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Marine spatial planning for the future: Using Public Participation GIS (PPGIS) to inform the human dimension for large marine parks

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ABSTRACT

Marine protected area (MPA) research continues to be dominated by biophysical interests. However, understanding social data, including people's values and preferences, is critical to both effective planning and management and long-term MPA success. Having these social data in a spatial form is essential, given that MPA planning and management increasingly uses marine spatial planning (MSP) approaches to carefully locate and mediate among potentially competing uses in both space and time. An online Public Participation GIS (PPGIS) survey was used to collect spatially explicit information on stakeholder values and management preferences for Australia's remote Kimberley region. The Kimberley coast and marine environment is characterised by a multiplicity of values and preferences. Key values included biological conservation, aesthetics, recreational fishing, Aboriginal culture and heritage, and nature based tourism. Management preferences were dominated by the desire to increase conservation/protection, exclude oil/gas development and commercial fishing, and to increase Aboriginal management. The diversity of values and preferences present suggests potential for conflict over management and permitted uses. Significant associations between value and preference distribution and the Kimberley's five marine protected areas were analysed. Accessibility and respondent familiarity appear linked to value attribution. More accessible MPAs were significantly associated with recreation values while more remote MPAs were characterised by a conservation ethos and general aversion to development. Our research demonstrates that PPGIS enables documentation of spatially explicit social data across large scales, highlighting potential synergies and conflicts in values and permitted uses, in a manner that can readily integrate with ecologically based marine spatial planning processes.

1. Introduction

Marine protected areas (MPAs) are being pursued across the globe as an essential tool for achieving marine and coastal conservation [1,2]. While biophysical elements have received comprehensive attention, analyses of the social dimensions of MPAs have been lacking [3–6]. Particularly important is the relationship between people and the marine environment, which may be reflected in the social values they express (e.g., benefits or ecosystem goods and services derived, people's preferences and opinions regarding management, their attitudes and perceptions). Understanding such social dimensions is essential for effective planning and management, particularly when 'public' assets such as MPAs are involved.

The public nature of MPAs implies that their management be guided by the 'public' interest; that is, by the values, attitudes, preferences and opinions of the people associated with a given area. However, planners and managers often consider these social aspects of marine conservation of lesser importance than ecological or biological concerns. Voyer et al. [3] for example, in their review of Australian marine park planning, note that the social values and impacts associated with such areas have been inadequately considered. They conclude that where social values and impacts have been considered, they have been accessed via public participation and economic modeling as surrogates for comprehensive research and analysis of social values, perceptions, and aspirations with respect to proposed (and existing) MPAs. Christie's [6] review of four MPAs in southeast Asia found that while touted as successful in achieving biological goals, MPA 'success' was undermined by adverse social impacts including conflict among diverse user groups, and social and economic displacement of user groups such as artisanal fishers. The review concluded that

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greater social research was required to complement the existing focus on biological research within MPA planning and management. Cornu et al.'s [4] global review of the incorporation of social data into marine and coastal planning concluded that despite practitioner recognition of the value of social data, its collection and integration receives little funding.

These and other examples illustrate that inadequate consideration of social data such as values and preferences can result in poor planning and decision-making, and may exacerbate conflict over MPAs. Agardy et al. [2] highlight conflict as arising from a number of factors including the apparent imposition of MPAs *sans* local consultation, attempts to limit access to resources (e.g. fish and other aquatic species) and the concomitant disruption of livelihood options, failure to consider unique cultural contexts and connections, and the elevation of certain user groups and preferences above others. These conflicts, and the failure to properly consider social data in both MPA planning and management, can facilitate overt and covert opposition to MPAs and compromise their long term success [2,6–9]. This understanding has led to growing calls for an improved social research agenda in the marine and coastal domain [e.g. 4,5].

Marine spatial planning (MSP) provides an overarching framework to explicitly address, and integrate, social data with ecologically based MPA management approaches. A tool for assisting in the management of conflicting uses, MSP is heralded as a key means of spatially identifying and mediating potentially competing uses in the marine environment [10,11]. However while MSP provides a useful framework for MPA planning and management [12], it too is characterised by criticisms of inadequate attention to social data [13], with Flannery et al. [14] discussing MSP as ‘asocial’.

This paper addresses this gap and presents a spatially explicit analysis of social values and preferences for the coastal and marine environment in Australia's vast, remote Kimberley region and the large MPAs it contains. The collection, analysis, and application of spatially explicit information on social values and preferences are described. Such data provide much needed information to support more effective MPA planning and management as well as contributing to broader marine spatial planning efforts in the region. Following a presentation of the case study results, the utility of participatory mapping for accessing place-based, social data for planning and management is discussed together with implications for MSP.

1.1. Using Public Participation GIS to collect social data

Public Participation GIS (PPGIS) offers one means of collecting social data that readily supports integration with MSP. PPGIS can identify spatially explicit information for range of planning needs such as place values, management preferences, and ecosystem services [15–17]. Recording social data in a spatially explicit manner facilitates integration with existing biophysical data layers within GIS-based decision support systems. A typical PPGIS study asks respondents to locate—and sometimes rank—values, ecosystem services and/or management preferences by placing markers onto an online or hard copy map of a given area. Such data provides planners and managers with socio-spatial information that can assist in assessing the compatibility of land uses (e.g., zoning in marine parks) with public values for those areas [18]; identifying the potential for conflict [19]; and providing guidance for managing public lands and waters [20,21].

PPGIS methodologies have been used extensively by natural resource managers for a variety of purposes including protected area planning and local through to regional scale conservation efforts. In Germany, Plieninger et al. [22] combined interviews with mapping to explore perceptions of cultural ecosystem services among 93 local residents. Their results highlighted a spatial clustering of ecosystem services that assisted in informing more targeted land management. Recreational services in particular, such as walking, swimming, hunting and angling, emerged as a key means for engendering local support for protected areas. On a broader scale, Brown et al. [23] used PPGIS to quantify social values and preferences associated with eleven different types of public lands (including national parks, state forests and wilderness parks) in Victoria, Australia. Their analyses identified a number of areas subject to potential conflict, and illustrate the utility of PPGIS for documenting broad-scale, spatially-explicit social data that supports applied decision making for nature conservation and recreation. Most PPGIS studies have focused on terrestrial domains, with far fewer studies conducted in marine or coastal environments. Research by Brown [24], Ruiz-Frau et al. [25], van Riper et al. [26], Klain and Chan [27] into values and ecosystem services associated with marine and coastal environments provide notable exceptions.

1.2. Marine planning in the Kimberley

The vast, remote Kimberley region, encompassing 423,500 km^2, is located in Australia's north-west. It offers a unique wilderness and ecotourism experience built upon remoteness, rich biodiversity and living cultural heritage, and a largely unspoiled coastal and marine environment. Its highly crenulated coastline extends 13,296 km at LWM [28]. Sparsely populated, the Kimberley has a population of 34,794 people, 43.5% of whom identify as Indigenous [29]. Most residents live in the towns of Broome, Derby and Kununurra. A limited number of sealed roads connect these centres, while the coastline remains largely inaccessible. Seasonality as well as remoteness from major economic hubs means the region is relatively underdeveloped.

