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INFLUENCE OF THE MEASUREMENT OF DISTANCE ON ASSESSMENT OF RECREATION ACCESS

Abstract

Residents' recreation behavior is highly influenced by their level of access to recreation opportunities. Distance is an important component of access. The purpose of this study was to measure levels of access to public beaches in the Detroit Metropolitan Area using four road travel distances (1, 6, 10, and 20 miles) and three access measures (minimum distance, travel cost, and covering). Findings indicate that while public beaches are geographically accessible for a majority of the DMA population within 20 miles according to all access measures, at distances less than 20 miles, level of access varies substantially by the access measure used. Future access studies should consider a range of travel distances rather than the single distance typical of most prior analyses and should also be sensitive to the differentials produced by the measure of access employed. Study limitations are identified and recommendations for further research discussed.

Keywords: access, distance, public beach, Detroit Metropolitan Area, geographic information systems (GIS)

INFLUENCE OF THE MEASUREMENT OF DISTANCE ON ASSESSMENT OF RECREATION ACCESS

Introduction

Parks, playgrounds, trails, and other public green spaces are locally desirable land uses (LDLUs) that provide communities with recreation and open space opportunities in addition to various other environmental, social, health, and economic benefits (Porter, 2001; Taylor, Floyd, Whitt-Glover, & Brooks, 2007; Wendel, 2011). Recreation behavior, including the use of recreation facilities, is highly influenced by residents' levels of access to LDLUs (Dishman & Sallis, 1994; Leitner & Leitner, 2004; McCormack, Giles-Corti, Bulsara, & Pikora, 2006). Access to LDLUs has also been identified as an important component of urban systems and an essential contributor to quality of life. As Pred (1977) explained, overall quality of life within a city is related to access to multiple service types, including recreational open space opportunities. Determining residents' levels of access to LDLUs is therefore a prerequisite to effective urban recreation planning and management. As a result, numerous studies have measured levels of residential access with regard to parks (Abercrombie, Sallis, Conway, Frank, Saelens, & Chapman, 2008; Boone, Buckley, Grove, & Sister, 2009; Byrne, Wolch, & Zhang, 2009; Maroko, Maantay, Sohler, Grady, & Arno, 2009; Moore, Diez Roux, Evenson, McGinn, & Brines, 2008; Nicholls, 2001; Nicholls & Shafer, 2001; Omer, 2006; Sister, Wolch, & Wilson, 2010; Talen, 1997, 1998; Wolch, Wilson, & Fehrenbach, 2005), trails (Estabrooks, Lee, & Gyurcsik, 2003; Lindsey, Maraj, & Kuan, 2001), playgrounds (Smoyer-Tomic, Hewko, & Hodgson, 2004; Talen & Anselin, 1998), golf courses (Deng, Walker, & Strager, 2008), recreational forests (Tarrant & Cordell, 1999), and campsites (Porter & Tarrant, 2001).

While walking distance proximity to LDLUs can encourage their use and, hence, elevate levels of participation in physical activity, people are also sometimes willing to travel outside their local neighborhood to reach certain types of recreational facilities (McCormack et al., 2006). As a result, it is apparent that the use of a range of distances when measuring the level of residential access to LDLUs is preferable to consideration of a single distance. The majority of previous studies, however, have measured access using only one travel distance (typically less than or equal to 1 mile), though a limited number of exceptions do exist (Deng et al., 2008; Nicholls, 1999; Talen, 1997). Similarly, most previous access studies have employed only a single method of measuring access even though multiple such methods are available.

The purpose of this study was to demonstrate the utility of measuring levels of access to recreation opportunities using a range of distances and access measures. Specifically, the primary objective was to determine the proportion of the population residing within four travel distances of one or more public beaches using three different methods of access measurement. Public beaches were selected for analysis for three reasons. First, previous access-related studies have concentrated on land-based opportunities; this study therefore expands the literature to include water-based recreation. Second, public beaches are LDLUs that provide a variety of water- and land-based recreation opportunities in addition to significant environmental (Goodhead & Johnson, 1996; Jennings, 2007), social (Edgerton, 1979), health (Meyer & Brightbill, 1964), and economic (Dixon, Oh, & Draper, 2012; Oh, Dixon, Mjelde, & Draper, 2008; Yang, Madden, Kim, & Jordan, 2012) benefits for local communities. Third, public access to beaches is a civil right in the United States based on the public trust doctrine (Negris, 1986). The remainder of the paper is divided into six sections. The first describes the concept of recreation opportunity in the context of LDLUs. Next, five methods of measuring accessibility to recreation opportunities are introduced. The third section discusses recreation behavior in the context of distance traveled to use recreation-based LDLUs. The fourth section describes the study area and research method. Following presentation of results, the article concludes with a discussion of study implications, limitations and recommendations for future research.

Recreation Opportunity and Locally Desirable Land Uses (LDLUs)

Participants in outdoor recreation not only seek to participate in preferred activities, but also seek specific settings in order to enjoy special experiences and subsequent benefits (Aukerman, 2011; Aukerman, Haas, Lovejoy, & Welch, 2004; Clark & Stankey, 1979; Driver & Brown, 1978; Driver, Brown, Stankey, & Gregoire, 1987; Manning, 1985; Petengill & Manning, 2011; Stankey & Wood, 1982). As outlined by Driver et al. (1987), these four components-activities, settings, experiences, and benefits-constitute a recreation opportunity. A recreation opportunity can thus be defined as an opportunity to engage in a preferred activity in a preferred setting in order to realize desired experiences and achieve certain benefits (Manning, 1985). Figure 1 depicts the key components of a recreation opportunity and the linkage between these four components. A number of types of LDLU, such as parks, playgrounds, urban trails, golf courses, lakes, and other public green and blue spaces, offer settings for recreation activities.

Insert Figure 1 about here

As suggested in figure 1, the role of public leisure agencies is to provide both recreation activities and settings that can contribute to the realization of particular types of experiences and subsequent benefits (Aukerman et al., 2004). Providing access to recreation settings is an essential responsibility of public leisure agencies in their quest to improve residents' quality of life.

Measuring Access to Recreation Opportunity

Although access is a term commonly used in everyday life, there is no universal agreement about its definition (Lotfi & Koohsari, 2009). Access is generally referred to as the ease with which activities or services can be reached or obtained (Johnson, Gregory, Pratt, & Watts, 2000; Morris, Dumbie, & Wigan, 1979; Nicholls, 2001). Access to goods and services is an important component of an urban system, and a contributor to quality of life. According to Pacione (1989), having close geographical accessibility to public services can contribute to personal welfare. Pred (1977) also emphasized the importance of access with regard to public services, including extensive recreational open space opportunities, for improving urban residents' quality of life. Accurately measuring levels of access to public services and facilities is therefore a prerequisite to effective urban planning and management.

Access can be measured both subjectively and objectively (Tilt, Unfred, & Roca, 2007). Objective measures relate to characteristics of the physical environment, while subjective measures depend upon the perceptions of citizens/users (Lotfi & Koohsari, 2009). In this study, access was measured in an objective manner. Methods for measuring objective access can be categorized into five different approaches: (1) the container approach; (2) the minimum distance approach; (3) the travel cost approach; (4) the spatial interaction model approach; and (5) the covering approach (Cho, 2003).

The Container Approach

The container approach defines access according to the presence of LDLUs within a geographic unit, such as a census tract, zip code, or local neighborhood unit (e.g., the number or total area of LDLUs within the geographic unit) (Lindsey et al., 2001; Zhang, Xu, & Zhuang, 2011). A container index Z_i^C is calculated as follows:

$$Z_i^C = \sum_j S_J, \in I$$

where Z_i^C is a container index for residential neighborhood i, and the number or aggregate size, S_J, is summed for those LDLUs located within the boundaries I of i. This approach is based on the fundamental assumption that the benefits of LDLUs are allocated only to the residents of the corresponding areal unit (Cho, 2003), and restricts accessibility to include only the number or area of LDLUs within that unit. The higher the number or the total area of LDLUs within each unit of analysis, the higher the level of access to LDLUs enjoyed by residents of that unit. The container approach has been employed extensively in political science and urban planning research due to its simplicity (Talen & Anselin, 1998; Lindsey et al., 2001). However, container-based measures have been criticized as unrealistic measures of access because, as noted above, spatial externalities of surrounding units of analysis are excluded from consideration (Cho, 2003; Nicholls, 2001).

Minimum Distance Approach

The minimum distance approach defines access as the distance that neighborhood residents must travel to reach the nearest LDLU (Smoyer-Tomic et al., 2004), with the distance inversely related to level of access. The minimum distance index, Z_i^M is estimated as follows:

$$Z_i^M = \min | d_{ij} | ,$$

where Z_i^M is the index for minimum distance from residential neighborhood i to the nearest LDLU j. This approach assumes that residents always use the nearest LDLU with the least travel cost, as measured by distance or time (Talen & Anselin, 1998). However, in reality, residents do not always visit the nearest LDLU (Cho, 2003); the choice of LDLU can be influenced by other factors, such as perceived or actual level of safety, environmental quality, size, quantity and quality of amenities, and general attractiveness (Zhang et al., 2011).

The Travel Cost Approach

The travel cost approach is adapted from location optimization models (Talen & Anselin, 1998) and defines access according to the average or total distance between each residential neighborhood and all distributed LDLUs (Cho, 2003). The travel cost index, Z_i^T, is expressed as follows:

$$Z_i^T = \sum_j [d_{ij} / N],$$

where d_{ij} is the distance between a residential neighborhood i and LDLU location j, and N is the total number of LDLUs. The ease of interpreting the resulting value, expressed in a simple distance unit, is one of the advantages of using this approach (Talen and Anselin, 1998). The lower the total or average distance, the higher the level of access to LDLUs an area and its residents has. However, in reality, most residents do not interact with all LDLUs within a defined spatial area (Zhang et al., 2011).

