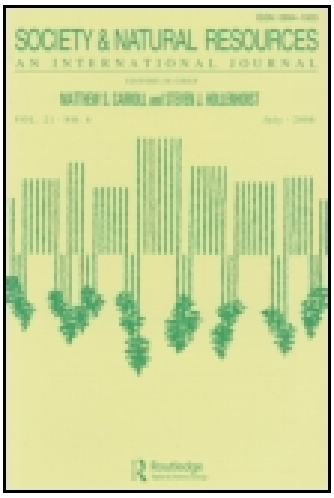

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Exploring Saturation of Themes and Spatial Locations in Qualitative Public Participation Geographic Information Systems Research

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Use of public participation geographic information systems (PPGIS) studies that collect local knowledge in a spatial format is increasing as a tool in natural resources management. Qualitative PPGIS studies have been conducted as individual interviews, as workshops, and in focus groups. As the number of qualitative PPGIS studies increases, so does the need to understand their quality. Saturation, the point when the researcher determines that the collection of additional data will provide minimal new information as it relates to a particular issue, directly reflects on the validity of the study. While the concept of saturation is well established, it is still inconsistently assessed and reported. Furthermore, how saturation applies to qualitatively collected spatial data has not been addressed. A method is presented to assess spatial saturation of qualitative PPGIS data from 19 focus groups that were conducted to investigate important places for recreation, livelihoods, and the environment in the Florida Panhandle.

Keywords methods, PPGIS, public participation, qualitative, saturation

Qualitative research is a scientific method of inquiry aimed at obtaining rich and in-depth contextual understanding as it relates to a particular subject or issue (Creswell 2007). Data are collected in a manner that allows study participants to determine the direction of the response and share their own thoughts, insights, and experiences. An inherent characteristic of qualitative research is that the researcher is directly accountable for systematically interpreting the data collected and drawing inference and understating from those findings while ensuring quality of the research (Creswell 2007; Morse et al. 2002). As a researcher collects data, the researcher analyzes the data in order to determine what information participants are providing and whether there are prevalent themes or ideas among participants, and to decide the direction of the next phase of the study before collecting more data (Miles and Huberman 1994; Strauss and Corbin 1990). Selection of participants usually follows a purposive sampling strategy (as opposed to random), as the goal is to understand the range of contextual meaning rather than to make generalizations about a larger population or to individuals within that population (Kruger and Casey 2009).

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Purposive sampling strategies are selected based on their ability to identify participants who can best inform or provide understanding of the central phenomenon under study (Creswell 2007; Kruger and Casey 2009). Qualitative studies frequently use a maxim variation strategy where widely varied (relative to the topic of interest) participants are selected in order to identify variations in or range of perspectives and to document common patterns in themes (Creswell 2007). However, once the "Who should participate?" question has been answered based on the purpose of the investigation, saturation of data should determine the "How many?" question. In formal qualitative research, the sample size in not predetermined and saturation of themes or theory is used to determine the point at which one has sampled or recruited enough participants (Morse et al. 2002; Kruger and Casey 2009). Saturation "means that sufficient data to account for all aspects of the phenomenon have been obtained" (Morse et al. 2002, 18) where the collection of additional data is unlikely to provide new insight (Creswell 2007; Mason 2010). Validity is a term used to describe the quality, credibility, or trustworthiness of research through the use and documentation of rigorous procedures to check the accuracy of analysis and findings (Creswell 2007; Kruger and Casey 2009) and internal verification strategies built into the research process such as sampling adequacy and saturation (Morse et al. 2002).

Saturation is a well-established concept in qualitative research (Glaser and Strauss 1967). There are a number of factors that can influence when saturation occurs, or if it is achieved at all, including the scope of the study, the topic, heterogeneity of the study population, methods of data collection, time and funding, constraints developed within a proposal, and skill of the interviewer, among others (Morse 2000, 2008; Mason 2010) However, while the concept of saturation is frequently used in qualitative research, researchers rarely document the methods used to determine that saturation was achieved (Bowen 2008; Mason 2010; Morse 2000). Recently, Guest et al. (2006) presented a post hoc systematic analysis of the point where they stopped adding new thematic codes to their data as a measure of saturation. When examined sequentially, analysis of the author's 60 interviews showed that 34 of the 36 final themes were identified by the sixth interview, indicating a large amount of data collected that provided very little thematic return (Guest et al. 2006). Nevertheless, a recent study of 560 PhD dissertations using qualitative approaches concluded that sample size was frequently premeditated and rarely based on application of the concept of saturation, as the most common sample sizes were 20, 30, 40, and 10, which is an unlikely result if saturation was used to determine a stopping point for additional data collection (Mason 2010). The lack of rigorous methods for estimating and reporting saturation is of significant concern for qualitative research, and directly reflects on the validity of a study (Morse et al. 2002).

