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Mixed methods participatory GIS: An evaluation of the validity of qualitative and quantitative mapping methods

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ABSTRACT

Participatory mapping in social research is characterized by methodological pluralism, with two common methods being qualitative mapping using stakeholder interviews and quantitative methods that engage larger public samples through digital, internet mapping. To date, there has been no systematic evaluation of the extent to which mixed methods in participatory mapping yield valid results when applied to the same research setting and research questions. A mixed methods research design (combined *exploratory sequential* and *convergent parallel*) was implemented in a large research project to identify marine and coastal values in the Kimberley region of Australia. Qualitative interviews (n = 167) were completed with stakeholders to identify place-based values using polygon mapping methods and internet-based public participation GIS (PPGIS) methods (n = 578). We defined and operationalized the concepts of *concurrent*, *commensurate*, and *convergent* validity to assess mixed methods research outcomes. We found that qualitative and quantitative methods resulted in moderate to high concurrent validity when assessing the importance of place values in the study area. Convergent validity (spatial) was highly variable by place value, with stronger convergent validity found with mapped aesthetic, recreational fishing, tourism, biodiversity, and Aboriginal culture values, and weakest with existence, therapeutic, and commercial fishing values. Convergent validity was influenced by weak commensurate validity through the use of different geometric features (polygons versus points) for mapping values across a large study area. The utility of mixed methods for planning decision support in a *convergent parallel* design depends on demonstrating convergence in construct meaning, spatial location, and consistency in values in the sampling populations.

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1. Introduction

Within the social and behavioral sciences, there is a distinct tradition that advocates the use of multiple methods where qualitative and quantitative research methods are viewed as complementary given the strengths and weaknesses found in single designs (Jick, 1979). These research strategies have been variously described as *triangulation* (Webb, Campbell, Schwartz, & Sechrest, 1966), *mixed research* (Onwuegbuzie & Johnson, 2006), and *mixed methods* (Creswell, 2014). Common rationales for employing mixed methods research include: (1) triangulation and corroboration of results, (2) elaboration and clarification of results, (3) development of new methods, (4) discovery of new or contradictory perspectives, and (5) expansion of the scope of inquiry (Bryman, 2006; Greene, Caracelli, & Graham, 1989). With increased use of mixed methods approaches, researchers are now challenged to evaluate mixed methods research where "validity" issues have yet to be fully developed (Creswell & Plano Clark, 2007; Onwuegbuzie & Johnson, 2006).

The concept of *validity* is core to social research but quantitative and qualitative researchers have tended to treat issues of validity differently (Dellinger & Leech, 2007). Within quantitative research, the concept of validity was originally conceived as three separate types of validation procedures (Cronbach & Meehl, 1955) that

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included content validity (does measurement reflect the domain of interest?), criterion validity (is the measurement related to, or predict an outcome?), and construct validity (does measurement reflect the intended construct?). Campbell and Stanley (1963) expanded the idea of validity to include research design by describing two types of validity, *internal* (the control of threats that provide alternative explanations), and *external* (the degree of generalization to other places or persons). Messick (1995) provided an expanded and comprehensive view of *construct validity* that incorporated validity issues in research design, measurement, and statistical inference.

Within the domain of qualitative research, the concept of validity is more ambiguous and contentious, a result of the diversity of philosophical perspectives about whether there is a reality external to human perception. There is no agreed-on definition of validity in qualitative research with as many as 17 terms identified in the literature (Dellinger & Leech, 2007). Thus, different standards may be applied to judging the soundness of qualitative research. For example, Guba and Lincoln (2005) proposed four criteria for judging the soundness of qualitative research (credibility, transferability, dependability, and confirmability) as an alternative to quantitative-related criteria.

Into this milieu of concepts and frameworks that describe validity issues in mixed methods research, this paper adds additional complexity—assessing the validity of mixed methods in a growing field of social research that uses participatory mapping and geographic information systems (GIS) to better understand and measure human-environment relationships. In participatory mapping, a spatial dimension is added to conventional social variables such as values and preferences making *construct validity* more challenging to assess. However, this additional challenge is partially offset by the potential for construct commensurability from the shared spatiality dimension.

The largest participatory GIS research project implemented to date with a mixed methods design was carried out in the Kimberley region of Australia (2013–2015) for purpose of marine spatial planning (Strickland-Munro, Kobryn, Moore, & Brown, 2015; Strickland-Munro, Moore, Kobryn, & Palmer, 2015). This project provides a unique opportunity to examine the strengths and limitations of mixed methods approaches within the growing field of participatory GIS. We first describe participatory mapping as a distinctive field of social research and then describe the limited number of studies that have used mixed method approaches. This is followed by an explanation of the mixed method design used in the Kimberley study and the specific criteria selected for assessing elements of mixed methods validity. The aim of the paper is to present one approach for assessing mixed methods research in participatory GIS while describing the practical challenges based on empirical findings from the case study.

1.1. Participatory mapping as social research

The terms *public participation GIS* (PPGIS), *participatory GIS* (PGIS), and *volunteered geographic information* (VGI) describe a range of participatory and social research methods where spatial information is a core component. These related fields have experienced significant growth as evidenced in the number of applications and academic publications (Brown & Kyttä, 2014; Mukherjee, 2015). As a social research method, participatory mapping seeks to identify place attributes that range on a continuum from objective locations based on participant knowledge or experience in the study area (e.g., activities, uses, behaviors) to subjective perceptions of place including the construct of place attachment (Brown, Raymond, & Corcoran, 2015).

The majority of participatory mapping studies have employed a single method design, either qualitative or quantitative, with quantitative approaches being dominant in publication. Qualitative mapping, usually conducted using semi-structured interviews, provide for an interpretive, inductive approach to the exploration of place values and meanings without a pre-defined typology (see e.g., Klain & Chan, 2012; Lowery & Morse, 2013; McLain et al., 2013; Rieprich & Schnegg, 2015). Sample sizes are typically small. In contrast, quantitative studies usually employ survey research methods with larger samples and provide a list or typology of spatial attributes for mapping (see Brown & Kyttä, 2014 for a review of quantitative studies). Relatively few participatory mapping studies have used mixed methods. The use of mixed methods approaches in participatory mapping has been motivated by an interest in enhancing the internal validity of new forms and types of spatial data mapping methods and to increase participation rates that pose a direct threat to the external validity of the results. The larger the number of modified research design features, the greater the challenge in assessing research validity because of potentially confounding effects.

In a mixed-methods study in Australia, sampled residents in the Otways region were requested to map landscape values on a hardcopy map using point features (sticker dots), while a smaller subset of residents was requested to map the same attributes with polygons (drawn with colored pencils). All other research design features were the same. The study results suggested the same spatial attributes (landscape values) identified by point and polygon features will converge on a collective spatial 'truth' within the study area provided there are enough observations, but the degree of spatial convergence was sensitive to the spatial attribute category and quantity of spatial data collected (Brown & Pullar, 2012). Pocewicz, Nielsen-Pincus, Brown, and Schnitzer (2012) implemented a mixed-methods study in the U.S. (Wyoming) in which the mapping technology varied between digital, internet-based maps and hardcopy maps. All other research design parameters were similar. The study found that hardcopy mapping resulted in a higher response rate, reduced participant bias, and greater mapping participation, but did not influence the spatial distribution of mapped data.

In the most complex mixed-methods mapping study, Brown, Donovan, Pullar, Pocewicz, Toohey, and Ballesteros-Lopez (2014) compared the results of an internet-based PPGIS that sampled random households with small-group, community workshops where participants mapped place values for the same study area. Differences in the methods included sampling groups (household vs. convenience), spatial data collection methods (individual mapping of values vs. small-group, multi-attribute tagging of locations), and mapping technology (internet vs. hardcopy maps). The internet-based survey PPGIS used a deductive approach for participatory mapping where participants were provided with a predefined set of landscape values with operational definitions. In the community workshop method, landscape values were derived inductively based on text annotations associated with the tagged map markers. The study evaluated the spatial information generated from the two methods and concluded that the weak spatial association found on most landscape values was attributable to less spatial data generated by the workshop method, and to differences in sampling and measurement methods. Thus, there were confounding effects in the mapped spatial results that were at least partially attributable to differences in research design.

Mixed methods approaches in participatory mapping will generate unequal spatial evidence, elevating the importance of assessing validity, especially given the potential for the data to be used for decision support. In principle, participatory mapping can generate spatial information with the potential for comparability across different methods, providing for the integration of mixed-methods results. The limited empirical evidence to date suggests that methodological differences in mapping technology—internet versus hardcopy—and the choice of spatial feature used for mapping—point versus polygon—can potentially yield comparable results between mapping methods under the right conditions. Methodological integration appears plausible. However, research design choices that target different sampling groups (see e.g., Brown, 2016; Brown, Kelly, & Whitall, 2014) and data collection methods (Brown, Donovan et al., 2014) suggest limitations to the direct comparison of results.

