (2000) study of the recovery of the port economy following the 1995 Kobe earthquake in Japan. Broader city or region-wide recovery of all business types have also been conducted (Nigg 1995; Tierny 1997; Webb et al. 2002). The fourth theme, recovery of the built environment, such as regaining the numbers of pre-storm housing and transportation infrastructure, is arguably the most commonly addressed in governmental and institutional reports of disaster recovery (Liu and Plyer 2009; McCarthy and Hanson 2008). Recovery of the built environment is necessary as a precursor to most other recovery processes and the relatively easy acquisition of useful data (e.g.: census data, tax records) likely accounts for the greater representation of work in this area. The final theme, recovery of the natural environment, such as forest re-growth and habitat renewal, is characterized very differently from the previous themes (e.g. the recovery of forest ecosystems damaged by a hurricane) (Walker 1991; Orr and Ogden 1992). Although recovery of the natural environment may be linked to other types of recovery, especially economic recovery of communities that rely on eco-tourism, it is generally not addressed in the hazards literature. Analysis of natural environment recovery uses a separate body of tools rooted in geology, biology, and the environmental sciences than those used to measure recovery of human systems. While individual studies may focus on a particular aspect of recovery, it is important to recognize that every type of recovery is linked to the human system and is therefore connected to and at least partially representative of the recovery process as a whole.

A fundamental disagreement within much of the disaster recovery literature, regardless of the type of recovery being examined, is whether recovery means returning to a stable state following a disaster, returning the affected area to pre-event conditions, or whether recovery necessitates an adaptation or betterment process (Bates and Peacock 1989; Mileti 1999; Quarantelli 1999; Kates et al. 2006; Anderson 2007; Alesch et al. 2008). For example, Rubin and Popkin (1990) describe a model of recovery that reconciles both the view of recovery as a return to normalcy and as a betterment process. However, this model does not clarify or quantify spatial or temporal differences in the recovery process. Recent research emphasizes the need to integrate betterment processes throughout disaster recovery, assess vulnerability issues that may have exacerbated the effects of the disaster, and use the recovery period following a disaster as an opportunity to address other preexisting social issues (Cutter et al. 2006; Kates et al. 2006; Olshansky 2006).

Measuring Recovery

Various studies have attempted to conceptually understand the drivers of recovery or qualitatively and quantitatively measure how much recovery has occurred in an affected area. Measuring recovery in social systems is often approached with interviews and field observations (Rodriguez et al. 2006; Runyan 2006). Physical and spatial indicators of recovery – changes to the built environment – have been assessed through surveys, geographic information systems, and other analysis and visualization techniques, including aerial and satellite photography, and spatial video acquisition systems (Laben 2002; Curtis et al. 2007; Liu and Plyer 2009). Unfortunately, many of these data sources only provide a snapshot of recovery at certain points in space and time, or through the lens of a select sample of research participants and do not take into account the underlying spatial and temporal interactions between the drivers and outcomes of the recovery process itself.

The type of recovery assessed (i.e.: social or physical), the methods of measurement utilized, and how results are interpreted have practical implications. Conclusions from these studies can influence how priorities for further recovery of an affected area are set, and whether and how improvements should be pursued. Therefore, it is important to understand how different methods can lead to varying conclusions and interpretations about the progress of recovery following a disaster.

Qualitative methods, such as interviews and field observations, are context based verbal and visual descriptions of phenomena. These methods can provide rich observation-based data and are better than quantitative methods for assessing individual case information. Qualitative methods are helpful for understanding the questions of “how” and “why,” such as why disasters affect people and impact the social constructs within a community in different ways (Johnson and Onweugbuzie 2004).

Interviews have been used to evaluate the perceptions and recovery experiences of disaster victims from different race, gender, and income backgrounds. For example, Bolin (1986) interviewed victims of the devastating Paris, Texas tornadoes (1982) to better understand differences in the perception of both economic and emotional recovery of black and white residents. In this case, interviews revealed the way resources were shared differently within racial groups and the types of aid that were more or less likely to be accessed depending on race.

Similarly, emotional recovery, due to its deep contextual nature and individual nuances, is better assessed using qualitative methods. Rodriguez et al. (2006) utilized extensive field observations to describe emergent prosocial behavior and its effects on disaster response and early stages of recovery following Hurricane Katrina. Their work contradicts a common belief that antisocial behavior is the dominant social force following a disaster and calls into question the necessity of command-and-control management following disasters. Although these and related methods can provide a deeper understanding of how and why communities utilize certain tools or aid sources, form social networks, and interact following a disaster, this type of data can often take longer to collect and analyze than many forms of quantitative research.

Quantitative methods provide relatively objective assessments of recovery that are more easily analyzed numerically – lending themselves well to analysis within and across different geographic areas. Quantitative data is often better for assessing the recovery of physical environments, understanding the statistical significance of relationships, and can be used to assess the validity of constructed theories (Johnson and Onweugbuzie 2004).

Surveys are a common quantitative tool which, like qualitative methods, can be used to assess perceptions, emotions, and social interactions. While surveys do not provide the contextual depth of an interview, they can reach a larger number of participants and provide data that is more easily analyzed statistically. Webb et al. (2002) used surveys to measure long-term business recovery. Both physical recovery (e.g. whether or not a business sustained physical damage) and economic recovery (e.g. whether businesses had reopened following the disaster and how their income had been affected) were investigated as was the business owners’ perception of the broader economic climate following disaster.

The most basic quantitative analyses, and those most often reported by government agencies and aid organizations, are simple numerical comparisons of pre- and post-event conditions. Examples include measuring household recovery by identifying when a home value returns to its pre-event level or comparing the number of housing units that have been rebuilt to what was in place before the event (Jaycox et al. 2006). These simple numeric approaches can provide useful measures of demographic trends and physical recovery post-disaster.

An extension of these quantitative comparisons is the development of recovery indices. Indices more formally compare recovery to a data baseline in order to track the progress of recovery. The New Orleans Index reports extensively on several recovery indicators including population recovery, the amount and location of new construction and repairs, housing and employment vacancy rates, school enrollment, retail sales, and the availability of schools, libraries, and childcare (Liu and Plyer 2009). Despite their ability to reflect several types of recovery, an accurate portrayal of recovery can be elusive as these indices cannot answer the important question of *why* certain recovery trends are occurring.