Spatial Studies Using Public Participation GIS

Public participation geographic information systems (PPGIS) is a new field of inquiry that involves the use of mapping procedures in which individuals provide spatial information in relation to a variety of subjects (Abbot et al. 1998; Talen 2000). This format is particularly useful in natural resources management (Sherrouse et al. 2011) because of its focus on incorporating local knowledge, the ability to include a variety of perspectives, and the capacity to interface with multiple data types (Carver 2003; Onsrud and Craglia 2003; Sieber 2006). Quantitative studies in natural resources management applying PPGIS are becoming numerous and have addressed issues

such as community and collaborative planning, tourism development, ecosystem services, and park planning, among others (Alessa et al. 2008; Brown 2005; Brown and Weber 2011; Nielsen-Pincus 2011; Raymond et al. 2009; Sherrouse et al. 2011). In these quantitative PPGIS studies, data are generally collected using surveys (paper or Internet) of a large representative sample of the population of interest.

Qualitatively conducted PPGIS for natural resource planning have also been used extensively in a wide variety of contexts, from rural areas in developing countries to urban areas in developed countries (for a review see Sieber 2006). Many of these are conducted as individual interviews, in workshops, or in focus groups, and use a spectrum from informal to formal qualitative research methodologies. There are a few examples of qualitative studies specific to mapping landscape values and sense of place, and these studies frequently collect data as polygons that are hand drawn onto a map (or "spray-can" painted within a computer program) and associated with elaborate textual descriptions from interviews and, less frequently, focus groups (Black and Liljeblad 2006: Cacciapaglia et al. 2012; Carver et al. 2009; Gunderson and Watson 2007; Lowery and Morse 2013). A recent analysis comparing the use of points or polygons in PPGIS concluded that "spatially significant areas can be determined with fewer polygon observations" and a smaller sample size, highlighting the usefulness of using polygons for qualitative data collection (Brown and Pullar 2012, 14). The use of qualitative methods with polygons has the advantage of allowing the participants to display their perspectives of scale, shape, and extent of their landscape meanings while also explaining their landscape meanings in detail (Cacciapaglia et al. 2012; Lowery and Morse, 2013; Watson et al. 2011). The ability to represent scale is critical, as several authors have identified differences in the scale of meanings identified by cultural groups, between meaning types, and between identification of special places and management actions (Cacciapaglia et al. 2012; Gunderson and Watson 2007; Watson et al. 2011). A segment of these studies apply a mapping technique that uses a standard desktop graphics "spray can" tool that was developed to add intensity and gradients to the participant mapping process, arguing that hard-line polygons do not represent participant "fuzzy" perceptions of landscape meanings (Cacciapaglia et al. 2012; Carver et al. 2009; Evans and Waters 2007; Gunderson and Watson 2007). These few innovative studies have used formal research methodologies, and some have employed data type and methodological triangulation and other techniques to corroborate their data. However, they infrequently define saturation for their study or report how or whether they achieved saturation, and thus the validity of the studies. Moreover, none have reported saturation spatially (fuzzy or otherwise), and methods to examine saturation of spatial places have not been developed.

Applying Saturation to Qualitative Public Participation GIS

It is suggested here that for qualitatively sampled PPGIS, saturation is reached when little to no new thematically coded geographical data (i.e., thematic places on a map) is provided by the inclusion of additional participants. The addition of place-based (mapped) themes adds a new dimension that needs to be part of the saturation discussion. For example, in spatially explicit studies, it is insufficient to document a repeat theme once if the same theme is related to a number of unique places. Instead, researchers have to identify each place-based theme in all of its places to have reached saturation. Measures of verification of spatial saturation are needed to demonstrate

sampling adequacy and that necessary theme relevant geographic information has been collected. Herein, several measures of spatial-thematic saturation that could be applied to PPGIS studies are presented.