In 2011 the Western Australian Government released the Kimberley Science and Conservation Strategy [30]. Under this Strategy and subsequent related policy developments, five MPAs were proposed in State waters (0–2NM offshore): Eighty Mile Beach, Roebuck Bay, Horizontal Falls, Lalang-garram/Camden Sound (Lalang-garram), and North Kimberley (Fig. 1). To date only three parks have been established: Eighty Mile Beach, Horizontal Falls and Lalang-garram. The MPAs vary in size, accessibility, and proximity to population centres (Table 1). Roebuck Bay is the smallest and most accessible MPA, while the vast and remote North Kimberley MPA covers over 19,000 km^2. Once formalised, the latter will boost the total area of State marine parks and reserves by more than 70% with the remote North Kimberley MPA being the second largest state MPA in Australia [31]. A number of marine reserves such as Oceanic Shoals (Fig. 1) have also been proposed further offshore in Commonwealth (Federal) waters (2–200NM offshore); however, these are not included in this analysis as they are beyond State jurisdiction.

MPAs in Australia are managed for multiple outcomes. Key uses for Kimberley MPAs include biodiversity conservation, Aboriginal culture and heritage, nature-based tourism, commercial fishing and aquaculture, science/education, recreation, and recreational fishing. As such, conflict between values and accompanying uses within MPAs is inevitable, making MSP with its promise of being able to separate conflicting uses in space and time an essential part of the policy armoury. Additionally, in the Kimberley region, much of the coastline and associated State coastal waters are either held under, or subject to negotiations for Native Title, and all MPAs are to be jointly managed with Aboriginal Traditional Owners. These complex governance arrangements further emphasise the importance of robust social data underpinning planning and policy decisions.

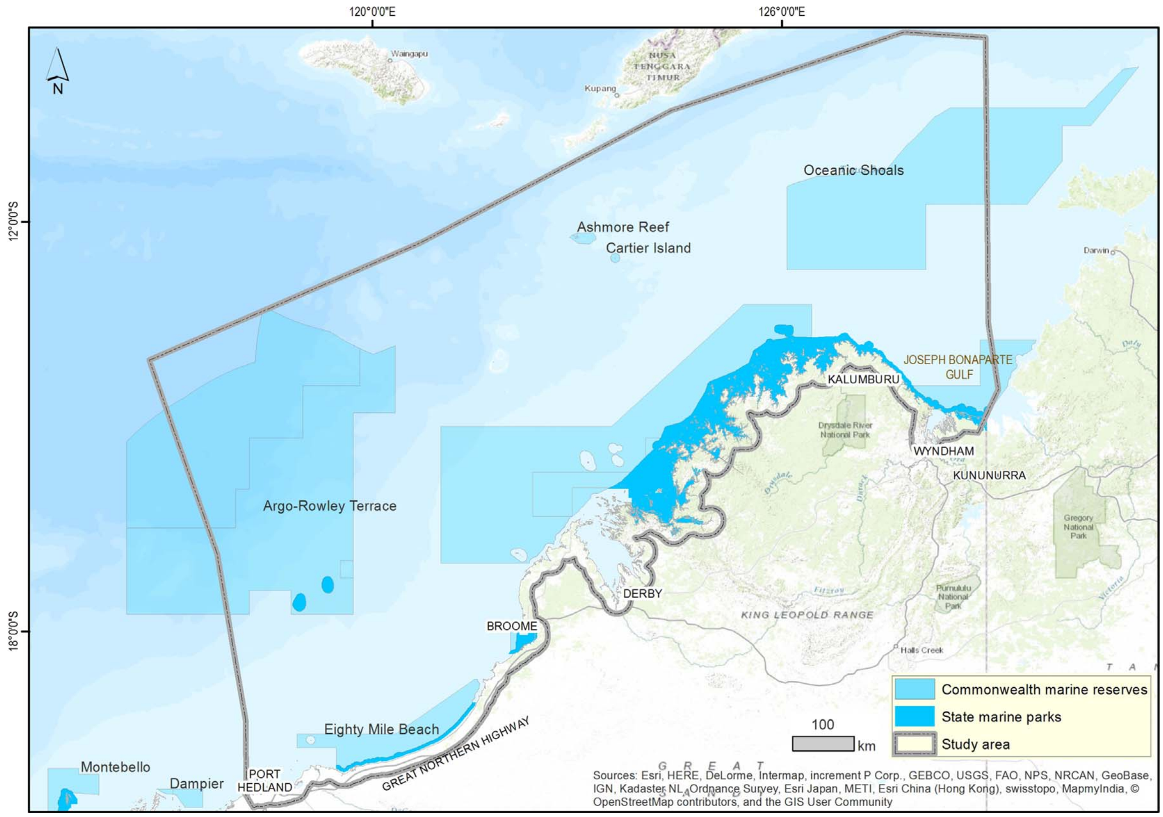

Fig. 1. Kimberley MPAs (current and proposed) [28; Department of Parks and Wildlife (pers comm.) Sept 2015].

Table 1
Characteristics of the Kimberley's current and proposed State MPAs.

MPA	Area (km^2)	Principal access		Nearest port/ town[a]	Native title
		Land	Sea		
Eighty Mile Beach	2043	×		Broome ~300 km	Established
Roebuck Bay (proposed)	338	×		Broome ~5 km	Established
Horizontal Falls	3581		×	Derby ~200 km	Established
Lalang-garram/ Camden Sound	6769		×	Derby ~200 km	Established
North Kimberley (proposed)	19,593		×	Wyndham ~300 km	Established

[a] Approximate distance to MPA centre.

2. Methods

Data collection relied on an online PPGIS survey with values and preference mapping as the central activity followed by non-spatial socio-demographic, knowledge, and stakeholder delineation questions. Participants were asked to drag and drop markers representing different values and management preferences onto a Google® maps interface of the study area (Fig. 2). Value and preference operational definitions were provided to eliminate potential confusion over their meaning; for example, European heritage was defined as areas 'valuable because they reflect European history associated with exploration, pastoralism, missions, commercial fishing and the Second World War'. These values and preferences were derived from earlier interview-based research in the Kimberley by the authors Strickland-Munro et al. [42] and were consistent with typologies used in previous PPGIS studies [32]. Participants were required to zoom into a minimum scale of 10 km before placing markers to ensure a reasonable level of mapping accuracy. Additional data layers including MPAs and national park boundaries were available as overlays to assist with place identification and map navigation.

To be truly effective, MSP needs to recognise multiple perspectives, power structures and social relations [14]. This research purposefully targeted a diverse range of local as well as geographically remote stakeholder groups associated with the coastline and marine environment. This approach assisted in documenting the suite of stakeholder interests present while ensuring recognition and inclusion of diversity in respondent employment, cultural and residential status. Broad stakeholder recruitment thus addressed dual MSP criticisms: MSP as lacking social data [13] and MSP as asocial, lacking acknowledgement of power structures and social relations [14]. Groups targeted for involvement included Aboriginal Traditional Owners; Kimberley residents; tourists and the tourism industry; commercial and recreational fishing, and aquaculture; scientists; federal, state and local government; industry (mining, oil, gas and tidal energy interests); marine transport and aviation; and environmental non-government organisations. A minimum sample of 350 participants across all stakeholder groups was sought. Over 120 official and informal groups were engaged through eight discrete recruitment approaches: email invitation; social media; personal referral; direct personal contact with researchers; direct postal invitation (Kimberley residents only); local newspapers; organizational newsletters; and printed invitation cards. Recruitment relied heavily on accessing the authors' pre-existing social networks and relationships built through previous research (cf. Strickland-Munro et al. [42]). A pilot version of the survey was tested and minor amendments made prior to the survey being open for data collection.

