Ocean & Coastal Management xxx (2017) 1–14

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Cultural ecosystem values of the Kimberley coastline: An empirical analysis with implications for coastal and marine policy

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A R T I C L E I N F O

Article history:
Received 21 January 2017
Received in revised form
5 September 2017
Accepted 6 September 2017
Available online xxx

Keywords:
Marine spatial planning
PPGIS
Spatial analysis
Coastal zone
Aboriginal culture
Ecosystem values

A B S T R A C T

Cultural ecosystem services have received increasing attention in land/marine use planning but remain poorly known, expressed, and utilised in planning processes. Progress in marine spatial planning requires better information regarding the full range of values and benefits received from ecosystem services, including cultural ecosystem values. This paper reports on an online Public Participation GIS (PPGIS) study that collected spatially explicit information on cultural ecosystem values in the remote Kimberley coastal region in northwestern Australia. The coastal zone – 20 km landwards and seawards – was found to be highly valued with values disproportionally located 0–2 km onshore. The number of value markers placed was related to tenure, access (i.e., density of tracks), population density, and geomorphology. Methodologically, Public Participation GIS describes the location and extent of values providing for the exploration of relationships between values and other planning features such as tenure and coastal access. Inclusion of such information in marine spatial planning and policy formulation can contribute to more thoughtful and inclusive decisions regarding the future of coastal zones. The use of internet-based Public Participation GIS is particularly useful for long, remote coastlines with widely dispersed stakeholder interests where other methods such as interviews and workshops are not feasible.

1. Introduction

Coastal ecosystems are among the most productive but threatened in the world (Agardy et al., 2005). Around 40% of the world's population and 61% of the gross world product are concentrated in a 100 km wide strip along the coast (Nobre, 2011), while Harvey and Caton (2003) posit that by 2020, two-thirds of the world's population will live within 60 km of the coast. Environmental deterioration due to human activity is intense and increasing with 50% of salt marshes, 35% of mangroves, 30% of coral reefs, and 29% of sea grasses lost or degraded worldwide (Barbier et al., 2011). The main anthropogenic threats include loss of natural habitats and biodiversity, declining water quality, waste disposal, unsustainable fishing practices, competition for space including demands on coastal areas for shipping, vulnerability to sea level rise, and recreation and tourism (Agardy et al., 2005; Nobre, 2011). Special attention to coastal management is needed because the coast is dynamic with changes brought about by natural processes as well as human use (Harvey and Caton, 2003).

Although the coast and its sustainability are critical for the wellbeing and livelihood of much of the world's population, there has been relatively little research to assess the value of marine and coastal ecosystem services. Where valuations have been undertaken, they have focused on development-related losses of habitat and associated services in coral reef, salt marsh and mangrove ecosystems (Barbier et al., 2011; Partelow et al., 2017). Arkema et al. (2015) comment that embedding ecosystem services in coastal and marine planning leads to better outcomes for both people and nature while Naeem et al. (2015) conclude that a lack of scientific knowledge of ecosystem services is impeding robust valuations.

Knowledge and valuation of the economic benefits provided by ecosystem services including provisioning (e.g., food), regulating (e.g., water purification), and supporting (e.g., nutrient cycling) benefits is highly variable, depending on the ecosystem. Generally however, researchers agree that progress is being made towards valuing these types of ecosystem services (Chan et al., 2012a). Absent from most research, however, is the fourth ecosystem service

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http://dx.doi.org/10.1016/j.ocecoaman.2017.09.002
0964-5691/

Please cite this article in press as: Kobryn, H.T., et al., Cultural ecosystem values of the Kimberley coastline: An empirical analysis with implications for coastal and marine policy, Ocean & Coastal Management (2017), http://dx.doi.org/10.1016/j.ocecoaman.2017.09.002

category – cultural ecosystem services (CES) – including aesthetic, spiritual, educational, and recreational services (MEA, 2005).

Some researchers explicitly exclude CES, saying that they can only be accessed and understood via the social sciences in separate, 'less scientifically-based' studies (e.g. Naeem et al., 2015), while others note their poor integration within the ecosystem services framework (Schaich et al., 2010; Daniel et al., 2012; Chan et al., 2012a, 2012b; Klain et al., 2014; Darvill and Lindo, 2015; Brown and Hausner, 2017). Satz et al. (2013) argue that while challenging, inclusion of CES in sustainability analyses is possible. Some progress is being made in including recreational/tourism services in broader studies of ecosystem services (e.g., Arkema et al., 2015) but the other elements of cultural ecosystem services continue to be challenging to operationalize and study (Pert et al., 2015). The inclusion of indigenous values is particularly problematic (Pert et al., 2015). This paper aims to help address this knowledge gap by providing a spatially explicit, empirically based analysis of the distribution of cultural ecosystem values in a highly valued and contested biome, the coastal zone.