Other important tools include using aerial photography, remote sensing, and geographic information systems (GIS) to assess the progression of recovery following a disaster. To date, these tools have generally been developed for data gathering in support of immediate response efforts and for preliminary damage assessment damage. However, as geospatial techniques continue to evolve they are used increasingly in recovery management and assessments, as well as mitigation and preparedness activities. While generally restricted to physical environment monitoring at present, these techniques can produce results that can be extrapolated to serve as indicators of other types of recovery. For example, QuickBird Satellite Imagery was used following the 2003 Algerian earthquake for assessing built environment recovery progress as well as determining the distribution of resources (Adams et al. 2003). Laben (2002) promoted GIS and remote sensing as a useful tool for informing emergency managers and decision makers about the progress of built environment recovery in order to help formulate budgets and refocus recovery efforts on the areas with the most need. GIS mapping can take a step beyond the collection of visual indicators of recovery by overlaying and analyzing several layers of information such as the spatial and temporal distribution of rebuilding, the level of disaster impacts, and demographic information (Jarmin and Miranda 2006). With accurate and timely data, GIS and visual imaging tools can provide insight into how far recovery of the built environment has come, where it is and is not occurring, and how trends change throughout the recovery period and across the landscape. Importantly, these tools may need to be supplemented by survey or qualitative information in order to draw more accurate conclusions about the drivers of recovery patterns and findings produced should be interpreted within the limits of the technology.

Methods

Creating useful information from spatial data is an important step toward the development of effective policies for disaster reduction. Utilizing building permit data as a surrogate for built environment recovery is a multi-step process which includes data collection, cleanup and standardization, and geocoding in advance of any analysis. This process, along with an overview of the study area and other data used in this research, is explained in the following sections.

Study area

Hurricane Katrina struck the U.S. Gulf Coast on August 29, 2005 and caused substantial damage and loss of life in Alabama, Mississippi, and Louisiana from wind, flooding, and storm surge. The eye of the storm passed over Waveland and Bay St. Louis on the western side of the Mississippi coast. Approximately 60 percent of the housing stock in the three coastal counties of Mississippi suffered some level of damage (Jaycox et al. 2006). The three Mississippi cities referenced in this paper received some of the greatest and most direct impacts from the storm. These cities include Bay St. Louis in Hancock County, and Pass Christian and Long Beach in Harrison County (Figure 1). Table 1 summarizes some general characteristics of each municipality. Each differs considerably from the other in overall population size, racial composition, and median income.

FIGURE 1 HERE

TABLE 1 HERE

Data

A tremendous volume of data, both spatial and non-spatial in nature, was collected following Hurricane Katrina. Much of this data was considered perishable and reflects the activity during the immediate response period. Data collected solely within this limited time frame do not provide the information needed to analyze and understand spatial and temporal trends in long term recovery. Accordingly, this research utilized three types of data that provide the spatial and temporal resolution necessary for a more comprehensive understanding of the recovery process. These data are derived from local building permits, Federal Emergency Management Agency (FEMA) damage classification categories, and the 2000 U.S. Census of population and housing.

Building Permits

Building permits issued post-disaster represent a novel measure of physical recovery from the storm. Permits are issued in Mississippi by the Building Code Office or the Building and Development Department at either the city or county level. Permits are necessary to legally begin any construction, structural remodeling, utilities adjustments (including gas, electric, plumbing), demolition, or siting a mobile home. The permits typically include the name of the permit applicant, the street address where the work will be completed, the type of work being done, the approximate value of the work, the permit fee charged, and date the permit was issued.

Permit summaries were collected from Building and Development Offices as geospatially enabled databases, as Microsoft Excel spreadsheets, in digital portable document format (PDFs), or as images of paper permits from ten municipalities. These municipalities, in addition to data from Mississippi's three coastal counties, Hancock, Harrison, and Jackson, include Waveland, Bay St. Louis, Pass Christian, Long Beach, Gulfport, Biloxi, Ocean Springs, Gautier, Pascagoula, and Moss Point (Table 2). This paper presents a focused analysis of Bay St. Louis, Pass Christian, and Long Beach. The permits cover activity from August 2005 through December 2008. Building permits are recorded daily and the work outlined in the permit must be initiated within 60-90 days of the issue date depending on the municipality's restrictions. This unique dataset is limited by the inability to confirm that the work was completed, the possibility of missing or incomplete date, and errors in either building valuation or the fee accessed for the permit (some municipalities did not charge for permits in the immediate aftermath of the storm). There is also no standard reporting format among the municipalities.

TABLE 2 HERE

Located within the public realm, building permit data can be obtained in several different ways. For this research we were able to receive digital data through telephone and email requests from two counties and three municipalities. The remaining jurisdictions either did not have the data digitally or had no way of sending the information in a computer-compatible format. A site visit to collect this information in paper format was necessary. In summary, the four data formats are paper permits that have not been made digital, scanned paper documents, digital reports, and geospatially enabled databases (Figure 2).

FIGURE 2 HERE

Latitude and longitude coordinates for each permit location were derived by using an address locator created in ESRI's ArcCatalog. Approximately 90 percent of all permits geocoded successfully. Those that did not geocode to a known address were excluded from all further analysis. Each of the geocoded permits was subsequently assigned a unique identification number. Of 17,529 individual permits from the three focus communities, 15,896 permits geocoded successfully. A geocoded permit can be spatially joined to census data or damage categories for more detailed analysis. To avoid representing the same property multiple times with separate permits for different work types, this study utilizes 8,870 of the geocoded permits as this subset is exclusively building permits rather than permits for electricity, plumbing, or other construction-related tasks requiring a different (additional) permit.

Damage Categories

Each permit location was also classified by the level of damage. The damage assessment dataset (damage polygons) was developed by the National Geospatial-Intelligence Agency (NGA) for the Federal Emergency Management Agency (FEMA) response to Hurricane Katrina. Shortly after Hurricane Katrina, FEMA made ESRI shapefiles of the estimated damage within affected areas available for download via the internet. The damages assigned to each permit location are described as:

1. Limited Damage: Generally superficial damage to solid structures…some mobile homes and light structures are damaged or displaced.
2. Moderate Damage: Solid structures sustain exterior damage…some mobile homes and light structures are destroyed, and many are damaged or displaced.
3. Extensive Damage: Some solid structures are destroyed, most sustain exterior damage…most mobile homes and light structures are destroyed.
4. Catastrophic Damage: Most solid and all light or mobile structures are destroyed. (Jarmin and Miranda 2006, 2).

