Mapping Heat Vulnerability in Michigan

MPHI Annual Report

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EXECUTIVE SUMMARY

Progress on FY2011 objectives:

1) Literature review
    - See Appendix B
2) Draft basic demographic maps
    - Seven draft maps were created, using data from the 2010 Census and 2004-2009 American Community Survey.
    - See Appendix A
3) Provide recommendations for FY2012 to produce more detailed maps of Michigan's heat-vulnerable populations
    - Major recommendations include:
        i. Investigating additional data sources and indicators for inclusion in mapping:

            - Physical Environment including temperature, land cover/land use, housing density

            - Individual health conditions which are exacerbated by high heat such as diabetes, cardiovascular disease, and obesity.

            - Outcome data regarding mortality rates due to heat related causes

            - Adaptive Capacity including cooling centers in Michigan

            - Metropolitan areas including data relevant and/or restricted to urban areas including neighborhood stability, heat distress calls and the built environment which would incorporate more detailed information regarding air pollution, heat islands, and dwelling structures

        ii. Drafting maps including additional data sources and new map styles to further refine our understanding of populations within Michigan which are vulnerable to adverse health outcomes during extreme heat events.

        iii. Construct a heat index for Michigan which would help to identify the areas at highest risk for heat-related health events across the state allowing state and local public health agencies to prioritize intervention efforts and minimize health impacts in the future.

MAPPING HEAT VULNERABILITY IN MICHIGAN

INTRODUCTION

In FY2011, the Michigan Department of Community Health (MDCH) received a Climate Ready States and Cities grant from the Centers for Disease Control and Prevention (CDC). Michigan's grant focuses on identifying and addressing health concerns related to extreme heat events. MDCH contracted with MPHI to develop a set of custom maps to locate populations at greater risk of illness or death during an extreme heat event. This information could be used by State or local public health agencies to improve readiness for extreme heat events.

MPHI's activities in FY2011 included gathering information on existing heat indexes and studies, drafting an initial set of basic maps based on Census data, assessing the availability of additional relevant data sources, and proposing a set of additional maps, as well as a strategy for indexing heat vulnerability in FY2012. This report describes those activities in greater depth, includes the initial set of maps based on demographic data in Michigan, and discusses the potential for developing a heat index and additional maps in the future.

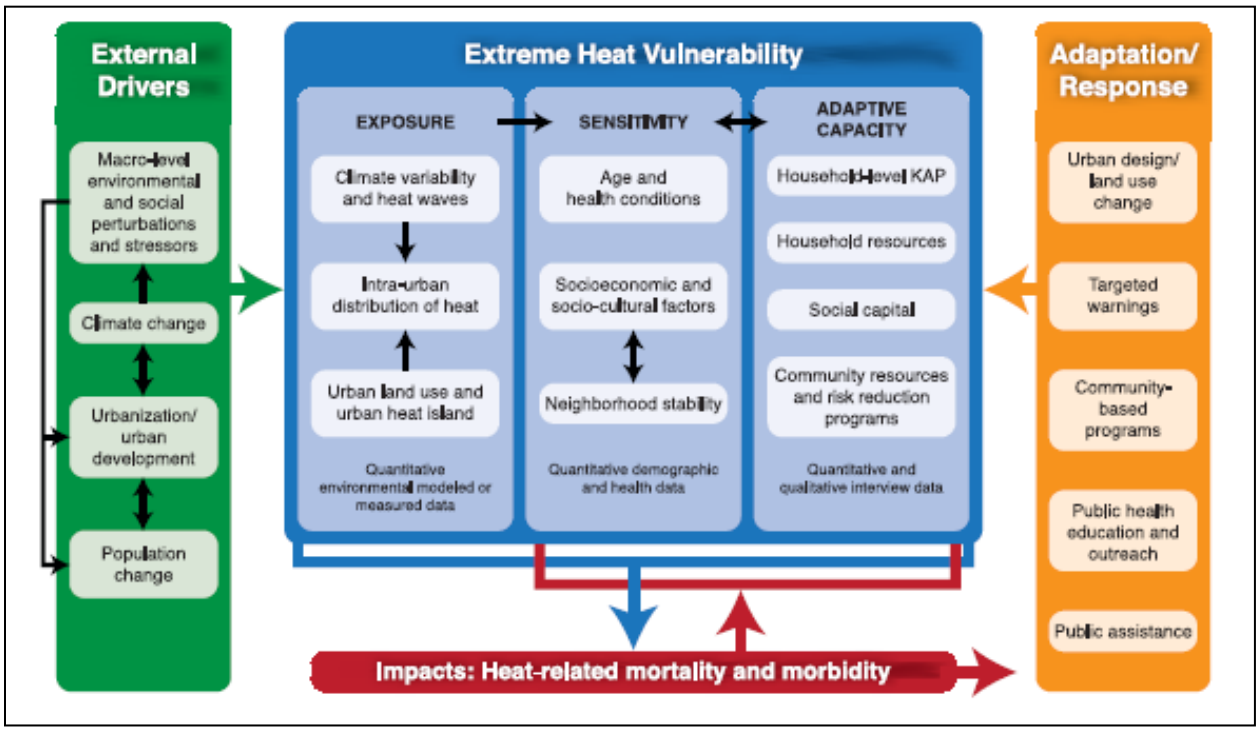
MPHI ACTIVITIES IN FY2011

A. REVIEW EXISTING DATA AND PREVIOUS STUDIES

MPHI began the mapping process with a review of the literature on heat vulnerability, including research on factors that limit or increase exposure to extreme heat and available data related to heat illness and death. The initial literature review included a wide range of articles, reports, and presentations from around the world, which represented a variety of approaches to conceptualizing and investigating heat vulnerability. An annotated bibliography of the references identified through the literature review is provided in Appendix B.

The literature describes several frameworks or models for understanding heat vulnerability, as well as wealth of indicators that have been used to measure heat vulnerability (e.g., Ishigami, et al, 2007; Loughman, et al; Rinner, et al, 2010; Kinney, O'Neill, Bell & Schwartz, 2008; and Reid, et al, 2009). Existing models or frameworks tend to include variables that describe social, environmental, and adaptive factors that correlate with adverse outcomes during extreme heat events. Although the factors that most influence heat vulnerability vary based on geographic and environmental context, Willhelmi and Hayden's model offers a comprehensive overarching framework for understanding the relationship between individual, environmental, and adaptive variables and heat-related morbidity and mortality. (see Figure 1).

Figure 1. Model of Heat Vulnerability. Wilhelmi, O., & Hayden, M. (2010)



MPHI generated a list of potential categories of indicators that could be measured and mapped using this theoretical model and the geographical, social and environmental factors that might be important in Michigan specifically. Based on our review of the literature, MPHI recommends including the following categories in a heat index: demographic, physical environment, built environment, adaptations, and outcomes.

B. Draft Base Demographic Maps

An initial set of maps displaying Michigan's demographic characteristics serves as both an opportunity to explore the potential of GIS mapping to meet MDCH's needs as they relate to this grant and to describe Michigan's population and social environment as a foundation for developing a heat index. MPHI began this portion of work by exploring the data available through the 2010 US Census. However, due to the elimination of the long-form questionnaire from the 2010 Census, many variables of interest were not available. Therefore, supplemental data from the American Community Survey were included. Population totals from the 2010 Census are available at the county level and were used to map population density.

The American Community Survey (ACS), also administered by the US Census Bureau, is an ongoing survey that collects information from randomly-selected households across the country. In 2008, 2.1% of households were sampled. The sample size is sufficient to generate one-year estimates only in areas with a population greater than 65,000. Areas with 20,000 to 65,000 people are provided estimates from three years of data combined, while areas with fewer than 20,000 people (including many census tracts) receive estimates from a five-year time period. In Michigan, five-year estimates from 2005-2009 are available for census tracts in the state.

Michigan data sets were downloaded from the U.S. Census Bureau at the county level, and merged into a single database for geocoding and mapping. The initial maps created with these data are included in this report in the section titled *Michigan Demographic Maps* (see Appendix A beginning on page 17).

C. Develop Recommendations for FY12 Mapping Activities

MPHI also investigated potential data sources for additional indicators of interest, identified through the literature review, that were not available through the US Census Bureau. National, state, county, and city resources were considered. Searches were conducted using internet and extended to individual inquiries when publicly available

information was insufficient. Data sources were considered if they provided information at the county level or smaller; sources that were available for part of the state (e.g. urban areas), but did not cover Michigan in entirely, were also retained for potential use. The mapping team noted the geographic level of measurement, specific variables available, and potential costs while evaluating the potential for each data source to be included in future mapping efforts. This process resulted in recommendations outlining future directions in mapping Michigan's heat-vulnerable populations related to data sources, additional maps, and guidance for creation of a heat index. These results are described in this report under *Recommendations* (see page 9).

D. MPHI TEAM ADMINISTRATIVE FUNCTIONS

The MPHI mapping team met bi-weekly to discuss ongoing tasks and monitor progress in alignment with the workplan. Meetings with MDCH were held prior to project implementation, and again in May 2011 to provide a process update. Additionally, on June 21st, 2011, MPHI presented at the MDCH MI Climate and Health Adoption Project (MICHAP) Advisory Committee Meeting. At that time the MPHI mapping team presented relevant literature in the field of heat vulnerability, offered an overview of the potential indicators being considered for use in Michigan, and outlined the scope of work intended for FY11. Following the May and June meetings, MPHI provided MDCH with a resource list of literature reviewed to-date.

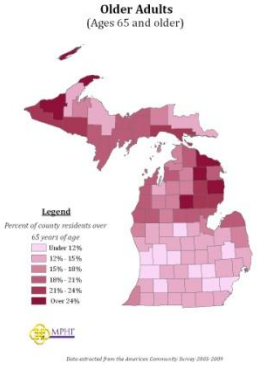
MICHIGAN DEMOGRAPHIC MAPS

MPHI drafted a set of maps in Michigan which display selected demographic data for residents. The demographics presented are all key factors in understanding heat vulnerability, as established by previous research. The following maps utilize data from the American Communities Survey (US Census Bureau), using the most recent 5-Year Estimates available. All data are reported at the county level. Each indicator has been displayed in both a standard deviation map and a choropleth map. The standard deviation map represents the difference between counties close to the average for the state, and those that are far above and below the state average. The choropleth maps display the data

in even ranges from counties with the lowest percentages/counts (light colors) to counties with the highest percentages/counts (darkest colors). Thumbnail images are included below, along with a short description of the map and justification for the indicator used; full-page maps are attached in Appendix A.

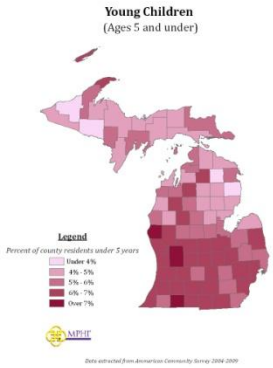
INDIVIDUAL VULNERABILITY

Map 1. Older Adults – Michigan residents ages 65 and older.



Individuals in this age group are particularly vulnerable to heat related stress and illness and show higher mortality and rates of hospitalization during heat waves (Reid et al, 2009). Additionally, older adults are more likely to have underlying physical and medical conditions that increase susceptibility to heat events, take medications which can interfere with thermoregulation, and have more limited mobility or access to potential adaptations such as cooling centers (Uejio et al. 2011; Semenza et al. 1999; Stafoggia et al. 2008; Whitman et al. 1997). The map displays the percentage of the population that is aged 65 and older by county. The two counties with the highest percentage of residents in this age category are Alcona County (28.6%), and Keweenaw County (26.93%).

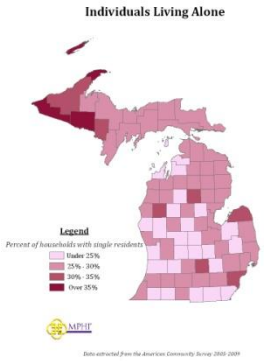
Map 2. Young Children – Michigan residents ages 5 and under. This group of children is highly vulnerable to heat-related stress and illness, due to both physiological and social factors. Their core body temperature is more susceptible to external factors, they require more time to adapt to changes in temperature than adults require.



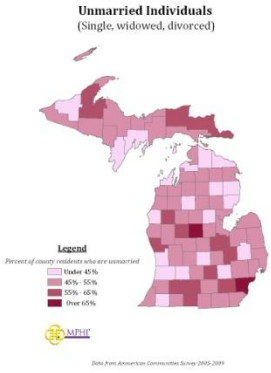
Young children may also be more likely to engage in high energy activities, spend more time outside, and be less likely to maintain adequate hydration (English et al, 2007). The map displays the percent of the population that is aged 5 and under by county. The county with the highest percentage of the population under the age of 5 is Kent County (7.63%), followed by St. Joseph County (7.5%) and Oceana County (7.25%).