1.2. A strategy for evaluating mixed methods research in participatory mapping

The Kimberley marine spatial planning project, the focus of this paper, provides an opportunity to assess some of the validity issues associated with mixed methods design in participatory mapping. The research strategy for the project is best described as a combination of two mixed methods designs identified by Creswell (2014) as *exploratory sequential* and *convergent parallel*. The project has characteristics of an *exploratory sequential* design because the research began with a qualitative phase (stakeholder mapping through interviews) that was analyzed and used in the development of the second quantitative phase (internet-based PPGIS). The purpose of an *exploratory sequential* research design is to develop better measurements and to see if data from a few individuals (qualitative phase) can be generalized to a larger sample of the population (quantitative phase). The qualitative and quantitative data are analyzed separately and researchers check for the validity of qualitative data as well as quantitative data. A key challenge with this design is the development of a valid instrument from the qualitative results that takes advantage of their richness.

The Kimberly participatory mapping project, however, can also be described as a *convergent parallel* design whose purpose is to analyze and compare the findings from the qualitative and quantitative phases to confirm (or disconfirm) each other. The *convergent parallel* design involves collecting data that uses the same or parallel variables/constructs under the assumption the qualitative and quantitative data will provide different information, providing an opportunity for analyses that would not be possible with one type of data alone. Whereas sample size in an *exploratory sequential* design is often small relative to quantitative sample size, in a *convergent parallel* design, the qualitative sample size tends to be larger, and even equal in size. In the case of the Kimberly project, the qualitative sample size was intentionally large ($n = 167$ interviews) to provide sufficient spatial data for comparative analysis.

In a *convergent parallel* design, the methodological challenge is the ability to converge or merge the data. With participatory mapping, the spatial variables from the qualitative and quantitative phases share the underlying dimension of spatiality and can be merged in a common database to provide comparative spatial analysis to assess the degree of convergence or divergence. According to Creswell (2014), the validity for this design should be based on establishing both quantitative and qualitative validity; however, he also raises the question whether a special form of mixed methods validity assessment is needed. Potential threats to validity include unequal sample sizes and the use of different concepts or variables in the qualitative and quantitative components.

With the concept of validity being addressed sparingly in the general mixed methods literature (Dellinger & Leech, 2007), and with limited empirical mapping research involving mixed methods, there is little formal guidance on how to assess research validity in mixed designs containing both quantitative and qualitative components. Further, many of the concepts and frameworks proposed for assessing the validity of non-spatial mixed methods research are essentially checklists that lack specific evaluative procedures. For this study, we selected and operationalized three validity concepts. These concepts and associated measures are intended to be a starting part for assessing the validity of mixed methods in mapping research. Consistent with Messick (1995) and Dellinger and Leech (2007), we consider these validity concepts to be closely related and subsumed under the meta-concept of *construct validity*.

Concurrent validity (non-spatial) is present if the results from qualitative mapping show general, non-spatial agreement with the quantitative mapping results. The relative importance of mapped attributes between the two methods, measured with rank correlations of frequencies, provides a non-spatial measure of concurrent validity. Since rank correlations require pairs of ranks, a key issue to how to handle spatial attributes that were identified and mapped by participants in one method (e.g., qualitative), but not in the other method. These attributes could be excluded from the correlation calculation and discussed separately, or they could be assigned numerically low ranks for inclusion in the calculation.

Commensurate validity (spatial) is present when the size, area coverage, and resolution of mapped attributes are similar when collected with different mapping features. Commensurate validity is not a common term in the validity literature, but merits special consideration in spatial research. Traditional psychometric variables share the common properties of the number system in measurement and are assumed to be commensurate for quantitative analysis. With spatial variables, the geometric features (e.g., points vs. polygons) used for data collection do not share the same underlying properties and cannot be assumed to be commensurate. The geometric feature used in mapping (e.g., point vs. polygon) influences the size of identified area which influences aggregated spatial coverage within the study area. In principle, point and polygon features can be mapped by study participants as similar-sized areas, but in practice, large differences are often present and vary by the specific attribute being mapped (Brown & Pullar, 2012). Point mapping typically results in finer resolution for interpretation of place features than the use of polygons. Commensurability of spatial features can be increased, however, by smoothing clusters of neighboring points to approximate polygon features.

Convergent validity (spatial) in participatory mapping is present when the spatial attributes from qualitative and quantitative methods show spatial concurrence or accordance within the study area which can be measured using a number of different statistical methods. A key issue for assessment is the difference in the quantity of spatial data collected with each method that influences the resulting statistics. Some type of normalization of the spatial data by area or frequency is usually required for fair comparison.

The purpose of this paper is to present one of many potential approaches for assessing the validity of mixed methods research in participatory GIS. In the next section, we describe the context and setting of the study, the specific research methods used in the qualitative and quantitative phases of the project, and the procedures for assessing the mixed methods validity concepts. The empirical results are followed by a discussion of the key challenges in assessing the validity of mixed methods in future participatory mapping research.

2. Methods

2.1. Study location and context

The context for this study was to provide information for marine and coastal planning in the Kimberley region of Australia through research funded by the Western Australian government and administered by the Western Australian Marine Science Institution (see Brown, Strickland-Munro, Kobryn, & Moore, 2016; Strickland-Munro, Moore et al., 2015). The Kimberley region is located in northwest Australia and extends from the southwestern end of Eighty Mile Beach to the Northern Territory border, a coastline of 13,296 km including islands (see Fig. 1). In 2011, the Western Australian Government introduced the Kimberley Science and Conservation Strategy (GoWA, 2011) with a commitment to implement a system of marine reserves through the establishment of four new, multiple-use marine parks located at Eighty Mile Beach, Roebuck Bay, Lalang-garram/Camden Sound and North Kimberley. The marine parks were to cover 48% of the Kimberley's coastal waters and increase the area of State marine parks and reserves from approximately 1.5 million hectares to 4.1 million hectares (Thomson-Dans, Overman, & Moncrieff, 2011). To date, three parks have been established at Eighty Mile Beach, Horizontal Falls and Lalang-garram/Camden Sound, with additional parks yet to be formalized. All existing and proposed State marine parks are to be managed with Aboriginal Traditional Owners under formal joint management agreements.

The Kimberly region is remote and sparsely populated with the towns of Broome, Derby, Wyndham, and Kununurra acting as important service centers. The region's population is about 35,000 with 43.5% being of Aboriginal heritage (ABS, 2011). The primary economic activities associated with the Kimberley coast and its islands include commercial fishing, pearling and other aquaculture (e.g., barramundi farming), oil and gas extraction, pastoralism, iron ore mining, and tourism.

2.2. Qualitative design and sampling (interviews)

Data were collected using face-to-face, semi-structured interviews (Neuman, 2012) and consisted of 8–10 open-ended questions where respondents used their own words to describe and map what was important to them in the study region. Maps served as a value elicitation tool with interviewees asked to identify and describe up to five places of importance without the benefit of a