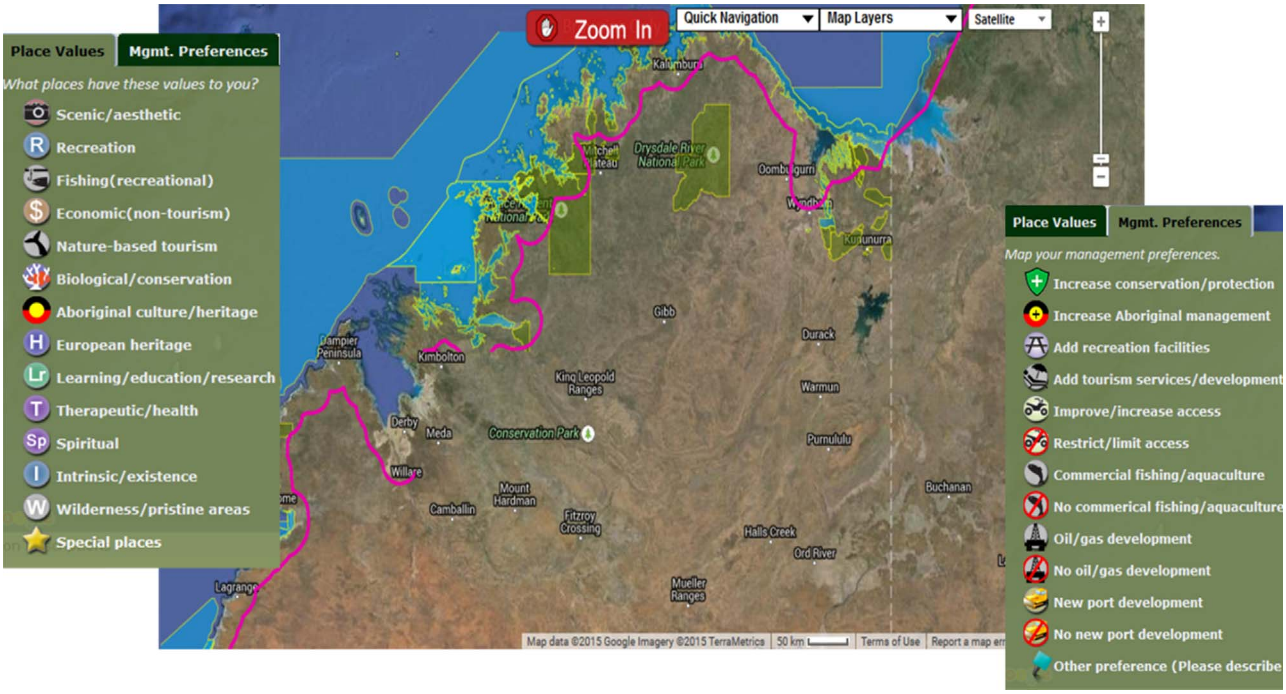

Fig. 2. PPGIS mapping interface showing values and preferences associated with the Kimberley coast.

2.1. Data analysis

Three phases of analysis were undertaken. First, maps displaying the spatial extent of markers representing individual values and management preferences were plotted. Second, point density maps were created by intersecting marker data (points) with 2 km grid cells, a resolution consistent with the extent of geographic features of interest e.g., river mouths and beaches. Point density was then calculated by i) defining a 20 km search radius ('the neighbourhood'), this being twice the minimum scale at which mapping was able to be undertaken; and ii) counting the number of points within the neighbourhood for each value or preference, and dividing by the total neighbourhood area. The resultant maps display the relative high and low densities for each value/preference. A histogram stretch of 2.5 standard deviations from the mean was applied as this suited all values and preferences.

Third, the relationship between the spatial distribution of mapped values and preferences and the five proposed and existing MPAs was examined. Radar charts display the value and preference profile characterising each MPA. Social landscape metrics [33] were then calculated for each MPA. These metrics provide important data on the structure and distribution of social values and preferences across the MPA network. Calculated metrics included value and preference counts; richness; and dominance, density and diversity indices. Counts provide an indication of the number of value and preference points while richness reports on the number of discrete value and preference types mapped within each MPA. Dominant marker (D) indicates the most common value or preference marker mapped. The dominance metric (D1) indicates whether the dominant value or preference (D) within each MPA is truly dominant in relation to other values or preferences, or only slightly more common. The dominance index is calculated by subtracting the second most frequently mapped value from the most frequently mapped value and dividing by the most frequently mapped value. For example, if the most frequently mapped value was 10 and the second most frequently mapped value was 5, the dominance index would be 0.5. Scores close to zero indicate little difference in dominance among the most frequently mapped values or preferences, while a score of 1.0 indicates only one value or preference is present. The density (D2) metric calculates the density of mapped values/preferences within each MPA. Larger values indicate more participants assigned values or preferences to a given MPA, normalised by area. The diversity metric (D3) calculates the number of different types of values/preferences within a given MPA, with scores ranging from 0 (no diversity in mapped data) to 1 (perfect diversity/ large number of different values or preferences), also indicating the potential for conflicting uses [33].

Chi-squared tests of independence and standardized residuals were used to assess whether values and preferences were significantly associated with the MPAs. Standardized residuals greater than +2.0 indicated significantly greater observed frequencies than expected, while standardized residuals less than −2.0 indicated significantly fewer observed counts than expected. Larger standardised residuals indicate a greater deviation from expected counts and warrant particular consideration.

3. Results

3.1. Response and participant characteristics

A total of 372 respondents mapped 19,157 markers. Almost 72% of these (13,756 markers) represented values (Table 2). A total of 5401 management preference markers were mapped. The majority of participants were recruited via direct email invitation (63.7% of all responses), followed by social media platforms (principally Facebook, 13.3% of responses) and personal referral (7.9%) (Table 2).

Table 2 provides a comparison of PPGIS participants with respect to Kimberley and West Australian Census data [29]. Participants had a greater median age yet were broadly comparable with both Kimberley and Western Australian census data in terms of gender, with slightly more males participating in the study. Participants reported higher levels of education (tertiary and

Table 2
Response and participant characteristics with comparison to Kimberley and Western Australia census data [29]. Note: Figures may not sum to 100% for questions that were multi-choice and optional.

Response characteristics for all respondents	
Sample size	372
Total markers mapped	19,157
Number of value markers mapped	13,576
Number of management preference markers mapped	5401
Range of markers mapped	1–341
Method of recruitment (%)	
Direct email invitation	63.7
Social media	13.3
Personal referral	7.9
Other	5.8
Postal invitation	4.4
Unspecified	1.9
Newspaper article	1.5
PPGIS website	1.1
Printed infocard	0.4

Participant characteristic	PPGIS participants	Kimberley 2011 Census	WA 2011 Census
Age (median)	50	30	36
Gender (%)			
Male	52.9	53.2	50.3
Female	45.9	46.8	49.7
Indigenous (%)	4.3	43.5	3.4
Highest level of education completed (%)			
Primary	1.3	5.6	4.0
Secondary	8.3	[a]	[a]
Undergraduate/Bachelor degree	29	9.1	15.2
Vocational/technical training	15.3	23.5	28.6
Postgraduate degree	31.7	2.9	2.9
Unspecified	1.3	21.1	20.4
Annual household income (median, $)	91,000	68,976	73,580

[a] Unable to ascertain accurate data.

postgraduate qualifications) and household income than Kimberley or West Australian residents, consistent with findings from other PPGIS studies [31]. Indigenous respondents were underrepresented in the survey (4.3%) in comparison to the Kimberley Indigenous population (43.5%). Lack of computer and Internet access provides partial explanation for this discrepancy as does the reliance on remote methods of recruitment (e.g. email and social media rather than in-person). Earlier interview-based research with 50 Traditional Owners, Aboriginal rangers and residents (comprising 21.5% of all respondents) (Strickland-Munro et al. [42]) partly addresses this underrepresentation and underpins the values and preferences used here.