While thorough, the damage polygon dataset may not account for all damages in each place and averaging damage for an area may mean being unable to account for internal variability in the damaged area.

Census Data

Finally, a digital polygon shape boundary file representing census tracts from the 2000 U.S. Census was spatially joined to the permit address coordinate point file using ESRI ArcGIS 9.3. Five categories of housing concentration, as measured by the number of housing units in each census tract, were created using natural breaks in the data. The number of pre-event housing units was chosen as a baseline indicator under the supposition that more permits would be issued where more units existed prior to the storm. Spatial deviations from these areas might suggest a new trend of rebuilding not in the original threatened location, but rather in a newer location, possibly further from the coast. Each permit was associated with a housing unit category through a tabular join. The clusters were then analyzed by their composition relative to these categorical data.

Spatial Scan Statistic

Spatial Scan Statistic (SaTScan) version 8.0 (www.satscan.org) was used to identify clusters of permits in the study area throughout the entire study period (August 2005-December 2008). Some recent work has expanded the use of the freely available SaTScan software into hazards applications. For example, Vadrevu (2008) used SaTScan to analyze the significance of wildfire occurrence clusters in India while Witham and Oppenheimer (2005) evaluated historic mortality clusters in England following the 1783-84 Laki Craters eruption. However, SaTScan technology has not been utilized to track the progress of recovery from major disaster events. This is likely due to the historical lack of data with the level of spatial or temporal resolution needed to evaluate “clusters” of recovery.

SaTScan uses a scan statistic to analyze either spatial, temporal, or space-time point data (Abe et al. 2006). The software is useful for this study as it provides outputs in a format compatible with ESRI ArcGIS. The software makes no assumptions about if and where clusters exist. Once clusters are identified by SaTScan, they are tested for significance using a Monte Carlo test. The Monte Carlo statistic tests the significance (*p*-

value) of each cluster by comparing the maximum likelihood, or the likelihood that a cluster could have occurred randomly in the data set. For this study, only those clusters with the highest significance (0.001 chance of occurring randomly) are discussed. The analysis is conditioned by the total number of observed points to calculate an expected value. The number of points in each scan window is then compared against the expected value to identify areas with higher than expected concentrations of permits (Kulldorff 1997; Abe et al. 2006). The scan window is composed of thousands of overlapping cylinders, with the base of the cylinder scanning the spatial component of the data and the height of the cylinder scanning the temporal component. For each window, the expected number of cases is compared to the observed number of cases in order to identify where clusters might be occurring. The SaTScan output includes a list of all clusters, a list of the unique permit identification numbers associated with each cluster, the numbers of observed and expected cases, and the *p*-value for each cluster.

The space-time probability model was chosen as the statistical test for this dataset as knowledge of both where and when permit clusters occurred is important in understanding the progression of recovery (as measured by building reconstruction). Although permits are recorded daily, time was aggregated by calendar month in the analysis.

Results

Time-Space Clusters with Damage Categories

Combining SaTScan outputs with GIS visualization techniques begins to illuminate the association between building permits' spatial and temporal locations relative to factors such as storm damage and number of housing units per tract. The first SaTScan output describes significant spatial-temporal clusters of building permits. Seven significant clusters were found, with varying spatial and temporal distributions. These clusters are displayed with NGA Damage Categories (Figure 3) and Housing Unit Categories (Figure 4). NGA Damage Classifications are shapefiles of initial damage assessments based on remote sensing data gathered by the National Geospatial Institute (Jarmin and Miranda 2006). The data is meant to present a quick assessment of the distribution and severity of damage following a major disaster event.

For building permit analysis, only permit data, including the issue date of the permit and its location (latitude, longitude), were used in SaTScan. Additional categorical data, including the damage classifications and Census housing data, were not considered in the statistical analysis in order to locate the clusters based solely on their spatial and temporal characteristics. Therefore the clusters are the same for both analyses. The maps simply help visualize where clusters are found relative to damage and housing classes and provide a baseline for understanding the drivers behind the pace and distribution of rebuilding.

Each cluster identifies an area of higher than expected concentration of building permits. The first significant cluster is found within Bay St. Louis in the western portion of the study area. The radius of this cluster is 0.37km, and all of the permits were issued in May, 2008. SaTScan found 184 cases in this cluster when the expected number of cases was only 19. Six other clusters of housing permit allocation were found in the study area as well, all of which had a *p*-value of 0.001.

The identification of several significant clusters demonstrates that building following Hurricane Katrina did not occur evenly through space and time. It was our hypothesis that clusters may be explained, at least in part, by the level of damage experienced in the area where the cluster exists. Therefore, each building permit found in the cluster was assigned a damage classification as described in the above methodology. The results of this association are described in Table 3. Clusters are named by the municipality where they are located (while clusters can transcend political boundaries, all of the clusters found in this study were contained completely within municipal boundaries) and numbered in temporal order from earliest to most recent.

The level of damage in an affected area could influence the time when building occurs. For example, clusters which are located completely in areas classified as catastrophic damage (Long Beach 2 and Long Beach 3) do not occur until 2007, over a year and a half after Hurricane Katrina. Conversely, clusters occurring nearer to the time of the storm, including Long Beach 1, Bay St. Louis 1, and Pass Christian 1, are concentrated in the moderate to limited damage categories. Long Beach 1, a cluster composed of permits issued from September 2005-November 2005, is more diverse than the rest of the clusters in terms of distribution within different damage classifications, which indicates that in the three months following the storm there was rebuilding both within lesser damaged areas and catastrophically damaged areas in Long Beach.