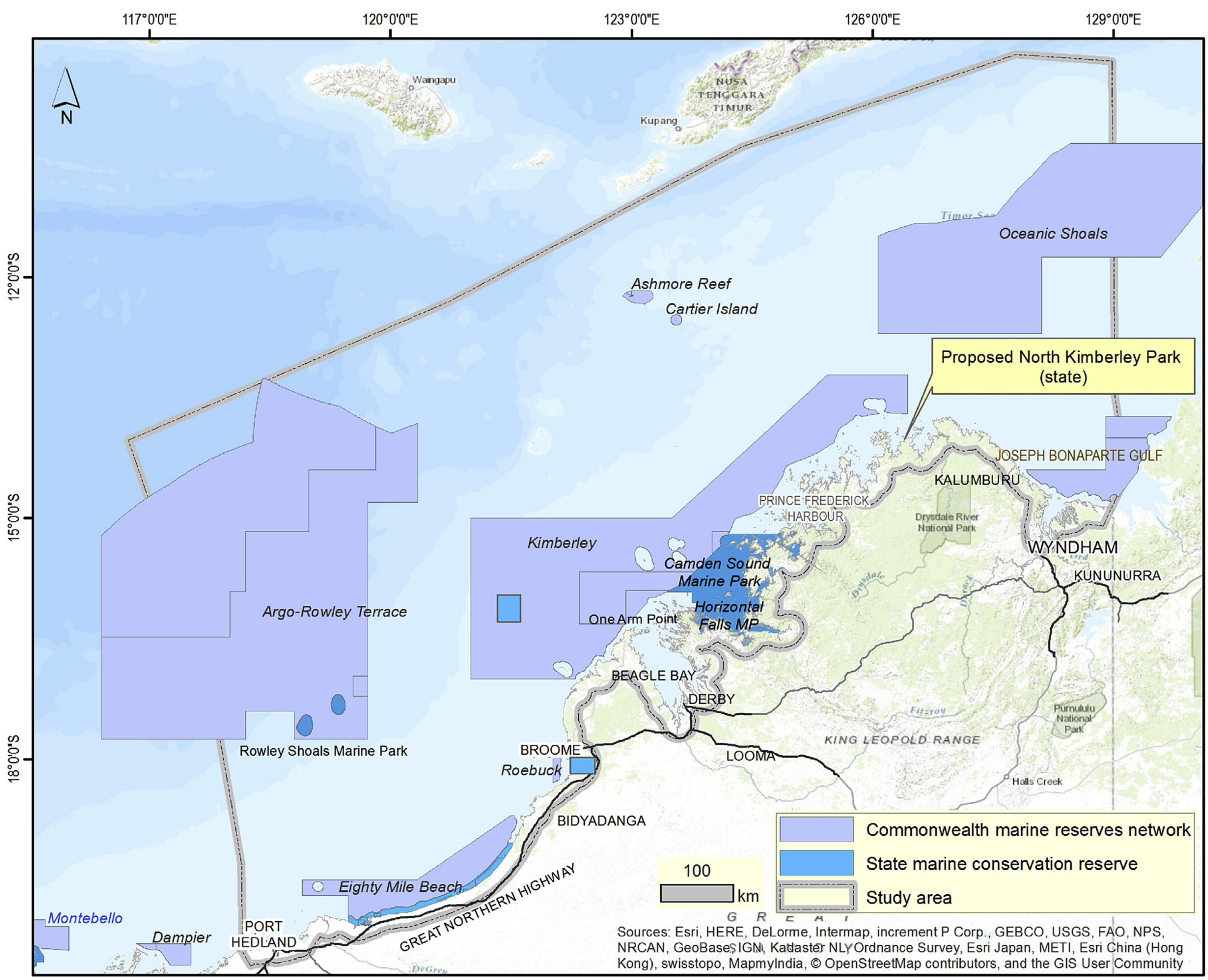

Fig. 1. Kimberley marine parks (current and proposed) (Source: Geoscience Australia 2014, Department of Parks and Wildlife).

pre-determined list of values. A similar 'unconstrained' approach was used by Klain and Chan (2012) in mapping coastal values in British Columbia, by Ramirez-Gomez, Brown, and Tjon Sie Fat (2013) in mapping values for five Indigenous villages in South America, and by Black and Liljeblad (2006) in mapping place attachment in the Bitterroot National Forest in the U.S. Most of the interview time was allocated to questions eliciting place values from participants with the questions, "Where are important places to you along the Kimberley coast?" and "Thinking about place [X], what do you value about it"? This inductive and 'interpretivist' approach to mapping values allowed exploration of the complex associations between the interviewee and the landscape (McIntyre-Tamwoy, 2004). There were also interview questions to identify respondent characteristics such as age, gender, education, place of residence, and affiliation based on their occupation and/or expressed interests at the time of interview.

Participatory mapping was completed using a series of six 1:1,000,000 topographical base maps covering the entire study area (see Fig. 1). A more detailed map of the Broome region encompassing the Dampier Peninsula (1:250,000) provided a finer scale for the most populated and visited section of the Kimberley coastline. Respondents were free to choose which, and how many, of the maps they marked their important places as polygons without restriction on the shape or spatial extent. Each of the mapped places was then discussed to explore the range of personal and broader societal values associated with the mapped place.

The sampling design for interviews focused on people living in, or having a direct interest in the Kimberley region (e.g., tourists visiting the Kimberley, oil and gas industry, government organizations, environmental NGOs) and targeted seven geographic areas: Darwin, Kununurra/Wyndham, Derby, Broome, the Dampier Peninsula, Eighty Mile Beach, and Perth. These areas provide the principal access routes to the Kimberley coast and are key tourist nodes. The goal was to obtain participation from as broad a range of stakeholders as possible. In the mapping of place values with polygons, Brown and Pullar (2012) recommend a minimum of 25 participants, however, this sample size was considered too small given the large number of different stakeholder groups.

We established a target sample size of 140–160 interviews based on the time available for fieldwork and the need to build relationships with Aboriginal Traditional Owners. Several strategies were used to identify and contact interviewees. For organizations in the region (e.g., Nyamba Buru Yaruwu, Shire of Broome, Mary Island Fishing Club), purposive sampling was used to directly contact the organization and arrange interviews with known representatives. Convenience sampling was used with tourists and residents accessible to researchers, particularly on the Dampier Peninsula. Snowball sampling was a third strategy used with organizations and residents in Broome, Derby, and Kununurra who were asked to recommend others for interviews. Overarching these sampling methods were minimum quotas to ensure representation from the full range of interests in the Kimberley. A more detailed description the sampling strategy is provided in Strickland-Munro, Moore et al. (2015).

Table 1
Values with operational definitions used in quantitative PPGIS.

Values	Operational definition
Scenic/aesthetic	These areas are valuable to me because they contain attractive scenery including sights, smells, and sounds.
Recreation	These areas are valuable because they are where I enjoy spending my leisure time with family, friends or by myself, participating in outdoor recreation activities (e.g., camping, walking, exploring).
Fishing (recreational)	These areas are valuable because they are where I can go fishing for fish and other marine life like crabs, cockles, and oysters.
Economic (non-tourism)	These areas are valuable because they provide natural resources that can be used by people (e.g., minerals, oil, gas, fish, pearls, pastoralism).
Nature-based tourism	These areas are valuable because they provide tourism opportunities, including Aboriginal cultural tourism, in a generally undisturbed environment.
Learning/education/research	These areas are valuable because they enable us to learn about the environment through observation or study.
Biological/conservation	These areas are valuable due to the presence of plants, wildlife & habitat including marine wildlife, reefs, migratory shorebirds & mangroves.
Aboriginal culture/heritage	These areas are valuable because they allow Traditional Owners to maintain connection to their coastal & sea country through identity and place, family networks, spiritual practice and resource gathering.
European heritage	These areas are valuable because they reflect European history associated with exploration, pastoralism, missions, commercial fishing & the Second World War.
Therapeutic/health	These areas are valuable because they make me feel better mentally and/or physically.
Spiritual	These areas are valuable because they are sacred, religious, or spiritually special places or because I feel reverence and respect for nature here.
Intrinsic/existence	These areas are valuable in their own right, no matter what I or others think about them.
Wilderness/pristine	These areas are valuable because they are wild, uninhabited, or relatively untouched by European activity.
Special places	These places are special. Please indicate why the place is special to you.

2.3. Data collection (quantitative PPGIS)

For quantitative mapping, the research team designed, pre-tested and implemented an internet-based application for data collection. The application used a Google® maps interface where study participants were requested to drag and drop digital markers onto a map of the Kimberley region (see Strickland-Munro, Kobryn et al. (2015) for a detailed description of the PPGIS web interface). The process involved participants entering the PPGIS website, providing informed consent, completing non-spatial survey questions (pre- and post-mapping), and undertaking the mapping activity. For the mapping activity, two different panels contained markers representing 14 values and 13 management preferences. The focus of this paper is on analysis of place value markers (see Table 1).

Sampling design and recruitment were intended to engage the greatest possible number of participants. The population of interest included people living in or visiting the Kimberley, as well as geographically remote individuals with interests in the region. Stakeholder groups contacted in the qualitative phase were also contacted to assist in recruitment for the quantitative PPGIS. A total of 120 official and informal representative bodies were contacted to assist with recruitment over the survey period of April–July 2015, with multiple methods of recruitment used. A prototype of the PPGIS website was pilot-tested in March 2015 with middle to senior level managers in the Western Australia Department of Parks and Wildlife, social science researchers at Murdoch University, and recreational users of the Kimberley coast.

2.4. Analyses

2.4.1. Spatial data preparation, distribution, and completeness/coverage

A total of 17 categories of values were extracted from analysis of the interviews using grounded theory and assisted by coding using NVivo® software. Similar elements extracted from the interviews were grouped into the same value category. For example, the value of “Aboriginal culture” included the interview elements of “cultural sites”, ”connection to country”, “evidence of historical use”, and “transmission of cultural knowledge”. Each place polygon mapped in the interview was digitized and tagged with one or more value categories based on interview coding. Thus, each polygon identified one or more place values and may be considered “multi-attribute”. The number of polygons marked in a single interview ranged between 1 and 30 with an average of six. For analysis, the qualitative category of “camping” value was combined with “recreation” value to be consistent with the operational definition used in the quantitative PPGIS. Of the 17 value categories derived from the qualitative interviews, 12 value categories informed and were included in the internet PPGIS and mapped as points. Unlike the polygons, each mapped point in the PPGIS identified a single value category.