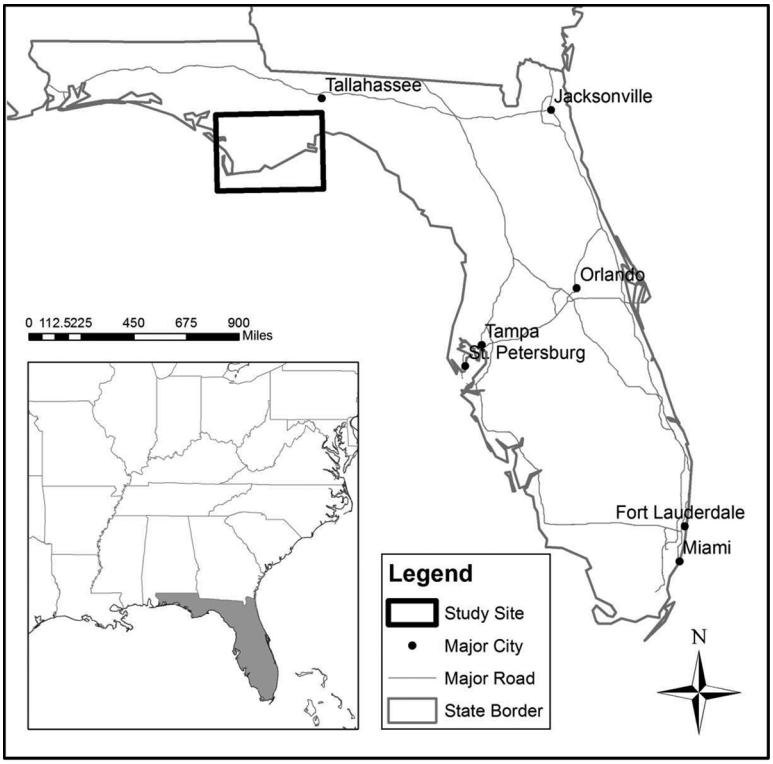
Qualitative Data Collection and Analysis in a Study in Florida

This article is based on research conducted to qualitatively understand and spatially represent the range of important places for recreation, livelihoods, and places of ecological importance in Franklin and Gulf counties, Florida (Figure 1A) (Lowery and Morse 2013). The population for this study was defined as stakeholder groups who lived in these counties and had an interest in possible changes to the landscape. All participants were recruited with the assistance of key informants and through the use of a snowball sampling technique (Creswell 2007). Snowball sampling occurred at the end of each focus group to identify additional group types as part of a maximum variation strategy.

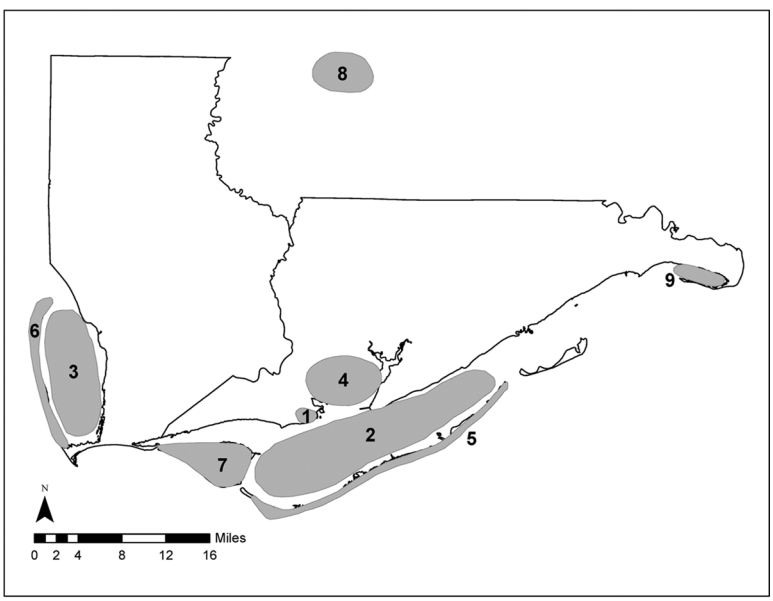
For this investigation, saturation was defined as the point where the lead researcher, in consultation with peer researchers, determined that no new thematic codes and no new geographic spaces (in terms of extent) were identified for three consecutive focus groups. Consistent with the goal of qualitative research to identify a range of ideas, we focused on the extent of meaning areas and the overlap of meaning extents. In the summer of 2010, 19 focus groups were conducted with 122 total participants to gather data. Each group was internally homogeneous and consisted of approximately 3 to 12 individuals of similar social or occupational backgrounds (Kruger and Casey 2009). Final focus groups included ecotourism workers (6), local recreational clubs (two groups of 12 and 5), educators (3), long-term residents and retirees (four groups of 9, 8, 8, and 5), marine industry workers (two groups of 6 and 3), new residents (4), professional biologists and foresters (9), Realtors (9), city administrators (6), second-home buyers (9), small business owners (3), and other local groups/clubs (three groups of 8, 6, and 3). The repeat group types are a result of participants suggesting the need to conduct similar groups in different locations in the study area and because the search for saturation (three consecutive groups with no new information) did not begin until a focus group was conducted with every group type identified by key informants or through snowballing.

A questioning guide containing open-ended questions was used for each focus-group discussion. Questions centered on important places for recreation and for livelihoods and on ecologically important places within Franklin and Gulf counties. One facilitator conducted all groups. Each discussion was audio recorded and transcribed verbatim. Primary coding categories included places important for recreation, livelihoods, and ecological reasons and contained additional subcategories to capture subthemes regarding what about the places made them important. All qualitative data were coded using the software NVivo v8.0.