FIGURE 3 HERE

TABLE 3 HERE

Time-Space Clusters with Housing Data

The pre-storm housing concentrations were also joined with each building permit by census tract to test the hypothesis that more building occurred in areas which had higher pre-storm housing concentrations. As seen in Table 4, only the Long Beach 2 cluster is composed of permits that land in the housing class with the highest number of housing units pre-storm (278-649 housing units per tract). Surprisingly, the tracts with the moderate to lower amounts of pre-storm housing tend to contain more of the building permit clusters. This may be attributed to the relatively low numbers of high category tracts. There are more census tracts that occur within the housing classes 1-3 than classes 4 and 5. However, it could be indicative of trends that go beyond simple housing concentrations, such as the desire of residents to move away from the hazard zone into areas away from the coast.

The Long Beach 1 cluster, as with the damage classification, is spatially dispersed throughout all housing classes. Building occurred in each housing class in this municipality, with the majority of permits found in class 2 (15-57 housing units per tract). While in Pass Christian there were portions of building clusters in every housing class throughout 2006 (Pass Christian 1 & 2), only the Long Beach 2 cluster occurs completely within the highest housing class. Additionally, this cluster does not occur until January 2007 indicating that, despite having a larger pre-storm population, recovery of the built environment in this area experienced barriers to rapid recovery in the year and a half directly following the storm.

Identifying and assessing the statistical significance of the relationships between pre-event housing and housing permit allocation (like the association between permits and damage classification) is outside of the scope of the current study. However, there do not appear to be clear relationships in space or time of building clusters with pre-event housing units. Therefore, it cannot be presumed that more rebuilding will occur where there had previously been more housing, and a vast number of different underlying physical, social, or political trends may be influencing the distribution of rebuilding in time and space.

FIGURE 4 HERE

TABLE 4 HERE

Space Only Clusters with Damage Categories

The same building permit data were assessed again in order to identify purely spatial clusters. The ordinal probability model, instead of the space-time scan, was utilized in SaTScan. The ordinal model located clusters using only spatial data. In a purely spatial scan, the issue date of each permit is not considered in the calculation of the most likely clusters. This was done to assess where the highest concentrations of issued permits were occurring throughout the entire study period. Additionally, in an ordinal model each permit is a case and each case belongs to one of several ordinal categories. For this analysis, those ordinal categories were damage classifications (assigned numerical values for statistical processing, 1 being limited damage and 4 being catastrophic damage). The model identifies clusters by searching for an excess of cases, considering damage classification as an additional attribute for association (Kulldorff et al. 2005).

The model identified six clusters which were significant, with *p*-values of 0.001. Note that the purely spatial clusters are distributed differently than the space-time clusters (Figure 5). Note that in Figure 5, Bay St. Louis 2 and Bay St. Louis 3 are presented together. They were identified by SaTScan as two distinct clusters, wit Bay St. Louis 2 existing on the western-most border of Bay St. Louis 3. These clusters are named for the municipality in which they are contained and then numbered from west to east since the time numbering does not apply for purely spatial clusters.

Independent of temporal variations in the allocation of permits there is more clustering in areas with moderate or limited damage. Table 5 indicates that only one cluster, Long Beach 1, is concentrated completely within the catastrophic damage class, while Bay St. Louis 2 and Pass Christian 1 are located completely within the moderate and limited damage classes respectively, and Bay St. Louis 1 is approximately 94 percent within the moderate damage class.

Bay St. Louis 3, which does not resemble the spatial location of any of the clusters in the space-time analyses, likely indicates an area which is experiencing a slow and steady rate of rebuilding over a longer period of time that was not captured by the space-time scan. This cluster is spatially distributed throughout the catastrophic, elevated, and moderate damage classes indicating again that it may take longer to rebuild in areas which have experienced catastrophic and extensive damage from disaster events. While substantial amounts of building may be occurring in this area, they will not be shown in a space-time cluster because the building is not temporally clustered. This finding points toward other underlying socio-economic, demographic, or political factors as impedances to long term recovery.

FIGURE 5 HERE

TABLE 5 HERE

Discussion

The application of spatial and temporal clustering analysis on building permit data for coastal Mississippi communities provides strong evidence of differential rebuilding across the study area. The identification of significant spatial and temporal clusters, using these methods, provides a new and novel approach to understanding long term rebuilding from disaster events. Additionally, the patterns observed in association with the damage categories demonstrate that with further examination the relationship between the levels of damage and where and when space-time clusters arise could be understood with greater clarity. Since areas within the catastrophic damage class do not completely contain building permit clusters until 2007 we can start to look more deeply into how limited access to catastrophically damaged areas following the storm could have slowed rebuilding. The likely higher amount of debris removal, demolition, and population recovery that needed to occur in areas experiencing catastrophic and extensive damage could cause rebuilding delays throughout the entire study period. Areas experiencing higher levels of damage may also have new building code requirements related to base flood elevations that could also decrease the number of people who are capable of rebuilding within a confined space and time. The lack of clusters in any specific geographic area does not indicate that no recovery was occurring in an area, only that it was spatially and temporally diffuse (or less than the expected statistical amount of recovery). These slower recovery areas could be explained by these and other “obstacles” linked to the relative damage.

In contrast to our original hypothesis, the majority of building clusters occur in areas with fewer housing units. Assuming that the relative distribution of housing units in each census tract remained constant between 2000 and 2005, more building is occurring in areas which had a smaller number of housing units before the storm. This could suggest trends of rebuilding in areas further from the coast that previously had a lower number of housing units. Further investigation and more temporally accurate data (2005 housing estimates) would provide a more comprehensive explanation of trends seen in the housing category data.

Additional information from the building permits can provide a more thorough understanding of the processes at work along the Mississippi Gulf Coast following Hurricane Katrina. As discussed above, only a portion of the available data was used in this analysis. Including additional data such as type of work, value of work, and value of housing would enable researchers to gain a more precise understanding of not only the spatial and temporal clustering of recovery, but also of the specific type of buildings and the value of buildings. This information could be linked to underlying data on pre-event housing stock, socio-economics, and demographics, providing a glimpse into who and what is being rebuilt. Additionally, the permits reveal that the types of buildings which constitute the clusters are often multi-family homes. The data indicate that the clusters of Bay St. Louis 1 & 2, Long Beach 2 & 3, and Pass Christian 2 in the space-time scan of building permits (Figures 2 and 3) consist primarily of very closely developed subdivisions or a collection of apartment buildings, with each unit requiring a different permit. This trend indicates that the largest surges of housing in the shortest amount of time occur when efforts are concentrated on large multi-family developments. While multi-family housing, which by its nature is denser than single-family homes, may be seen as skewing the spatial analysis within SaTScan, clusters dominated by multi-family housing are legitimate because a large amount of housing is being built or repaired within a close space-time span. Planners and other decision makers needing to find solutions for housing following a disaster could benefit from knowing that multi-family developments are an efficient way of providing the maximum amount of housing in the shortest amount of time.