To compare the polygon data from interviews with the point data from the internet PPGIS, we constructed a 2 km “fishnet” (vector grid) over the Kimberly study area ($n = 45,846$ cells). The number of intersecting polygons and mapped points for each of the 12 value categories were counted for each cell. To assess spatial data coverage for the point and polygon mapping methods, the number of unique participants who mapped one or more spatial attributes that fell within a given cell was also counted. These mapped attribute and participant counts per common cell area provide the data for assessing convergence using multiple measures of spatial association and spatial concurrence. Because spatial attributes mapped with points typically represent spatial areas larger than 2 km, the point data were analyzed using both simple point counts per cell and point counts that were “smoothed” by using a 5 km search radius around each cell.

2.4.2. Assessing concurrent and commensurate validity

To assess *concurrent* validity, we examined the relative importance of mapped values from the qualitative and quantitative methods. Concurrent validity is indicated when the two methods indicate similar ranked levels of study area importance. We tabulated the frequency of mapped attributes (polygons and points) for each value, as well as the number of individuals that mapped each value. The frequency counts were converted to ranks and Spearman's rank correlation was calculated *between* qualitative and quantitative rankings. We also calculated the correlation between the number of spatial features and number of participants mapping the spatial feature *within* each mapping method.

We assessed *commensurate* validity subjectively by examining and comparing the general spatial distribution of mapped values with additional evidence provided by the convergent validity metrics described below. In this study, commensurate validity was focused on the geometric feature used in participatory mapping for identifying a place value—points versus polygons. The *prima facie* assumption is that points and polygons are not commensurate under most mapping conditions given they capture variable-sized spatial areas. However, Brown and Pullar (2012) demonstrated through simulation that spatial data convergence for the same value is theoretically possible using points or polygons under the right research conditions.

2.4.3. Assessing convergent validity (global spatial statistics)

To assess the extent of spatial association and concurrence between the polygon and point data representing the same values in the study area, we calculated three “global” or whole study area statistics:

(1) Spearman's correlation coefficients were calculated using the grid cell counts of points and polygons for the same place value across the study region ($n = 45,846$ cells). Spearman's coefficient ranges from -1 to $+1$ with the strongest correlations approaching either end of the scale, with a value of 0 indicating no relationship.

(2) Spatial association was also examined using bivariate spatial autocorrelation (Bivariate Moran's I) between the point and polygon data for the same place value. The Bivariate Moran's I statistic measures the extent to which two variables are clustered in space based on the proximity of high and low grid cell counts. Possible values for Bivariate Moran's I range between -1 and $+1$ with 0 implying no spatial autocorrelation. Positive values indicate spatial clustering and negative values indicate spatial dispersion.

(3) Spatial concurrence (overlap) for the same value within the study area was calculated using the phi-coefficient statistic, which measures the strength of relationship between two binary distributions. The phi-coefficient (φ) is a variation of the Pearson correlation coefficient that is used for binary data (Chedzoy, 2006; Zhu, Pfueller, & Whitelaw, 2010). The phi-coefficient measures the strength of the relationship on a scale from -1 to $+1$ with the statistical significance of the relationship determined by the chi-square statistic, where $\chi 2 = n\ \varphi 2$. Fitz-Gibbon and Morris (1987) suggest interpretation of phi as follows: $\varphi < 0.2$––little or no association, $0.2 \le \varphi < 0.4$––weak association, $0.4 \le \varphi < 0.6$––moderate association, and $\varphi \ge 0.6$––strong association. The phi-coefficient was calculated for the whole study area (all cells) as well as for a subset of cells identified as “hotspots”. The global hotspots for the polygon and point data were determined by examining the frequency distribution of

polygon and point cell counts in the study area and selecting the largest cell frequencies from each distribution that created approximately equal-sized areas. For a fair comparison, the point and polygon hotspots had to meet two criteria—(1) the cell counts had to be in the upper third (or higher) of the distribution (the "heat" criterion), and (2) the total hotspot area for points needed to approximate the total hotspot area for polygons ("normalized"). These value hotspots represented the upper 4–33% of the cell count frequency distribution depending on the place value. In addition to the phi-coefficient, the percent of areal overlap between the hotspots of the two distributions for each place value was calculated.

2.4.4. Assessing convergent validity (local indicators)

Local indicators of spatial association (LISA) were also examined and mapped using the Getis-Ord (Gi*) statistic (Getis & Ord, 1992) and the local Moran's I statistic, also known as Anelsin's LISA (Anselin, 1995). The Gi* statistic identifies "local" spatial clusters of points with values higher in magnitude than one would expect to find by random chance. For polygon features (i.e., vector grid cells), polygon centroids were calculated prior to analysis. The output of the Gi function is a z score for each grid cell, which represents the statistical significance of clustering within a specified distance, in this case, set to the 2 km grid cell size. This Gi* hotspot analysis was performed on "smoothed" grid cell point densities (point counts based on a 5 km search radius) and on the number of overlapping polygons in each grid cell.

Local spatial autocorrelation was examined with bivariate LISA that determines whether standardized values derived from the cross-product of two variables at a given location are significantly different from neighboring locations if conditions of spatial randomness are assumed. The output of bivariate LISA is a high-low cluster map showing statistically significant areas of high or low clusters of values. Bivariate LISA maps were generated using GeoDa™ software for the paired grid cells containing polygon and smoothed point counts.

3. Results

3.1. Participation numbers and participant profiles

A total of 167 interviews were completed with 232 people with interview length varying between 20 min and 2 h. Most interviews were completed with one person but some interviews had two or more people present. Only one map was generated per interview. The largest categories of interviewees were tourists (n = 66), Aboriginal Traditional Owners (n = 31), Kimberley residents (n = 24), tourism representatives (n = 18), yacht owners (n = 18), and Aboriginal rangers (n = 12). Other smaller categories of participants included local, State, or Commonwealth government employees, individuals working in commercial fishing or aquaculture, employees in the oil and gas industry, and members of environmental non-government organizations. A comprehensive list of interviewees is provided in Strickland-Munro, Moore et al. (2015). The interviews generated 986 place locations (polygons) for analysis, but because each polygon could have multiple place value attributes, there were 2216 polygons for 12 place values available for analysis (Table 2).

A total of 763 individuals fully or partially participated in the PPGIS internet survey. A partial completion was an individual that accessed the website and mapped one or more markers, but did not complete the survey. Of the participants, n = 206 individuals originated from an online internet panel while the remainder came from other recruitment methods. Participants mapped a total of 15,823 value point locations in the study area, of which 13,884 were associated with the 12 values used in the analysis.

The qualitative interview participants were selected based on stakeholder role and there was no attempt to achieve sociodemographic representativeness with the general population in Western Australia. The sociodemographic profile of PPGIS participants was compared to Kimberley and Western Australia census data (ABS, 2011). Participants were 52% female compared to census data of 50% for WA and 47% for the Kimberley region. The largest groups of participants were aged 55–64 (21%), 35–44 (21%), and 45–54 (20%) respectively, with this age profile being somewhat younger than comparable census data. Aboriginal participants were significantly underrepresented in the quantitative PPGIS with only about 2% of participants identifying themselves as Aboriginal compared to 43.5% of the Kimberley population and the statewide proportion in Western Australia of 3.4%. Participants were strongly biased toward higher levels of formal education (bachelor or postgraduate degrees), a finding consistent with previously reported PPGIS studies (Brown & Kyttä, 2014).

3.2. Concurrent validity

The two methods (qualitative interviews and quantitative PPGIS) were consistent in the relative frequency of place values mapped by study participants, with the rank order of the 12 values significantly correlated (Spearman's rho = 0.76, $p < 0.01$). Physical landscape (aesthetics) was the most frequently mapped value with 407 polygons and 2517 points respectively, while biodiversity value was second most frequently mapped with PPGIS (n = 2391 points) and recreation was second most frequently mapped with interviews (n = 403 polygons) (Table 2). The largest difference was therapeutic value, which was the least frequently mapped in PPGIS but ranked sixth among interview mapped values. The frequency of mapped values using interviews was also strongly correlated with the number of participants identifying the values ($r = 0.99$, $p < 0.001$), while the number of points mapped was less strongly correlated with the number of mapping participants ($r = 0.87$, $p < 0.001$). This difference in correlation is likely the result of interviewees being more limited in the number of polygons they could map whereas the PPGIS mappers were unrestricted in the number of points that could be placed.