During focus groups, participants discussed and spatially mapped places of importance (i.e., drew polygons). The end result was a thorough understanding of why places were important to participants (i.e., qualitative coded themes of place meanings) and where those places were geographically located (i.e., spatial locations). Spatial data was collected by providing each focus group with a 36 inch by 48 inch aerial photograph of Franklin and Gulf counties with major highways and towns labeled and at a scale of 1 inch equal to 1.43 miles (2.54 cm is equal to 2.3 km). As important places were discussed and drawn, each polygon was assigned a unique



(A)



(B)

Figure 1. (A) Locator map of Franklin and Gulf counties, Florida. (B) Map of the nine hotspots that contained the three major qualitative themes of recreation, livelihoods, and the environment. The numbers within the map identify each hotspot.

identifier associated with the corresponding qualitative text. All polygons for each focus group were manually digitized into ESRI ArcGIS and assigned specific attributes under the general thematic codes of recreation, livelihoods, and environment.

Maps were developed for each theme and hotspot maps were generated that classified locations where all three of the qualitative themes were identified at least once during the focus groups (Figure 1B). Classifying the data by these qualitative and spatial standards allows our study to specifically examine: (1) saturation of all spatial locations irrespective of qualitative theme (i.e., how many focus groups are needed until few or no new spatial locations are identified), (2) saturation of spatial locations associated with each qualitative theme (i.e., how many focus groups are needed until few or no new spatial locations are identified in regard to recreation, livelihoods, or the environment independently), (3) saturation of qualitative themes at each individual hotspot (i.e., how many focus groups are needed until all themes present at a hotspot have been identified), and (4) saturation of qualitative themes over all hotspots (i.e., how many focus groups are needed until all themes reported at individual hotspots have been identified at all hotspots). The combined assessment of all four objectives offers an original and new opportunity to methodically analyze the concept of saturation from both thematic qualitative and spatial perspectives within a qualitative PPGIS study. These methods were developed and conducted post hoc with the data set, but could be done as data is gathered to determine saturation as the study is being conducted.

Exploring and Demonstrating Saturation Procedures

Determining whether saturation has been attained or determining the sample sizes required to reach saturation typically requires the use of saturation curves, that is, curves relating the number of samples (x axis) to the total number of different responses (y axis). As the number of samples increases, fewer new responses are acquired, until the total number of different responses reaches an asymptote, at which point saturation of responses has been reached. The total number of responses available (i.e., the asymptote) can be estimated using nonlinear regression; however, because the order in which responses are accumulated can be very important to how quickly saturation curves approach asymptotic levels, randomization procedures are often used either alone or in conjunction with nonlinear regression.

In the first analysis, the saturation of spatial locations was examined sequentially and irrespective of qualitative theme. This analysis addressed the question of how many focus-group discussions were needed until few or no new spatial locations were identified. Within ArcGIS, each focus group's polygons were selected separately from the original shapefile containing all polygons and made into a new shapefile, thus resulting in 19 total shapefiles. Once all shapefiles had been created, a process of merging together each focus group's shapefiles in the successive manner in which the data was collected was conducted. This was used to determine the cumulative area covered. This process allowed us to explore saturation by understanding how much additional area was added to the cumulative area covered as each new focus group's polygons were merged. For this analysis, we deemed that saturation had been achieved when 90% of the total cumulative area was identified. The 90% cutoff was chosen as one possible criterion for reaching saturation based on the idea that relatively few (<10%) new places would likely come from each additional focus group.

The second analysis was similar to the first except that saturation of spatial locations was examined in association with each of the three main qualitative themes of recreation, livelihoods, and the environment. This analysis allowed us to answer the question of how many focus-group discussions were needed until few or no new spatial locations were identified in regard to the themes. Similar methods of combining polygons were followed. In total, 57 new shapefiles were created, with each of the 19 focus groups having 1 shapefile for each theme. Again this successive merging process was repeated until all 19 focus groups' shapefiles were combined, with the recreation, livelihood, and environment shapefiles being merged separately, and the total cumulative area calculated. A 90% cutoff was again utilized to demonstrate that saturation had been achieved.

For the third analysis we examined the saturation of qualitative themes at hotspots. This analysis allowed us to answer the question of how many focus groups were needed until all themes recognized at a particular hotspot were identified at that particular hotspot. Such a classification captured both spatial and qualitative measures and allowed hotspots to be defined by both standards. Hotspots meeting thematic requirements were identified by first taking all of the polygons from all the focus groups and creating three new shapefiles, with one containing only recreation polygons, one containing only livelihood polygons, and one containing only ecological polygons. Next, an intersection of all three shapefiles was performed using the intersect tool in ArcGIS. The end product was a shapefile displaying only the areas where all three themes were present, thus making it possible to identify locations that were hotspots based on qualitative criterion (Figure 1B).