3.2. Spatial extent and point density maps for values and management preferences

The most frequently mapped values were biological/conservation (16.4% of all value markers mapped), scenic/aesthetic (15.4%), recreational fishing (13.4%), Aboriginal culture and heritage (11.7%), wilderness (10.2%) and nature based tourism (10%). Collectively, these values accounted for over 70% of all value markers (N = 13,756) placed in the survey. Therapeutic and spiritual values were least mapped (< 2% of all value markers).

Fig. 3 depicts point density maps for three frequently mapped values – biological/conservation, scenic/aesthetic and Aboriginal culture and heritage – as well as three lesser mapped values – European heritage, intrinsic/existence, and spiritual values. These maps serve to illustrate the diversity of mapping in the survey; however, only a selection of values and preferences are depicted here and so the full range of hotspots evident from the research are not depicted. From these point density maps it is apparent that: (1) values are spatially associated with the entire Kimberley coast, and (2) more frequently mapped values display a larger spatial footprint than do lesser mapped values, which have a greater proportion of 'unmapped' coastline. The existence of 'unmapped' coastline does not indicate a lack of associated value, as the study collected presence data only rather than presence/absence data. Thirdly, distinct hotspots or areas of greater value density are evident, as indicated by yellow-red shading. Hotspots evident from Fig. 3 for the three most frequently mapped values centre on Roebuck Bay MPA, James Price Point, and the northern tip of Dampier Peninsula; the latter two being outside of MPAs. All three areas are renowned for their stunning vistas and landscapes, and biodiversity values. Roebuck Bay in particular is renowned for its migratory shorebirds, snubfin dolphins and macroinvertebrate populations. Additionally, these areas offer unmatched opportunities to engage with contemporary and historic Aboriginal culture through an array of cultural tourism opportunities, with the northern Dampier Peninsula home to several award-winning aboriginal tourism ventures. European heritage, intrinsic/existence and spiritual values display more varied hotspots including those located within Lalang-garram MPA and the North Kimberley MPA (Fig. 3). European heritage values displayed a large number of hotspots despite recording lesser markers. These hotspots reflect the location of valued areas relating to pearling, missionary and European explorer history, such as the Sunday Island and Kalumburu mission sites and Philip Parker King's famous inscribed boab tree at Careening Bay.

Of the 5401 management preference markers mapped, the majority (84.9%) related to 'pro-conservation' preferences. Preferences for increased conservation/protection (27.4% of all preference markers mapped), no oil/gas development (23.7%), no commercial fishing/aquaculture (12.6%), increased Aboriginal management (9.3%) and no new port development (7.4%) were most prevalent. 'Pro-development' preferences (15.1%) accounted for the remaining mapped preferences. Of these, resource-related preferences supporting commercial fishing/aquaculture, new port and oil/gas developments received the least number of markers (5.5% of all preference markers mapped). Fig. 4 illustrates the spatial footprint of three 'pro-conservation' and three 'pro-development' preferences. As before, it is evident that the entire Kimberley coast is associated with some form of management preference. Hotspots centre on Roebuck Bay MPA, Lalang-garram MPA, James Price Point, the northern tip of Dampier Peninsula, the Buccaneer Archipelago and King George Sound near Derby, with last three being outside of MPAs (Fig. 4).

3.3. Relationship between the spatial distribution of values and preferences and the Kimberley State MPAs

3.3.1. Radar charts providing comparable visual profiles for the five MPAs

Frequency distribution of mapped value and preference data within the five MPAs were examined. The southernmost and most accessible Eighty Mile Beach and proposed Roebuck Bay MPAs had similar value profiles, with both characterised by more frequent mapping of recreational fishing, scenic and biological values, with nature-based tourism additionally valued at Roebuck Bay. The three northernmost, least accessible MPAs were also characterised by biological and scenic values, with nature-based tourism highly valued in Lalang-garram MPA, and recreational fishing in North Kimberley MPA (Fig. 5). Preference profiles for the five MPAs were similar. All MPAs displayed a bias towards 'increase conservation'

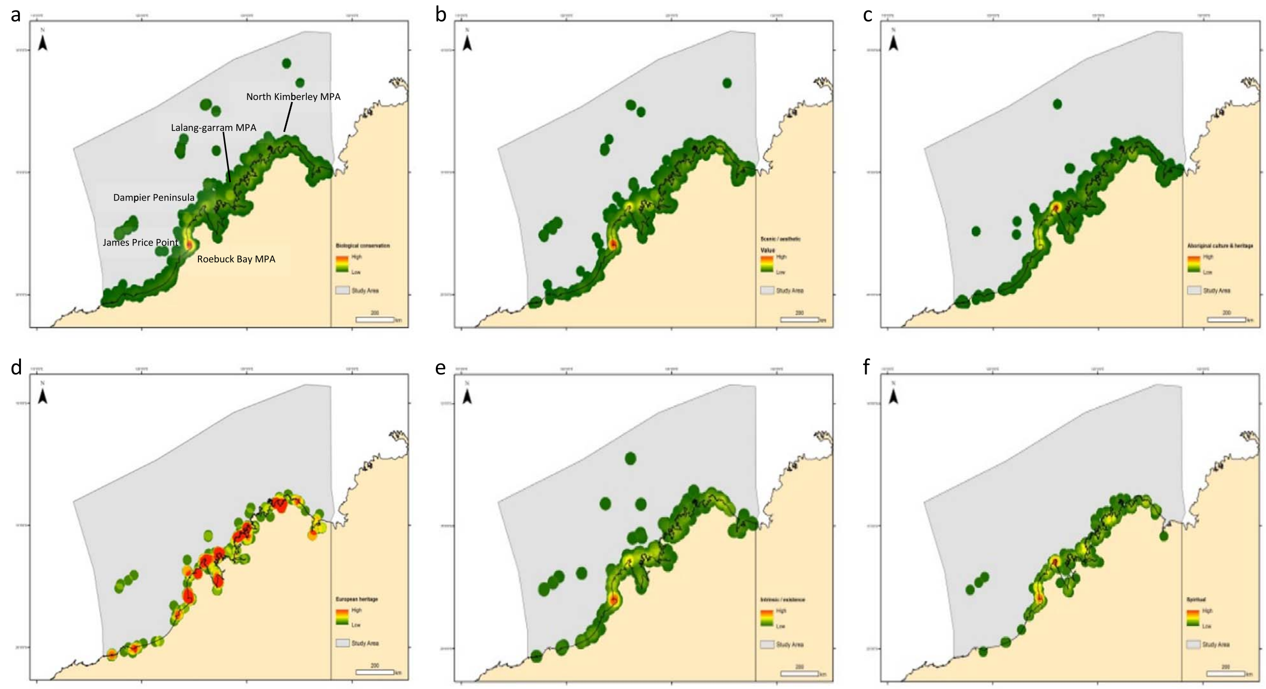

Fig. 3. Point density maps for values: (a) biological/conservation, (b) scenic/aesthetic, (c) aboriginal culture and heritage, (d) European heritage, (e) intrinsic/existence and (f) spiritual values. [Note. Fig. 2 provides the value markers and definitions provided to respondents.].

and ‘no commercial fishing’ preferences. Adding recreation facilities was an important management preference for Eighty Mile Beach MPA, while for the other four MPAs no oil/gas development was important (Fig. 6).