The Spatial Interaction Model Approach

The spatial interaction model approach identifies levels of human interaction between origins (residential neighborhoods) and destinations (LDLUs). According to Zhang et al. (2011), gravity models have been employed extensively with the following assumptions: (1) "spatial interaction declines with a larger spatial separation (travel distance or time) between origins and destinations;" and (2) "spatial interaction increases with a greater demand at origins or with higher supply capacity and/or attractiveness at destinations" (p. 3). Thus, LDLUs are weighted by their size (or attractiveness) and "friction of distance" (Cho, 2003; Talen & Anselin, 1998). The gravity model index, Z_i^G, is measured as follows:

$$Z_i^G = \sum [S_j / d_{ij}^a],$$

where S_j reflects the number or size of LDLUs, and for each LDLU location j, d_{ij}^a is a distance decay factor, with distance d_{ij} between residential neighborhood i and LDLU j, and friction parameter a. However, the choice of the magnitude of the friction parameter a and the issue of self-potential when $d_{ij} = 0$ are two methodological problems to be considered when using the gravity model (Talen & Anselin, 1998).

The Covering Approach

The last approach is the covering approach, which defines access within a certain service boundary measured not from residential neighborhoods to LDLUs but from LDLUs to residential neighborhoods (Cho, 2003). The basic assumption of this approach is that residents are said to have access to an LDLU if they are located within its service area, but they are deemed to have no access if they are not (Nicholls, 2001). Since a service boundary is defined by a critical radius or network distance, identification of that radius or distance is critical when delineating the service area of the LDLU (Omer, 2006). A number of types of LDLU, including parks, are associated with recommended location criteria that include the definition of preferred service areas (Nicholls, 2001).

Insert Table 1-2 about here

Table 1 summarizes the use of each of these five access measures with respect to recreation-related LDLUs in the previous literature; Table 2 illustrates the variations in findings for those studies that have employed more than one distance or access measure. Since study results can clearly be significantly affected by the type of access measure and distance employed, these choices are a substantial methodological issue when measuring access to LDLUs. Authors such as Talen and Anselin (1998) have highlighted the need for urban service delivery research to focus more explicitly on methodological and measurement issues. In this study, three of the five methodological approaches to measuring access – ‘the minimum distance approach,’ ‘the travel cost approach,' and 'the covering approach' – were applied. The container and spatial interaction approaches were not considered due to differences in, and the subsequent lack of comparability between, the outputs of these methods (Table 3).

Insert Table 3 about here

Distances Traveled to Use LDLUs and Residents' Recreation Behaviors

Residents' recreation behavior is highly associated with proximity to LDLUs such as trails (Troped, Saunders, Pate, Reininger, Ureda, & Thompson, 2001; Moudon, Lee, Cheadle, Collier, Johnson, Schmid, & Weather, 2005), parks (Giles-Corti & Donovan, 2002; Giles-Corti, Broomhall, Knuiman, Collins, Douglas, Ng, Lange, & Donovan, 2005), and beaches (Bauman, Smith, Stoker, Bellew, & Booth, 1999; Humpel, Owen, Iverson, Leslie, & Bauman, 2004). As noted by Moore and Graefe (1994), distance is an important component of proximity to recreation opportunities. One mile has often been recognized as a reasonable walking distance to represent residents' proximity to LDLUs (Tarrant & Cordell, 1999), and numerous studies have employed a one mile distance when measuring the level of access to LDLUs such as urban parks (Maroko et al., 2009; Moore et al. 2008), golf courses (Deng et al., 2008), recreational forests (Tarrant & Cordell, 1999), and campsites (Porter & Tarrant, 2001).

However, in many areas, urban sprawl has resulted in increased travel distances between residential neighborhoods and LDLUs (McCormack et al., 2006). According to Ross (2000), activities such as shopping, recreational and other activities are generally no longer undertaken in local neighborhoods. Ross's argument is supported by data from the Western Australian Government (2000) that show that while 24% of leisure and recreational trips occur less than 1 km (0.6 miles) from home, 30% occur between 1 and 5 km (0.6 and 3.1 miles) and 46% occur at distances greater than 5 km (3.1 miles). Lobo (1988) also noted that people in Perth traveled beyond their local area to use certain types of recreational facilities such as indoor sporting and tennis facilities.

Travel distance may increase for other LDLUs such as beaches. Houghton (1988) indicated that 43.8% of residents in Western Australia visited beaches that are located within 10 km (approximately 6 miles) from their home. A survey conducted by the Strategy Institute on behalf of the East Bay Regional Park District estimated that 10-20 miles was the distance residents were willing to travel for beach-based recreation activities such as boating, fishing and swimming (Hass, 2009). As noted by McCormack et al. (2006), "use of public open space is sensitive to distance from home" (p. 2). Reductions in physical activity caused by the increasing distance between households and recreation opportunities may give rise to health problems such as obesity (McCormack et al., 2006). The analyses presented here therefore emphasize the importance of the method of measurement during the assessment of recreation access.

Method

The discussion of methods is divided into five sections: study area; data acquisition; GIS software; data preparation; and, access/distance measurement.

Study Area: Detroit Metropolitan Area (DMA), Michigan

According to the U.S. Bureau of the Census (2010), southeast Michigan's DMA (also referred to as metro Detroit), is the 12th largest metropolitan area in the US. The DMA includes three counties (Oakland, Wayne, and Macomb) and had a population of 3,863,924 and an area of 1,958.96 square miles (3,463.2 km^2) in 2010. The DMA was chosen as the study area for two reasons. First, the DMA contains a high density of public beaches. According to the Michigan Department of Environmental Quality (MDEQ, 2013), approximately 14.5% (n=178) of the public beaches in Michigan (n=1,224) are located in the DMA. Second, the DMA is the most densely populated and demographically diverse area in Michigan. According to the U.S. Census Bureau (2010), while the population density of Michigan is 174.8 inhabitants per square mile (67.5/ km^2), the population density of the DMA is 2,792.5 inhabitants per square mile (1,078.2/km^2).

The results of spatial data analysis are sensitive to the nature of the areal unit employed and the choice of areal unit is a substantial issue. For example, results are sensitive to the modifiable areal unit problem (MAUP), a statistical bias that can radically affect the results of statistical tests due to the choice of district boundaries (O'Sullivan & Unwin, 2003); MAUP therefore refers to the tendency of results to vary when the areal unit of analysis is changed (Porter, 2001). This study used the census block group (CBG) as its unit of analysis because the CBG offers a good approximation of a neighborhood environment with reliable social and economic data available from the U.S. Census Bureau (Frank, Andersen, & Schmid, 2004). A CBG is defined as a subdivision of a census tract with a mean population of 600 to 3,000 people (Iceland & Steinmetz, 2003). There are 3,341 CBGs in the DMA. Figure 2 shows the locations of the 178 public beaches and the boundaries of the 3,341 CBGs within the DMA. Recognizing the potential influence of the edge effect, the problem that "sites in the center of the study area can have nearby observations in all directions, whereas sites at the edges of the study area only have neighbors toward the center of the study area" (O'Sullivan & Unwin, 2003, p. 34), public beaches outside of the DMA but within 20 miles of the centroid of a CBG within the DMA were also considered in a separate suite of analyses. However, these analyses indicated the lack of any edge effect and so those findings are not discussed in any further detail here.

Insert Figure 2 about here

Data Acquisition

Location data (latitude and longitude) for the public beaches in the study area were downloaded from the MDEQ (http://www.deq.state.mi.us/beach/). Geographic data such as CBG boundaries and the street network were downloaded from the Michigan GIS data library (http://www.mcgi.state.mi.us/mgdl/). Population data were obtained from the U.S. Census Bureau.

GIS Software

ArcGIS (version 10.0), a package produced by the Environmental Systems Research Institute, was used to display the study area and data. Network analysis was implemented using the Network Analyst extension.

Data Preparation

Once all the relevant geographic and census data had been collected, they were entered and integrated into the GIS environment in GIS shape file (.shp) form. All shapefiles were projected and displayed in the NAD 1983 Hotine Oblique Mercator projection. The location of each public beach was represented by the centroid of its parking lot. If multiple parking lots existed at a single beach (as was the case for 19 [10.6%] of the beaches), the nearest parking lot to the beach was used.

Access/Distance Measurement

As previously noted, the study employed three of the five classic methods of measuring access – 'the minimum distance approach,' 'the travel cost approach,' and 'the covering approach.' The shortest road network distance from each census block group centroid to the nearest public beach was used as the minimum distance measure. The travel cost approach was implemented based on average road network distance to all 178, and just the nearest 7, beaches. The nearest 7 beaches were used to counter the unrealistic assumption of the travel cost approach that residents interact with all LDLUs in the environment, one solution to which is to use a smaller subset of LDLUs (Zhang et al., 2011). According to Saaty and Ozdemir (2003), “seven plus or minus two” is the upper limit of our brain’s capacity to process information simultaneously, hence the selection of a subset of seven. Network-based service areas were identified using a range of distances to operationalize the covering approach.

Network analysis was employed to calculate all distances. Several previous studies have indicated the preferability of using network-based rather than Euclidean (straight-line) distance (Lofti & Koohsari, 2009; Nicholls, 2001; Nicholls & Shafer, 2001; Talen, 1997). Analysis was conducted at four network travel distances: walking distance (1 mile) and driving distance (6 miles, 10 miles, and 20 miles). A CBG was defined as falling within a certain distance if its geographic center (rather than its entirety) fell within that distance. The numbers and proportions of CBGs and of the DMA population within each distance were calculated to determine the level of access offered according to each measure.