Once hotspots had been identified, Microsoft Excel was used to organize the data and run Monte Carlo simulations of the data as a sensitivity analysis of the temporal order of the focus groups. Specifically, random reshuffling of the order of the data allowed us to examine how the order in which data were collected influences the resulting conclusions about when, or whether, saturation was achieved. We argue that saturation is achieved when the asymptote of the saturation curve appears to have been reached prior to the last focus group, regardless of the order in which the data was collected. In Excel a spreadsheet was created that contained 19 rows, with each row representing one focus group, and each hotspot containing three columns for each of the three main themes. The spreadsheet was enumerated by placing a 1 in each cell in which a particular theme was identified by a particular focus group at each hotspot (i.e., if focus group 4 identified recreation and livelihoods at hotspot 3 then a 1 was placed in the corresponding cells). Monte Carlo simulations were then conducted using the Poptools add-in for Excel for each individual hotspot, allowing the order in which the 19 rows appeared to be randomly determined. One thousand iterations were completed for each individual hotspot. Once all iterations had been run, the mean, median, and 95% upper and lower confidence limits were calculated to determine how many focus groups were needed, if conducted in random order, to identify all themes present at a particular hotspot (i.e., achieve saturation of qualitative themes at a particular hotspot).

The fourth analysis was similar to the third except that rather than examining saturation of themes at each individual hotspot separately, saturation of themes was examined at all hotspots simultaneously. This analysis allowed us to answer the question of how many focus groups were needed until all themes present at hotspots were identified at all hotspots. The same Excel spreadsheet as in our third analysis was utilized. However, for this analysis, rather than conducting Monte Carlo

simulations for each individual hotspot separately, the order in which the 19 rows appeared for all hotspots was simulated all at once. Ten thousand iterations were conducted. Once all iterations had been run the mean, median, and 95% upper and lower confidence limits were calculated to determine how many focus groups needed to be conducted, if conducted in random order, to identify all three themes present at all hotspots.

Study Findings

Examination of polygons hand drawn by focus-group participants in this study revealed a total of 347 polygons drawn in regard to places important for recreation, livelihoods, or ecological reasons. On average each group drew slightly more than 18 polygons, with a maximum of 43 polygons drawn and a minimum of 7 polygons. There were 232 polygons referencing recreational places of importance, 64 polygons for livelihoods, and 149 polygons for ecologically important places, with several polygons referencing multiple themes (Lowery and Morse 2013).

Saturation of Spatial Locations Regardless of Qualitative Theme

The results for achieving saturation of spatial locations without regard to qualitative theme appear in Figure 2A. As the analysis was conducted, we noted that one large polygon drawn by participants in the 13th focus group had a strong impact on the total cumulative area being covered. The polygon covered a large spatial area and according to the interview transcripts was drawn to demonstrate a very general area that was important to those participants for livelihoods and ecological reasons, a systemic perspective. This ability to directly connect the polygon to in-depth descriptions from interviews is one advantage of qualitative PPGIS research (Cacciapaglia et al. 2012; Gunderson and Watson 2007; Lowery and Morse 2013). Inclusion of the large polygon from the 13th focus group resulted in the area under livelihood, ecological, and subsequently total cumulative area covered being close to the total area covered by all 19 focus groups. Thus saturation was achieved at the 90% level immediately following the inclusion of the 13th focus group. With one polygon having such a strong impact on saturation levels we conducted a sensitivity analysis of the impact of this polygon in the form of two analyses: one analysis with the large polygon included (Figure 2A) and one analysis with the large polygon not included (Figure 2B). The multiple analyses are done so that we are conservative in our estimation of saturation; the thematic and spatial data are in no way excluded from analysis of the study, as they are critical representations of multiple scales of representation of landscape meanings.

When including the large polygon drawn by the 13th focus group, the total cumulative area covered by all polygons from all focus groups without regard to qualitative theme equaled 4,040.9 km^2. Saturation of all spatial locations, defined as at least 90% coverage of the total cumulative area, was achieved after the 13th focus group (cumulative area = 3,683.9 km^2; cumulative percent = 91.2%; Figure 2A). When excluding the large polygon drawn by the thirteenth focus group the total cumulative area covered by all polygons from all focus groups without regard to qualitative theme equaled 3,910.5 km^2 and saturation of all spatial locations was achieved after the 15th focus group (cumulative area = 3,785.5 km^2, cumulative percent = 96.8%; Figure 2B).