Conclusion

Recovery is a dynamic and multifaceted process and therefore the spatial and temporal scales at which it is measured affect the outcome of these studies. Although there has been an increased interest in understanding the dynamics of long-term recovery following Hurricane Katrina, it is still under-studied and the mechanisms driving recovery as a holistic and interlinked process are not well understood. The major contribution of this research is the application of a technique, a spatial scan statistic, and the utilization of building permit data to empirically assess locally-based trends in disaster recovery. The application of this technique demonstrates that space-time clusters of rebuilding during the period of recovery following Hurricane Katrina (or any disaster) can be identified and analyzed using freely available data and software. Additionally, this research fills a significant gap in the current literature by providing a much higher temporal resolution for the analysis of the recovery process. Results indicate that rebuilding following a disaster does not occur uniformly; rather it is concentrated at various points in space and time due to the influence of underlying event damage and pre-event housing concentration. While other studies may have described the unequal distribution of recovery, few have been able to quantify exactly where and when a certain type of recovery is taking place.

Two of the underlying characteristics that influence the pace and distribution of recovery were examined utilizing both SaTScan and ArcGIS software. The amount of damage experienced by an area influences the timeliness of rebuilding and how rebuilding is spatially distributed. For example, it may take over a year for areas which have experienced catastrophic damage to have high levels of rebuilding. Since, even in a purely spatial analysis, there are not many spatial clusters within the catastrophically damaged areas, we know that either high levels of rebuilding have not occurred in these areas due to obstacles and more building will occur in these areas in the future, or that building has shifted to areas that did not experience such high levels of damage. The connection of the pace and distribution of rebuilding and the number of houses per tract is less clear. However, the finding that more building clusters have occurred in places that had fewer housing units pre-storm is counter-intuitive and may indicate shifting trends of redevelopment away from the more densely populated and hazardous coast.

Laben (2002) and others have developed tools that can help track short-term recovery and help make decisions about aid distribution. The method presented in this paper, on the other hand, can be used to track the distribution of rebuilding over the long-term and help recovery managers and decision makers use information about where and when recovery has occurred, to determine how to distribute resources. Similarly, by understanding where and when clusters of rebuilding occurred, the drivers and “best practices” of rebuilding can be identified and utilized as a model for areas which have not experienced the desired level of rebuilding.

This research can act as a springboard for future investigations into the relationships between the level of damage, pre-event housing densities, and other variables with spatial and temporal clusters of rebuilding. In addition to generally increasing the understanding of how long-term rebuilding and recovery manifests in space and time, the tools and techniques presented are available to most municipal or county building and development offices. This method can help planners and long-term recovery managers identify areas where rebuilding has been concentrated and help them better understand how to focus and distribute their resources.

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List of Tables

Table 1: Study area, Municipal statistics (American FactFinder, 2000)

	Total Population	**Total Housing Units**	**Median Household Income ($)**	**% White/Black/Other**
Bay St. Louis	8,209	3,817	34,106	80.2/ 16.6/ 3.2
Pass Christian	6,579	3,351	40,743	65.9/ 28.2/ 5.9
Long Beach	17,320	7,203	43,289	87.5/ 7.4/ 5.1

Table 2: Condition of building permit data upon acquisition

County/*Municipality*	**Scanned**	**Digital**	**Standard Format**	**Geo-coded**
Hancock County	X			
Waveland		X	X	
**Bay St. Louis*		X	X	
Harrison County	X			
**Pass Christian*		X	X	
**Long Beach*		X	X	
Gulfport	X			
Biloxi		X		X
Jackson County		X	X	
Ocean Springs		X	X	
Gautier		X	X	
Moss Point	X			
Pascagoula		X	X	

*municipalities investigated in this paper

Table 3: Percent of permits from each cluster by damage category

	Catastrophic	**Extensive**	**Moderate**	**Limited**	**N/A**	
Cluster	%	%	%	%	%	**Issue Dates**
Long Beach 1	28.83	0	0	50.5	20.5	9/1/05-11/30/05
Pass Christian 1	2.01	2.58	58.17	24.07	0	2/1/06-10/31/06
Bay St. Louis 1	0	0	100	0	0	6/1/06-6/30/06
Pass Christian 2	23.81	0	0	69.05	7.14	10/1/06-10/31/06
Long Beach 2	100	0	0	0	0	1/1/07-1/31/07
Long Beach 3	100	0	0	0	0	9/1/07-9/30/07
Bay St. Louis 2	0	0	100	0	0	5/1/08-5/31/08

Table 4: Percent of permits from each cluster by housing unit category

	Class 1 (0-16)	**Class 2 (17-57)**	**Class 3 (58-134)**	**Class 4 (135-277)**	**Class 5 (278-649)**	
Cluster	%	%	%	%	%	**Issue Dates**
Long Beach 1	16.5	52.49	16.1	7.75	7.16	9/1/05-11/30/05
Pass Christian 1	0	0	40.97	17.19	41.83	2/1/06-10/31/06
Bay St. Louis 1	0	100	0	0	0	6/1/06-6/30/06
Pass Christian 2	30.95	23.81	45.24	0	0	10/1/06-10/31/06
Long Beach 2	0	0	0	0	100	1/1/07-1/31/07
Long Beach 3	0	100	0	0	0	9/1/07-9/30/07
Bay St. Louis 2	0	0	71.74	28.26	0	5/1/08-5/31/08

Table 5: Percent of permits from each spatial cluster by damage category

	Catastrophic	**Extensive**	**Moderate**	**Limited**	**N/A**
Cluster	%	%	%	%	%
Bay St. Louis 1	4.62	0	94.27	0	1.11
Bay St. Louis 2	0	0	100	0	0
Bay St. Louis 3	13.48	16.05	67.38	0	3.09
Pass Christian 1	0	0	0	100	0
Long Beach 1	100	0	0	0	0
Long Beach 2	2.99	0.11	1.39	73.32	22.2