SOCIOECONOMIC VULNERABILITY

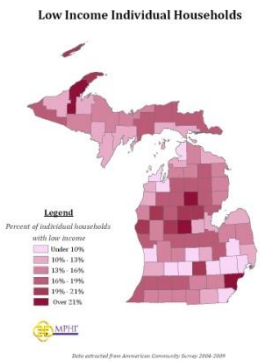
Map 3. Individuals Living Alone – single resident households in Michigan. Individuals living alone are at higher risk of social isolation, and may be less likely to be aware of heat warnings, seek resources during times of high heat, or have access to necessary transportation or assistance in getting to these resources (Uejio et al. 2011; Klinenberg 2003) (Reid et al. 2009; Klinbenberg, 2003; Semenza et al. 1996). The map displays the percentage of single resident households by county. The highest percentage of single resident households can be seen in Iron County (37.3%) and Keweenaw County (37%).

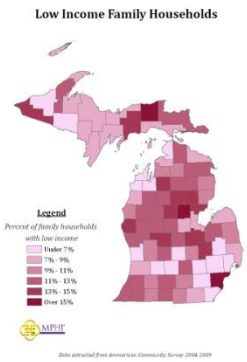


Map 4. Unmarried Individuals: Separated/Widowed/Divorced –In European studies, married people were less likely to die from heat related illness/stress than individuals who were separated, widowed, divorced, or never married (Uejio et al. 2011; Fouillet et al. 2006; Stafoggia et al. 2008; Foroni et al. 2007; Reid et al. 2009;). Marital status is measured as a possible indicator of social isolation, which can contribute to heat vulnerability for similar reasons as living alone. The map displays the percent of county residents who are unmarried. The highest percentage of unmarried residents reside in Wayne County (68.16%) and Isabella County (65.54%).

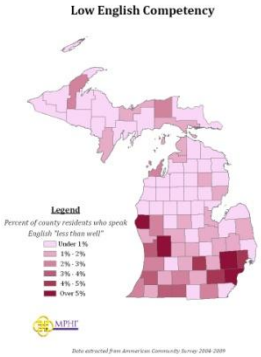


Map 5. Low Income Households – Percent of homes per county that fall below the poverty level. In the US and Korea, lower income has been associated with higher rates of mortality (Reid et al, 2009; Curriero et al. 2002; Naughton et al. 2002, Kim and Joh 2006). Low income may be a proxy for a variety of mechanisms through which individuals are at increased vulnerability to health outcomes during extreme heat events; for example, reluctance to run an air conditioner





due to cost, limited transportation to seek cooling centers, and less access to medical care to treat underlying healthy concerns or initial heat illness. Poverty levels have been mapped to display both the percent of individual homes and the percent of family households under the poverty level. The county with the highest percentage of individual homes under the poverty level is Isabella County (28.97%), followed by Houghton County (22.63%). Wayne County (16.86%) and Luce County (16.33%) had the highest percentage of family households living under the poverty level.



Map 6. Low English Competency – Michigan residents who report they speak English "less than well." Low competency with English can interfere with an individual's ability to recognize warnings regarding a heat event, locate resources, and understand the community resources and coping strategies that are available. In Kent county 5.59% of the adults who claimed a primary language other than English indicated they spoke English less than well." In Oakland County 5.2% of residents indicated they spoke English "less than well."

PHYSICAL ENVIRONMENT

Map 7. Population Density –Population density can affect heat vulnerability by raising surrounding temperatures in urban areas. Areas with a high population density tend to be urban, which experience higher mortality and morbidity rates due to the urban 'heat island' effect as well as built environment concerns such as multi-level buildings, which can compound raised temperature levels and health effects from heat events (Kalkstein & Sheridan 2003). A study in the US, England, and Wales found a higher incident rate of heat-related deaths in urban counties as compared to rural areas (Reid et al. 2009; Martinez et al. 1989; Hajat et a.

2007). Wong reports a difference in the average daytime surface temperature between developed and rural areas of 18 to 27 degrees F (Wong, 2008). Data from the 2010 U.S. Census were mapped to display the average number of people in each Michigan County per square mile. In 2010, the counties with the highest number of residents per square mile were Wayne County (2,833 residents per square mile), followed by Macomb County (1,738 residents per square mile), and Oakland County (1,326 residents per square mile).

RECOMMENDATIONS

This section contains information regarding data sources that can be used to map variables related to heat vulnerability, as well as recommendations from MPHI for future activities and resources related to mapping heat vulnerability in Michigan.

DATA SOURCES & INDICATORS

The information below is grouped by the overarching factors and contains descriptions of potential indicators and sources for these data. A complete list of data sources and the geographic level of analysis is included at the end of this section in Table 1.

PHYSICAL ENVIRONMENT

Three indicators of the physical environment may be useful to incorporate into future work: temperature; land cover/land use; and housing density (Reid et al. 2009; Uejio et al. 2010; Wilhelmi 2011). Temperature data is clearly relevant to understanding heat vulnerability. There are a multitude of ways to map temperature information – highest temperature vs. average temperature, county-wide estimates vs. data from specific observed locations. The website www.weatherbase.com draws current and historical information from a variety of public domain sources, including National Climatic Data Center.

Land cover/land use data includes the existence of green space in a community and has been associated with decreased risk of heat-related health outcomes (Reid et al 2009;

Tan et al, 2007). These data can be obtained through the State of Michigan Center for Geographic Information within the Department of Information Technology.

It would also be valuable to investigate the geographic distribution of air pollution and atmospheric indicators. Extensive data are available through the United States Environmental Protection Agency (EPA) regarding air quality and contaminant levels. Analysis and inclusion of this data would require expertise in this area.

INDIVIDUAL

Individual health characteristics are highly relevant to understanding the health consequences of extreme heat events. Research has identified a number of health conditions that are exacerbated by high heat and demonstrated that reactions to heat distress can be magnified by various health conditions (English et al. 2007; Reid et al. 2009). In FY2012, MPHI suggests using data available through the Behavior Risk Factor Surveillance System (BRFSS) to incorporate information on diabetes, cardiovascular disease, obesity, and other health conditions. Knowledge of counties with high instances of these preexisting health conditions could highlight areas that face increased risk during heat emergencies. These data would likely only be available at the county- or health-department level. Additionally, MPHI suggests a continued search for data sources on other linked medical conditions including renal disease, nervous disorders, emphysema, epilepsy, cerebrovascular disease, pulmonary conditions, and mental health conditions (Reid et al. 2009; Chestnut et al. 1998; Curriero et al. 2002; Medina-Ramon et al. 2006; Mastrangelo et al 2007; Baraga et al. 2002; Dolney and Seridan 2006).

OUTCOME DATA

Use of mortality data can help to identify and visualize the factors that correlate most closely with heat fatalities in Michigan. Michigan Vital Records documents cause of death information for each death in Michigan, using standardized ICD-10 codes. Therefore, all deaths related to heat can be identified. However, due to confidentiality concerns, the geographic level of measurement and the time span of included deaths may be broad. Michigan is currently developing an application for retrieving these data; the timing of this

application release and the capabilities for data acquisition will affect the availability of data.

Morbidity data may be available through the Healthcare Cost and Utilization Project (HCUP) from the State Inpatient Database (SID). The SID includes information regarding hospitalizations according to diagnosis code by metropolitan area and county. Heat-related illness can include heat stress, heat cramps, heat exhaustion, and heat stroke (English et al. 2007) along with other conditions which are classified under the ICD-9 diagnosis codes 992.x. Further investigation is required regarding the extent of data reported from each county in Michigan and the cost of acquisition. Another potential source of hospitalization and morbidity data could include Medicare and Medicaid claims data. Using appropriate ICD-9 and ICD-10 codes, geographically linked data could be requested from the MDCH Data Warehouse and the Centers for Medicare and Medicaid Services (CMS). Content, availability, and access to the Data Warehouse and CMS data will require further investigation. An understanding of the rates of hospitalization due to heat can help identify areas at greatest risk. Additionally, maps that correlate the rates of hospitalization with adaptive capacity resources and other vulnerability indicators can be valuable in analysis and identification of vulnerable populations and areas.

Adaptive Capacity

Adaptive capacity refers to the ability of a population to reduce harm from current and future weather related events. It is influenced by the availability of information and technology; access to material, economic and human resources; cultural knowledge, practices and beliefs; institutional capabilities; and social capital which includes social networks that connect individuals to community resources (Morss et al. 2011). Both individual and community level factors are effected by the availability of and barriers to resources and contribute to overall adaptive capacity. Some community level adaptations include climate preparedness plans, coordinated heat watch/warning systems, programs intended to improve access to services/resources, programs aimed at individual knowledge and behavioral change, and changes to the physical environment (Wilhelmi 2011).

One of the main sources of adaptive capacity for Michigan residents is access to cooling centers. However, cooling center locations are not standardized or consistently documented. Mapping these resources would involve defining locations considered as cooling centers (e.g., libraries, community centers, senior centers, indoor shopping malls), and then collecting and geocoding such locations. Also of interest are existing notification systems and other emergency preparedness plans that counties have implemented. This information is not collected systematically and may prove to be difficult to compile in a valid and reliable format.

Detailed information regarding existing public transportation systems, costs, and coverage could also be helpful in understanding adaptive capacity at the community level. However, this information is not universally available throughout the state in a condensed manner and could be very time intensive to compile.

METROPOLITAN AREAS

Some data sources are available for urban areas only; in Michigan, this generally includes the metropolitan area of Detroit, but occasionally encompasses other areas (Lansing, Grand Rapids, etc). In urban areas more information is also available at a more localized level as well (for example, by census tract or street address). By focusing on major cities, data can be mapped at the census tract level to gain an understanding of neighborhood composition which can assist with more targeted intervention efforts. For FY2012, MPHI recommends developing additional maps focused on the Detroit metropolitan area (and possibly other urban areas, as the data allows).

The information available for metropolitan areas includes indicators of the built environment, neighborhood stability, outcome data such as heat dispatch calls. The American Housing Survey (available for the Detroit metropolitan area only) offers a variety of data on the built environment including height of buildings, density of units within buildings, and presence of air conditioning (in-wall units and central air). NASA provides surface temperature data and information regarding vegetation health and density through Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images. Further investigation into this data set would provide information regarding the

complexities involved in incorporating this information into maps that reflect risks related to the built environment. Additionally, information regarding impervious surfaces from the National Land Cover Database could provide additional data regarding the sensitivity of surface temperature in an area (Uejio et al. 2009; Yaun and Bauer, 2007). Inclusion of ASTER and impervious surface data in 2012 may require additional expertise in specialized content areas.

It is also possible to display data regarding neighborhood stability in urban areas. Data from the U.S. Census, American Community Survey (ACS) and Michigan Incident Crime Reporting (MICR) can be utilized to map neighborhood stability. This analysis could include vacancy rates (U.S. Census), owner-occupied housing (ACS), median housing value (U.S. Census), and crime rate (MICR).

Mapping at the city or metropolitan level could also include more detailed outcome information, such as dispatch calls from emergency responders related to heat, or hospitalization rates due to heat-related illness. Restricting the geography to a smaller area of interest may facilitate the process of obtaining access to data; for example, obtaining information from one hospital system in Detroit is more feasible than gathering such data at the state level and may compliment any data available and mapped on the state level.

Table 1. Indicators, data sources and geographic levels

Indicators	Data Source(s)	Geographic level
Demographic		
Older adults (Aged 65 and over)	ACS*/2010 US Census**	County, census tract*
Young children (Ages 5 and under)	ACS/US Census	County, census tract
Individuals living alone	ACS	County, census tract
Unmarried individuals	ACS	County, census tract
Low income households	ACS	County, census tract
Low English comprehension	ACS	County, census tract
Physical Environment		
Population density	US Census	County, census tract
Temperature	www.weatherbase.com	City
Surface temperature	NASA	National (raster file can be segmented by various levels)
Land cover/land use	State of Michigan/National	National (raster file),

	Land Cover Land Use	State
Air pollution	Environmental Protection Agency	State, county
Vegetation health and density	NASA	National raster files
Built Environment		
Building height	ACS	Metropolitan (Detroit)
Unit density within buildings	ACS	Metropolitan (Detroit)
Air conditioning	ACS	Metropolitan (Detroit)
Impervious surfaces	National Land Cover Database	National (raster file)
Individual Vulnerability		
Morbidity	BRFSS; MDCH.DataWarehouse	State, county
Social Vulnerability/Neighborhood Stability		
Crime rates	MICR	County
Vacancy rates	U.S. Census**	County, census tract
Owner occupied housing	ACS*	County, census tract
Median housing values	U.S. Census**	County, census tract
Outcome Data		
Morbidity	MDCH.DataWarehouse; HCUP	County
Mortality	Michigan Vital Records	County
Adaptive Capacity		
Cooling centers	Various sources, e.g. publiclibraries.com, Google	Urban areas
Public transportation	Various sources, e.g. MDOT, metropolitan transportation departments	Urban areas
Emergency preparedness	County Health Departments	County

*American Community Survey (ACS), data for five year estimates is available at the census tract level, 3 year estimates provide data for geographic areas with populations of 20,000 or more, and 1 year estimates are available for populations over 65,000.