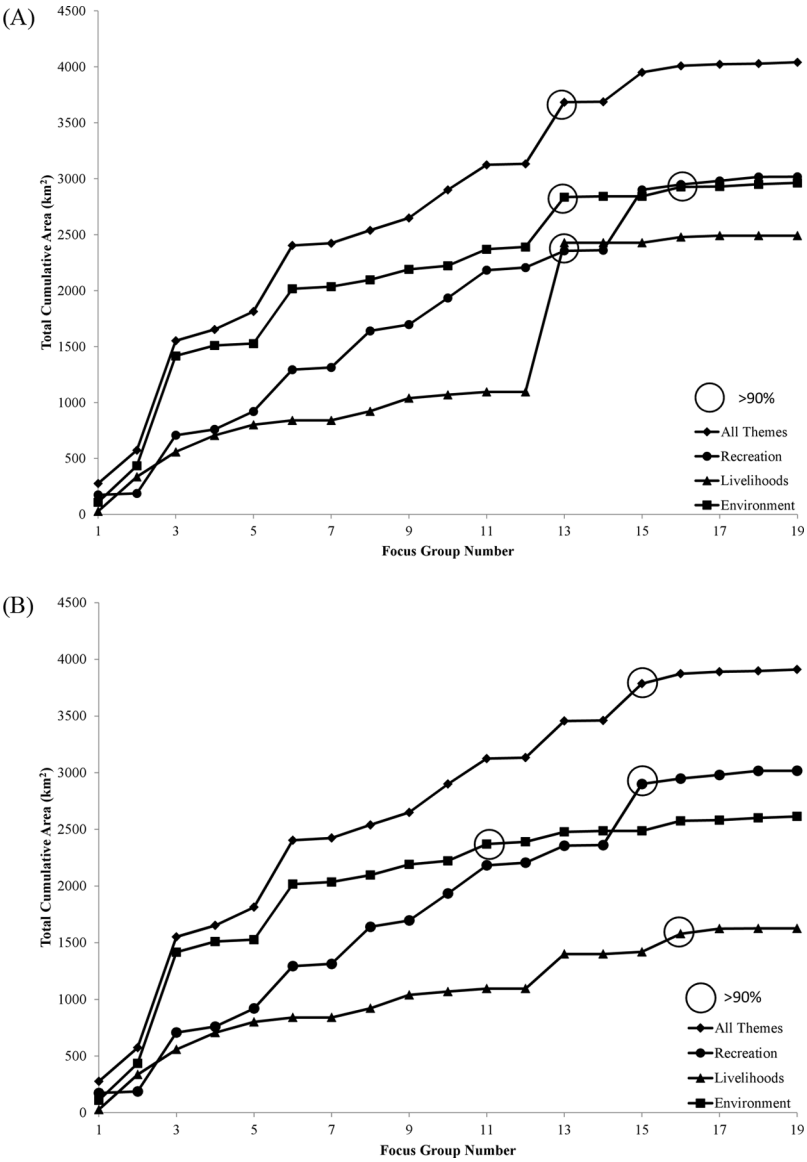


Figure 2. (A) The total cumulative area covered by all polygons, recreation polygons, livelihood polygons, and environmental polygons drawn by focus-group participants. (B) A large polygon drawn by the 13th focus group has been removed.

Saturation of Spatial Locations by Qualitative Theme

The results for achieving saturation of spatial locations in association with each of the three main qualitative themes of recreation, livelihoods, and the environment also appear in Figure 2. For examining saturation of spatial locations associated with livelihoods and the environment the same twofold approach of including and excluding the large polygon drawn by the 13th focus group was employed.

The total cumulative area covered by all recreation polygons from all focus groups equaled 3,017.2 km^2. Saturation of recreation locations was achieved after the 15th focus group (the large polygon did not represent recreation; cumulative area = 2,900.5 km^2; cumulative percent = 96.1%; Figure 2A). When including the large polygon drawn by the 13th focus group for analyzing the saturation of livelihood locations the total cumulative area covered by all livelihood polygons from all focus groups equaled 2,491.3 km^2. Saturation of livelihood locations was achieved after the 13th focus group (cumulative area = 2,428.0 km^2; cumulative percent = 97.5%; Figure 2A). When excluding the large polygon drawn by the 13th focus group the total cumulative area covered by all livelihood polygons from all focus groups equaled 1,626.3 km^2 and saturation of all spatial locations was achieved after the 16th focus group (cumulative area = 1,579.3 km^2, cumulative percent = 97.1%; Figure 2B). When including the large polygon drawn by the 13th focus group for analyzing the saturation of ecological locations, the total cumulative area covered by all ecological polygons from all focus groups equaled 2,963 km^2. Saturation of ecological locations was achieved after the 13th focus group (cumulative area = 2,836.2 km^2; cumulative percent = 95.7%; Figure 2A). Without the large polygon drawn by the 13th focus group the total cumulative area covered by all ecological polygons from all focus groups equaled 2,614.2 km^2 and saturation of all spatial locations was achieved after the 11th focus group (cumulative area = 2,370 km^2, cumulative percent = 90.7%; Figure 2B).