There were four additional values identified in the qualitative interviews (bequest, economic value (commercial fishing), social interaction, and experiential) that were not included in the PPGIS, and one value that was included in the PPGIS, but not coded from the interviews (wilderness value). Bequest value and economic value (commercial fishing) had low frequency of mapping in the qualitative interviews (9 and 48 polygons respectively) while social interaction and experiential values had higher frequencies (187 and 114 polygons). Bequest value has been included in other quantitative PPGIS studies as "future" value with results consistently showing low mapped frequencies compared to other values, similar to results in this study. Social interaction as a value was included in a different quantitative PPGIS study (Hausner, Brown, & Lægreid, 2015) and its rank order importance based on mapping frequency was also similar to this study. Economic value from commercial fishing was a subset of the economic value in the PPGIS operational definition in this study. It is likely that if this value were measured independently in PPGIS, it would have relatively low mapping frequency similar to the polygon results in this study. Overall, the results indicate a moderate to high level of concurrent validity between qualitative and quantitative methods in assessing the relative importance of mapped values in the study area. One can

Table 2
Summary descriptive statistics for mapped polygons and points.

Spatial attribute		Polygon mapping					Point mapping		
Polygon coding[a]	Point category[b]	Polygon count (rank)[c]	Number of polygon mappers (rank)[d]	Max area (km^2)	Mean polygon area (km^2)	Range in number overlapping polygons[e]	Point count (rank)	Number of point mappers	R[f]
Physical landscapes (aesthetics)	Scenic/aesthetic	407 (1)	113 (2)	59,603.2	1894.0	1–38	2517 (1)	498 (1)	0.32
Recreation	Recreation	403 (2)	123 (1)	52,033.2	1053.1	1–24	1404 (6)	401 (3)	0.30
Biodiversity	Biological/ conservation	321 (4)	112 (3)	52,033.0	1833.0	1–34	2391 (2)	318 (6)	0.39
Recreation—fishing	Recreational fishing	348 (3)	103 (4)	52,033.0	929.0	1–20	2185 (3)	397 (4)	0.34
Aboriginal culture	Aboriginal cultural	261 (5)	93 (5)	59,603.0	1892.0	1–23	1844 (4)	350 (5)	0.36
Economic—tourism	Nature-based tourism	139 (7)	53 (7)	52,033.0	2010.0	1–17	1636 (5)	410 (2)	0.39
Learning and research	Learning/research	94 (8)	49 (8)	40,397.0	1705.0	1–14	467 (7)	191 (7)	0.32
Historical	European heritage	78 (9)	46 (9)	39,742.0	1490.0	1–13	430 (8)	185 (8)	0.28
Economic—commercial fishing & aquaculture	Economic (non-tourism)	48 (10)	29 (10)	59,603.0	3952.0	1–9	341 (9)	159 (9)	0.30
Spiritual	Spiritual	41 (11)	27 (11)	42,854.0	1958.0	1–5	264 (11)	119 (10)	0.44
Therapeutic	Therapeutic	207 (6)	87 (6)	40,397.0	902.0	1–21	105 (12)	73 (12)	0.55
Existence	Intrinsic/existence	9 (12)	5 (12)	40,397.0	6886.0	1–4	300 (10)	102 (11)	0.41

[a] Values coded but not included in comparative analysis (n = 4) were social, experiential, subsistence, and bequest value.
[b] Value collected in PPGIS but not included in comparative analysis (n = 1) was wilderness value.
[c] Spearman correlation between polygon and point frequency ranks is 0.76 ($p < 0.01$).
[d] Spearman correlation between polygon count rank and number of polygon mappers is 0.99 ($p < 0.001$).
[e] Spearman correlation between point count rank and number of point mappers is 0.87 ($p < 0.001$).
[f] R is a ratio of observed distances between points to the expected distances between points if the points were randomly distributed. R ranges from R = 0 (completely clustered) to R = 1 (random) to R = 2.149 (completely dispersed). From the R statistic, a standardized z score is computed to test the hypothesis that the point distribution deviates from randomness, either toward clustering or uniformity. The hypothesis of complete spatially random (CSR) distribution of points is rejected for all spatial attributes in this study.

only speculate how concurrent validity measures might change if the list of values were identical in the two methods.

3.3. Commensurate validity

A visual examination of the distribution of the polygons and points in Fig. 2, in combination with the mean areas mapped with polygons (see Table 2), suggest low commensurate validity between the qualitative and quantitative methods that used different spatial features for mapping. For example, one can observe that qualitative participants often drew polygons to cover larger coastal areas such as the entire Buccaneer Archipelago, whereas the PPGIS participants used points to identify more specific areas such as Horizontal Falls located within the Archipelago. The use of points versus polygons results in the propensity for participants to map values at different scales. When points were generalized to a larger area using a 5 km search radius, the degree of spatial convergence (described below) increased, but could not be considered strong. We also converted the polygons to points using centroids and compared with the point distributions. The degree of spatial convergence was also not large. Given the differences in the mixed methods with sample size, non-equivalency of sampling groups, and differences in the number of spatial attributes mapped, it is not possible to determine whether the differences in mapped locations resulted from these confounding variables or issues with commensurability. Subjectively, we found insufficient evidence to reject the assumption that points and polygons, which are *prima facie* incommensurate, will become commensurate in participatory mapping outcomes.

3.4. Convergent validity (global indicators)

Two quantitative metrics (Spearman correlation and phi coefficient) were used to assess the degree of spatial concurrence (overlap) of mapped features. Spearman's correlation coefficients ranged from r = 0.21 for *aesthetic* and *recreational fishing* values to r = 0.00 for *existence* value for calculations based on point counts in the 2 km cells (Table 3). When point counts were increased by including points found within a 5 km search radius, the correlation coefficients increased significantly for all values, with *biodiversity* and (r = 0.60) and *recreational fishing* (r = 0.59) values showing the largest degree of spatial concurrence.

Spatial concurrence was also calculated using the phi coefficient (φ), with all mapped values showed little spatial concurrence ($\varphi < 0.2$) when calculated based on the presence/absence of points and polygons found within each 2 km cell, but increased when point cell counts were modified by using a 5 km search radius. *Recreational fishing*, *tourism*, and *Aboriginal culture* values had the highest degree of spatial concurrence with phi coefficients of 0.51, 0.44, and 0.42 respectively. There was little spatial concurrence with *economic* value (commercial fishing) ($\varphi = 0.04$) or *existence* value ($\varphi = 0.04$). While the results of the two spatial concurrence measures (Spearman and phi) tended to be consistent, there was one anomaly—*biodiversity* value—which had a relatively high Spearman correlation (r = 0.60) but a relatively low phi coefficient ($\varphi = 0.18$).

The small phi coefficient for biodiversity was a result of numerous "misses" between dispersed biodiversity points and biodiversity polygons. Where spatial convergence was found between the biodiversity points and polygons, the agreement was strong, with multiple participants identifying the same location. These places were biodiversity "hotspots". When the biodiversity phi coefficient was calculated using only the areas identified as "hotspots", the phi coefficient was relatively large ($\varphi = 0.51$). Thus, the two metrics (Spearman's and phi) generally track together, but can yield different assessments of spatial concurrence because the metrics are sensitive to the quantity of mapped data, the underlying spatial distribution of the mapped data (i.e., whether values are clustered vs. dispersed), and the size of the area that is compared (whole region vs. "hotspot").

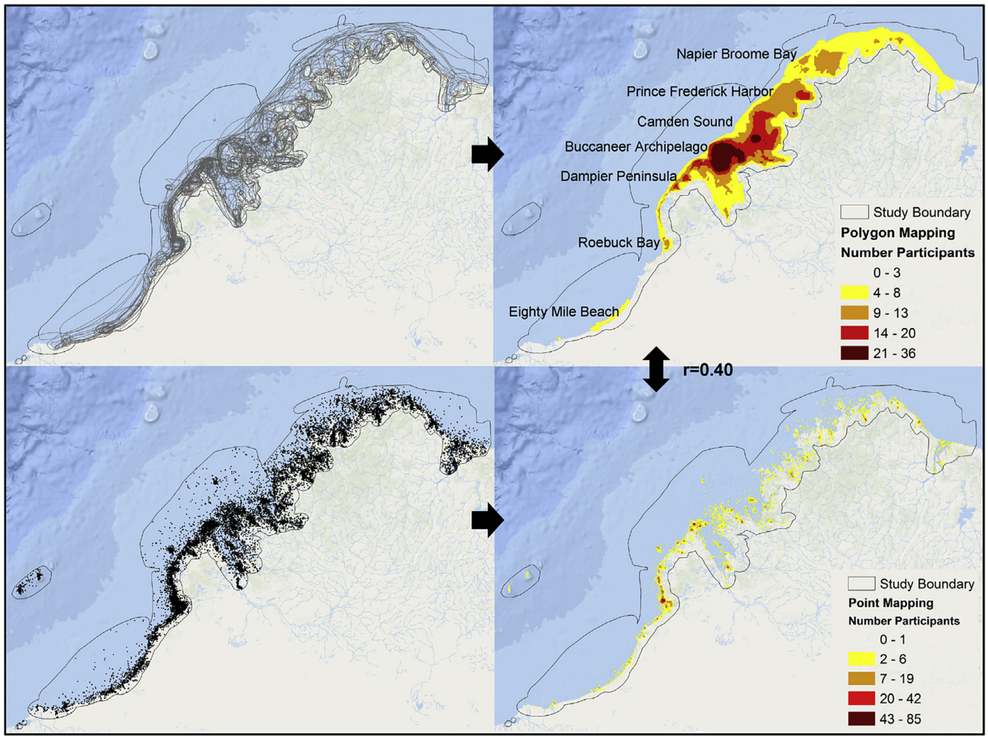

Fig. 2. Polygon (qualitative interviews) and point (quantitative PPGIS) data converted to vector grid (2 km cell) showing the number of participants that mapped any place value attribute by study area location. The correlation between the number of participants identifying values in a given cell between the two methods was r = 0.40, p < 0.001.