**The U.S. Census administered the short from in 2010 which provides limited data at the census tract level. In 2000 the Census Bureau administered the long form which contained additional information.

MAPS

For FY2012, we recommend developing additional maps, using additional data sources and new map styles, to further refine our understanding of the sectors of Michigan's population that would be vulnerable in an extreme heat event. Prospective additional data sources have been described, including data to be used in additional county-level maps as well as data to be used for Detroit-area maps.

Using more complex map styles will produce a more nuanced understanding of heat vulnerability in Michigan. For example, maps could be created to visualize two types of vulnerability in relation to each other, or to visualize a potential risk factor in relation to a heat outcome indicator.

MICHIGAN HEAT INDEX

A heat index would help to identify the areas at highest risk for heat-related health events across the state, and allow state and local public health agencies to prioritize intervention efforts and minimize health impacts in the future. In addition, developing a composite variable to identify the areas in Michigan with multiple dimensions of heat vulnerability would help to simplify the variety of data indicators identified throughout this project. Ideally, a heat index would incorporate elements from each of the major areas of heat vulnerability: individual characteristics, physical environment, built environment, and adaptive capacity. This composite variable could be displayed with heat-related health outcome information, in order to explore the relationship and validate the index variable. However, data availability will play a role in the extent to which it is possible to create a meaningful composite variable.

UNAVAILABLE VARIABLES OF INTEREST

Some variables that are challenging or difficult to acquire and incorporate include additional information on individual medical status, socioeconomic vulnerability, and elements of the built environment.

There are some medical conditions which predispose individuals to an increased vulnerability to heat events that are difficult to obtain information about. Among these conditions are renal disease, nervous disorders, emphysema, epilepsy, cerebrovascular disease, pulmonary conditions (Reid et al. 2009). Data regarding some of these diseases are not currently collected at the state level due to availability or privacy protections that are in place. Additionally, medication use can impact an individual's susceptibility to heat related distress (English et al. 2007). Medication data is also unobtainable.

The homeless population is particularly vulnerable to the elements and therefore is at increased risk during extreme heat events. They may also experience social isolation, which can lead to lack of information regarding heat events and decreased access to adaptive capacity resources in the community. Information regarding rates and distribution of the homeless population in Michigan is not systematically reported and could be difficult to obtain across all counties in Michigan.

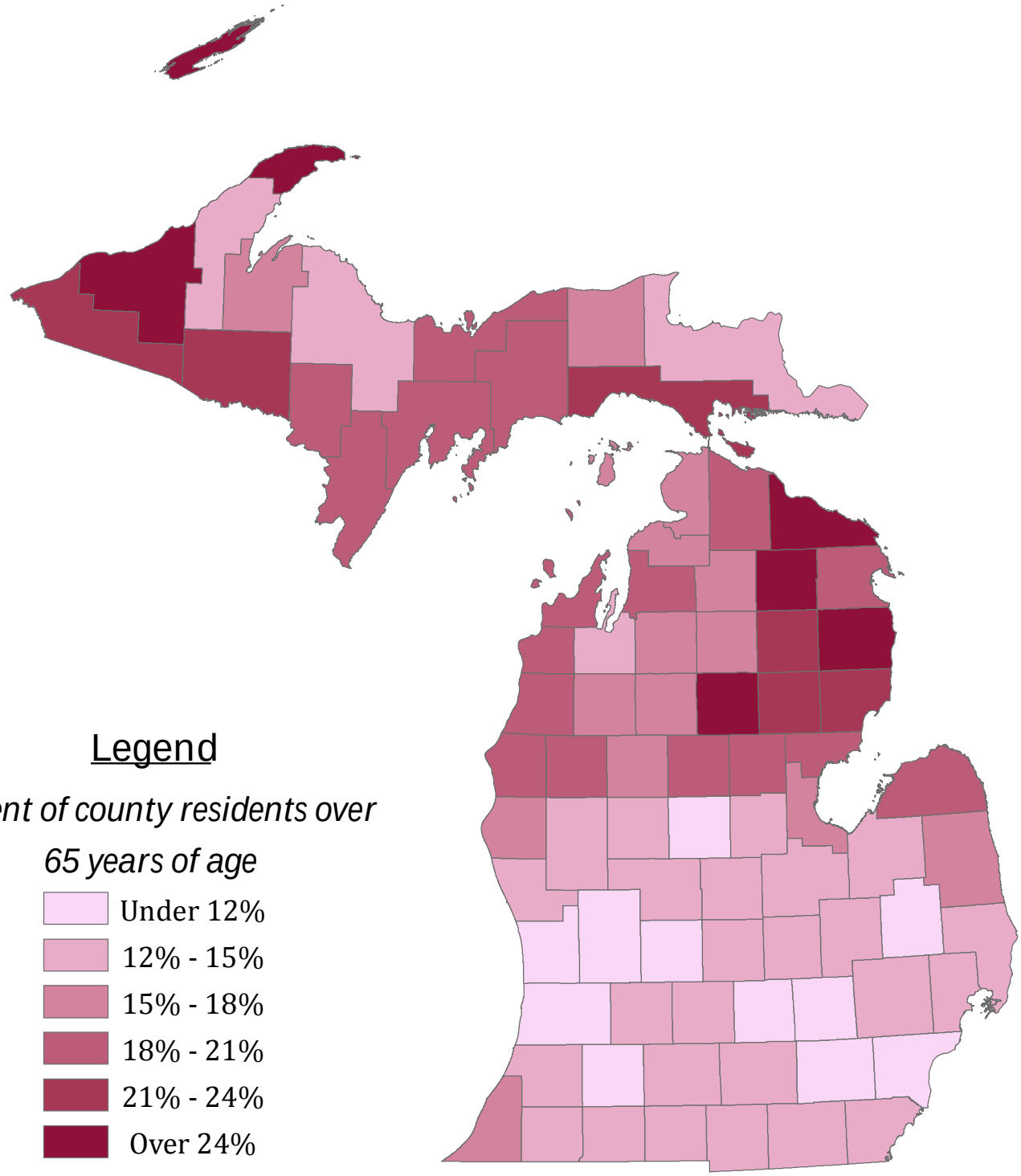
The built environment can affect individual and population vulnerability during extreme heat events in a number of ways. One set of factors for which there is little data is housing structures. This could include detailed information regarding insulation, ventilation, number of floor levels, and external material construction (Loughan, nd). Collectively, these data could be considered for inclusion with other elements of the built environment such as air conditioning when looking at the effect of housing characteristics on susceptibility levels.

CONCLUSION

MPHI's initial process of reviewing current literature, searching for existing data sources and mapping the initial demographic maps demonstrates there is adequate information available to generate maps that would provide a valuable resource to help identify populations and areas in Michigan that are vulnerable to heat-related events. By continuing work with our partners at MDCH, MPHI could incorporate a greater array of data sources, draft additional maps of relevance, and work toward developing a Michigan heat index. Future mapping efforts can help to generate information that could be used to protect Michigan's vulnerable populations. Though this project will likely be limited by a lack of available data for some factors, it is possible to create more complex maps and incorporate more diverse data sources.

Appendix A: Michigan Maps

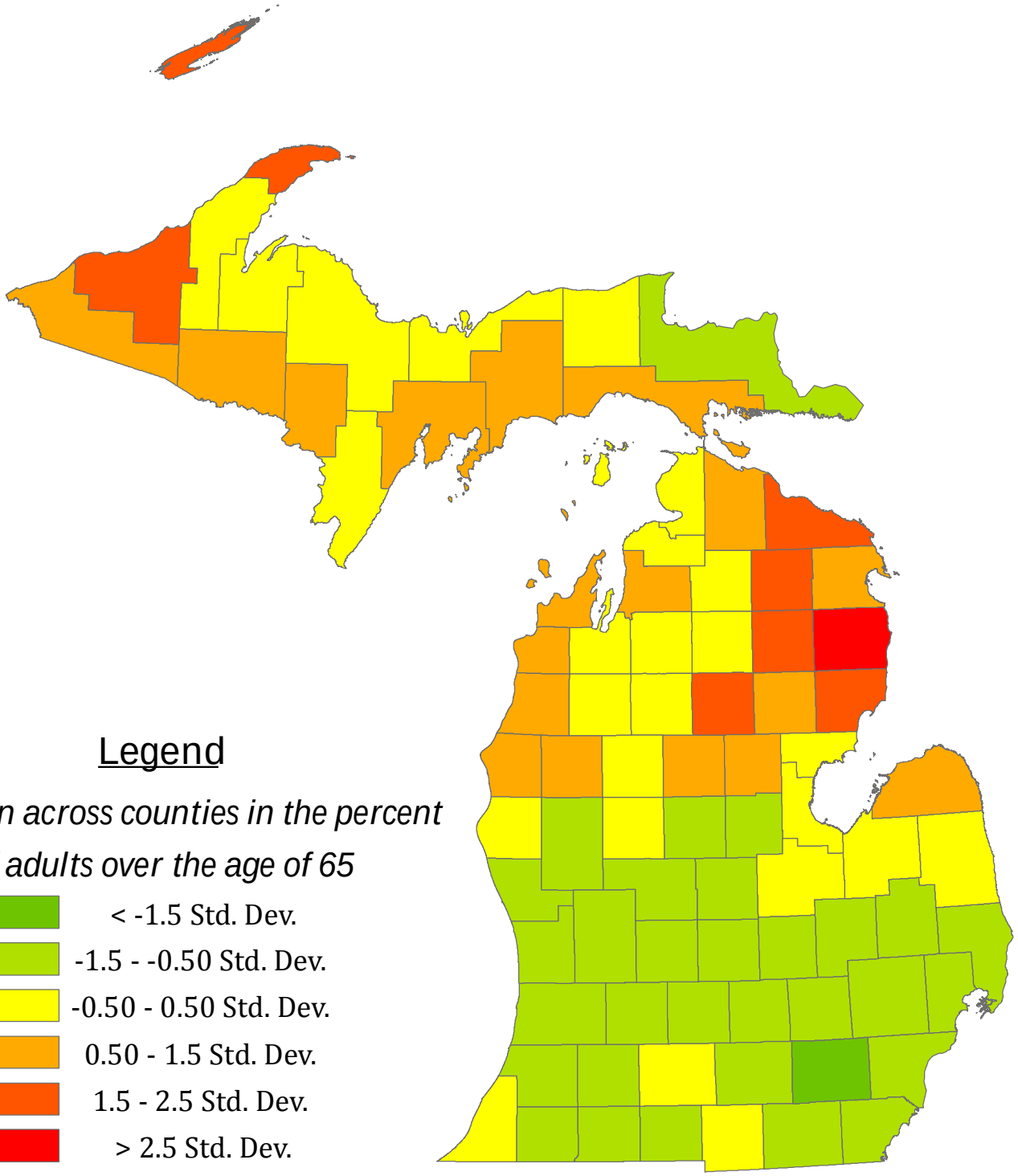
Older Adults
(Ages 65 and older)



MPHI®

Data extracted from the American Community Survey 2005-2009

Older Adults
(Ages 65 and older)