3.3.2. *Social landscape metrics exploring the relative richness and diversity of the MPAs*

Social landscape metrics were calculated for the five MPAs (Table 3). The three smaller MPAs – Eighty Mile Beach, Roebuck Bay and Horizontal Falls – were characterised by values relating to their primary attractions: recreational fishing, nature-based tourism and scenic values, respectively. *Lalang-garram* and North Kimberley MPAs were characterised by biological values. Low dominance indices (Table 3, D1: 0.04–0.14) indicate that the most frequently mapped value in any given MPA was similar in count to the second most frequently mapped value. The preference to

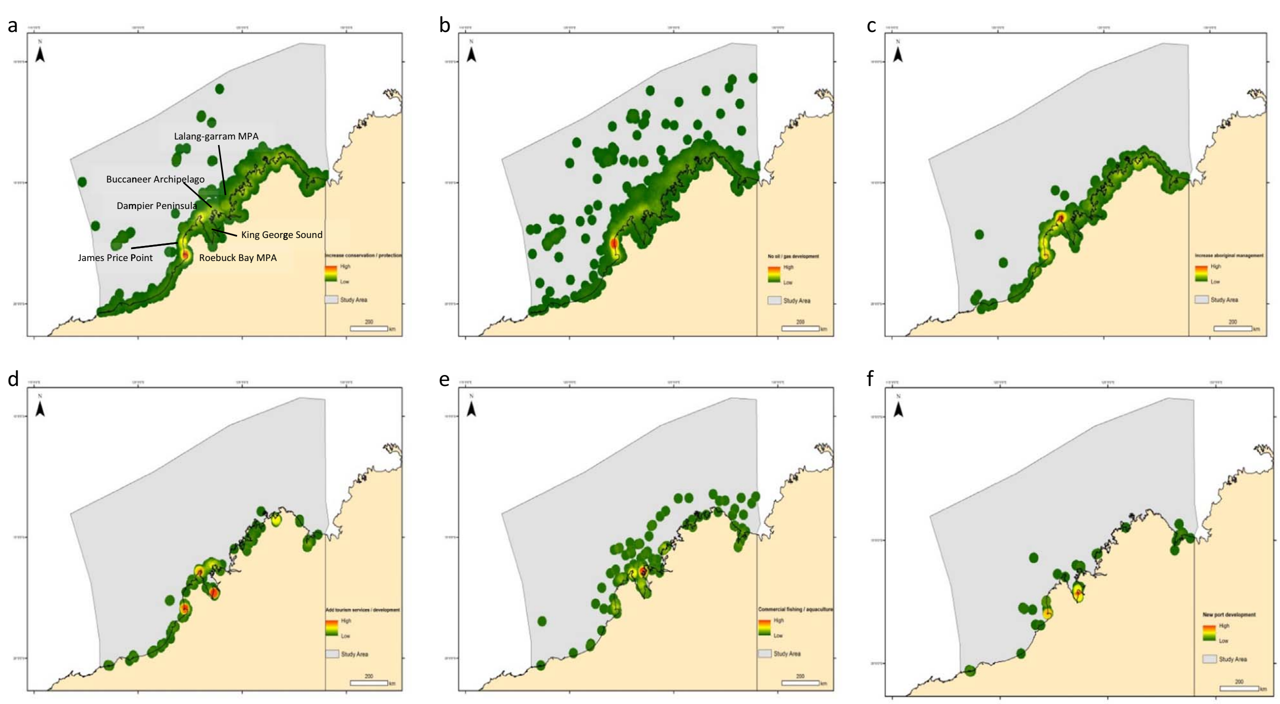

Fig. 4. Point density maps for management preferences: (a) increase conservation/protection, (b) no oil/gas development, (c) increase Aboriginal management, (d) add tourism services/development, (e) commercial fishing and aquaculture and (f) new port development. [Note. Fig. 2 provides the management preference markers and definitions provided to respondents.].

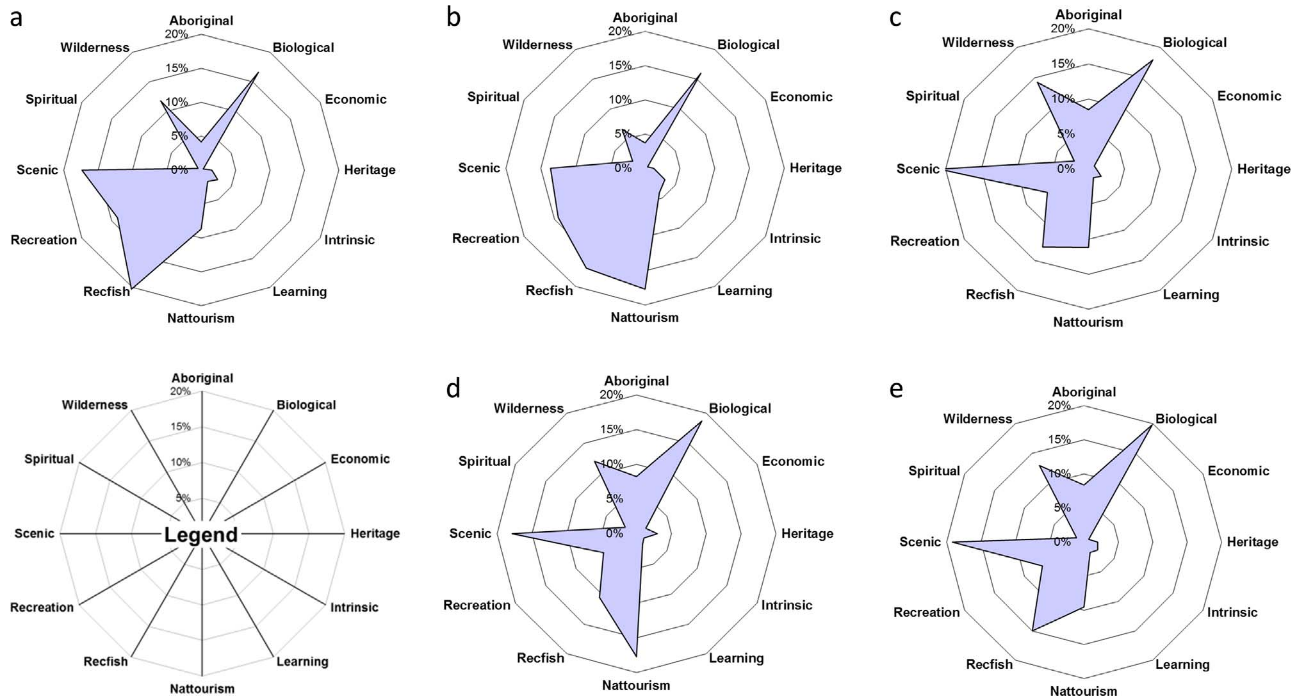

Fig. 5. Value profiles based on the 12 most commonly mapped values (%) characterising each State MPA: (a) Eighty Mile Beach, (b) Roebuck Bay (proposed), (c) Horizontal Falls, (d) Lalang-garram, and (e) North Kimberley (proposed).