Saturation of Qualitative Themes at Individual Hotspots

In total, nine hotspots were identified from the original data set (Figure 1B) that contained the three major qualitative themes of recreation, livelihoods, and the environment. On average, each of the 9 hotspots that met the spatial requirements was identified by almost 10 focus groups (mean = 9.56). Hotspot 2 was identified by 15 groups, representing the maximum number of identifications, and hotspots 8 and 9 were identified by 5 groups, representing the minimum number of identifications.

The results for achieving saturation of qualitative themes at each individual hotspot appear in Table 1. Examination of the data in the actual order in which the focus groups were conducted reveals that on the low end only 1 focus group was needed to achieve saturation of all themes present at hotspot 2 and on the high end 17 focus groups were needed to achieve saturation of all themes present at hotspots 1 and 7. From our Monte Carlo simulations, where the 19 focus groups appeared in random order, hotspots 2 and 3 represent the low end of the number of focus groups needed before saturation is reached when examining hotspots on an individual basis. Both hotspots contain a mean (hotspot 2 = 2.489; hotspot 3 = 2.833) value that demonstrate that between 2 and 3 focus groups needed to be conducted in order for all three themes to be identified at those hotspots. The confidence limits for both hotspots demonstrate that as few as 1 focus group and as many as 6 for hotspot 2 and 8 for hotspot 3 may be needed to identify all themes present at each hotspot respectively. Hotspots 2, 3, and 4 represents the high end of the number of focus groups needed before saturation of all qualitative themes present is reached. In order to identify all three themes present at hotspot 4, an average of more than 13 focus groups (mean = 13.245) must be conducted. The confidence limit demonstrates at least 4 focus groups must be conducted and all 19 may have to be conducted in order to identify all themes present.

Table 1. Results displaying the number of focus groups needed to achieve saturation of qualitative themes at individual hotspots and at all hotspots combined

Hotspot number	Number of groups identifying hotspot	Actual order[a]	Mean[b]	Variance[b]	Median[b]	Lower CL[b]	Upper CL[b]
Hotspot 1	7	17	10.219	28.598	10	1	19
Hotspot 2	15	1	2.489	2.248	2	1	6
Hotspot 3	12	3	2.833	4.063	2	1	8
Hotspot 4	10	16	13.245	18.840	14	4	19
Hotspot 5	11	9	5.849	10.603	5	1	14
Hotspot 6	9	3	10.535	21.833	10	3	19
Hotspot 7	12	17	10.535	25.917	10	2	19
Hotspot 8	5	11	10.089	29.645	10	1	19
Hotspot 9	5	9	8.389	20.236	8	1	17
All hotspots	NA	17	16.304	6.028	17	11	19

[a]The number of groups needed to achieve saturation based on the actual order the data was collected.
[b]Findings based on Monte Carlo simulations in which the order the data appeared was randomly determined.

Saturation of Qualitative Themes at All Hotspots

The results for achieving saturation of qualitative themes at all nine hotspots combined appear in Table 1. Examination of the data in the actual order in which the focus groups were conducted reveals that 17 focus groups are needed to achieve saturation of all themes present at all hotspots. If the 19 focus groups are conducted in random order, an average of more than 16 (mean = 16.304) focus groups were needed in order for all themes present at all hotspots to be identified. The associated confidence limit demonstrates at least 11 focus groups must be conducted and all 19 may have to be conducted.

Discussion

Saturation by Spatial Theme (Extent)

In order to develop a method to explore saturation within a qualitative PPGIS framework we conducted a post hoc examination of data from a recent study on place meanings and attachment in the Florida Panhandle. Results related to saturation of spatial locations demonstrate that a single large polygon will impact how quickly (i.e., number of focus groups needed) spatial saturation is reached. In certain analyses where the large polygon was removed saturation was achieved more rapidly (i.e., ecological locations, because it was saturated by the 11th group), and in other analyses saturation was not achieved until additional focus groups were conducted (i.e., all locations and livelihood locations). However, regardless of the large polygon's inclusion or exclusion, examination of all analyses reveals saturation was reached for extent, and extent by our three place meanings, at the 90% level by at least the 16th focus group of the 19 that were conducted when examined sequentially. The

original qualitative benchmark for saturation in this study was that few or no new thematic or spatial information (in terms of extent) was revealed for at least three focus groups, consecutively, and this part of the post hoc analysis demonstrates that the qualitative researcher understanding of the thematic spatial data saturation corresponded nicely. The easy-to-conduct sequential spatial analysis of extent provides one form of demonstrable evidence of saturation of data in this regard.