When analysis was limited to normalized hotspot areas, hotspot overlap between qualitative and quantitative methods was greatest with *aesthetic* value (69%), followed by *recreational fishing* (68%), *tourism* (63%), *biodiversity* (61%), *Aboriginal culture* (60%), and *recreation* value (51%). The lowest spatial overlap occurred with *economic* (commercial fishing) (28%), *therapeutic* (21%), and *existence* value (13%). These latter values had the least quantity of mapped data, were spatially dispersed, and covered relatively larger areas compared to other values.

Calculations using bivariate Moran's I, similar to the Spearman correlation results, gave autocorrelations that were lower in magnitude when assessed for 2 km cells and larger when cell counts included a 5 km search radius. The largest bivariate spatial autocorrelations occurred with *biodiversity* (0.43), *recreational fishing* (0.31), *tourism* (0.31), *aesthetic* (0.31), and *Aboriginal culture* (0.31), while the least associated values in space were *existence* (0.00), *economic* (commercial fishing) (0.13), and *therapeutic* values (0.19).

Table 3
Evaluation of spatial convergence between qualitative polygon mapping and quantitative point mapping.

Polygon coding	Point category	Analysis with 2 km grid cell size					Analysis with 2 km grid cell size and 5 km search radius for points		
		Spearman's rho[a]	Bivariate Moran's I	Phi (present/absent)	Hotspot overlap[b]	Hotspot phi	Spearman's rho[a]	Bivariate Moran's I	Phi (present/absent)
Physical landscapes (aesthetics)	Scenic/aesthetic	0.21**	0.15	0.06**	69%	0.53**	0.57**	0.31	0.13*
Recreation—general + camping	Recreation	0.14**	0.17	0.04**	51%	0.38**	0.39**	0.32	0.12**
Recreation—fishing	Recreational fishing	0.21**	0.22	0.17**	68%	0.53**	0.59**	0.31	0.51**
Biodiversity	Biological/conservation	0.20**	0.20	0.06**	61%	0.51**	0.60**	0.43	0.18**
Aboriginal culture	Aboriginal cultural	0.16**	0.14	0.13**	60%	0.43**	0.50**	0.31	0.42**
Economic—tourism	Nature-based tourism	0.16**	0.14	0.14**	63%	0.45**	0.51**	0.31	0.44**
Economic—commercial fishing	Economic (non-tourism)	0.05**	0.05	0.02	28%	0.13**	0.16**	0.13	0.04**
Learning and research	Learning/research	0.11**	0.13	0.09**	42%	0.33**	0.37**	0.39	0.33**
Historical	European heritage	0.09**	0.11	0.07**	38%	0.25**	0.29**	0.21	0.26**
Spiritual	Spiritual	0.08**	0.08	0.07**	32%	0.23**	0.31**	0.27	0.30**
Therapeutic	Therapeutic	0.06**	0.07	0.05**	21%	0.17**	0.22**	0.19	0.19**
Existence	Intrinsic/existence	0.00	0.00	0.01	13%	0.00	−0.04**	0.00	0.04**

**significant at 0.01.
[a] Correlation between point and polygon counts in same cells (n = 45,846 cells).
[b] Hotspots equal largest polygon and point counts with approximate equal area (range upper 4–33% of distribution).

In summary, the quantitative metrics of spatial association and convergence showed that the level of convergent validity between qualitative and quantitative mapping methods is highly variable and depends on the spatial attribute being mapped. *Aesthetic*, *recreational fishing*, *tourism*, *biodiversity,* and *Aboriginal culture* values showed consistently higher levels of convergent validity while *economic (commercial fishing), therapeutic*, and *existence* values had consistently low levels of convergent validity.

3.5. Convergent validity (local indicators)

Polygon and point hotspots for most mapped values were concentrated in the central reach of the coastal study area that includes Roebuck Bay, the Dampier Peninsula, Buccaneer Archipelago, and Camden Sound, and the northern coastal reach that includes Admiralty Gulf and Napier Broome Bay (Figs. 3–5). Polygon hotspots tended to be large and contiguous while point hotspots tended to be smaller and fragmented.

The Anselin LISA maps in the same figures (right hand 'column' of maps in Figs. 3–5) reveal local areas where there is significant joint clustering of polygons and points (high-high), clustering of polygons but not points (high-low), clustering of points but not polygons (low-high), and areas without significant clustering of either feature (low-low). Visually, the areas identified in dark red (high-high clusters) show statistically significant local spatial convergence between qualitative (polygon) and quantitative (point) mapping methods (i.e., "hits") while all other colors indicate "misses". Using this interpretation, local spatial convergence was greatest for *recreational fishing*, *aesthetic*, and *biodiversity* values, and lowest for *learning/research*, *historical*, and *therapeutic* values which contain larger areas of misses (pink areas) relative to hits (dark red). In summary, the local hotspot and cluster maps reveal the complexity of interpreting convergent validity for spatial constructs such as landscape values because the assessment of convergent validity appears non-uniform, value-dependent, and place-specific.

4. Discussion

Mixed methods in participatory mapping research is recent with few published studies, but can be expected to grow with the massive increase in the internet-based use of geospatial information that encourages public participation and citizen engagement (UN-GGIM, 2015). In this study, we assessed validity concepts using results from a large mixed-methods participatory mapping study. We found moderate to high levels of *concurrent* validity (non-