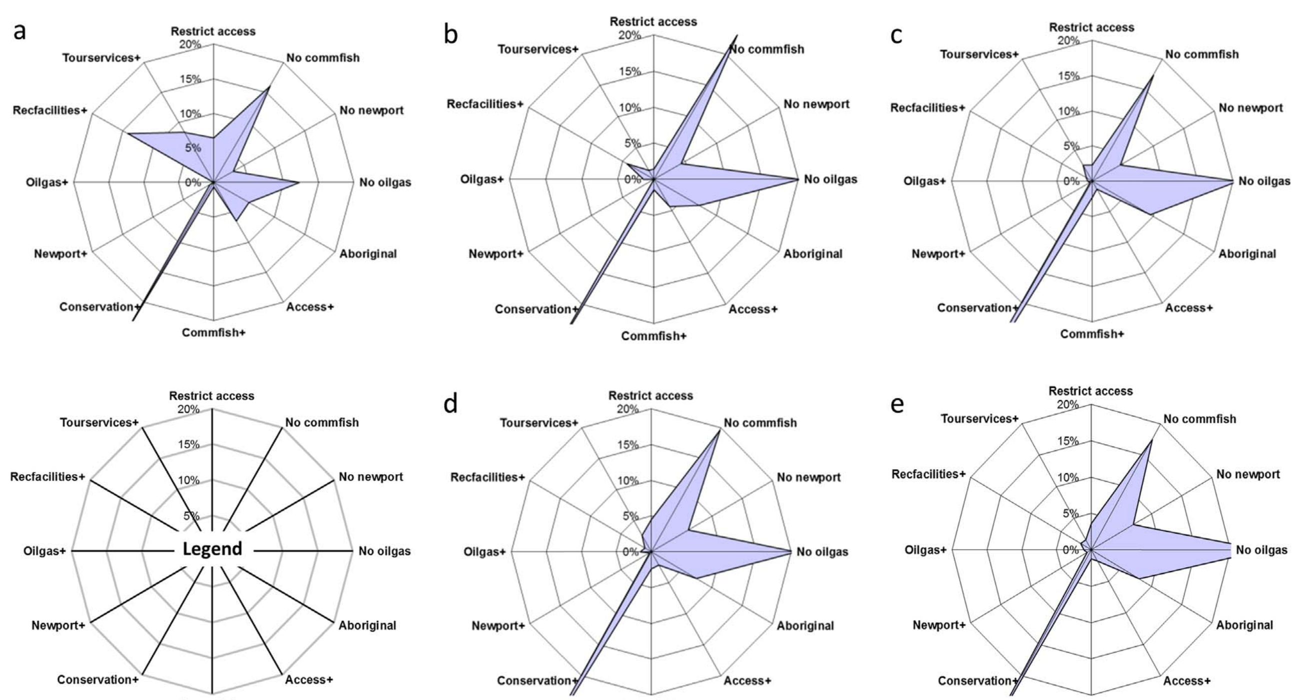

Fig. 6. Management preference profiles based on the 12 most commonly mapped preferences (%) characterising each State MPA: (a) Eighty Mile Beach, (b) Roebuck Bay (proposed), (c) Horizontal falls, (d) Lalang-garram, and (e) North Kimberley (proposed). + indicates a preference to add or increase.

increase conservation and protection was common to all MPAs and was more dominant over other mapped preferences with dominance indices ranging from 0.19 to 0.44 (Table 3).

Relatively high diversity indices (Table 3, D3 values: 0.84–0.87, D3 management preferences: 0.72–0.84) indicate the MPAs have a multiplicity of mapped values and preferences. The three smallest MPAs display diversity indices on par with the two larger MPAs, challenging the assumption that larger MPAs would be associated with a greater diversity of mapped data. The proposed North Kimberley MPA recorded the greatest number of mapped values and preferences. While this was expected, given its size, density indices (D2) indicate that on a km^2 basis, Roebuck Bay had the highest density of mapped values and preferences (Table 3, D2 value: 0.72, D2 management preference: 0.20).

3.3.3. *Chi-squared tests assessing significant associations between values, preferences and MPAs*

There was a statistically significant association between values

Table 3
Social landscape metrics for values and preferences mapped in the proposed and existing MPAs.

Social metric Dominant Value (D)	Eighty Mile Beach Recreational fishing	Roebuck Bay (proposed) Nature-based tourism	Horizontal Falls Scenic	Lalang-garram/ Camden Sound Biological	North Kimberley (proposed) Biological
Count	577	243	1084	971	2647
Percent	8.35	3.52	15.68	14.05	38.29
Richness	13	14	13	14	14
Dominance (D1)	0.14	0.05	0.14	0.05	0.04
Density (D2)	0.28	0.72	0.30	0.14	0.14
Diversity (D3)	0.84	0.87	0.86	0.87	0.86
	Management preference metrics				
Dominant Preference (D)	Increase conservation	Increase conservation	Increase conservation	Increase conservation	Increase conservation
Count	155	69	304	376	1133
Percent	2.42	0.99	4.39	5.44	16.39
Richness	11	11	12	12	12
Dominance (D1)	0.38	0.24	0.44	0.34	0.19
Density (D2)	0.08	0.20	0.08	0.06	0.06
Diversity (D3)	0.84	0.75	0.72	0.77	0.75

and MPAs (X^2=246.671, df=66, $p < 0.001$) (Table 4). Larger standardised residuals are of particular interest. For example, Eighty Mile Beach MPA was significantly associated with recreational fishing (+3.9) and recreation (+5.5) while Lalang-garram MPA was notable for its disproportionate association with nature-based tourism (+6.3) and less-than-expected counts for recreational fishing (−4.1) and recreation (−3.4) values. The North Kimberley MPA was disproportionately associated with Aboriginal culture and heritage (+3.2) and under-represented by nature-based tourism (−4.5) value.

Management preferences were also significantly associated with the MPAs (X^2=246.671, df=66, $p < 0.001$) although this association was relatively weaker than for values (Table 5). Significant, disproportionate associations were evident between Eighty Mile Beach MPA and 'increase access' (+3.2), 'add recreational facilities' (+7.8), and 'add tourism services' (+4.5); and North Kimberley MPA and 'no oil/gas' (+4.0). Larger, under-representative associations were apparent for North Kimberley MPA, 'add recreation facilities' (−4.0) and 'add tourism services/development' (−3.2). The proposed Roebuck Bay MPA was not significantly associated with any preferences.

4. Discussion

Douvere [10] observed there are few frameworks that facilitate integrated strategic, comprehensive marine planning and that managing places is a key characteristic of ecosystem-based management. Such an approach differentiates from existing approaches that usually focus on a single species, sector, activity, or concern. Further, a range of tools and measures are needed to implement the multiple objectives of ecosystem-based management using MSP. Participatory mapping, with its place-based assessment of values, preferences, activities, or other indicators of social importance, provides an important means to make "conflicts and compatibilities among human uses visible" [10, p. 765]. In this study, an online participatory mapping approach was used to capture stakeholder's place-based values and preferences across a system of large MPAs as well as the broader coastal and marine environment of the Kimberley region. The discussion below focuses on the utility of participatory mapping for accessing place-based, social data for planning and management, with implications for MSP highlighted.