Results

The four sets of access results for public beaches in the DMA are displayed in Figures 3 (the container approach), 4 and 5 (the travel cost approach) and 6 (the covering approach). Table 4 illustrates the proportion of the DMA’s population considered to have access to one or more public beaches within the range of distances and access measures employed.

Insert Figures 3-6 and Table 4 about here

According to the minimum distance approach, the minimum distance to the nearest public beach varied from 0.1 miles (in Waterford township, Oakland county) to 20.3 miles (in Grosse Ile township, Wayne county), with a mean of 7.1 miles; 134 (4.1%) of the 3,341 CBGs fell within 1 mile of a public beach, 1,542 (45.2%) within 6 miles, 2,508 (73.8%) within 10 miles and 3,337 (99.8%) within 20 miles. In terms of population, only 3.9% of the population of the DMA lives in a CBG within a 1 mile walking distance of one or more public beaches according to the minimum distance approach; 46.4%, 77.7% and 99.8% of the population of the DMA live in a CBG within 6 miles, 10 miles, and 20 miles of at least one public beach, respectively.

According to the travel cost approach, the average distance to the nearest 7 public beaches from each block group centroid varied from 0.5 miles (in Waterford township, Oakland county) to 23.3 miles (in Grosse Ile township, Wayne county), with a mean of 12.1 miles. Eleven (0.3%) of the 3,341 CBGs fell within 1 mile of the nearest 7 public beaches, 528 (15.8%) within 6 miles, 1,069 (31.8%) within 10 miles and 3,240 (97.0%) within 20 miles. Only 0.3% of the population of the DMA lives in a CBG within 1 mile of their nearest 7 public beaches according to the travel cost approach, with 16.7% within 6 miles, 31.8% within 10 miles, and 96.9% within 20 miles, respectively.

According to the travel cost approach, the average distance to all 178 public beaches from each block group centroid varied from 11.2 miles (in Waterford township, Oakland county) to 50.8 miles (in Brownstone township, Wayne county), with a mean of 27.1 miles; no CBGs fell within 1, 6 or 10 miles, while 630 (18.8%) of the 3,341 CBGs fell within 20 miles. In terms of population, 21.1% of the population of the DMA lives in a CBG within 20 miles of all 178 public beaches according to the travel cost approach.

According to the covering approach, 93 (2.8%) of the 3,341 CBGs fell within 1 mile of one or more public beaches, 1,547 (45.3%) within 6 miles, 2,475 (73.3%) within 10 miles, and 3,331 (99.7%) within 20 miles. In terms of population, 2.9% of DMA residents live in a CBG within 1 mile of one or more public beaches according to the covering approach, 45.9% within 6 miles, 77.2% within 10 miles, and 99.7% within 20 miles, respectively.

Overall, the findings indicate that one or more public beaches are accessible within 20 miles for a majority of the DMA's population, though access to a public beach within 1 mile, a more reasonable walking distance, is very low. The findings also demonstrate that the population living in a CBG deemed to have access to public beaches varies substantially by both the type of access measure and the distance indicator employed. As shown in Figures 3-6, access to public beaches is less prevalent in both Macomb and Wayne counties; in contrast, residents of Oakland county appear to have extremely good access to public beaches.

Discussion

This paper has demonstrated the differential impact associated with the use of varying measures of access and distance when determining the level of access to recreation opportunities such as public beaches. It is the first in the leisure and recreation realm to employ multiple sets of access measure over a range of distances, directly addressing calls to explicitly incorporate methodological and measurement issues into urban service delivery research and making both methodological and practical contributions to the park and recreation literature.

As shown in Table 4, the proportion of the population indicated to have access to one or more public beaches varied both between the different network distances (1, 6, 10 and 20 miles) and the three methods of access (minimum distance, travel cost, and covering) employed. Figures 3 through 6 confirm this variability. While public beaches are geographically accessible for the vast majority of the DMA population within 20 miles, at distances less than 20 miles the estimated population living in CBGs accessible to a public beach varies substantially by access measure. In particular, there is a substantial differential between levels of access as indicated by the minimum distance and covering approaches, and the travel cost approach, most notably at the 1, 6 and 10 mile levels; similarly, noticeable differences exist between the levels of access indicated by the two variations of the travel cost approach (based on all, and just the nearest 7, beaches). Though the minimum distance approach indicates the highest levels of access at all four distances, this approach also makes the potentially flawed assumption that all residents always use their nearest facility; this may not be the case due to a variety of objective and perceptual factors including lack of awareness of this facility, dislike of some aspect of the facility, etc. The covering approach indicates similarly high levels of accessibility, and is less restrictive than the minimum distance approach in that any CBG or other unit of analysis may fall within the service area of more than one facility, allowing for some degree of choice on the part of potential users. Further analysis could be conducted to ascertain the number of facilities accessible from each CBG within each distance. An additional benefit of both the minimum distance and covering approaches is their computational simplicity relative to the travel cost method; processing times for the four sets of analyses presented here were 30 minutes (covering), 48 minutes (minimum distance), 574 minutes (travel cost, nearest 7 beaches), and 1,440 minutes (travel cost, all beaches).

Though more complicated to implement, the travel cost approach provides important perspective on possible sources of variation in accessibility results. Most critically, the version focused on just the nearest 7 beaches explicitly incorporates residents' psychological limits of spatial cognition when deciding which recreation facility to visit. The proportion of the population indicated to have access according to the travel cost approach was much lower than for the minimum distance or covering approaches. The travel cost method based on all 178 beaches indicates by far the lowest levels of accessibility. In reality, though, it is unlikely that any DMA resident is even aware of all of those opportunities. Thus, while the minimum distance and covering approaches may overestimate levels of access, the ‘all facilities’ travel cost approach likely underestimates. Utilization of two or more access measures provides a better sense of the range of actual levels of access and is therefore preferable to the employment of any one approach.

Distance is a critical element of access. Delineating LDLU service areas, as shown in Figures 3-6, is a meaningful activity, but distance clearly matters and the choice of the most appropriate distance, or range of distances, is important. This choice should ideally incorporate consideration of factors such as the type and size of facility, typical or preferred travel distances (based on any prior research into willingness to walk/drive to particular facility types within the community), and levels of community mobility (e.g., degree of private auto ownership, extent of public transportation options; the importance of factors related to mobility is discussed in more detail below). For example, the distance and distance range appropriate when considering access to a small neighborhood park should likely be shorter and smaller, respectively, than those for regional or special use facilities. Again, as with the type of access measure employed, use of two or more distance cut-offs can provide a more complete portrayal of levels of access than any one distance alone.

Access measures in this study also considered spatial cognition and spatial destination choice set issues, which have been recognized as serious methodological problems in prior access research. As previously noted, although a citizen could theoretically access all LDLUs in their local environment, destination choice with regard to LDLUs such as urban parks is, in reality, based on a more compact choice set due to individuals' limited spatial knowledge and information processing capacity (Fotheringham & Curtis, 1999; Zhang et al., 2011). Seven has been recognized as the number of pair-wise comparisons that the typical individual can make among all alternatives (Miller, 1956; Saaty & Ozdemir, 2003; Zhang et al., 2011). This paper included a more realistic beach access measure by incorporating this psychological upper limit of individual information processing, though further, survey-based research would help ascertain community- and facility-specific levels of cognition.

The approach highlighted in this study can help public leisure agencies assess and address complex planning and management issues. First, the results can be discussed in the context of environmental justice and equity. Access to recreation opportunities has been shown to be associated with the individual and community health and wellbeing of urban populations (Byrne et al., 2009; Sallis & Saelens, 2000). Disparities in levels of access to recreation opportunities based on residents' demographic and socioeconomic characteristics represent an environmental justice concern (Deng et al., 2008; Floyd & Johnson, 2002; Porter & Tarrant, 2001; Sister et al., 2010; Tarrant & Cordell, 1999; Taylor et al., 2007). The conceptualization and measurement of recreation access is critical to the evaluation of the spatial accessibility of recreation opportunities relative to the distribution of surrounding populations. As Talen and Anselin (1998) noted, "accessibility is a tool used to discover whether or not equity has been achieved, and the two concepts of accessibility and equity are the primary building blocks used to assess the spatial distribution or spatial pattern of public services" (p. 596). The access measures demonstrated in this paper can be used as input into the more comprehensive assessment of equity. Such findings may be used by public leisure agencies to allocate limited budgets more efficiently and in a more equitable manner by identifying vulnerable (low access) areas and populations. Moreover, the results of this study can facilitate a more informed decision making process. Active stakeholder involvement, an essential part of the participatory approach, can be positively influenced by increased access to information (Yang et al., 2012). In particular, visualization of information is a critical component of the decision making process (Talen, 1998). Compared to tabular data, maps can communicate information in a more intuitive manner (Fekete, Wijk, Stasko, & North, 2008). Information regarding spatial patterns of access to public recreation facilities could contribute to a more participatory approach to planning, e.g., via a spatial decision support system employing Web-based GIS.

Second, use of these measures can provide a platform via which to identify the action steps possible and necessary to improve public access. All four sets of access measure employed in this study indicate that there is regional disparity with regard to access to public beaches. Although only a small proportion of the population lives in a CBG accessible within a 1 mile walking distance, public beaches are accessible for higher proportions or a majority of the population at different driving distances (6, 10, or 20 miles). However, the latter statement assumes access to a reliable and affordable means of transportation, which in the case of the DMA may not be a realistic assumption. As seen in Figure 7, the proportion of households without a vehicle is spatially heterogeneous, exhibiting especially high levels in Wayne County, where levels of access to public beaches are generally low. The spatial mismatch between access to public beaches and to private transportation could directly inform local community policy makers in the development of innovative and effective public recreation planning strategies to improve beach access and use. While the acquisition of new beach access points is unlikely, being dependent not only on economic resources but on the physical geography of a place (i.e., the existence of public bodies of water and of vacant land adjacent to them via which to provide access), parks and recreation agencies could partner with local transportation authorities to provide free or low-cost passes to beach access sites. Thus, measuring levels of access to recreation opportunities over a range of distances is a useful precursor to community evaluation and planning interventions when considered in combination with access to other public and private resources.