Legend

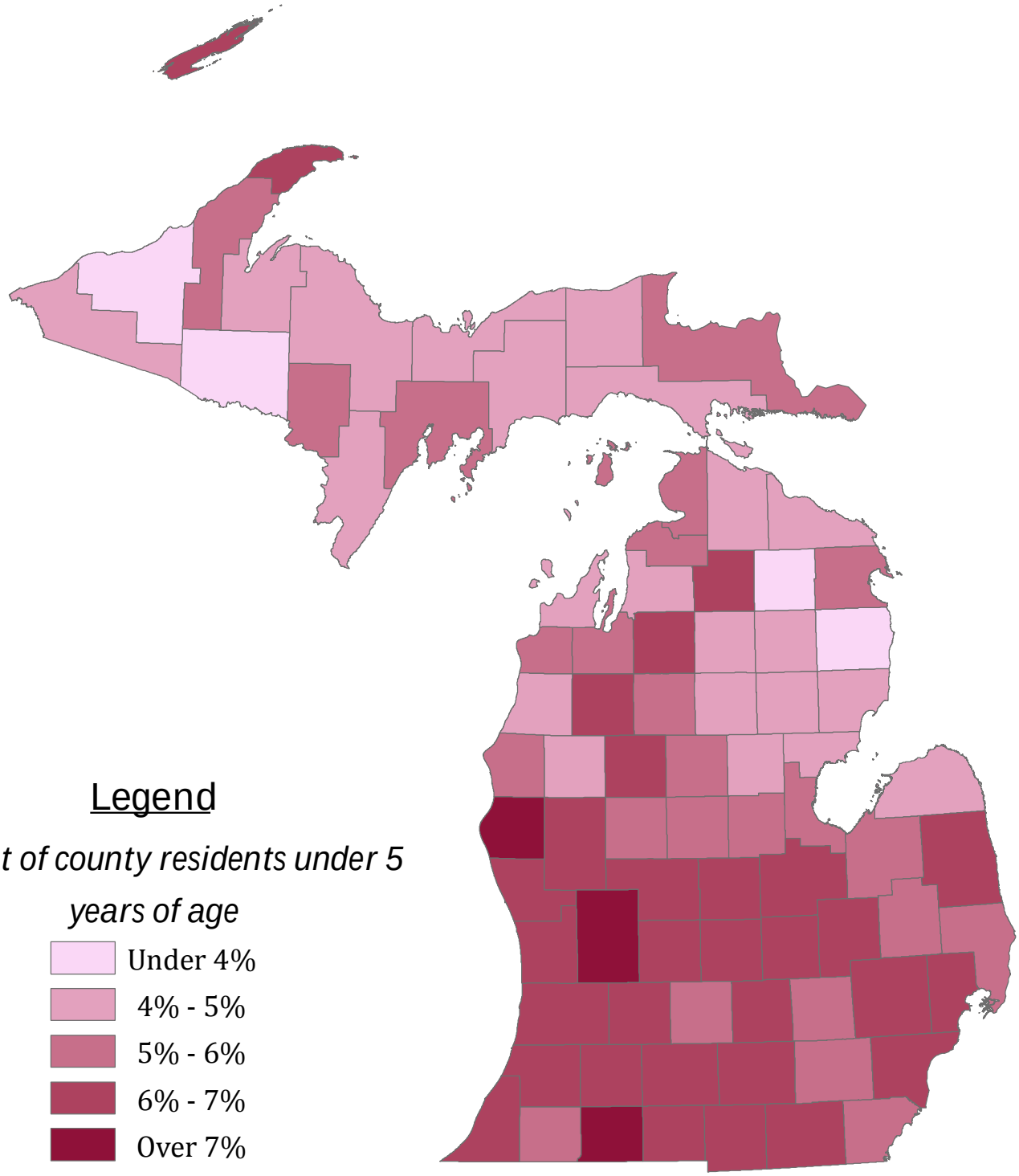
Variation across counties in the percent of adults over the age of 65

- < -1.5 Std. Dev.
- -1.5 - -0.50 Std. Dev.
- -0.50 - 0.50 Std. Dev.
- 0.50 - 1.5 Std. Dev.
- 1.5 - 2.5 Std. Dev.
- > 2.5 Std. Dev.

MPHI®

Data extracted from the American Community Survey 2005-2009

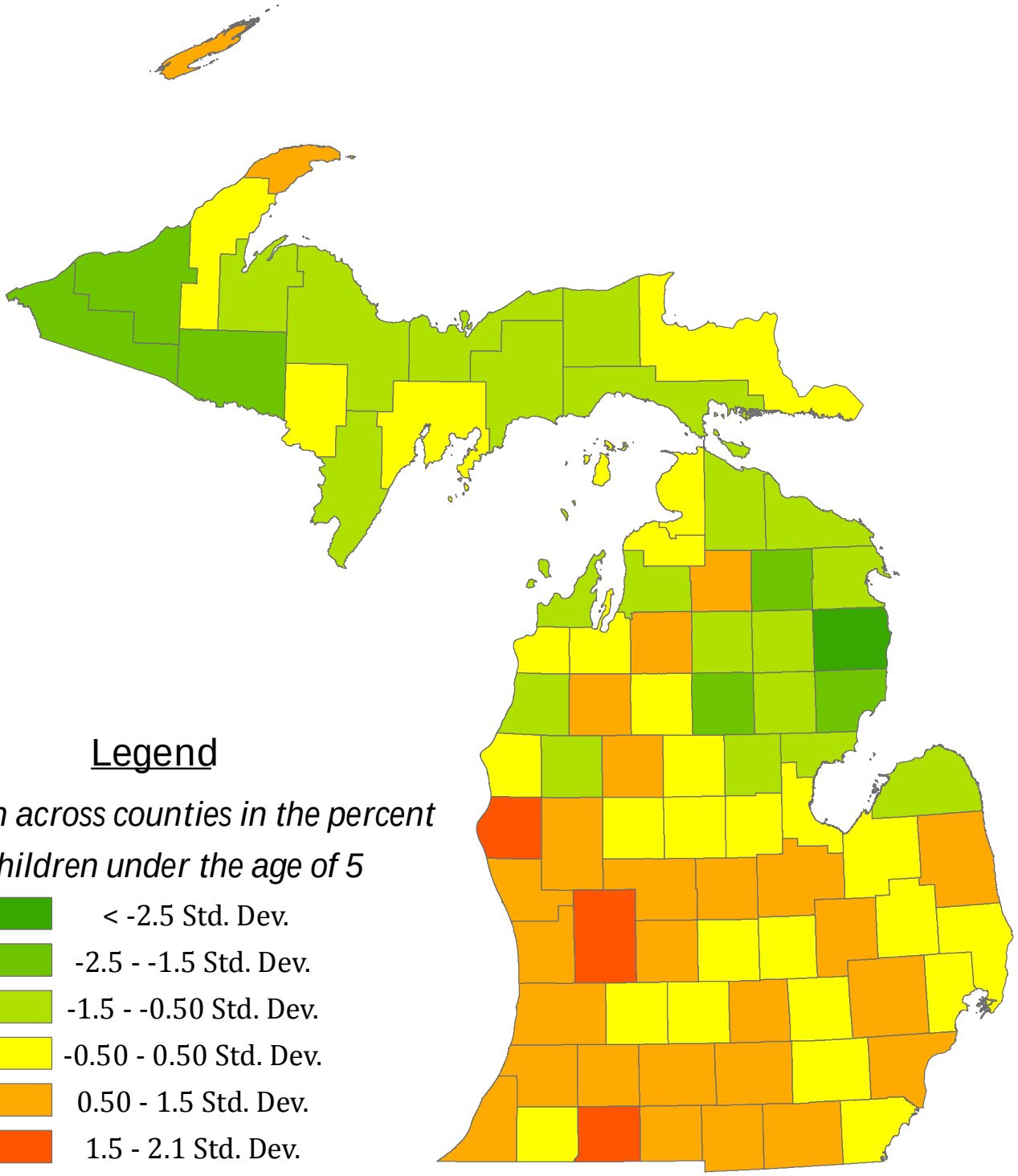
Young Children
(Ages 5 and under)



MPHI®

Data extracted from the American Community Survey 2005-2009

Young Children
(Ages 5 and under)



Legend

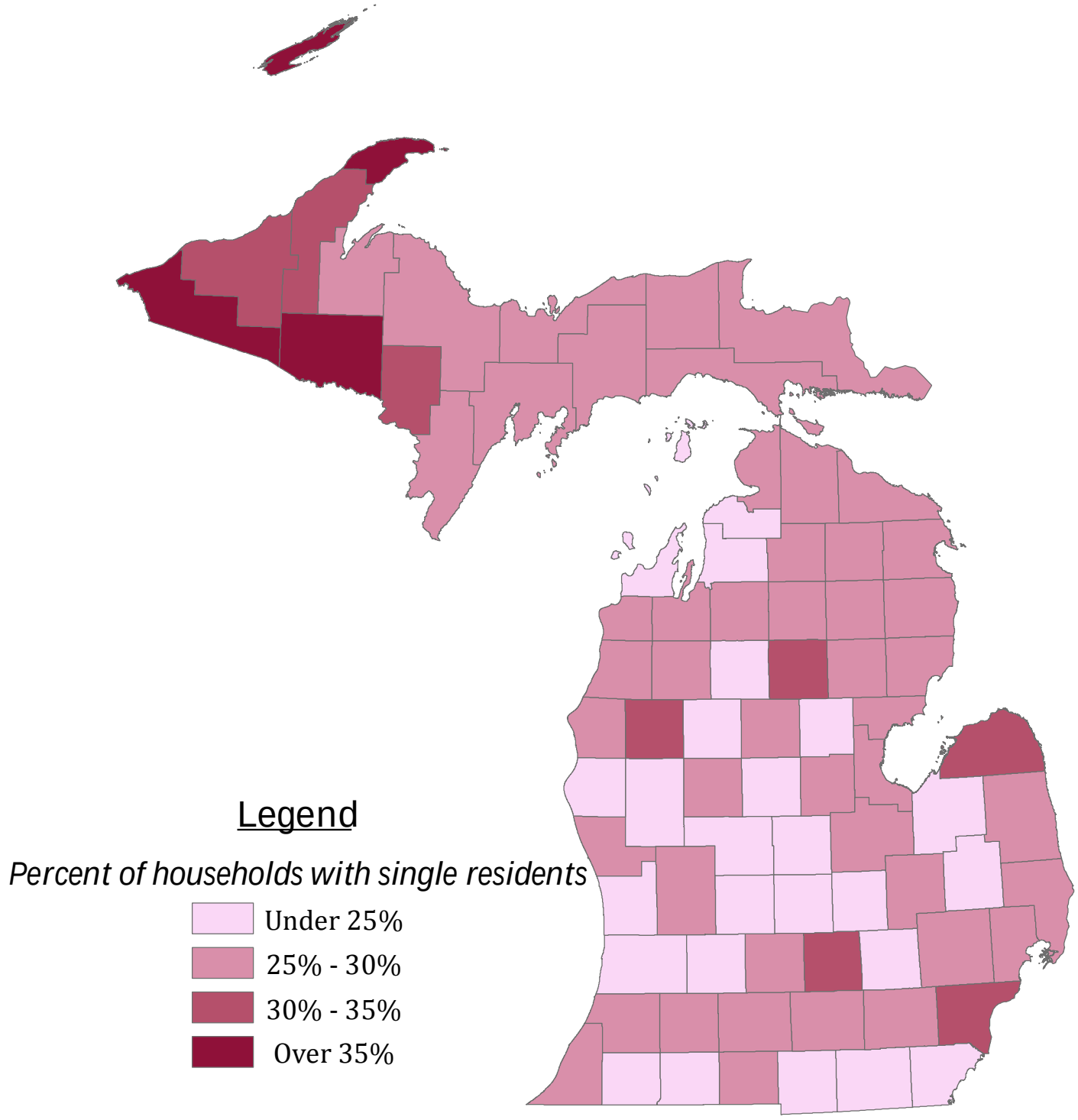
Variation across counties in the percent of children under the age of 5

- < -2.5 Std. Dev.
- -2.5 - -1.5 Std. Dev.
- -1.5 - -0.50 Std. Dev.
- -0.50 - 0.50 Std. Dev.
- 0.50 - 1.5 Std. Dev.
- 1.5 - 2.1 Std. Dev.