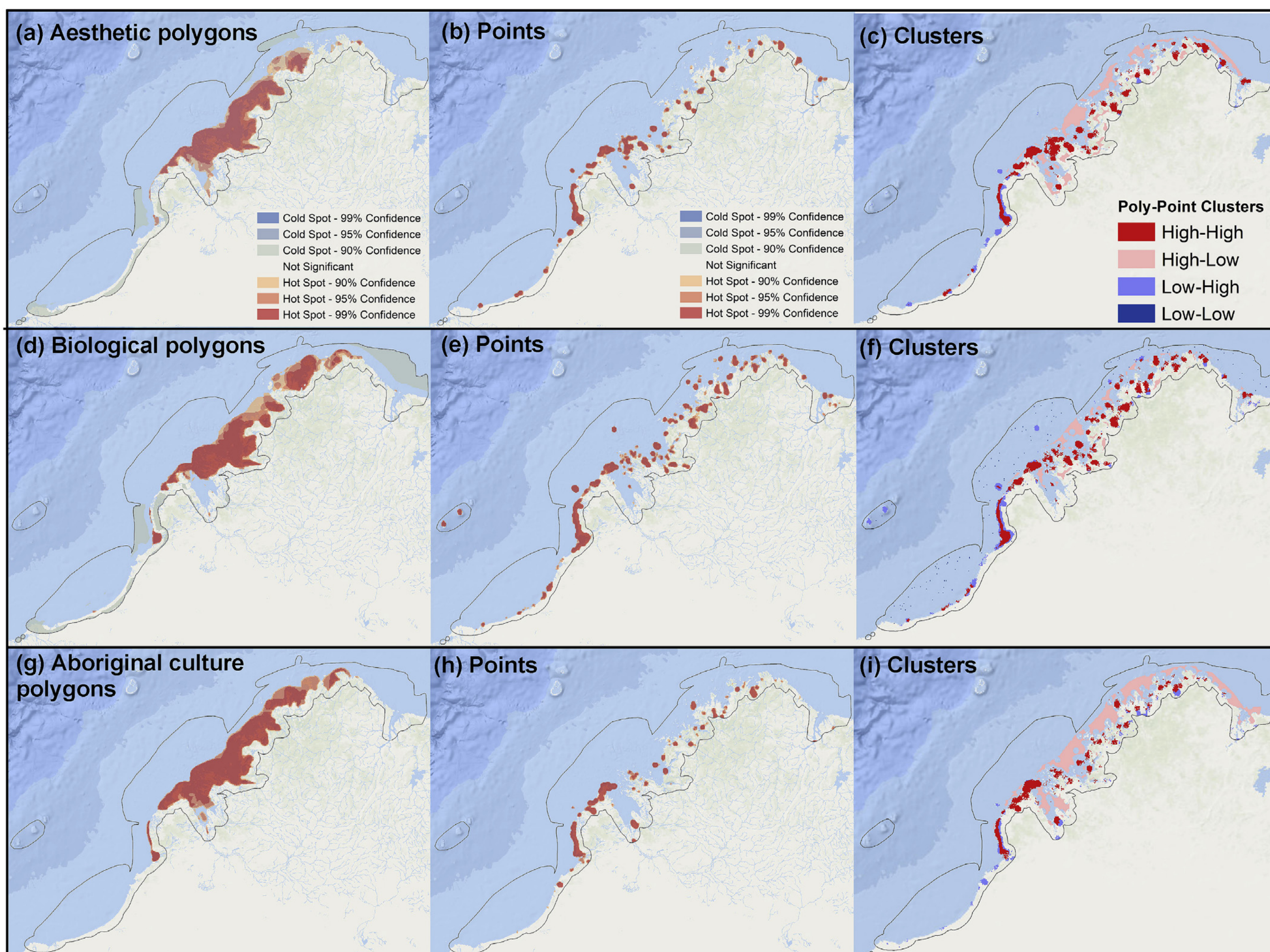

Fig. 3. Maps showing local hotspots/coldspots (Getis Ord Gi*) for (a) aesthetic polygons and (b) points; (d) biological polygons and (e) points; and (g) Aboriginal culture polygons and (h) points. Significant bivariate spatial clusters ($p < 0.05$) for (c) aesthetic; (f) biological; and (i) Aboriginal culture values.

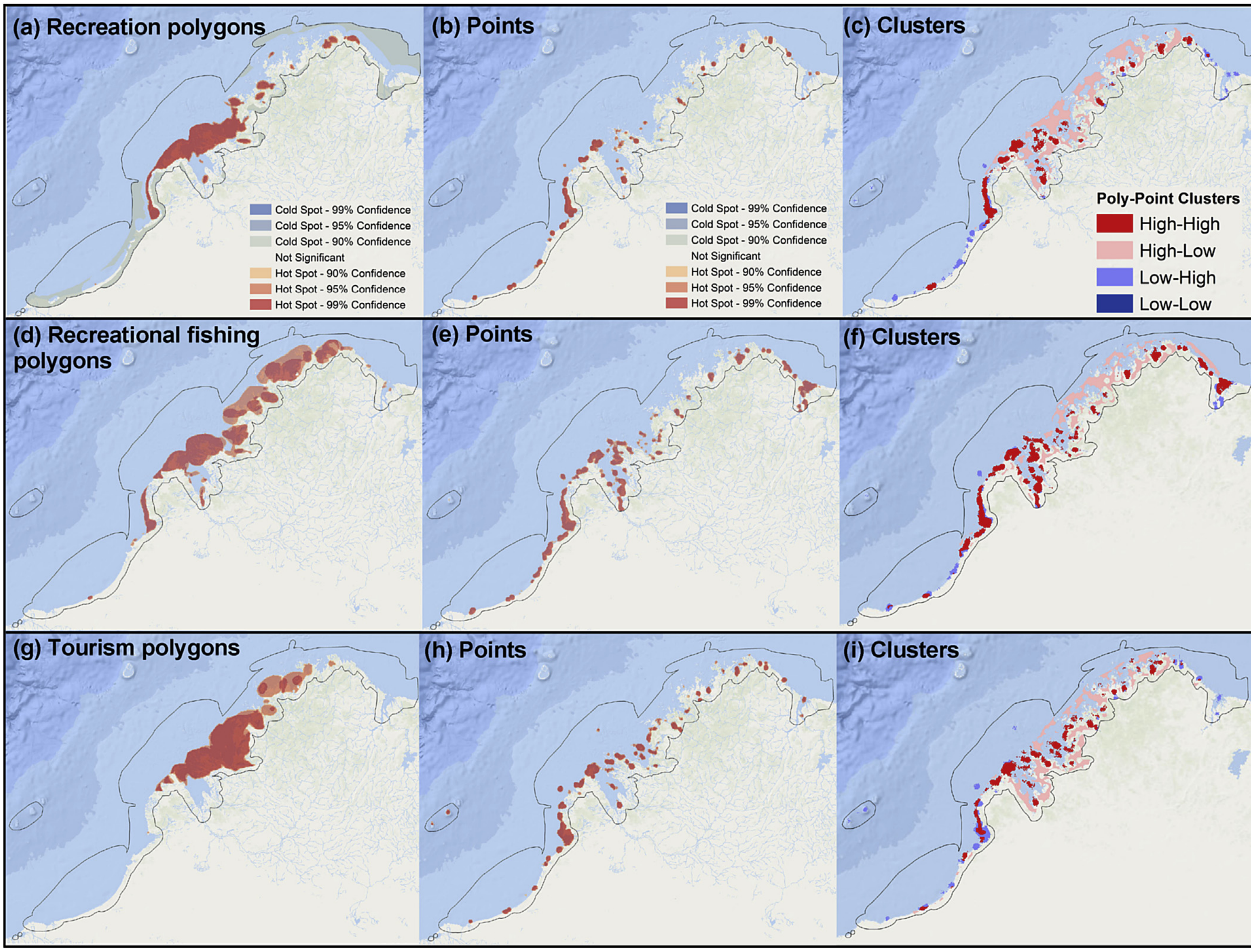

Fig. 4. Maps showing local hotspots/coldspots (Gi*) for (a) recreation polygons and (b) points; (d) recreational fishing polygons and (e) points; and (g) tourism polygons and (h) points. Significant bivariate spatial clusters ($p < 0.05$) for (c) recreation; (f) recreational fishing; and (i) tourism values.

spatial) between qualitative and quantitative mapping methods when measuring the relative importance of place values. Similar frequencies of important place values emerged whether using qualitative interviews or quantitative, internet-based PPGIS.

If this study is viewed as an *exploratory sequential* mixed methods design, what contribution did the qualitative component make to the quantitative PPGIS? The inductive place values that emerged from the qualitative interviews were not significantly different from those found in other PPGIS studies and the majority of quantitative PPGIS studies provide an “other” mapping category for identifying values not explicitly listed in the typology. Although existing place value typologies could have been used for implementing a quantitative PPGIS without the qualitative findings, the interviews were essential to reach challenging segments of the sampling population, especially Aboriginal Traditional Owners who were less likely to participate in a quantitative PPGIS. Further, the non-research objective of participatory mapping—to engage broader communities in planning and management discourse—is vitally important and may exceed the actual research value of the information collected.

If this study is viewed more as a *convergent parallel* mixed methods design given the large qualitative sample, the concepts of *commensurate* and *convergent validity* appear most relevant to evaluating the outcomes. We were unable to definitively assess commensurate validity associated with the use of points versus polygons given multiple confounding influences between the design components, but subjectively conclude there was relatively low commensurate validity based on the spatial distribution of the results. Convergent validity (spatial) in mixed methods research is still possible in the absence of commensurate validity with the key determination being whether the mixed methods identify the same areas as having similar mapped values.

Here, we conclude that the degree of convergent validity in the mixed methods design was place-value (construct) specific, with more commonly mapped values (aesthetics, recreation, biological, and Aboriginal culture) showing higher levels of convergent validity, and less frequently mapped (and more widely dispersed) values (existence, therapeutic, spiritual) showing low convergent validity. These results were not unexpected because mapping frequency is related to the cognitive challenge of identifying a construct spatially; the more cognitively challenging the mapping construct, the fewer the markers placed by participants (Brown, 2016). The results also suggest the potential of using different mapping features (e.g., polygon vs. point) for mapping given that participants appear to internalize different map scales for different place values.