The marine environment is characterised by growing conflict among user groups and desired uses [10,11]. Findings indicate the Kimberley coast and its nascent MPA network is associated with a broad, diverse range of values and preferences. Biological/conservation, scenic/aesthetic, recreational fishing and Aboriginal culture and heritage values were mapped most frequently while 'pro-conservation' preferences accounted for almost 85% of all mapped preferences. While the attribution of multiple values to parks and protected areas was not unexpected [23], the diversity of values and preferences associated with the study region suggests the potential for conflict regarding future management. This is particularly so given the likelihood of growing economic and tourism interests in the region conflicting with pro-conservation preferences and potentially Aboriginal cultural and heritage aspirations. Other place-based values studies note similar tensions between conservation and development [e.g. 19,23,34]. Mediating among these potential conflicts is an important aim at both local MPA and higher MSP scales, and findings of value and preference diversity such as those reported here underscore the need to integrate and account for social data in MSP.

As expected, the more accessible coastal MPAs displayed higher mapping densities than did more remote MPAs (Table 3). This finding likely reflects proximity to the main population centre of Broome and resultant higher levels of respondent familiarity/visitation. Klain and Chan [27] similarly relate the accessibility of coastal locations in Vancouver Island (and the attendant increased visitation and likely respondent familiarity) with significant, positive value associations. However, while the larger more remote MPAs evidenced a lesser density of mapped values and preferences, this study as others [e.g. 24] documented significant value associations with more remote areas (Tables 4 and 5). For example, Lalang-garram had significant, positive associations with nature-based tourism and the North Kimberley MPA with Aboriginal culture and heritage, and scenic values.

The presence of significant associations indicates that i) inaccessibility is no barrier to the attribution of value, and ii) there are no 'empty', unvalued places along the coastline. Further, it challenges any supposition that these MPAs will be conflict-free by virtue of their remoteness. Across the globe, large, more remote MPAs often arise through a process of 'residual reservation' and are located to minimise potential impacts and conflicts [35]. In this instance, however, *the data provide clear direction to* maintain the remote seascape qualities currently characterising the region and suggest that any moves to introduce or increase existing levels of economic development (including tourism) in these remote

Table 4
Association of mapped values with MPAs. Overall association is significant (X^2=412.271, df=78, $p < 0.001$) with standardised residuals greater than +2.0 (yellow) or less than −2.0 (purple) highlighted.

Value category	MPA	Eighty Mile Beach	Roebuck Bay (proposed)	Horizontal Falls	Lalang-garram/ Camden Sound	North Kimberley (proposed)	Totals
Aboriginal culture & heritage	Count	24	9	92	80	221	462
	%	4.1%	3.6%	8.2%	8.0%	8.2%	7.0%
	Residual	-2.9	-2.2	1.8	1.4	3.2	
Biological	Count	96	39	195	182	526	1261
	%	16.3%	15.5%	17.4%	18.2%	19.4%	19.0%
	Residual	-1.7	-1.4	-1.5	-.7	.7	
Economic	Count	2	1	10	15	21	53
	%	0.3%	0.4%	0.9%	1.5%	0.8%	0.8%
	Residual	-1.3	-.7	.4	2.7	-.2	
European heritage	Count	9	3	12	29	53	114
	%	1.5%	1.2%	1.1%	2.9%	2.0%	1.7%
	Residual	-.4	-.7	-1.8	3.1	1.2	
Intrinsic	Count	16	8	22	12	61	150
	%	2.7%	3.2%	2.0%	1.2%	2.3%	2.3%
	Residual	.8	1.0	-.7	-2.4	.0	
Learning	Count	11	10	15	17	47	37
	%	1.9%	4.0%	1.3%	1.7%	1.7%	0.6%
	Residual	-.4	2.1	-2.0	-1.0	-1.8	
Nature-based tourism	Count	50	43	121	172	252	784
	%	8.5%	17.1%	10.8%	17.2%	9.3%	11.8%
	Residual	-2.3	2.9	-.7	6.3	-4.5	
Recreational fishing	Count	117	41	139	103	398	6643
	%	19.9%	16.3%	12.4%	10.3%	14.7%	100.0%
	Residual	3.9	.8	-2.2	-4.1	.4	
Recreation	Count	81	35	72	53	185	529
	%	13.8%	13.9%	6.4%	5.3%	6.8%	8.0%
	Residual	5.5	3.5	-2.1	-3.4	-2.8	
Scenic	Count	100	33	226	173	507	1156
	%	17.0%	13.1%	20.1%	17.3%	18.7%	17.4%
	Residual	-.3	-1.8	2.6	-.1	2.3	
Special place	Count	9	3	35	24	53	145
	%	1.5%	1.2%	3.1%	2.4%	2.0%	2.2%
	Residual	-1.1	-1.1	2.3	.5	-1.1	
Spiritual	Count	3	5	25	18	33	92
	%	0.5%	2.0%	2.2%	1.8%	1.2%	1.4%
	Residual	-1.9	.8	2.6	1.2	-1.0	
Therapeutic	Count	2	6	4	6	11	37
	%	0.3%	2.4%	0.4%	0.6%	0.4%	0.6%
	Residual	-.7	4.0	-1.0	.2	-1.4	
Wilderness	Count	68	16	155	117	343	784
	%	11.6%	6.3%	13.8%	11.7%	12.7%	11.8%
	Residual	-.2	-2.7	2.3	-.1	1.8	
Total	Count	588	252	1123	1001	2711	6643
	%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

regions is likely to meet with opposition.

From a methodological viewpoint, the benefit of participatory mapping for MSP lies in its ability to document place-based social data that are relevant to both local and higher scale planning processes. Spatially explicit hotspots offer important visual information on areas of potential synergy and conflicts among value and preferences to help inform on-ground MPA planning and management such as zoning and associated resource allocation. In this study, value and preference hotspots centred on the proposed Roebuck Bay and Lalang-garram MPAs and areas outside MPAs including James Price Point, the northern tip of Dampier Peninsula, the Buccaneer Archipelago, and King George Sound near Derby (Figs. 3 and 4).

The presence of hotspots outside existing or proposed MPAs reinforces the importance of undertaking broader, coast-wide surveys beyond the official MPA estate and of integrating individual or network MPA planning within a more strategic, comprehensive MSP approach. MSP's broader scale explicitly views

Table 5
Association of mapped preferences with MPAs. Overall association is significant ($X^2 = 246.671$, $df = 66$, $p < 0.001$) with standardised residuals greater than +2.0 (yellow) or less than −2.0 (purple) highlighted. [Note caution is necessary in interpreting results as 32% of cells have expected counts less than 5].