However, the results related to the inclusion or exclusion of such a large polygon reveal the complexity of qualitative participatory mapping methods and analyzing saturation of such data. During PPGIS studies some participants draw extremely detailed and specific polygons to capture localized attributes, while others draw large and general polygons to capture more systemic attributes (Brown and Pullar 2012; Cacciapaglia et al. 2012; Gunderson and Watson 2007). In both instances the participants are conveying valuable information, but how does a researcher use these polygons when determining saturation and the subsequent cessation of data collection? In these studies, small sample size allows for the textual data to be reviewed to understand the meanings underlying the specific polygon(s) and decide the appropriateness of including the polygon(s) in the determination of saturation. A sensitivity analysis such as the one described here could be conducted. Alternatively, two analyses of saturation could be conducted, one for system-wide meanings and another for more spatially specific meanings.

Saturation by Thematic Hotspots

Results related to saturation of qualitative themes at hotspots demonstrate that the number of focus groups needed to achieve saturation varies widely by hotspot. For several hotspots, 2–3 focus groups were needed, while for a number of others 10 or more groups were needed before saturation of qualitative themes was reached. Furthermore, examination of each hotspot's confidence limit reveals that for several hotspots as few as 1 focus group or as many as all 19 may be needed to achieve saturation of the three qualitative themes. Mean and median values from each hotspot's analysis and from the all hotspots' analysis reveal that saturation was likely reached prior to conducting the 19th focus group. However, examination of confidence limit values demonstrates that saturation of qualitative themes at some individual hotspots and for the all hotspots analysis may not be reached until all 19 focus groups have been conducted. However, 19 groups is a hard wall for the confidence interval because that was the limit of the data collected. In this case, the upper end of the confidence interval of the 4 individual hotspots (and the combination of all hot spots) that reaches 19 suggests that the study identified some of the spatial themes in some locations only once. For the Monte Carlo technique, this hard wall on the confidence interval will continue to occur until all spatially associated places have been mentioned at least twice. However, the definition of saturation is that no new additional information is likely to be uncovered, not that every theme has to be identified twice. When the Monte Carlo analysis is examined in the context of Figures 1A and 1B (which demonstrate that very little new spatial thematic data is likely to be added), confidence in the achievement of saturation increases.

As the data demonstrate, multiple measures may need to be examined when exploring saturation. The sequential thematic exploration demonstrated that there was likely to be very little new area added to any thematic area with additional focus groups. Furthermore, the means and medians of the Monte Carlo simulation suggest

this study was in the right range of number of focus groups needed to identify hot spots. However, the confidence intervals provide some evidence that additional focus groups may have provided new thematic hot spots. This type of Monte Carlo simulation can provide one additional measure of thematic spatial saturation otherwise not available.

Conclusions

Implementation of qualitative PPGIS studies will likely only increase as a means for understanding a variety of spatial issues, such as the public's attitudes regarding land use decisions, community planning, ecosystem services, and sense of place, among others. As such, there is a need to document the validity or trustworthiness of the methodology. Both thematic and spatial saturation should be sought and reported in qualitative PPGIS studies. It is suggested here that the methods presented are simple and effective procedures for identifying thematic spatial saturation useful for PPGIS studies. These methods would be useful to perform during the research as part of the iterative process of data analysis and data collection. Moreover, the same Monte Carlo procedures can be applied to strictly thematic (not spatial) qualitative studies such as those presented by Guest et al. (2006), providing an additional method for reporting saturation in purely textual qualitative (nonspatial) research.

Future Research

Additional technical solutions to explore saturation would be to run Monte Carlo type randomizations within GIS on the total or thematic spatial extent and not just on hot spots. Furthermore, while most methods using polygons and "fuzzy" mapping can partially address the issue of scale regarding different perspectives on landscape meanings in PPGIS, further exploration is needed (Cacciapaglia et al. 2012). As qualitative research is intended to identify a range of ideas, interpretation of intensity areas of "fuzzy" mapping and how to assess saturation of them using ours or similar methods is necessary to ensure validity. Relevant spatial considerations for all PPGIS that are not included in this analysis are those of precision (the exactness of marking the polygon on the map) and accuracy (how the drawn polygon reflects of the actual spatial dimensions of the attribute) (see Brown and Pullar 2012). Ultimately, researchers conducting qualitative PPGIS studies should continue to explore saturation of both qualitative themes and spatial locations and how they interact in order to understand the validity of such a novel study design.

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