MPHI®

Data extracted from the American Community Survey 2005-2009

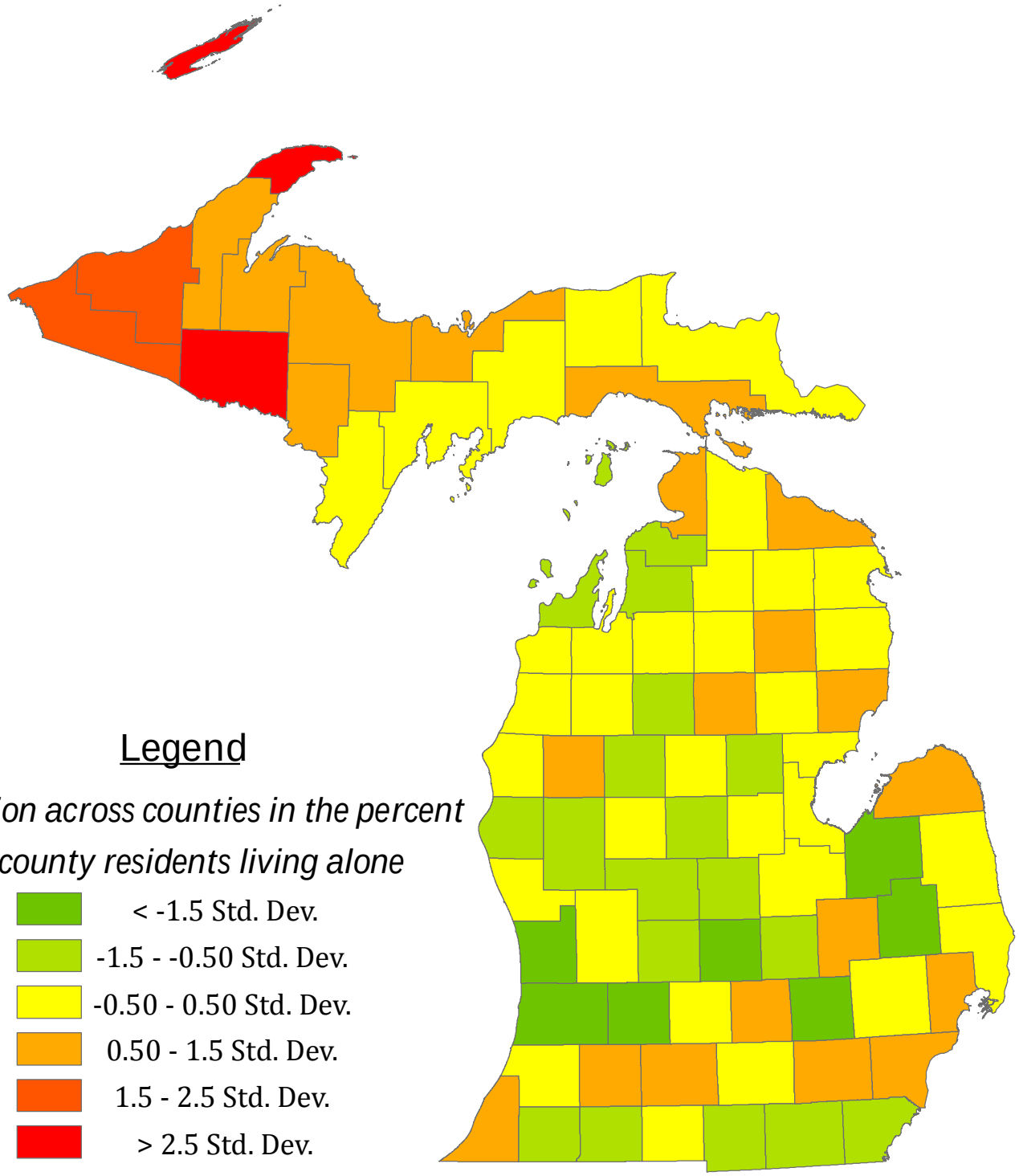
Individuals Living Alone



MPHI®

Data extracted from the American Community Survey 2005-2009

Individuals Living Alone



Legend

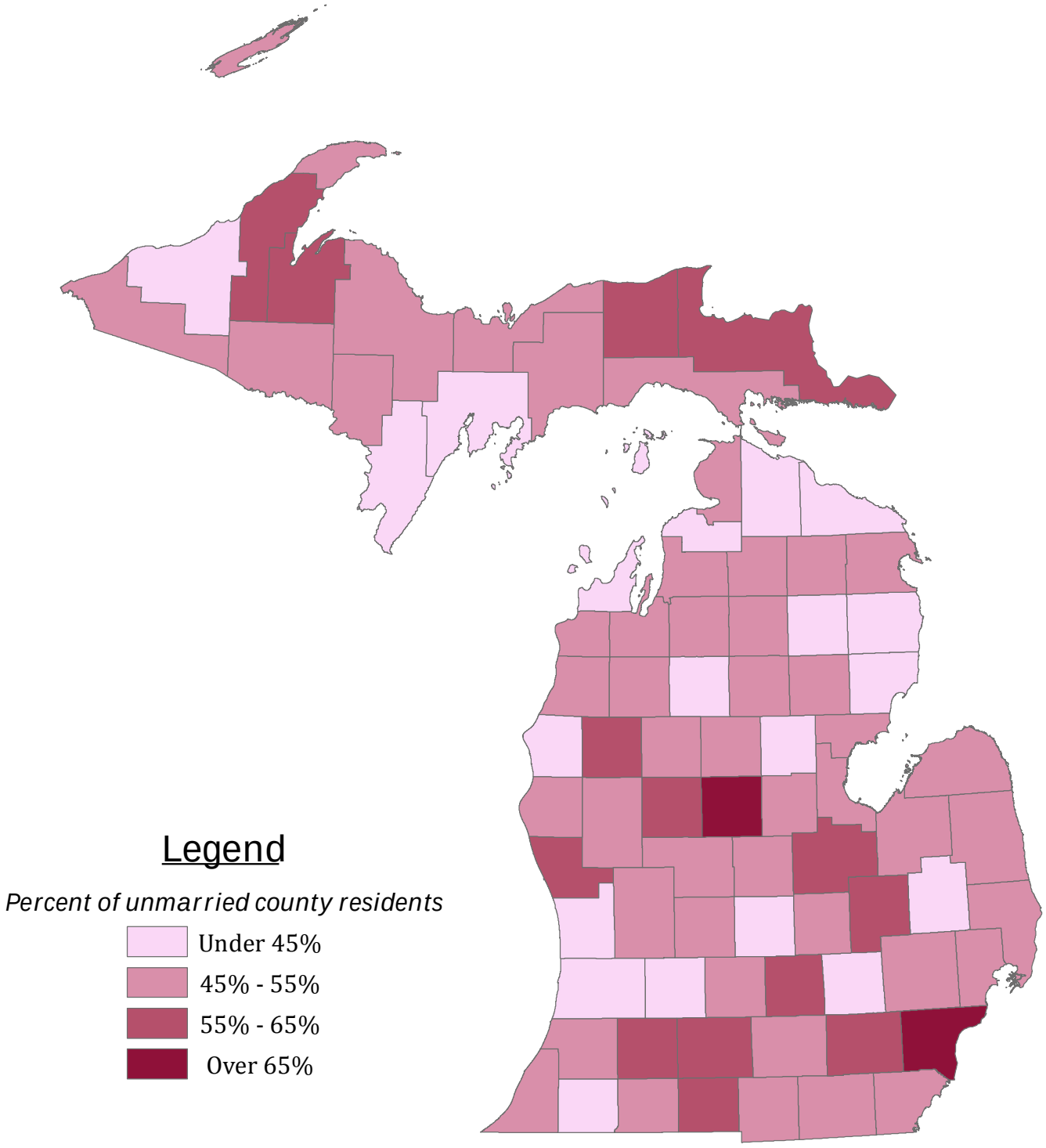
Variation across counties in the percent of county residents living alone

- < -1.5 Std. Dev.
- -1.5 - -0.50 Std. Dev.
- -0.50 - 0.50 Std. Dev.
- 0.50 - 1.5 Std. Dev.
- 1.5 - 2.5 Std. Dev.
- > 2.5 Std. Dev.

MPHI®

Data extracted from the American Community Survey 2005-2009

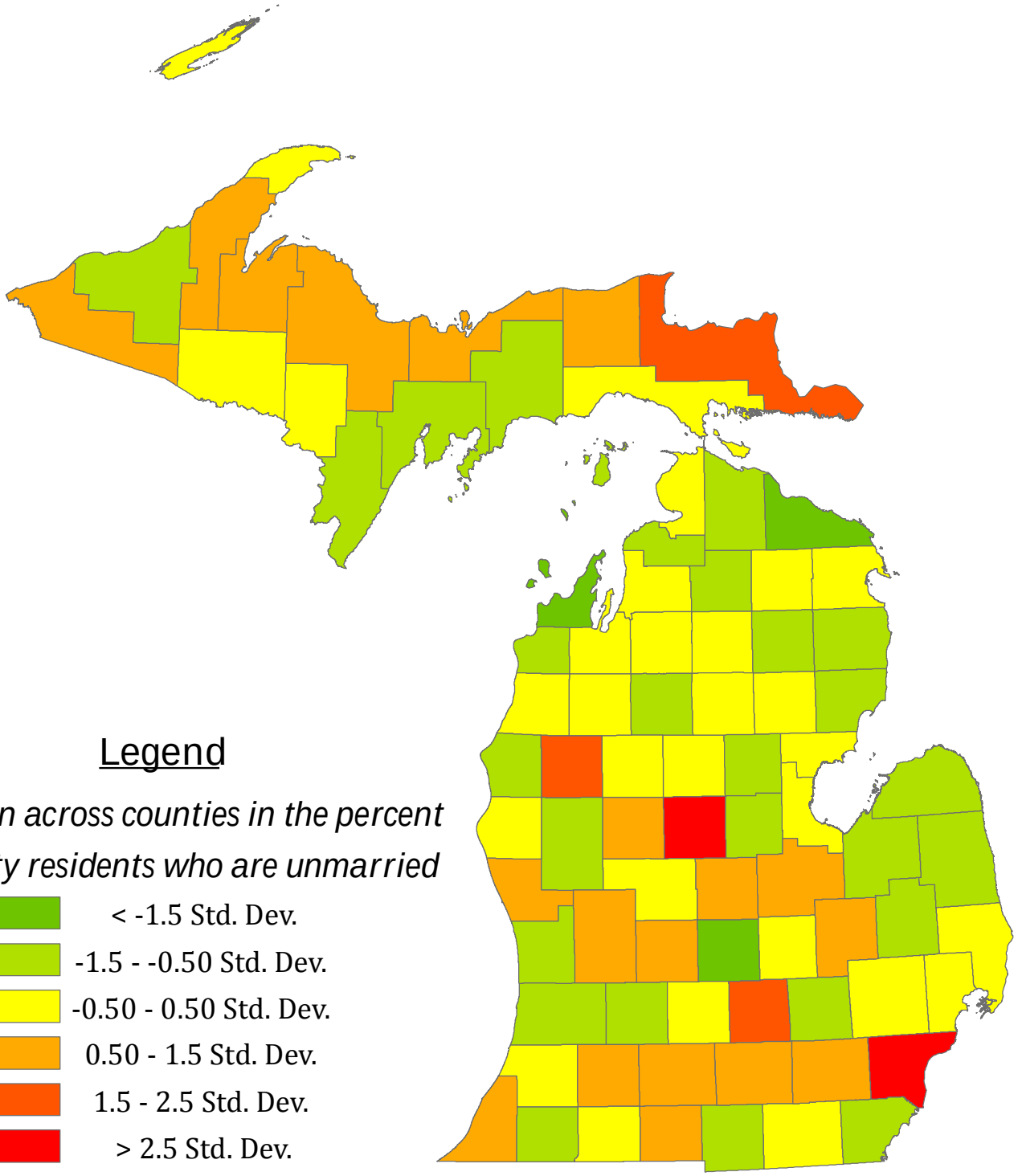
Unmarried Individuals
(Single, widowed, divorced)



MPHI®

Data from the American Communities Survey 2005-2009

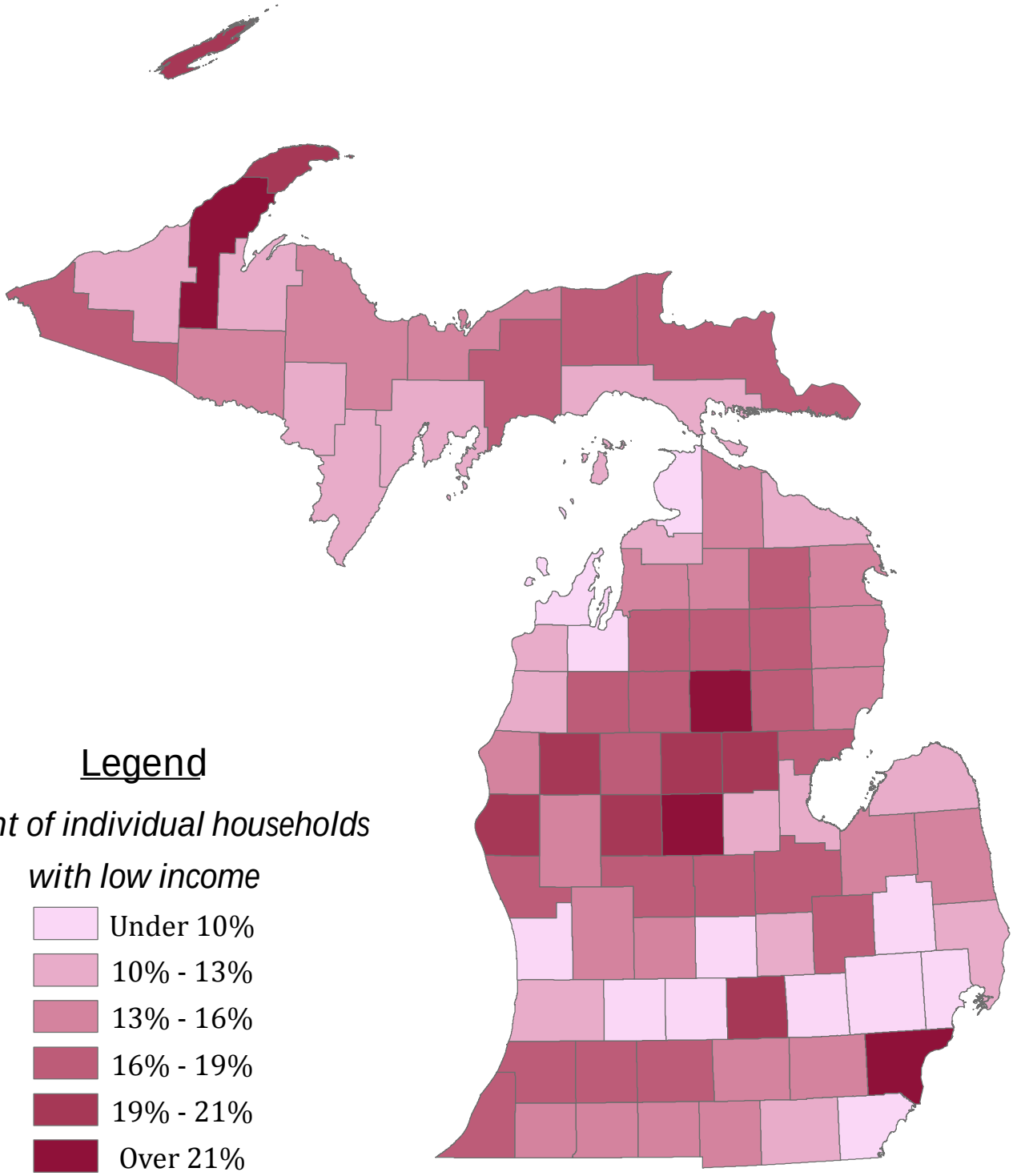
Unmarried Individuals
(Single, widowed, divorced)