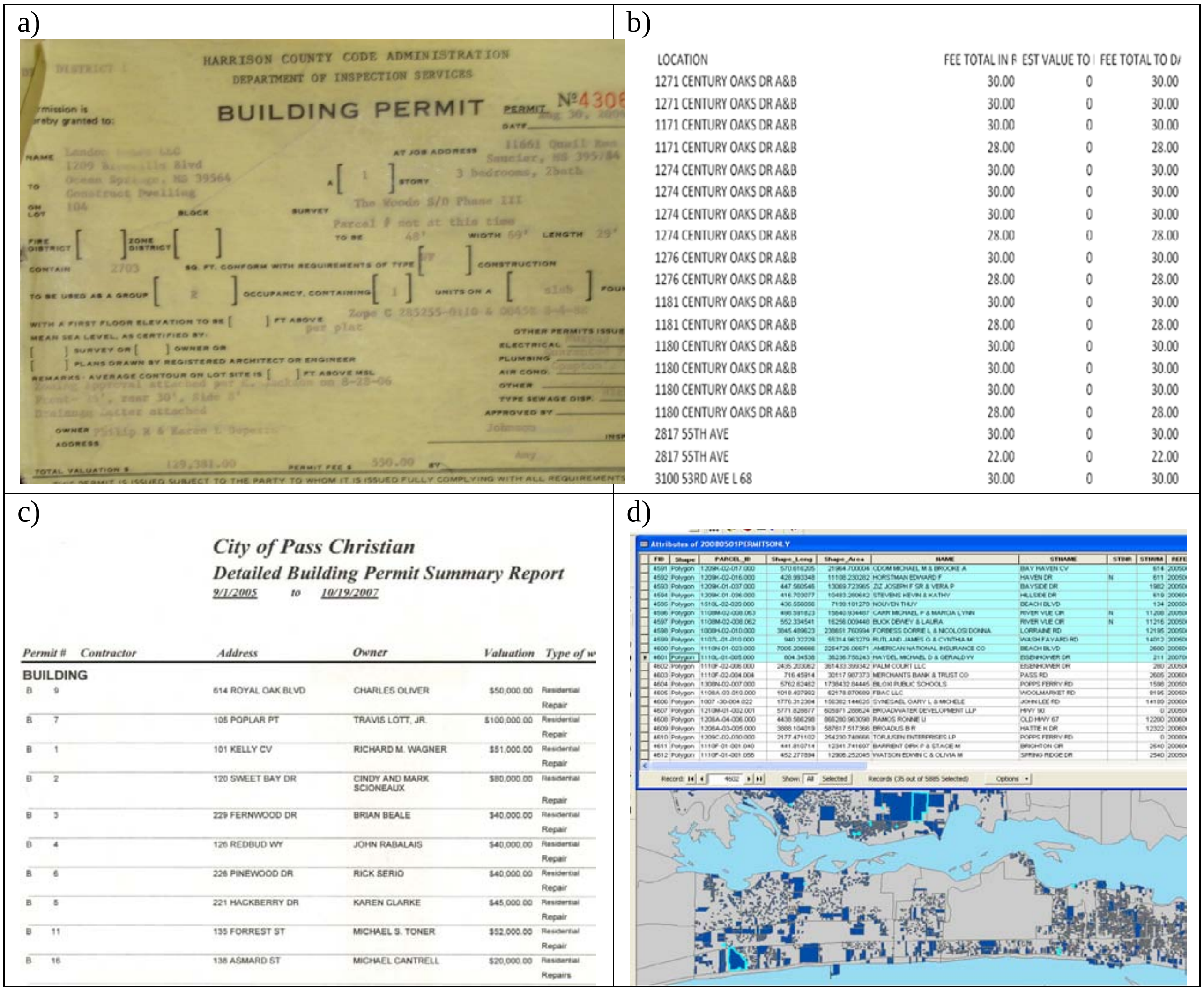
Using Building Permits to Monitor Disaster Recovery: A spatio-temporal case study of coastal Mississippi following Hurricane Katrina

List of Figures

Figure 1. Coastal Mississippi Study Area

Figure 2. Building Permit Types

a. paper permit – Harrison County; b. scanned permit – Gulfport; c. digital permit – Waveland; d. geospatially enabled information – Biloxi



a)

DISTRICT 1

HARRISON COUNTY CODE ADMINISTRATION
DEPARTMENT OF INSPECTION SERVICES

BUILDING PERMIT

PERMIT №4306

mission is
reby granted to:

DATE Aug 30, 200

NAME Landon [illegible] LLC
1209 [illegible] Blvd
Ocean Springs, MS 39564

AT JOB ADDRESS 11661 Quail Run
Saucier, MS 39574

TO Construct Dwelling

A [1] STORY 3 bedrooms, 2bath

ON LOT 104 BLOCK SURVEY The Woods S/D Phase III

Parcel # not at this time

FIRE DISTRICT [ ] ZONE DISTRICT [ ] TO BE 48' WIDTH 69' LENGTH 29'

CONTAIN 2703 SQ. FT. CONFORM WITH REQUIREMENTS OF TYPE [V] CONSTRUCTION

TO BE USED AS A GROUP [R] OCCUPANCY, CONTAINING [1] UNITS ON A [slab] FOUN

Zone C 285255-0110 & 00455 3-4-86

WITH A FIRST FLOOR ELEVATION TO BE [ ] FT ABOVE per plat
MEAN SEA LEVEL, AS CERTIFIED BY:
[ ] SURVEY OR [ ] OWNER OR
[ ] PLANS DRAWN BY REGISTERED ARCHITECT OR ENGINEER

REMARKS - AVERAGE CONTOUR ON LOT SITE IS [ ] FT ABOVE MSL
Zoning approval attached per E. Jackson on 8-28-06
Front- 15', rear 30', Side 5'
Drainage Letter attached