Third, the mapping of spatial distributions of level of access to public beaches (Figures 3-6) could contribute to development of a regional water and land recreation opportunity spectrum (WALROS). WALROS is a zoning system or framework that identifies a spectrum of water and land-based recreation opportunities on a continuum ranging from “primitive” to “urban” (Aukerman, 2011). As a specialized recreation opportunity spectrum that is based on the concept of recreation opportunity, WALROS can provide planners and managers with a framework and procedures for making better decisions in order to conserve a spectrum of high-quality and diverse water and land-based recreation opportunities by incorporating a variety of physical, social and managerial attributes (Aukerman, 2011). Access is one of the critical physical attributes in the context of WALROS planning. The spatial patterns of access to public beaches as portrayed in this paper could be used as input into WALROS planning.

Finally, though beyond the scope of this paper in terms of any detailed discussion, the methodological principles developed can be applied to a range of other urban services and facilities to which good access is typically considered desirable. These might include health clinics, libraries, supermarkets, and schools.

Limitations and Future Study

Despite the methodological and practical contributions of this study, several limitations should be acknowledged. First, measuring the level of access to public beaches based on distance (i.e., objectively) ignores other objective and subjective factors, such as facility size, perceived or actual levels of safety, willingness or ability to walk or drive, environmental quality, perceived or actual levels of crowding, noise levels, and the presence of commercial development, all of which can influence residents' recreation destination choice (Oh et al., 2009). Future studies should incorporate one or more of these variables into their analyses to provide more comprehensive assessments of overall accessibility. Second, the results of this study are limited by geographic location and facility type. As a case study of public beaches in the DMA, the results may not be generalizable, since every area has its own unique population characteristics, recreation opportunities, street networks, and other elements of regional heterogeneity. Analysis of other geographic regions and types of recreation opportunity would shed additional light on the utility and applicability of the approach tested. In particular, consideration of substitutable opportunities would be useful, e.g., in this case, public swimming pools. Third, this study does not consider the modifiable areal unit problem (MAUP). The choice of a different scale (census block or census tract) might have produced different results than those found at the scale of the CBG. Future studies should employ different scales as well as compare different access measures and distances.

References

Abercrombie, L. C., Sallis, J. F., Conway, T. L., Frank, L. D., Saelens, B. E., & Chapman, J. E. (2008). Income and racial disparities in access to public parks and private recreation facilities. *American Journal of Preventive Medicine*, 34(1), 9-15.

Aukerman, R. (2011). *Water and land recreation opportunity spectrum (WALROS) users' guidebook*. Denver, CO: US Department of the Interior.

Aukerman, R., Haas, G. S., Lovejoy, V., & Welch, G. (2004). *Water recreation opportunity spectrum (WROS) users' guidebook*. Denver, CO: US Department of the Interior.

Boone, C. G., Buckley, G. L., Grove, J. M., & Sister, C. (2009). Parks and people: An environmental justice inquiry in Baltimore, Maryland. *Annals of the Association of American Geographers,* 99(4), 767-787.

Bauman, A., Smith, B., Stoker, L., Bellew, B., & Booth, M. (1999). Geographical influences upon physical activity participation: evidence of a 'coastal effect'. *Australian and New Zealand Journal of Public Health*, 23(3), 322-324.

Byrne, J., Wolch, J., & Zhang, J. (2009). Planning for environmental justice in an urban national park. *Journal of Environmental Planning and Management,* 52(3), 365-392.

Cho, C. M. (2003). *Study on effects of resident-perceived neighorhood boundaries on public services accessibility & its relation to utilization: Using geographic information system, focusing on the case of public parks in Austin, Texas* (Unpublished doctoral dissertation). Texas A & M University, College Station, TX.

Clark, R. N., & Stankey, G. H. (1979). *The recreation opportunity spectrum: A framework for planning, management, and research (General Technical Report: PNW-98).* Corvallis, OR: USDA Forest Service.

Deng, J., Walker, G., & Strager, M. (2008). Assessment of territorial justice using geographic information systems: a case study of distributional equity of golf courses in Calgary, Canada. *Leisure/Loisir,* 32(1), 203-230.

Dishman, R. K., & Sallis, J. F. (1994). Determinants and interventions for physical activity and exercise. In C. Bouchard, R. J. Shephard, & T. Stephens (Eds.), *Physical activity, fitness, and health* (214-238). Champaign, IL: Human Kinetics.

Dixon, A. W., Oh, C. O., & Draper, J. (2012). Access to the beach comparing the economic values of coastal residents and toursits. *Journal of Travel Research*, 51(6), 742-753.

Driver, B. L., & Brown, P. J. (1978). *The opportunity spectrum concept and behavioural information in outdoor recreation resource supply inventories: a rationale (General Technical Report: RM-55, 24-31).* Corvallis, OR: USDA Forest Service.

Driver, B. L., Brown, P. J., Stankey, G. H., & Gregoire, T. G. (1987). The ROS planning system: Evolution, basic concepts, and research needed. *Leisure Sciences,* 9(3), 201-212.

Edgerton, R. B. (1979). *Along together: Social order on an urban beach*. Berkeley, CA: University of California Press.

Estabrooks, P. A., Lee, R. E., & Gyurcsik, N. C. (2003). Resources for physical activity participation: Does availability and accessibility differ by neighborhood socioeconomic status? *Annals of Behavioral Medicine,* 25(2), 100-104.

Fekete, J., Wijk, J., Stasko, J. T., & North, C. (2008). The value of information visualization, *Information Visualization*, 4950, 1-18.

Fotheringham, A. S., & Curtis, A. (1999). Regularities in spatial information processing: implications for modeling destination choice. *Professional Geographer*, 51(2), 227-239.

Floyd, M .F., & Johnson, C. Y. (2002). Coming to terms with environmental justice in outdoor recreation: a conceptual discussion with research implications. *Leisure Sciences*, 24(1), 59-77.

Frank, L. D., Andersen, M. A., & Schmid, T. L. (2004). Obesity relatinoships with community design, physical, activity, and time spent in cars. *American Journal of Preventive Medicine*, 27(2), 87-96.

Giles-Corti, B., & Donovan, R. J. (2002). Socioeconomic status differences in recreational physical activity levels and real and perceived access to a supportive physical environment. *Preventive Medicine*, 35(6), 601-611.

Giles-Corti, B., Broomhall, M. H., Knuiman, M., Collins, C., Douglas, K., Ng, K., & Donovan, R. J. (2005). Increasing walking: how important is distance to, attractiveness, and size of public open space?. *American journal of preventive medicine*, *28*(2), 169-176.

Goodhead, T., & Johnson, D. (1996). *Coastal recreation management: the sustainable development of martitime leisure*. London, England: E & FN Spon.

Hass, K. (2009). *Measuring accessibility of regional parks: a comparison of three GIS techniques* (Unpublished master's thesis). San Jose State University, San Jose, CA.

Hewko, J. (2001). *Spatial equity in the urban environment: assessing neighborhood accessibility to public amenities* (Thesis of master's degree). University of Alberta, Calgary, AB.

Hewko, J., Smoyer-Tomic, K. E., & Hodgson, M. J. (2002). Measuring neighbourhood spatial accessibility to urban amenities: Does aggregation error matter? *Environment and Planning A*, 34, 1185-1206.

Houghton, D. S. (1988). *Beach use in the Perth Metropolitan Area.* Perth, Australia: The University of Western Australia.

Humpel, N., Marshall, A. L., Iverson, D., Leslie, E., & Owen, N. (2004). Trial of print and telephone delivered interventions to influence walking. *Preventive medicine*, 39(3), 635-641.

Iceland, J., & Steinmetz, E. (2003). *The effects of using census block groups instead of census tracts when examining residential housing patterns.* Bureau of the Census.

Jennings, G. (2007). *Water-based tourism, sport, leisure, and recreation experiences*. Burlington, MA: Routledge.

Johnson, R. J., Gregory, D., Pratt, G., & Watts, M. (2000). *The dictionary of human geography*. Oxford, England: Blackwell Publishing.

Lobo, J. A. F. An attitudinal study of park and recreation space and facility provisions in metropolitan Perth. *Australian Parks and Recreation*, 24, 8-13.

Leitner, M. J., & Leitner, S. F. (2004). *Leisure enhancement.* New York, NY: The Haworth Press.

Lindsey, G., Maraj, M., & Kuan, S. (2001). Access, equity, and urban greenways: An exploratory investigation. *The Professional Geographer,* 53(3), 332-346.

Lotfi, S., & Koohsari, M. J. (2009). Measuring objective accessibility to neighborhood facilities in the city (A case study: Zone 6 in Tehran, Iran). *Cities*, 26(3), 133-140.

Manning, R. E. (1985). Diversity in a democracy: Expanding the recreation opportunity spectrum. *Leisure Sciences*, 7(4), 377-399.

Maroko, A. R., Maantay, J. A., Sohler, N. L., Grady, K. L., & Arno, P. S. (2009). The complexities of measuring access to parks and physical activity sites in New York City: A quantitative and qualitative approach. *International Journal of Health Geographics*, 8(1), 1-23.