Preference	MPA	Eighty Mile Beach	Roebuck Bay (Proposed)	Horizontal Falls	Lalang-garram/ Camden Sound	North Kimberley (Proposed)	Totals
Restrict access	Count	10	1	7	17	41	100
	%	10.0%	1.0%	7.0%	17.0%	41.0%	100.0%
	Residual	1.4	-1.2	-1.8	.3	-1.4	
No commercial fishing	Count	25	16	53	74	199	418
	%	6.0%	3.8%	12.7%	17.7%	47.6%	100.0%
	Residual	-.5	1.2	-.1	1.1	-.2	
No new port	Count	5	3	14	23	79	138
	%	3.6%	2.2%	10.1%	16.7%	57.2%	100.0%
	Residual	-1.4	-.5	-1.0	.2	2.2	
No oil/gas	Count	19	14	63	78	282	505
	%	3.8%	2.8%	12.5%	15.4%	55.8%	100.0%
	Residual	-2.9	-.2	-.3	-.3	4.0	
Increase Aboriginal management	Count	9	5	29	28	90	177
	%	5.1%	2.8%	16.4%	15.8%	50.8%	100.0%
	Residual	-.8	-.1	1.4	.0	.8	
Increase access	Count	10	3	4	8	20	60
	%	16.7%	5.0%	6.7%	13.3%	33.3%	100.0%
	Residual	3.2	1.0	-1.5	-.6	-2.3	
Commercial fishing/ aquaculture	Count	1	1	7	9	14	41
	%	2.4%	2.4%	17.1%	22.0%	34.1%	100.0%
	Residual	-1.1	-.2	.8	1.1	-1.8	
Increase conservation/ protection	Count	40	21	113	118	350	743
	%	5.4%	2.8%	15.2%	15.9%	47.1%	100.0%
	Residual	-1.6	-.2	2.3	.0	-.6	
New port	Count	1	0	1	1	8	13
	%	7.7%	0.0%	7.7%	7.7%	61.5%	100.0%
	Residual	.2	-.6	-.6	-.8	1.0	
Oil/gas	Count	0	1	2	6	12	24
	%	0.0%	4.2%	8.3%	25.0%	50.0%	100.0%
	Residual	-1.3	.4	-.7	1.2	.2	
Add recreational facilities	Count	22	3	3	4	20	78
	%	28.2%	3.8%	3.8%	5.1%	25.6%	100.0%
	Residual	7.8	.5	-2.4	-2.7	-4.0	
Add tourism services	Count	13	1	8	10	18	64
	%	20.3%	1.6%	12.5%	15.6%	28.1%	100.0%
	Residual	4.5	-.7	-.1	-.1	-3.2	
Total	Count	155	69	304	376	1133	2361
	%	6.6%	2.9%	12.9%	15.9%	48.0%	100.0%

MPAs as influenced by ecological and social processes originating in other locations and scales. Thus while MPA management provides an essential component of the overall picture, a comprehensive approach is essential to provide social data for MSP more generally [2]. Hotspot maps as produced in this study provide data to support integrated, broad-scale MSP – i.e. inclusive of yet extending beyond existing MPA boundaries – and can be used as tools to help negotiate among competing users and priorities across large areas.

All too often, MPAs are politically driven designations or lack sufficient stakeholder involvement during planning phases to engender lasting public support. This failure to account for local contexts can foster local resistance and antagonism, complicating ongoing management [2]. Participatory mapping is a powerful tool to connect resource users, planners and managers across scales. In the study area, the MPA network was proposed in response to growing concerns regarding protection of the Kimberley's unique biodiversity and the potential pressures associated with economic extraction (e.g. oil, gas, tourism), as well as, some would argue, political grandstanding. Pajaro et al. [36] note the typically limited local-level input to MPA planning and development, citing large stakeholder numbers, the complexity and immediacy of many conservation concerns, and potential conflict between cross-sectoral policies as factors hindering greater links between local and higher scales. By documenting the place-based values and preferences of a broad range of stakeholders, participatory mapping as used here bridges the gap between State or externally imposed MPAs and local contexts and uses, thereby contributing to more grounded, comprehensive and representative MPA planning.

In Australia, marine and coastal management has been plagued by inadequate recognition of diverse values, knowledge systems and cultural contexts [37]. While successful in documenting the values and preferences of a broad range of stakeholders for the marine and coastal environment, this study recorded limited Aboriginal participation. This likely reflects equity issues in terms of access to computer infrastructure and Internet services as well as the fact an online platform is not ideal for engaging with Aboriginal people in a discussion around sensitive, context-specific relationships to country. Other, more intensive and culturally appropriate engagement methods are better suited for this purpose and the development of such methodologies presents an important area for future research.

Indeed, in-person approaches that draw on established relationships are ideal for research involving stakeholder groups where trust and credibility play a large role in willingness to engage [38], including Aboriginal people. Low Aboriginal participation is a clear limitation, given the preeminent role of Aboriginal people as custodians of country both culturally and legally through Native Title determinations. As such, findings are best considered together with literature detailing Aboriginal values and aspirations in regards to management of country, such as Healthy Country Plans [e.g. 39,40]. Study findings are also underpinned by, and should be considered in conjunction with, earlier qualitative research that recorded significant Aboriginal participation (Strickland-Munro et al. [42]). A co-existence of Indigenous and non-Indigenous knowledge explicitly recognises the difficulty and inherent inequity of integrating different knowledge systems into MSP's Western science-driven epistemology, and furthermore, recognises Aboriginal knowledge as legitimate in its own right [14].

Despite low Indigenous participation, the widespread documentation of values and preferences relating to Aboriginal culture and management suggests that participatory mapping can provide a valid means of accessing information on cultural values, as reported in other studies [e.g. 24,27]. Further, that such information can be accessed from non-Indigenous stakeholder groups. Intangible and context-specific, cultural values are often difficult to document in a form readily accessible to planners and managers, yet are critical in determining use and value, particularly in areas with significant Indigenous populations and history such as the Kimberley. Being able to capture cultural values in a spatially explicit manner facilitates their inclusion into planning, providing invaluable broad-scale information to address the deficit of social data that has plagued MSP to-date. Future research could focus on achieving greater representation of Aboriginal values alongside that of other stakeholders. This could take place through more appropriate, qualitative approaches on country (as discussed previously, e.g. Strickland-Munro et al. [42]) and ideally such research should be carried out in partnership with relevant Traditional Owner groups to ensure proper recognition of cultural sensitivities and the delivery of mutually negotiated outcomes and benefits. As with any research however, cognisance of potential issues arising from differences in stakeholder power, knowledge and standing is imperative [41] and researchers should take utmost care to ensure equitable representation of all relevant views.

5. Conclusion

Social data has been described as a 'missing layer' within MSP [13]. Understanding stakeholder's place-based values and preferences, therefore, is critical to support improved marine spatial planning. In their social science research agenda for MPAs, Gruby et al. [6] noted the need to address human dimensions such as the identification of stakeholders and the full range, magnitude, and distribution of actual and perceived benefits associated with MPAs. This study contributes to calls for increased, better integrated social data in the marine domain, particularly in relation to MPA planning and management and MSP more generally [4,13]. For MSP, the benefit of the participatory mapping methods described herein lies in the ability to document place-based social data that are relevant to both local (i.e., MPA) and higher scale (i.e., MSP) planning processes.

This study has provided critical baseline socio-spatial data to inform future MPA planning and broader regional MSP, and has documented stakeholder values and preferences at a larger scale, both geographically and in terms of stakeholder engagement, than previous marine and coastal PPGIS studies. However, the dynamic nature of social values and preferences suggests that planners and managers would be wise to monitor changes in the social environment through further participatory mapping studies. Such spatially explicit investigation of social data is essential in any circumstance where planning and policy decisions must be made for coastlines and marine environments with high conservation values and potentially conflicting uses.

As noted in a recent review [32], the use of participatory mapping methods for spatial planning is a rapidly evolving area with significant challenges including the need to increase participation rates, identify and control threats to spatial data quality, enhance the "participatory" component, and integrate the spatial data into decision support. These challenges are especially applicable to MSP where the effective integration of social data has been historically lacking, but appears essential to future MPA planning and management. Our experience in this study suggests that participatory mapping can effectively generate important social, spatial data layers for integration in MSP, but social data, like biophysical data, is subject to data limitations and uncertainty. Achieving high quality social spatial data for MSP is further challenged by the size of the marine planning area and the diversity of social interests. In future participatory mapping for MSP, the greatest need will be to ensure broad and inclusive participation that is truly representative of the diversity of social interests in the marine areas. A high level of participation in mapping will not only increase trust in the resulting spatial data, but provide a means for identifying the social acceptability of MPA management alternatives.

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