MPHI®

Data from the American Communities Survey 2005-2009

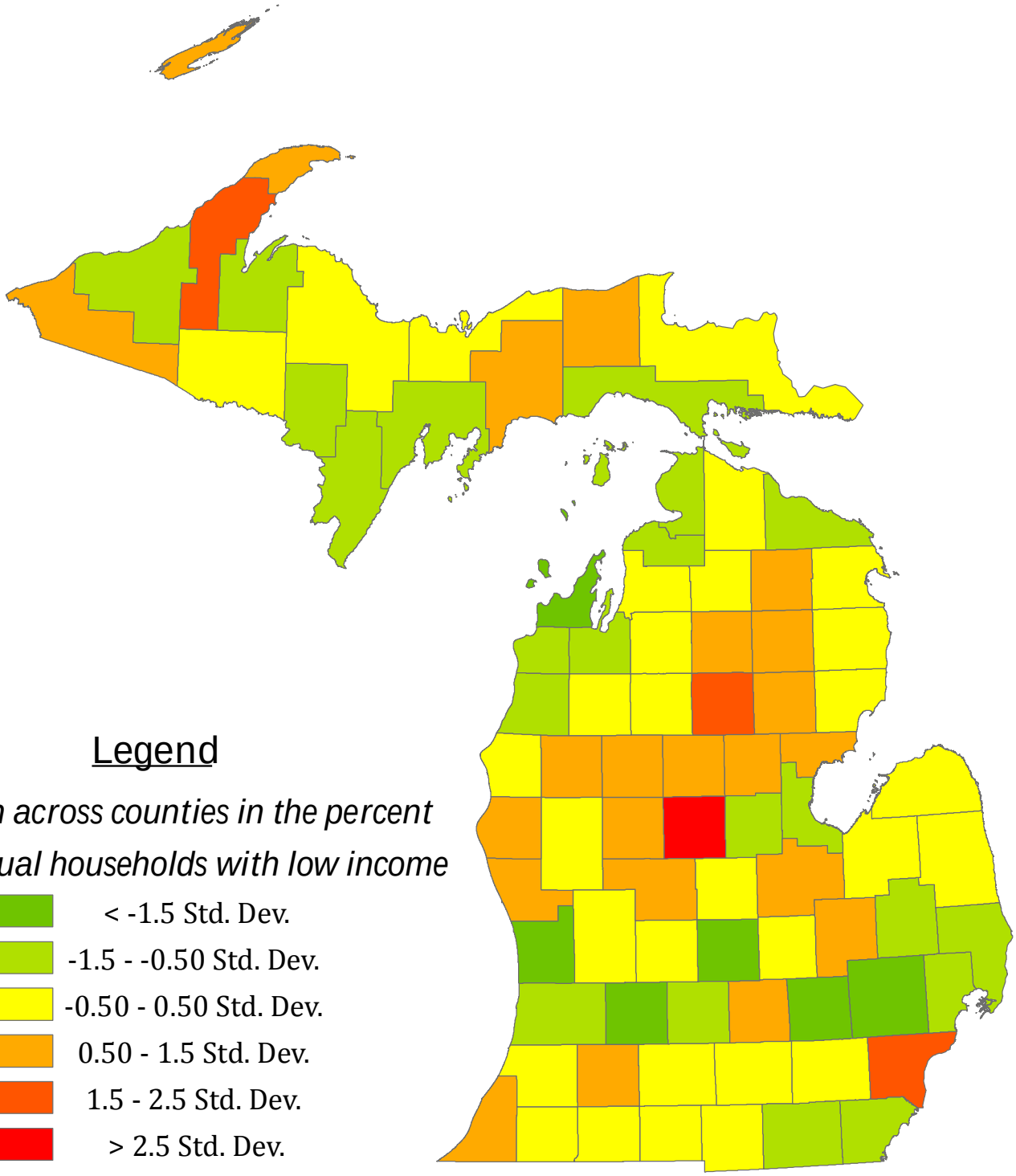
Low Income Individual Households



MPHI®

Data extracted from the American Community Survey 2005-2009

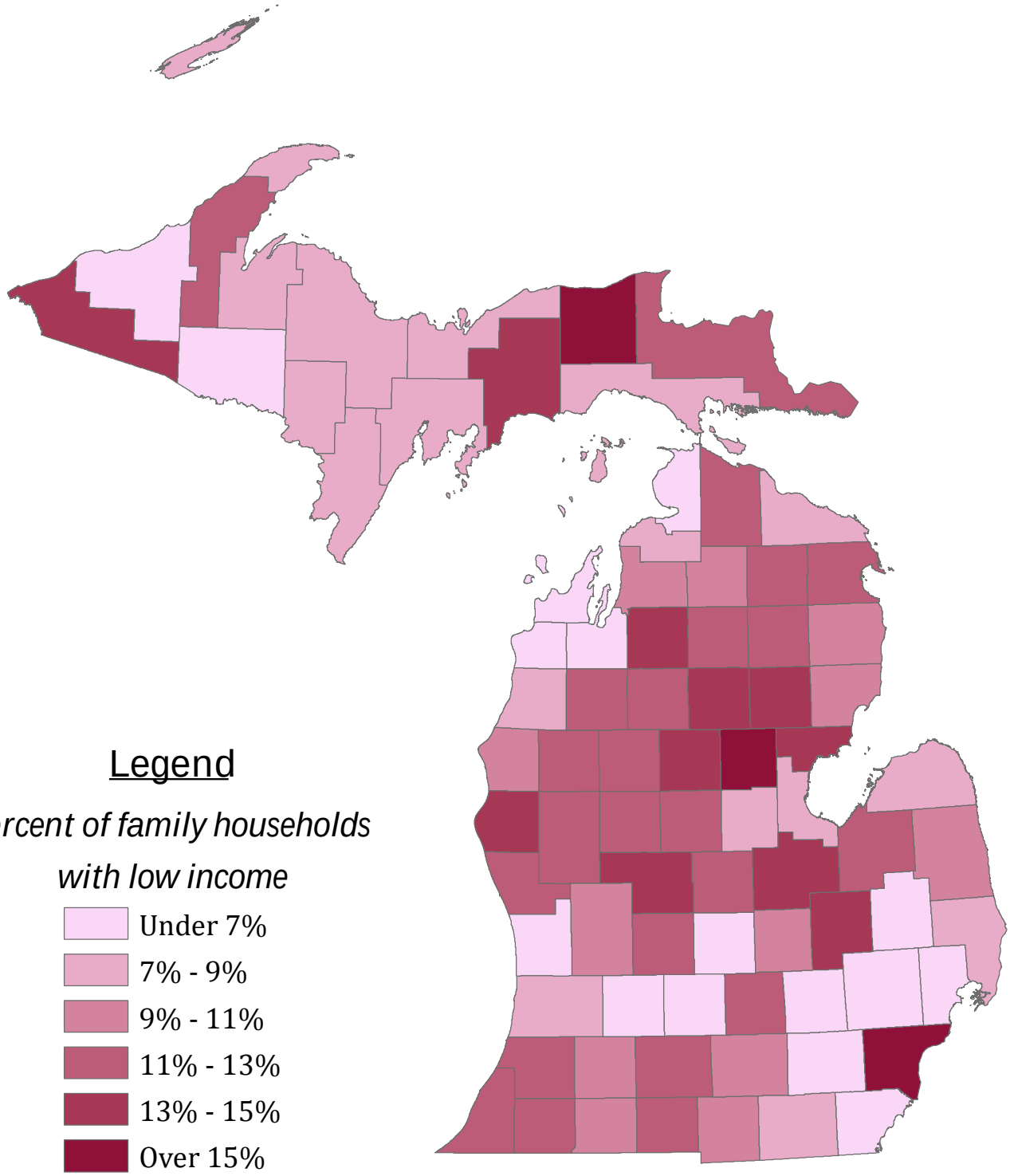
Low Income Individual Households



MPHI®

Data extracted from the American Community Survey 2005-2009

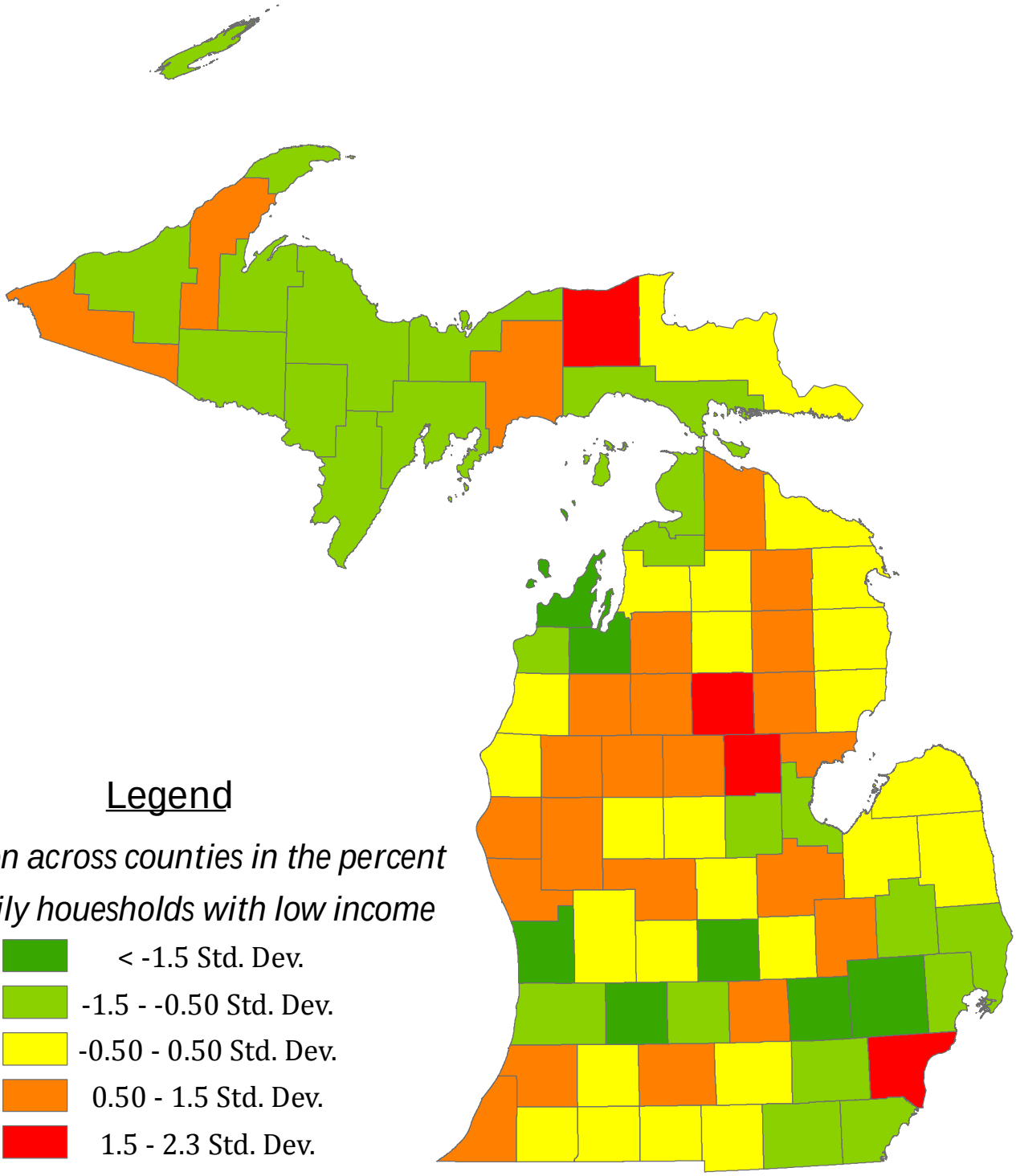
Low Income Family Households



MPHI®

Data extracted from the American Community Survey 2005-2009

Low Income Family Households



Legend

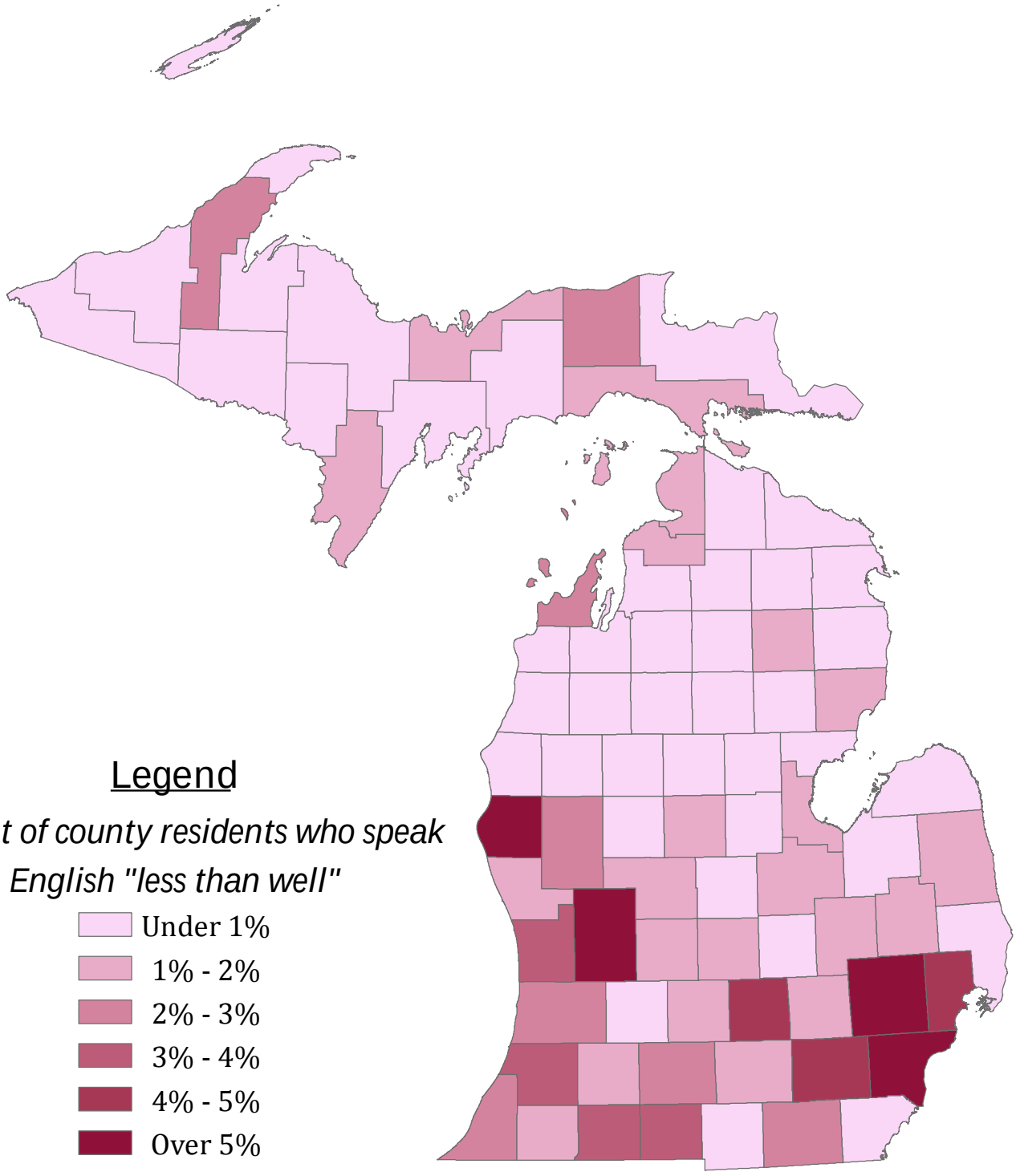