McCormack, G. R., Giles-Corti, B., Bulsara, M., & Pikora, T. J. (2006). Correlates of distances traveled to use recreational facilities for physical activity behaviors. *International*

Journal of Behavioral Nutrition and Physical Activity, 3(1), 18-28.

Meyer, H. D., & Brightbill, C. K. (1964). *Community recreation: A guide to its organization*. Englewood Cliffs, NJ: Prentice-Hall.

Michigan Department of Environmental Quality. (2013). *Michigan beaches.* Retrieved November 30, 2014, from http://www.deq.state.mi.us/beach/.

Miller, G. (1956). The magical number seven, plus or minus: some limits on our capacity for processing information. *Psychological Review*, 63(2), 81-97.

Moore, R. L., & Graefe, A. R. (1994). Attachments to recreation settings: The case of rail-trail users. *Leisure Sciences*, *16*(1), 17-31.

Moore, L. V., Diez Roux, A. V., Evenson, K. R., McGinn, A. P., & Brines, S. J. (2008). Availability of recreational resources in minority and low socioeconomic status areas. *American Journal of Preventive Medicine*, 34(1), 16-22.

Morris, J. M., Dumbie, P. L. & Wigan, M. R. (1979). Accessibility indicators for transportation planning. *Transportation Research A*, 13, 91-109.

Moudon, A. V., Lee, C., Cheadle, A. D., Collier, C. W., Johnson, D., Schmid, T. L., & Weather, R. D. (2005). Cycling and the built environment, a US perspective. *Transportation Research Part D: Transport and Environment*, 10(3), 245-261.

Negris, K. A. (1986). Access to New Jersey beaches: The public trust doctrine. *Columbia Journal of Law and Social Problems*, 20, 437-460.

Nicholls, S. (1999). *Measuring the accessibility and equity of public parks: a case study using GIS* (Unpublished master's thesis). Texas A&M University, College Station, TX.

Nicholls, S. (2001). Measuring the accessibility and equity of public parks: A case study using GIS. *Managing Leisure*, 6(4), 201-219.

Nicholls, S. (2002). *Does open space pay? measuring the impacts of green spaces on property values and the property tax base* (Unpublished doctoral dissertation). Texas A&M University, College Station, TX.

Nicholls, S., & Shafer, C. S. (2001). Measuring accessibility and equity in a local park system: The utility of geospatial technologies to park and recreation professionals. *Journal of Park and Recreation Administration,* 19(4), 102-124.

O'Sullivan, D., & Unwin, D. J. (2003). *Geographic information analysis*. New York, NY: Wiley.

Oh, C.-O., Dixon, A. W., Mjelde, J. W., & Draper, J. (2008). Valuing visitors' economic benefits of public beach access points. *Ocean & Coastal Management,* 51(12), 847-853.

Omer, I. (2006). Evaluating accessibility using house-level data: A spatial equity perspective. *Computers, Environment and Urban Systems*, 30(3), 254-274.

Pacione, M. (1989). Access to urban service: The case of secondary scholls in Glasgow. *Scottish Geographic Magazine*, 105, 12-18.

Petengill, P. R., & Manning, R. E. (2011). *A review of the recreation opportunity spectrum and its potential application to transportation in parks and public lands.* Portland, ME: The Paul S. Sarbanes Transit in Parks Technical Assistance Center (TAC).

Porter, R. (2001). *Environmental justice and north Georgia wilderness areas: A GIS based analysis* (Unpublished doctoral dissertation). University of Georgia, Athens, GA.

Porter, R., & Tarrant, M. A. (2001). A case study of environmental justice and federal tourism sites in southern Appalachia: A GIS application. *Journal of Travel Research,* 40(1), 27-40.

Pred, A. R. (1977). *City-systems in advanced economies: Past growth, present processes and future development options*. London, England: Hutchinson.

Ross, W. (2000). Mobility and accessibility: The yin and yang of planning. *World Transport*

Policy and Practice, 6, 13-19.

Saaty, T. L., & Ozdemir, M. S. (2003). Why the magic number seven plus or minus two. *Mathematical and Computer Modeling*, 38(3-4), 233-244.

Sallis, J. F., & Saelens, B. E. (2000). Assessment of physical activity by self-report: status, limitations, and future directions. *Research Quarterly for Exercise and Sport*, 71(2), 1-14.

Sister, C., Wolch, J., & Wilson, J. (2010). Got green? Addressing environmental justice in park provision. *GeoJournal*, 75(3), 229-248.

Smoyer-Tomic, K. E., Hewko, J. N., & Hodgson, M. J. (2004). Spatial accessibility and equity of playgrounds in Edmonton, Canada. *The Canadian Geographer/Le Géographe Canadien,* 48(3), 287-302.

Stankey, G. H., & Wood, J. (1982). The recreation opportunity spectrum: An introduction. *Australian Institute of Parks and Recreation*, 6-14.

Talen, E. (1997). The social equity of urban service distribution: An exploration of park access in Pueblo, Colorado, and Macon, Georgia. *Urban Geography,* 18(6), 521-541.

Talen, E. (1998). Visualizing fairness: Equity maps for planners. *Journal of the American Planning Association*, 64(1), 22-38.

Talen, E., & Anselin, L. (1998). Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds. *Environmental and planning A*, 30(4), 595-613.

Tarrant, M. A., & Cordell, H. K. (1999). Environmental justice and the spatial distribution of outdoor recreation sites: An application of geographic information systems. *Journal of Leisure Research*, 31(1), 18-34.

Taylor, W., Floyd, M., Whitt-Glover, M., & Brooks, J. (2007). Environmental justice: A framework for collaboration between the public health and parks and recreation fields to study disparities in physical activity. *Jounral of Physical Activity & Health*, 4(1), 50-63.

Tilt, J. H., Unfried, T. M., & Roca, B. (2007). Using objective and subjective measures of neighborhood greenness and accessible destinations for understanding walking trips and BMI in Seattle, Washington. *American Journal of Health Promotion*, 21(4), 371-379.

Troped, P. J., Saunders, R. P., Pate, R. R., Reininger, B., Ureda, J. R., & Thompson, S. J. (2001). Associations between self-reported and objective physical environmental factors and use of a community rail-trail. *Preventive medicine*, *32*(2), 191-200.

United States Bureau of the Census. (2010). *American fact finder.* Retrieved October 17, 2013, from http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml.

Wolch, J., Wilson, J. P., & Fehrenbach, J. (2005). Parks and park funding in Los Angeles: An equity-mapping analysis. *Urban Geography*, 26(1), 4-35.

Western Australian Government. (2000). *Mobility behaviour melville 2000.* Perth, Australia: Department of Planning and Infrastructure.

Wendel, H. W. (2011). *An examination of the impacts of urbanization on green space access and water resources: a developed and developing world perspective (*Unpublished doctoral dissertation*)*. University of South Florida, Tampa, FL.

Yang, B., Madden, M., Kim, J., & Jordan, T. R. (2012). Geospatial analysis of barrier island beach availability to tourists. *Tourism Management*, 33(4), 840-854.

Zhang, X., Lu, H., & Holt, J. B. (2011). Modeling spatial accessibility to parks: A national study. *International Journal of Health Geographics*, 10(31), 1-14.

TABLE 1 Summary of access approaches employed in prior LDLU accessibility research

Study	LDLU	Study Area	Distance (Measure)	A
Abercrombie et al., 2008	Urban park	Metro Baltimore/D.C area	Within each census block group	
Estabrooks et al., 2003	Urban trail	Small American Midwestern city (not specified)	Within census tract	
Maroko et al., 2009	Urban park	New York, NY	Using 1 mile kernel bandwith (Euclidean)	
Moore et al., 2008	Urban park	Forsyth County, NC/ New York, NY/Baltimore, MD	Using 1 mile kernel bandwidth (Eucliean)	
Timpiero et al., 2007	Open space	Melbourne, Australia	Within each postal district	
Wolch et al., 2005	Urban park	Los Angeles, CA	Within 0.25 miles of urban parks (Euclidean)	
Zhang et al., 2011	Urban park	USA	Average distance between residents' home and the nearest 7 urban parks (Euclidean)	S
Boone et al., 2009	Urban park	Baltimore, MD	Within 0.25 miles of urban parks (Euclidean)	
Deng et al., 2008	Golf course	Calgary, Canada	Within 1, 1.5 and 2 km (0.6, 0.9 & 1.2 miles) of golf courses (Euclidean)	
Lindsey et al., 2001	Urban trail	Indianapolis, IN	Within 0.5 miles of urban trails (Euclidean)	
Nicholls, 2001	Urban park	Bryan, TX	Within 0.25 miles of urban parks (Euclidean & network)	
Nicholls & Shafer, 2001	Urban park	College Station, TX	Within 0.25 miles of urban parks (Euclidean & network)	
Porter & Tarrant, 2001	Campsite	Southern Appalachia area	Within 1,500 m (0.9 miles) of campsites (Euclidean)	
Talen, 1997	Urban park	Pueblo, CO/Macon, GA	Within 1 mile & 2 miles of urban parks (Network)	
Tarrant & Cordell, 1999	Recreational forest	Chattahoochee, GA	Within 1,500 m (0.9 miles) of recreational forest (Euclidean)	
Haas, 2009	Urban park	East Bay area, CA	Minimum: distance (network); travel cost: distance (Network); covering: within 11 miles of urban parks (Network)	Mi t
Smoyer-Tomic et al., 2004	Playground	Edmonton, Canada	Minimum: distance (Euclidean); covering: within 0.5 miles of playgrounds (Eucliean)	Mix
Omer, 2006	Urban park	Tel Aviv, Israel	Container: within each neighborhood; minimum: distance (Euclidean); covering: within 250 m (0.15 miles) of urban parks (Euclidean)	Mix
Talen, 1998	Urban park	Pueblo, CO	Minimum, travel cost, & spatial interaction model: distance (not specified); covering: within 1 mile of census block	Mix trav
Talen & Anselin, 1998	Playground	Tulsa, OK	Container: within each census tract; minimum: distance (not specified); travel cost: distance (not specified); spatial interaction model: distance (not specified); covering: within 1 mile of census tract	Mix dist