OTHER PERMITS ISSUE
ELECTRICAL
PLUMBING
AIR COND.
OTHER
TYPE SEWAGE DISP.
APPROVED BY

OWNER Phillip R & Karen L [illegible]
ADDRESS

Johnson

INSP

Amy

TOTAL VALUATION $ 129,381.00 PERMIT FEE $ 550.00 BY

THIS PERMIT IS ISSUED SUBJECT TO THE PARTY TO WHOM IT IS ISSUED FULLY COMPLYING WITH ALL REQUIREMENTS

b)

LOCATION	FEE TOTAL IN F	EST VALUE TO	FEE TOTAL TO D/
1271 CENTURY OAKS DR A&B	30.00	0	30.00
1271 CENTURY OAKS DR A&B	30.00	0	30.00
1171 CENTURY OAKS DR A&B	30.00	0	30.00
1171 CENTURY OAKS DR A&B	28.00	0	28.00
1274 CENTURY OAKS DR A&B	30.00	0	30.00
1274 CENTURY OAKS DR A&B	30.00	0	30.00
1274 CENTURY OAKS DR A&B	30.00	0	30.00
1274 CENTURY OAKS DR A&B	28.00	0	28.00
1276 CENTURY OAKS DR A&B	30.00	0	30.00
1276 CENTURY OAKS DR A&B	28.00	0	28.00
1181 CENTURY OAKS DR A&B	30.00	0	30.00
1181 CENTURY OAKS DR A&B	28.00	0	28.00
1180 CENTURY OAKS DR A&B	30.00	0	30.00
1180 CENTURY OAKS DR A&B	30.00	0	30.00
1180 CENTURY OAKS DR A&B	30.00	0	30.00
1180 CENTURY OAKS DR A&B	28.00	0	28.00
2817 55TH AVE	30.00	0	30.00
2817 55TH AVE	22.00	0	22.00
3100 53RD AVE L 68	30.00	0	30.00

c)

City of Pass Christian
Detailed Building Permit Summary Report
9/1/2005 *to* *10/19/2007*

Permit #		Contractor	Address	Owner	Valuation	Type of w
BUILDING						
B	9		614 ROYAL OAK BLVD	CHARLES OLIVER	$50,000.00	Residential Repair
B	7		105 POPLAR PT	TRAVIS LOTT, JR.	$100,000.00	Residential Repair
B	1		101 KELLY CV	RICHARD M. WAGNER	$51,000.00	Residential Repair
B	2		120 SWEET BAY DR	CINDY AND MARK SCIONEAUX	$80,000.00	Residential Repair
B	3		229 FERNWOOD DR	BRIAN BEALE	$40,000.00	Residential Repair
B	4		126 REDBUD WY	JOHN RABALAIS	$40,000.00	Residential Repair
B	6		226 PINEWOOD DR	RICK SERIO	$40,000.00	Residential Repair
B	5		221 HACKBERRY DR	KAREN CLARKE	$45,000.00	Residential Repair
B	11		135 FORREST ST	MICHAEL S. TONER	$52,000.00	Residential Repair
B	16		138 ASMARD ST	MICHAEL CANTRELL	$20,000.00	Residential Repairs

d)

Attributes of 20080501PERMITSONLY

	FID	Shape	PARCEL_ID	Shape_Leng	Shape_Area	NAME	STNAME	STDIR	STNUM	REFE
	4591	Polygon	1209K-02-017.000	570.616205	21964.700004	ODOM MICHAEL M & BROOKE A	BAY HAVEN CV		614	20050
	4592	Polygon	1209K-02-016.000	428.993348	11108.230282	HORSTMAN EDWARD F	HAVEN DR	N	611	20050
	4593	Polygon	1209K-01-037.000	447.560546	13069.723965	ZIZ JOSEPH F SR & VERA P	BAYSIDE DR		1982	20050
	4594	Polygon	1209K-01-036.000	416.703077	10483.260642	STEVENS KEVIN & KATHY	HILLSIDE DR		619	20060
	4595	Polygon	1510L-02-020.000	436.550000	7139.101270	NGUYEN THUY	BEACH BLVD		134	20050
	4596	Polygon	1108M-02-008.063	498.591623	15640.934467	CARR MICHAEL P & MARCIA LYNN	RIVER VUE CIR	N	11208	20050
	4597	Polygon	1108M-02-008.062	552.334541	16256.009448	BUCK DEWEY & LAURA	RIVER VUE CIR	N	11216	20050
	4598	Polygon	1008H-02-010.000	3845.489623	238651.760994	FORBESS DORRIE L & NICOLOSI DONNA	LORRAINE RD		12195	20050
	4599	Polygon	1107L-01-010.000	940.32229	55314.963279	RUTLAND JAMES O & CYNTHIA M	WASH FAYARD RD		14012	20050
	4600	Polygon	1110N-01-023.000	7006.206666	2264726.06671	AMERICAN NATIONAL INSURANCE CO	BEACH BLVD		2600	20060
▸	4601	Polygon	1110L-01-005.000	604.34536	38236.755243	HAYDEL MICHAEL D & GERALD W	EISENHOWER DR		211	20070
	4602	Polygon	1110F-02-006.000	2435.203062	361433.399342	PALM COURT LLC	EISENHOWER DR		280	20050
	4603	Polygon	1110F-02-004.004	716.45914	30117.987373	MERCHANTS BANK & TRUST CO	PASS RD		2605	20060
	4604	Polygon	1308N-02-007.000	5762.62462	1738432.84445	BILOXI PUBLIC SCHOOLS	POPPS FERRY RD		1598	20050
	4605	Polygon	1108A-03-010.000	1018.407992	62178.070689	FBAC LLC	WOOLMARKET RD		8196	20060
	4606	Polygon	1007 -30-004.022	1776.312304	150382.144625	SYNESAEL GARY L & MICHELE	JOHN LEE RD		14109	20060
	4607	Polygon	1210M-01-002.001	5771.828877	605871.288624	BROADWATER DEVELOPMENT LLP	HWY 90		0	20050
	4608	Polygon	1208A-04-006.000	4438.586298	868280.963098	RAMOS RONNIE U	OLD HWY 67		12200	20060
	4609	Polygon	1208A-03-005.000	3888.104019	587617.517366	BROADUS B R	HATTIE K DR		12322	20060
	4610	Polygon	1209C-02-030.000	2177.471102	254230.748666	TORJUSEN ENTERPRISES LP	POPPS FERRY RD		0	20060
	4611	Polygon	1110F-01-001.040	441.810714	12341.741607	BARRENT DIRK P & STACIE M	BRIGHTON CIR		2640	20060
	4612	Polygon	1110F-01-001.056	452.277894	12906.252045	WATSON EDWIN C & OLIVIA M	SPRING RIDGE DR		2540	20050