Variation across counties in the percent of family houesholds with low income

- < -1.5 Std. Dev.
- -1.5 - -0.50 Std. Dev.
- -0.50 - 0.50 Std. Dev.
- 0.50 - 1.5 Std. Dev.
- 1.5 - 2.3 Std. Dev.

MPHI®

Data extracted from the American Community Survey 2005-2009

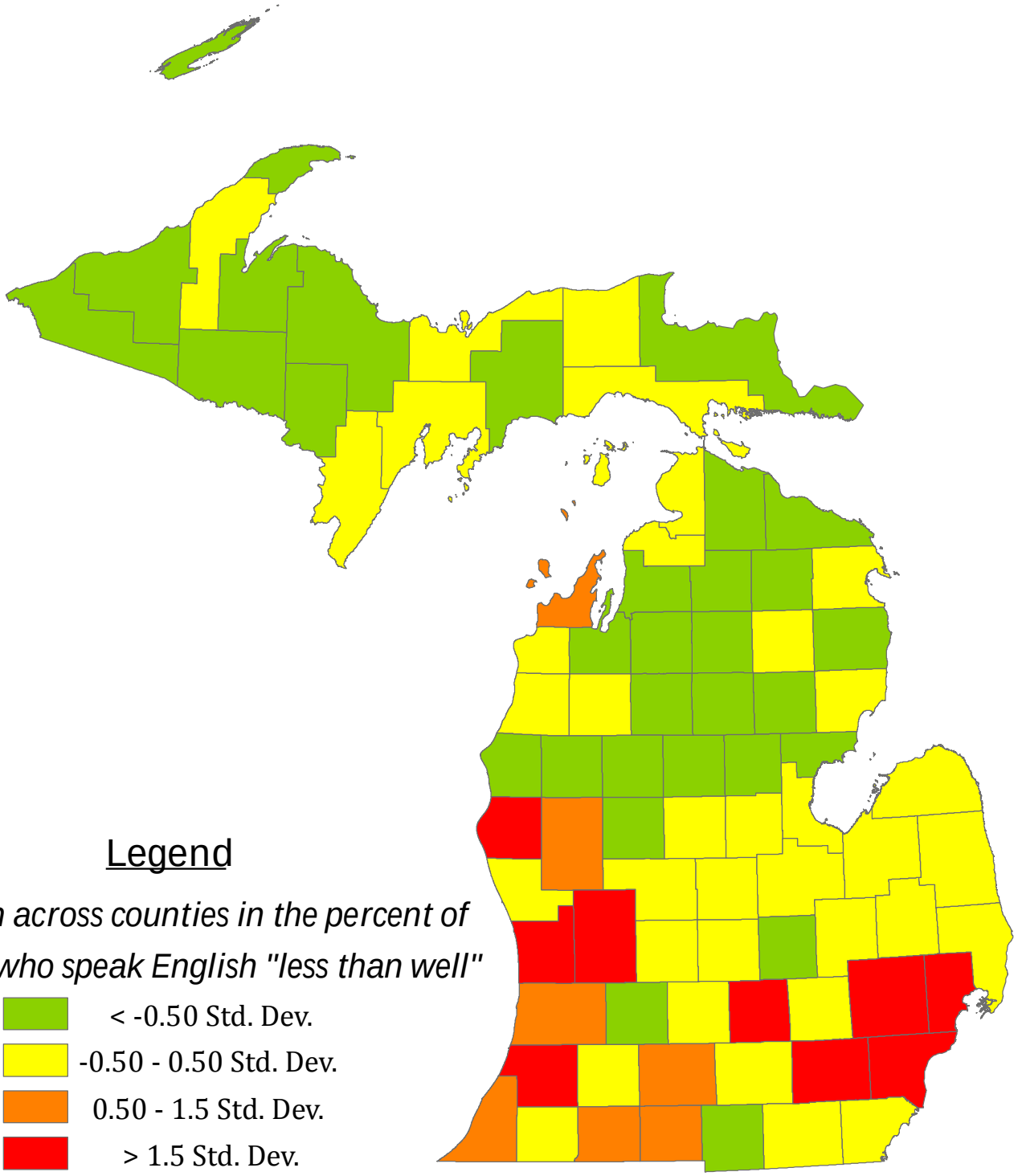
Low English Competency



MPHI®

Data extracted from the American Community Survey 2005-2009

Low English Competency



Legend

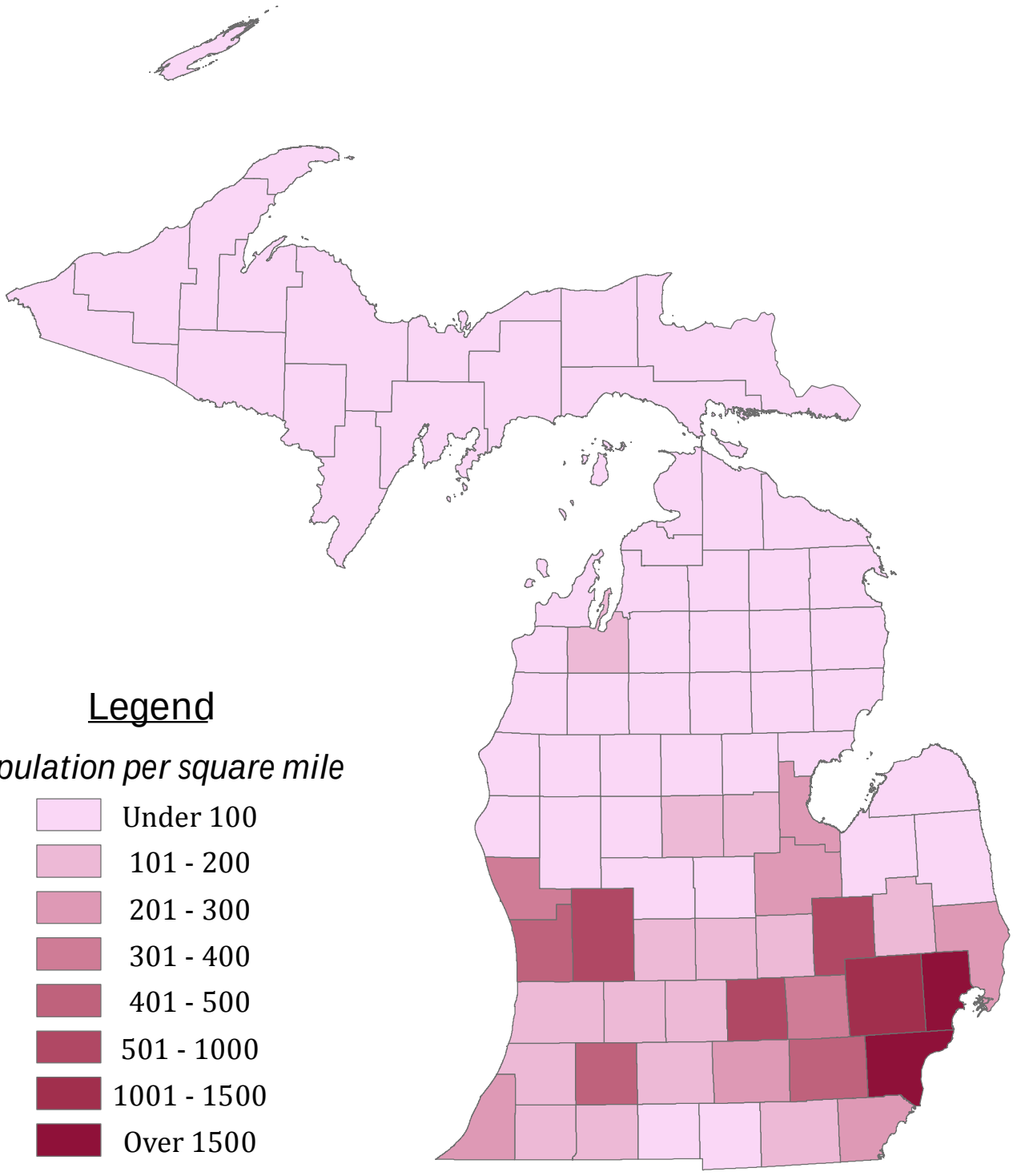
Variation across counties in the percent of residents who speak English "less than well"

- < -0.50 Std. Dev.
- -0.50 - 0.50 Std. Dev.
- 0.50 - 1.5 Std. Dev.
- > 1.5 Std. Dev.