TABLE 2 Summary of previous studies that compared two or more distances or access measures

Study	Study Area	Finding
Deng et al., 2008	Calgary, Canada	Proportions of census tracts covered by golf courses in 1991, 1996 and 2001, respectively: 22.7%, 22.5%, & 25.9% (using 0.6 miles), 38.6%, 42.7%, & 40.3% (using 0.9 miles); 56.5%, 62.0%, & 62.4% (using 1.2 miles)
Nicholls, 2001	Bryan, TX	Proportions of the population covered by urban parks: 55% (radius analysis) vs. 38% (network analysis)
Nicholls & Shafer, 2001	College Station, TX	Proportions of the population covered by urban parks: 66.5% (radius analysis) vs 41.5% (network analysis)

Note: though other studies listed in Table 1 have employed two or more distances or access measures, results are not presented in a directly comparable manner and thus are not included here

TABLE 3 Measurement of access by access measure type

Access measure	Measure
Container approach	Number or area of LDLUs contained within each unit of analysis
Minimum distance approach	Distance from centroid of each unit of analysis to the nearest LDLU
Travel cost approach	Average or total distance between each residential location and all (or some subset of) LDLUs
Spatial interaction model approach	LDLUs (weighted by their size) divided by distance (adjusted for the ‘friction of distance’)
Covering approach	Population residing within defined service area of one or more LDLUs

TABLE 4 Level of access to public beaches in the DMA by access measure and distance

Access Measure		Distance				Total (%)
		1 mile	6 mile	10 mile	20 mile	
MDA	Population	158,050 (3.9)	1,836,598 (46.4)	3,072,678 (77.7)	3,949,450 (99.8)	3,953,952 (100.0)
	CBG (n)	130 (3.7)	1481 (44.3)	2,550 (76.3)	3,440 (99.9)	3,441 (100.0)
TCA (n=7)	Population	13,252 (0.3)	662,614 (16.7)	1,258,956 (31.8)	3,833,246 (96.9)	3,953,952 (100.0)
	CBG (n)	7 (0.2)	48.9 (14.6)	926 (27.7)	3,315 (96.3)	3,441 (100.0)
TCA (n=178)	Population	0 (0.0)	0 (0.0)	0 (0.0)	837,614 (21.1)	3,953,952 (100.0)
	CBG (n)	0 (0.0)	0 (0.0)	0 (0.0)	630 (18.8)	3,441 (100.0)
CA	Population	116,537 (2.9)	1,815,485 (45.9)	3,053,590 (77.2)	3,904,158 (99.7)	3,953,952 (100.0)
	CBG (n)	101 (3.0)	1,454 (43.5)	2,520 (75.4)	3,400 (98.8)	3,441 (100.0)

Note. MDA: minimum distance approach; TCA: travel cost approach; CA: covering approach; CBG: census block group

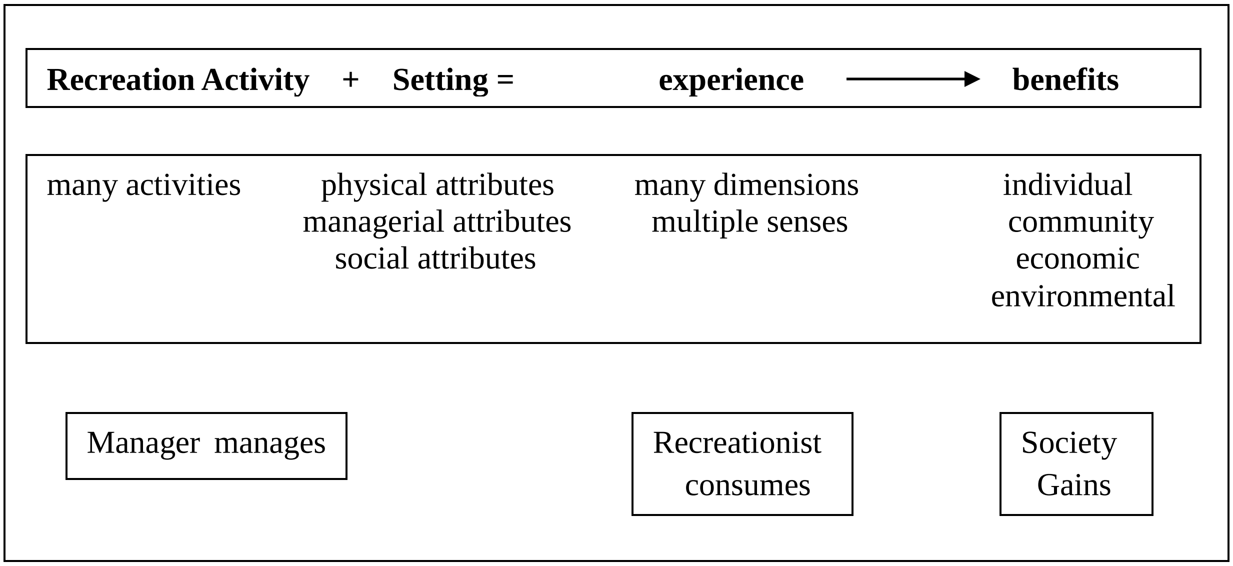

FIGURE 1 The components of a recreation opportunity (Aukerman et al., 2004, p. 4)