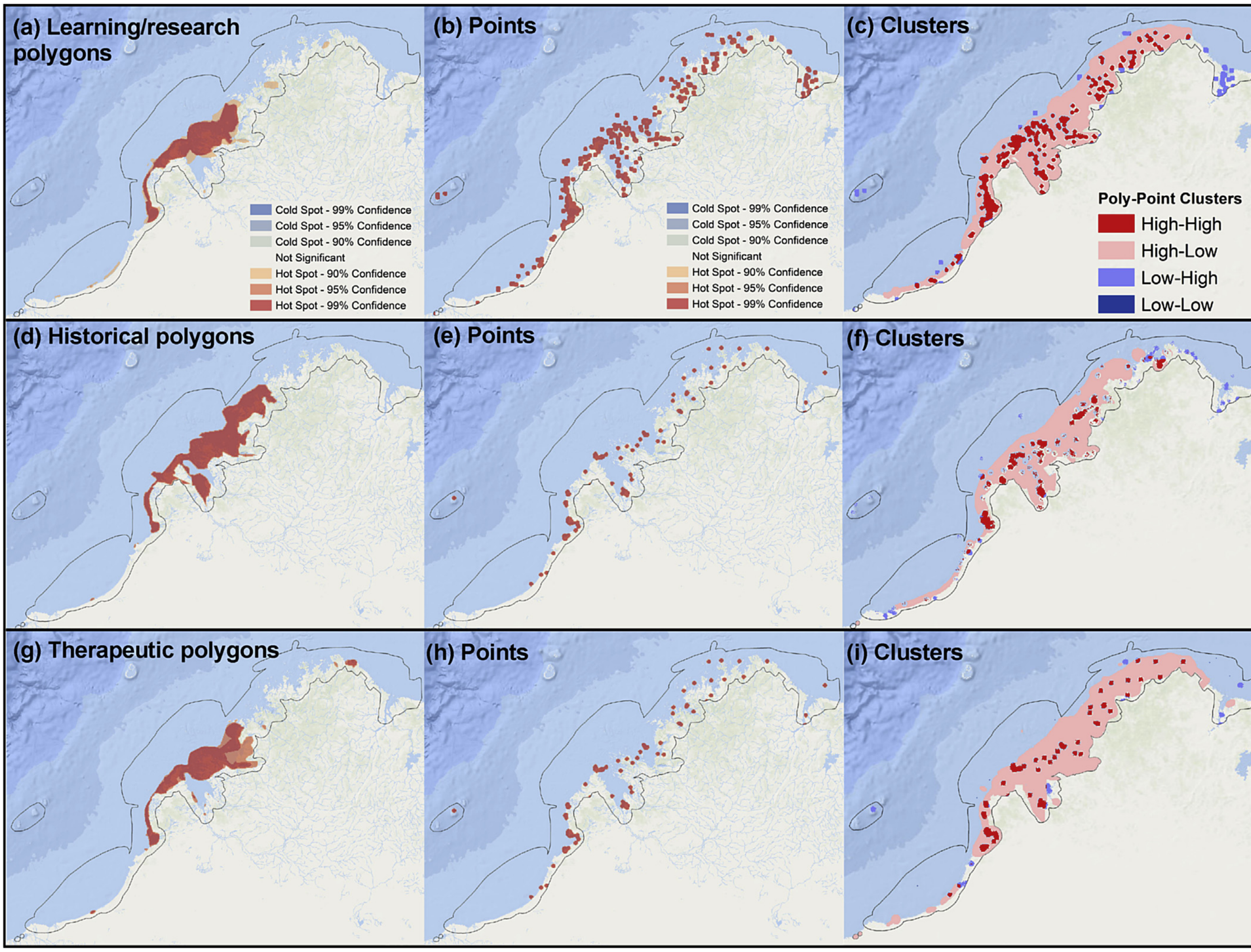

Fig. 5. Maps showing local hotspots/coldspots (Gi*) for (a) learning/research polygons and (b) points; (d) historical (European) polygons and (e) points; and (g) therapeutic polygons and (h) points. Significant bivariate spatial clusters ($p < 0.05$) for (c) learning/research; (f) historical; and (i) therapeutic values.

Given the moderate, at best, convergent validity between the more frequently mapped place values, the question becomes how to use the resulting spatial information. Participatory mapping is intended to be an applied field of research to inform place-based management decisions. When researchers are asked by the agency responsible for making management decisions about the lands/waters under their jurisdiction about the validity and credibility of the different types of spatial information generated by mixed methods, how should researchers respond? There appear to be three options: 1) conclude that one method is more valid than the other and use only that spatial data for decision support (e.g., the larger quantitative PPGIS component), 2) combine the spatial data under the assumption that both methods are legitimate, while acknowledging that low commensurate validity influenced the level of convergent validity in the spatial data, and 3) select and use only the data with high concurrent validity. If the mixed methods design was intended to be *exploratory sequential*, one would select the first option, and if the design was intended to be *convergent parallel*, the second or third options would be taken. In the study, the research strategy had characteristics of both mixed method designs so treatment of the data for decision support is less clear.

Spatial data from mixed methods have an advantage over psychometric data in that spatial overlays can identify areas of apparent agreement, disagreement, and areas of ambiguity in the data, which translates into confidence levels in the results. Agencies can be informed that for areas where results from the two methods spatially coincide, there is *high confidence* that the mapped values exist in the area. These areas appear as significant high-high clusters in Figs. 3–5. There would be *low confidence* about places where neither mapping method identified the places as valuable. An important caveat is that the absence of spatial data should not be interpreted by agencies as areas having no or low value because other variables such as participant familiarity and domicile can strongly influence what place locations get mapped. This is especially important in remote and less accessible regions like the Kimberley where the study population is likely to have reduced familiarity in general.

The interpretive conundrum for spatial mixed methods results is how to treat divergent spatial results. These areas appear as high-low clusters in Figs. 3–5. One could associate *medium confidence* with these mapped areas and advise the agency to apply the precautionary principle in management by assuming that the mapped values exist in these areas, although identified by only one method. Alternatively, one could argue that the majority of these areas appear to be an artefact of the qualitative polygon mapping method that identified larger spatial areas with less spatial resolution than point mapping. In other words, one could interpret these areas as indicators of measurement error for which the results should be effectively discounted.

As described by Brown, Donovan et al. (2014) in a mixed study involving community mapping workshops and internet PPGIS, the source of the measurement error could derive from the inductive coding process, the multi-attribute nature of the polygons in contrast with single attributes for points, the subjective nature of the place value constructs, and non-equivalent sampling groups. The authors of that study concluded that the relatively low level of spatial convergence between the two methods did not warrant combining the spatial data, suggesting there may be a spatial convergence threshold at which it would be appropriate (or inappropriate) to combine mixed methods spatial results. However, no specific quantitative guidelines were provided as to what that the combining threshold might be, or whether combining the data should be applied to all values, or just those with higher spatial convergence. An argument can be made that the significant clusters (high-high) found in Figs. 3–5 provide sufficient spatial convergence for use in planning decision support.

The prospect for increased use of mixed methods research in participatory mapping research is uncertain. Mixed methods approaches may be a luxury in public sector research where agencies are likely to be forced, due to financial constraints, to choose one method over another. With constrained funding, our view is that the spatial mapping method offering the greatest external validity (quantitative PPGIS) would be preferred over the method offering potentially greater internal validity (qualitative mapping). However, assessing trade-offs in research design is never easy and other researchers would likely arrive at a different conclusion. Researchers are likely to choose to operate, however, within the research paradigm where they are most comfortable.

5. Conclusion

This study provided criteria for assessing validity in mixed methods participatory mapping research and illustrates their application using empirical data. The evidence indicates that both qualitative and quantitative methods are valid for identifying the range and meaning of place-based values within a study region. But this conclusion represents a low bar for assessing the validity of spatial mixed methods. The primary purpose of participatory mapping research is to inform place-based planning and management where validity requires convergence in construct meaning, spatial location, and consistency of values within the population of interest. Given the number of places of importance within a study area is likely to be large, complete spatial convergence of results obtained by different methods should not be expected. An augmented approach to the spatial convergence measures illustrated herein would be to select key reference sites and assess the number of “hits” and “misses”. At present, we resist advocating a universal quantitative threshold for convergent validity because the threshold is likely to vary by study region and population. A 50% spatial overlap or reference site “hit” may indicate a high standard for validity in a large, diverse study area, but a poor standard for a smaller, less diverse study area. However, there may be merit in imputing validity to significantly clustered areas (high-high) within a mixed methods design.

A final issue with mixed methods validity concerns not just convergence in construct meaning and spatial location, but the universality of place perception within the population of interest. The finding that individuals and groups within society perceive different place values is well-established in participatory mapping research (Brown, Kelly et al., 2014; Brown, 2016). In other words, *who* does the mapping matters. In this context, convergent validity is more than the hit/miss between methods, but involves an assessment of the level of agreement within the population and sub-populations of interest and requires disaggregation and analysis of the spatial data by sampling group. Those who would use the information for decision support will want to know whose values are represented across the methods to achieve *political legitimation* (Onwuegbuzie & Johnson, 2006) and therefore acceptance of the meta-inferences stemming from both the quantitative and qualitative components of a study.

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