Figure 3. Building permit spatial-temporal clusters and damage categories

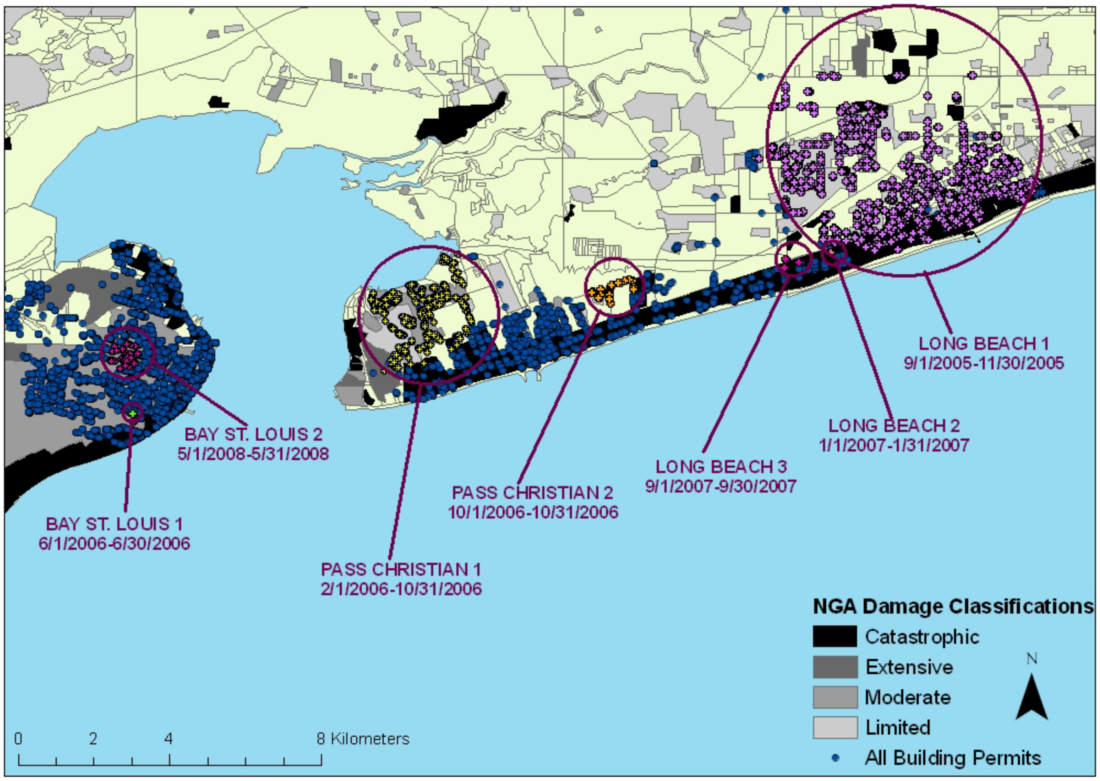


Figure 4. Building permit spatial-temporal clusters and number of housing units per tract

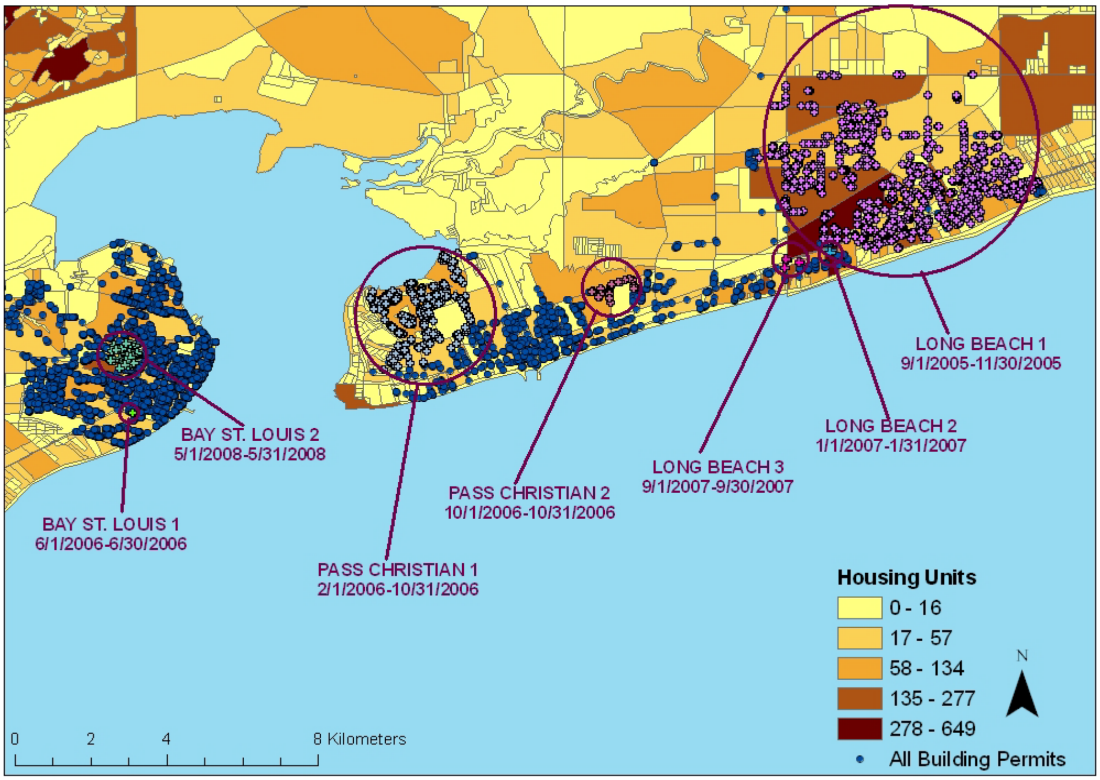


Figure 5. Building permit purely spatial permits and damage categories