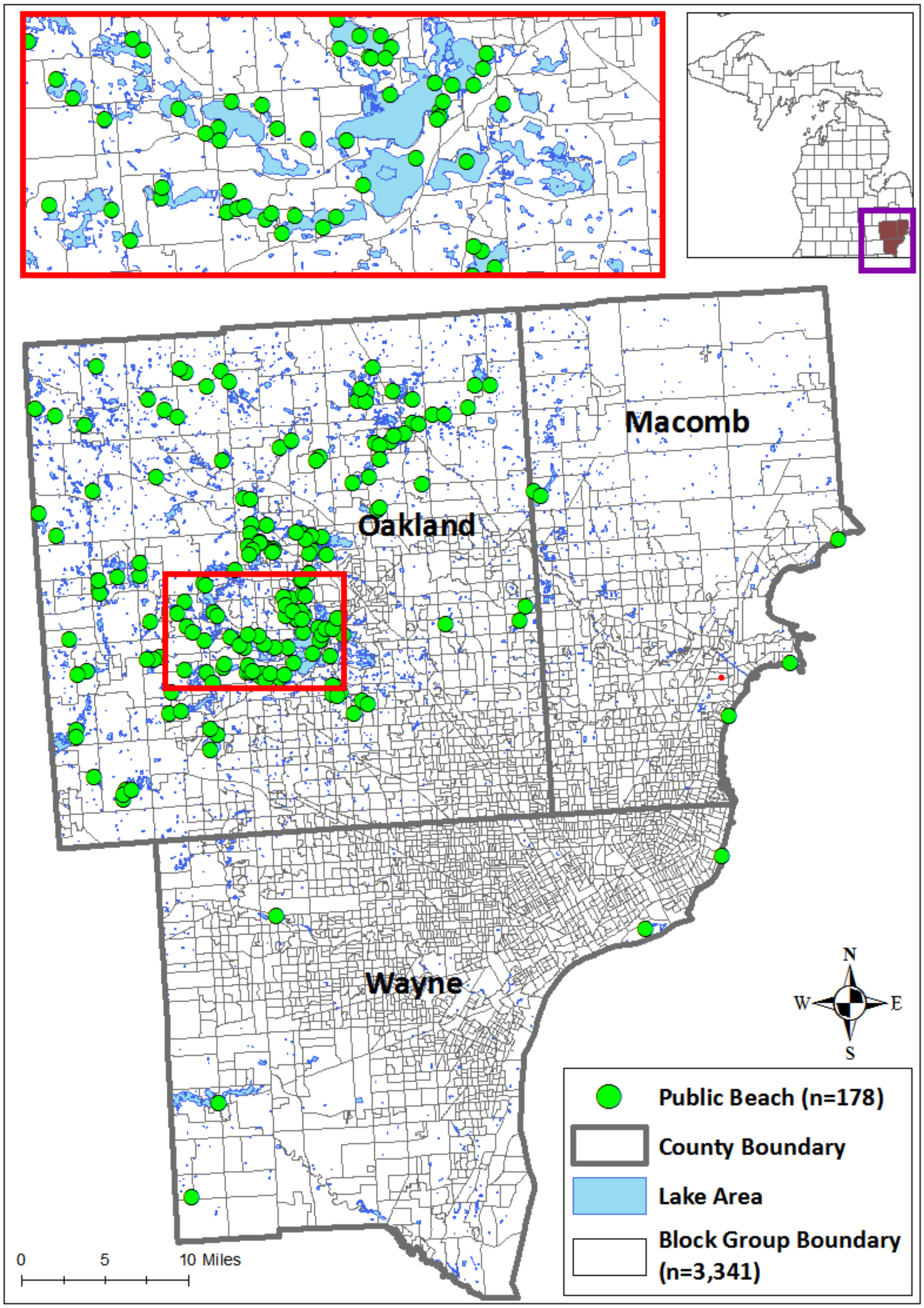

FIGURE 2 Study area

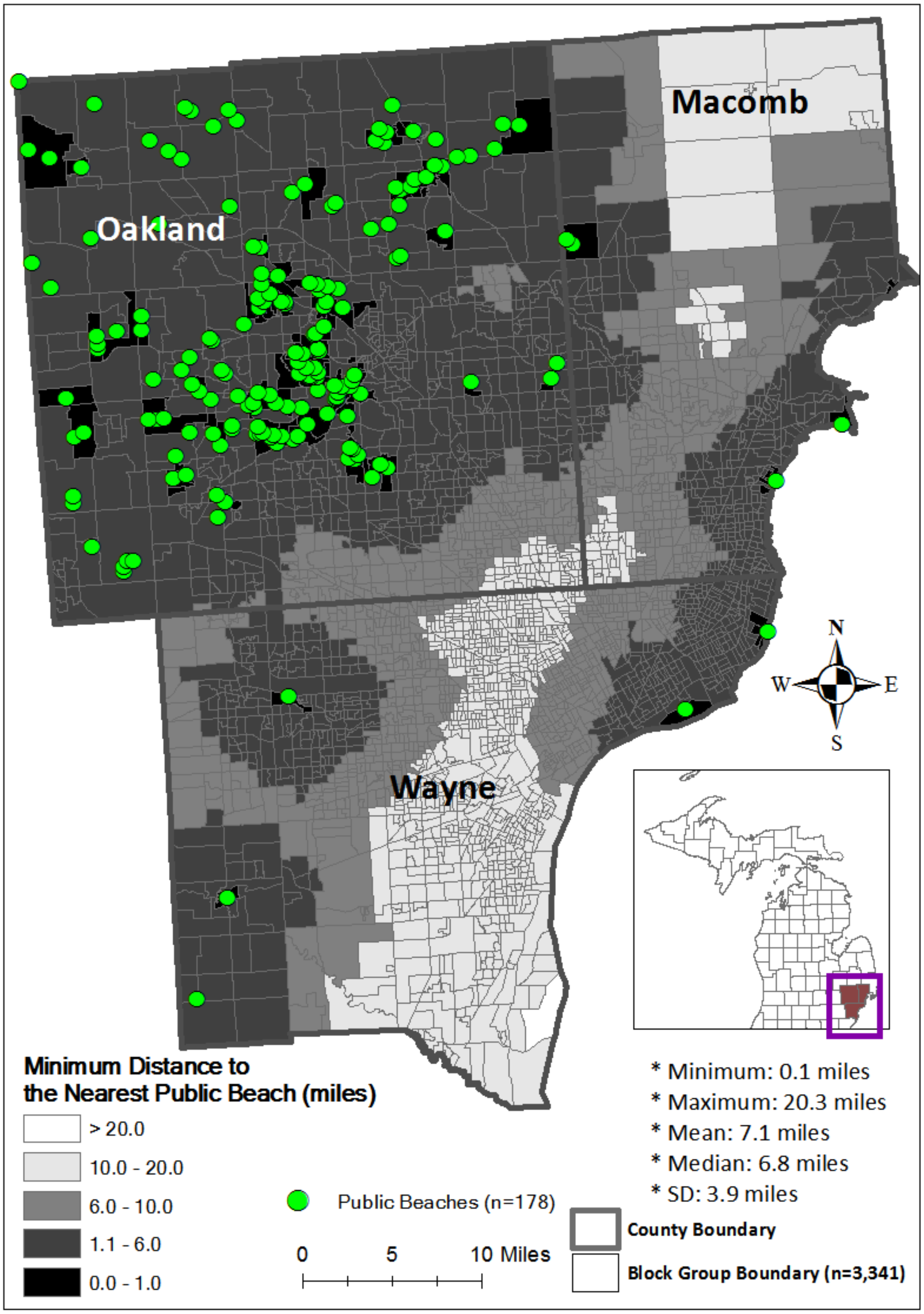

FIGURE 3 Level of access to public beaches according to the minimum distance approach