MPHI®

Data extracted from the American Community Survey 2005-2009

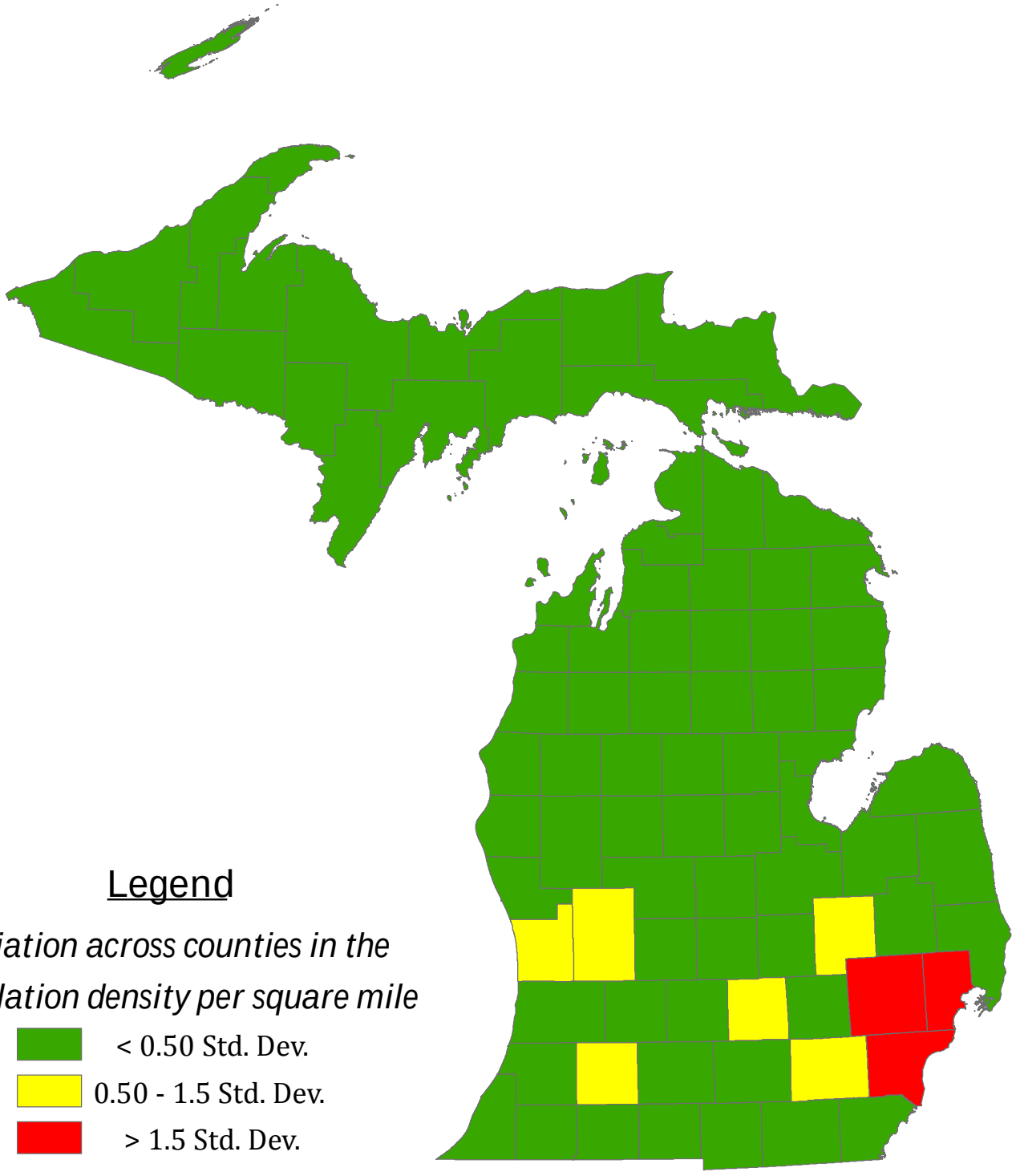
Population Density Per Square Mile



MPHI®

Data extracted from 2010 U.S. Census Bureau

Population Density Per Square Mile



MPHI®

Data extracted from 2010 U.S. Census Bureau

Appendix B: Annotated Literature Review

Mapping Heat Vulnerability – Literature Review Listing
MPHI 2011

American Public Health Association. (2011). *Climate Change: Mastering the Public Health Role*. Available online at http://www.apha-environment.org/pdf/APHA_ClimateChg_guidebook.pdf

- This guidebook offers information on a global view of climate change. Included is basic information regarding climate change and health implications.
- Planning for climate change in public health and opening communication regarding this issue is also discussed.
- Prevention and adaptation information to ensure preparedness and EPA and HHS perspectives

Climate Change Public Health Impacts Assessment and Response Collaborative. (2007). *Public Health Impacts of Climate Change in California: Community Vulnerability Assessments and Adaptation Strategies*. California Department of Public Health & the Public Health Institute. Available online at http://www.ehib.org/papers/Heat_Vulnerability_2007.pdf

- This report summarizes the community vulnerability assessment conducted in California to identify locations and/or populations with high risk for heat-related illness.
- Heat-related illnesses along with community vulnerability for heat-related morbidity and mortality
- Prevention strategies, adaptation and mitigation efforts
- In conclusion, the authors offer short-term and long-term recommendations for the state of California.

Cox, J., Hodges, S., Parshall, L., Rosenzweig, C., & Solecki, W. (2005). *Skin of the Big Apple: Characterizing the Surface Heat Island of New York City & Integration with MM5 Climate Model.* EPA Conference Call, January 26. Available online at http://www.epa.gov/heatisland/resources/pdf/SurfaceUHI_EPA4.pdf

- This presentation accompanied a teleconference in 2005 hosted by the EPA discussion the surface heat characteristics of New York City. The slides present the statistical relationship between surface temperature and a set of variables, and discuss merging these findings with the MM5 Climate Model.

ISEE 22nd Annual Conference, Seoul, Korea, 28 August-1 September 2010. (2011). *Epidemiology , 22* (1), S13-S27.

- Included in this article are a series of abstracts from the 22nd Annual Conference in Seoul, Korea. Forty-nine different articles are featured with a wide range of topics from climate change and environmental health to work environment and respiratory effects.

Ishigami, A., Hajat, S., Kovats, R. S., Bisanit, L., Rognoni, M., Russo, A., et al. (2008). An ecological time-series study of heat-related mortality in three European cities. *Environmental Health, 7*(5).

- This article reviews heat-related mortality in three European cities (Budapest, London, Milan) to discuss environmental and social determinants.
- The authors calculated the increased risk of death for each degree increase in temperature, and compared the risk from different types of mortality (external, respiratory, and cardiovascular causes of death are increased at higher temperatures). The authors found no clear evidence of risk by socio-economic status. In conclusion, the authors discuss the consistent determinants (age, gender, and cause of death) and confirm the lack of a strong socio-economic gradient in health heat effects in the locations of interest at that time.

Kinney, P., O'Neill, M., Bell, M., & Schwartz, J. (2008). Approaches for estimating effects of climate change on heat-related deaths: challenges and opportunities. *Environmental Science and Policy, 11*(1), 87-96.

- Addresses effect of populations and social adaptation in reviewing and predicting effects of climate change on heat-related deaths
- Metrics for modeling heat, and challenges in studying heat and mortality, and information needed and methods for estimating heat-related impacts in urban areas in the future

Loughnan, M., Nicholls, N., & Tapper, N. *'Hot Spots' Project: Spatial vulnerability to heat events in Melbourne, Australia.* Monash University Climate Group. Melbourne, Australia: Monash University. Available online at http://www.fbe.unsw.edu.au/cf/staff/peter.rickwood/soac2009/PDF/Loughnan%20Margaret.pdf

- In this report, the authors discuss the background for heat-related health risks, and risk factors in Australia. The basis of their research was to develop a spatial index of population vulnerability to heat events.
- Presents a methodological framework for variable selection and the index variables

Reid, C., O'Neill, M., Gronlund, C., Brines, S., Brown, D., Diez-Roux, A., et al. (2009). Mapping Community Determinants of Heat Vulnerability. *Environmental Health Perspectives*, 117 (11), 1730-1736.

- The authors describe 10 vulnerability factors for heat-related morbidity and mortality in the US. These factors are mapped and a factor analysis is performed to create a heat vulnerability index value. From this, they propose a template for future mapping efforts regarding local and regional heat vulnerability.

Rinner, C., Patychuk, D., Bassil, K., Nasr, S., Gower, S., Campbell, M. (2010). The Role of Maps in Neighborhood-Level Heat Vulnerability Assessment for the City of Toronto. *Geography Publications and Research*, 37 (1), 31-44.

- Conceptual framework used: exposure and sensitive determine potential vulnerability; potential vulnerability and adaptation result in residual vulnerability
- Considered the effect of portraying indicators at various levels of geographic specificity
- Vulnerability index: dwellings requiring major repairs; dwellings constructed before 1986; apartments in buildings with 5+ stories; dwellings rented; low-income persons; persons speaking neither English nor French; recent immigrants; visible minority; those without a degree; persons aged 75 and older; rates of ambulatory hospital visits for circulator and respiratory disease
- Maps of optimistic and pessimistic approaches to indexed vulnerability

Rinner, C., Patychuk, D., Jakubek, D., Nasr, S., & Bassil, K. (2009). *Development of a Toronto-Specific, Spatially Explicit Heat vulnerability Assessment: Phase 1.* Toronto Public Health.

- Lit review of indicators & conceptual approaches
- Also includes review of statistical methods used in heat vulnerability

Seguin, J., & Berry, P. (2006). *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity.* Climate Change and Health Office, Safe Environments Directorate, Health Canada. Ottawa, Ontario: Health Canada.

- The Synthesis Report offers a condensed perspective on the broad impacts of climate change on human health. The full report includes a chapter on vulnerabilities, adaptation, and adaptive capacity in Canada. The full report is extensive but focuses largely on topics beyond the scope of our work.

Stafoggia, M., Forastiere, F., Agostini, D., Biggeri, A., Bisanti, L., Cadum, E., et al. (2006). Vulnerability to Heat-Related Mortality: A Multicity, Population-Based, Case-Crossover Analysis. *Epidemiology*, *17* (3), 315-323.

- Reviewed deaths from 1997-2003 in 4 Italian cities (Bologna, Milan, Rome, and Turin); investigated the association between temperature on the day of death and mortality rates.
- Older people, women, widows/widowers, low income, previous psychiatric disorders, depression, heart conduction disorders, circulatory disorders of the brain, living in a nursing home, and being hospitalized also increased odds of mortality.

World Health Organization (WHO). (2003). *Methods of assessing human health vulnerability and public health adaptation to climate change.* Health and Global Environmental Change, Series No. 1. Available online at http://www.euro.who.int/__data/assets/pdf_file/0009/91098/E81923.pdf

- A 100-page reference report that compiles the consequences of climate change on humans. Chapter 5, on the direct health effects of heat and heat waves, and Chapter 12, on vulnerable populations, are most relevant.

Wilhelmi, O. (2008). Spatial Patterns of Societal Risk and Vulnerability to Extreme Heat. *3rd NCAR Community Workshop on GIS in Weather, Climate and Impacts*. National Center for Atmospheric Research (NCAR). Boulder, Colorado. Available online at http://www.gis.ucar.edu/08workshop/pdf/Olga_Wilhelmi_vulnerability.pdf

- Powerpoint presentation that provides an overview of heat vulnerability in the US and describes ongoing studies in Phoenix and Philadelphia
- Outcomes of interest: heat mortality (Philadelphia), heat distress calls (Phoenix)
- Plan to combine morbidity/mortality data with household surveys to add more individual & qualitative information

Wilhelmi, O., & Hayden, M. (2010). Connecting people and place: a new framework for reducing urban vulnerability to extreme heat. *Environmental Research Letters*, *5*, 14-21.

- Thorough background review on heat and health, relevant indicators
- **extreme heat vulnerability analysis framework (external drivers, extreme heat vulnerability, adaptation/response)
- Vulnerability is a function of three interactive components: exposure, sensitivity, and adaptive capacity
- Theoretical paper to propose framework that includes "drivers of vulnerability at multiple scales, connecting people- and place-based vulnerability assessment approaches and enhancing the ability of communities and stakeholders to develop proactive programs to mitigate risk and respond efficiently to heat emergencies."

Wong, E. *Reducing Urban Heat Islands: Compendium of Strategies*. U.S. Environmental Protection Agency, Office of Atmospheric Programs. October 2008. Available online at http://www.epa.gov/heatisland/resources/compendium.htm

- Describes the causes and impacts of urban heat islands, and heat island reduction strategies (including voluntary and policy efforts by state and local governments)
- Chapter 1, Urban Heat Island Basics, is a good introduction to understanding heat islands

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