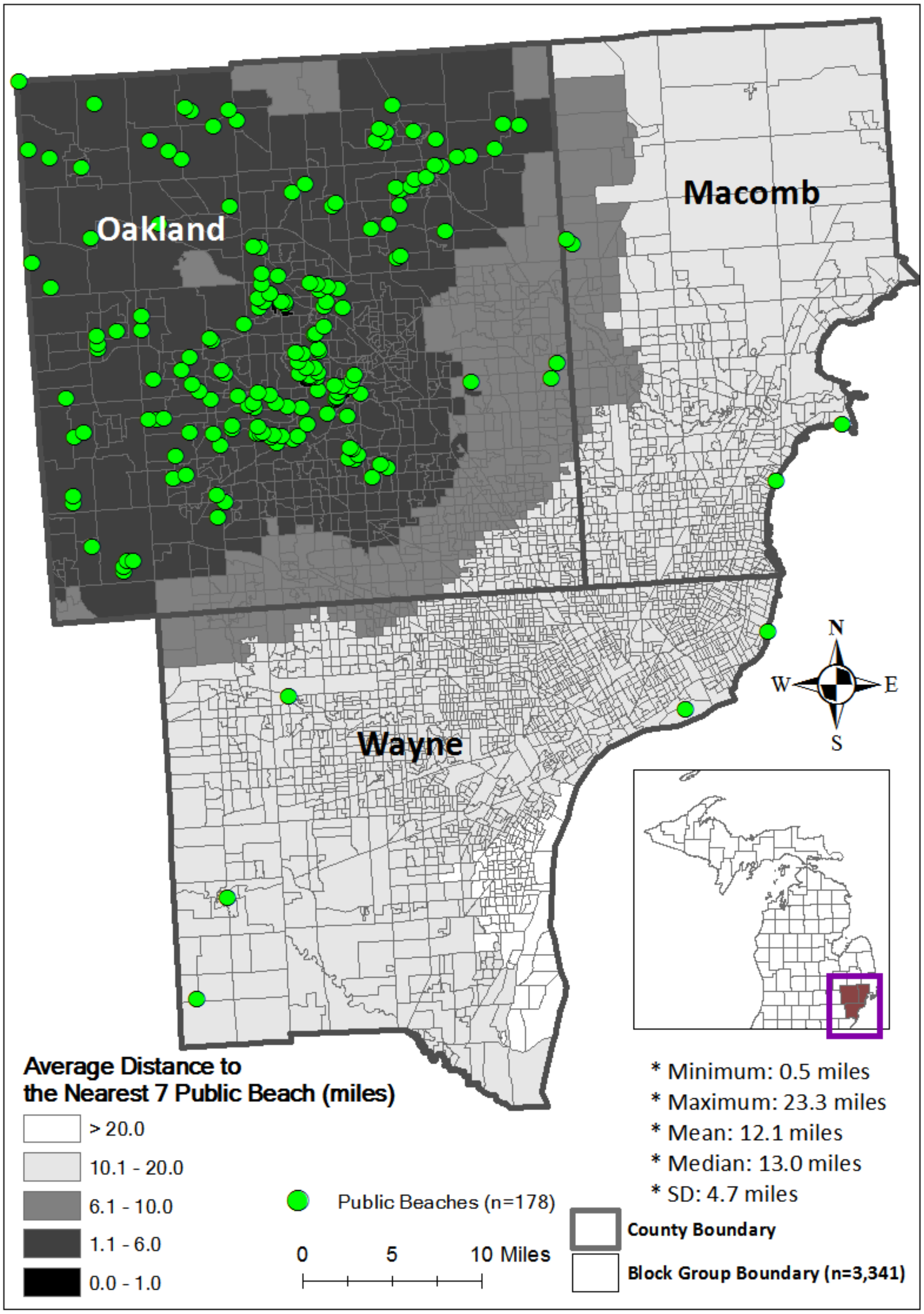

FIGURE 4 Level of access to public beaches according to the travel cost approach

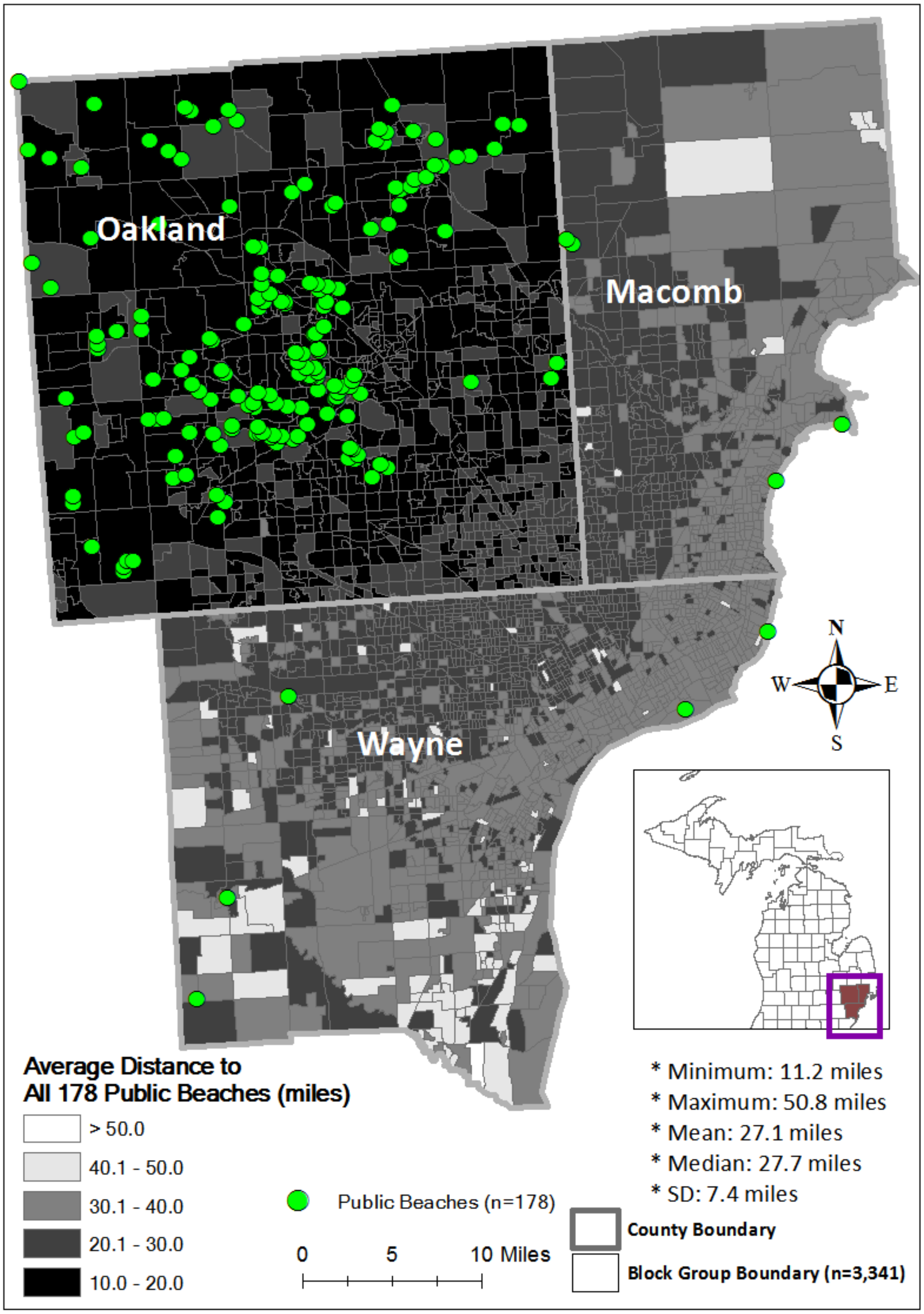

FIGURE 5 Level of access to public beaches according to the travel cost approach

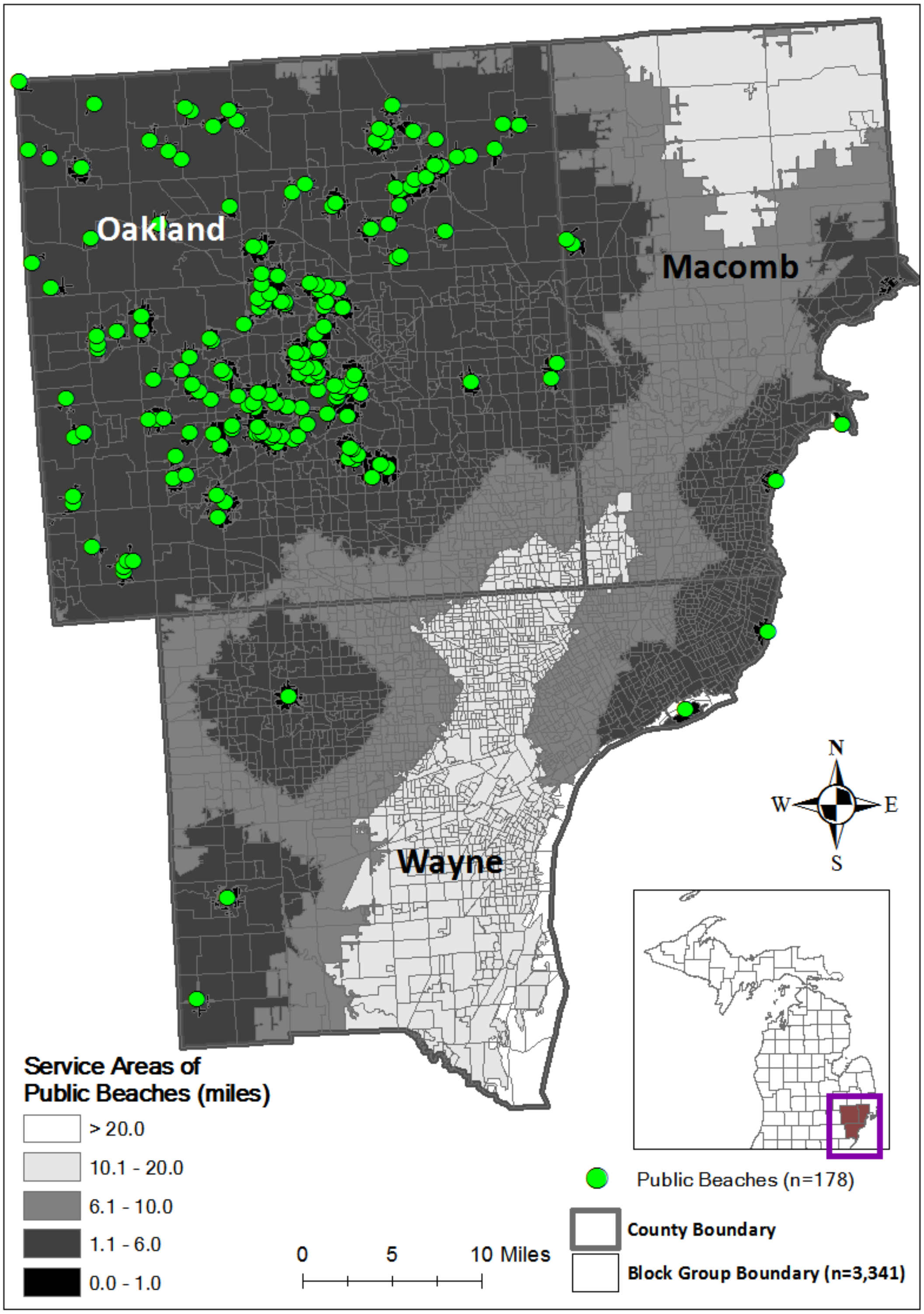

FIGURE 6 Level of access to public beaches according to the covering approach

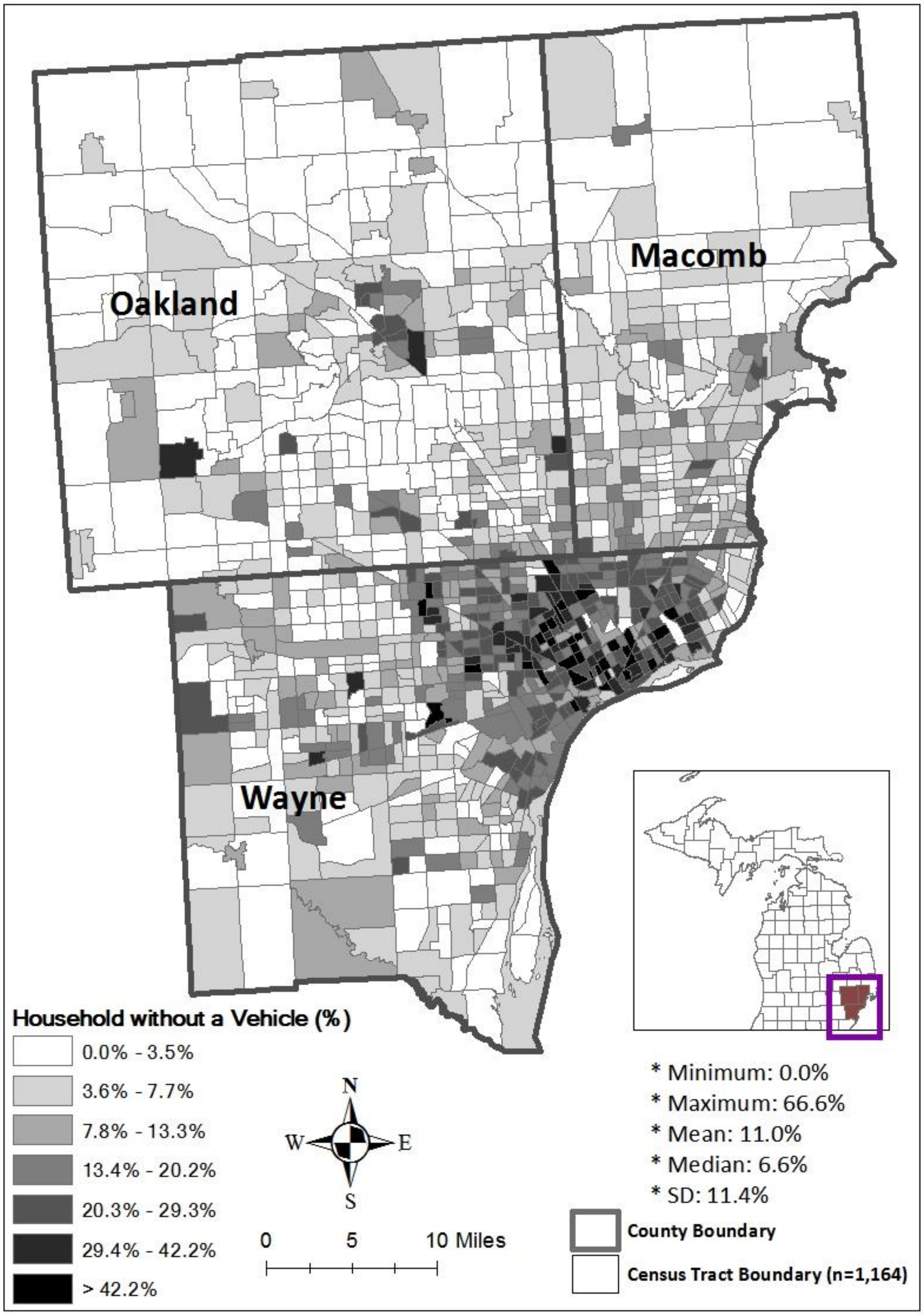

FIGURE 7 Proportion (%) of household without a vehicle by census tract, DMA (2010)