1.1. Cultural ecosystem services, benefits, and values

CES are non-material benefits obtained from ecosystems. Included in these benefits are "spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (MEA, 2005, p 40). A review of ecosystem services research cited by Schaich et al. (2010) showed that although 524 quantitative indicators relating to supporting, provisioning, and regulating services have been developed, there was not a single study that measured cultural services explicitly. Issues in developing indicators and a framework within which they can be positioned include: failure to consider diverse values; the difficulty in applying or using monetary value for CES; difficulties linking a particular change in a social-ecological system to cultural benefits; cultural benefits are related to many services, not only CES; and conflation of services, values, and benefits (Chan et al., 2012a, 2012b). CES matter, however, and cannot be left out of decision making as very often these intangible dimensions matter more to people than material benefits (Chan at al. 2012b).

A broad suite of measures for cultural services has been used; however, only 23% of the studies reviewed by Hernandez-Morcillo et al. (2013) used spatially explicit information. Indicators are essential as most CES (and values even more so) are not immediately observable in the landscape and their inclusion in analyses depends on indicator measures. Participatory mapping offers another approach, where spatially explicit empirical research provides the required information on values (Klain and Chan, 2012; Brown and Fagerholm, 2015).

This paper addresses several of the issues raised by Chan and colleagues (Chan et al., 2012a, 2012b; Klain and Chan, 2012). We chose to focus on values based on the assumption that the value assigned to a place reflects the services or benefits an individual obtains from that place (Chan et al., 2012b; Martin et al., 2016; Brown and Hausner, 2017). Thus, a focus on values provides a means of capturing cultural ecosystem services in a spatially explicit way. An explicit focus on values and clear acknowledgment of the relationship between services, benefits, and values rather than their conflation avoids another of the problems identified by previous researchers. Our focus on the relationships between cultural values and the administrative, demographic, and physical features of this study area helps address the linkages between cultural benefits and particular changes in the social-ecological system.

1.2. Cultural ecosystem values and the administrative, demographic, and physical landscape

An important challenge in current CES research is to relate these services to landscape features to help predict where such services might be present, and to understand how variables such as tenure, for example, might affect their location. Of particular interest is how to articulate a spatial understanding of CES with other ecosystem services in a form that is useful for land (and sea) use planning and policy. Thus, attributes of the administrative, demographic, and physical landscapes (e.g., tenure, population density, coastal geomorphology, and ease of access) provide a logical point for research focus. Brown and Hausner (2017) provided a useful starting point with a comparative study of the distribution of cultural ecosystem values found in five coastal regions, but the number and type of administrative, demographic, and physical landscape variables examined, as well as the depth of analyses, was necessarily limited given the differences in study regions and participants.

Marine spatial planning (MSP) is increasingly acknowledged as a way of achieving sustainable use of the seas and coastlines through integrated consideration of ecological, economic and social concerns (Douvere and Ehler, 2009). While much progress has been made regarding the mapping of the human dimension of the marine environment but there is much more to do (Koehn et al., 2013). Current data collection efforts for MSP do not capture the complexity of human relationships to places and resources. Such a gap has persisted despite knowing that marine ecosystems include human values, knowledge, needs, processes, and impacts (St Martin and Hall-Arber, 2008). Mapping cultural ecosystem values, as per this study, and then relating these mapped values to the distribution of social and ecological landscape features, such as tenure and coastal geomorphology, provides much-needed data for marine spatial planning. Relating spatial social data to well-known ecosystem features can facilitate the uptake of such data in MSP, which is largely ecosystem-driven (Jentoft and Knol, 2014; Vince, 2014).

1.3. Defining the coastal zone and shoreline

Defining the coastal zone is central to the purpose of this paper. However, no standard definition for the coastal zone exists. For practical purposes, it can be generally defined as the landward limit of marine influence and the seaward limit of terrestrial influence, embracing the inter-, sub-, and supra-tidal realms (Carter, 1998). Researchers and policy makers alike, however, note that scientific definitions of the coastal zone based on coastal processes or landforms are insufficient. Rather, the definition should vary depending on the nature of the problem and the objectives of management (Harvey and Caton, 2003). In Australia, this approach is evident in the Australian Government's definition of the coastal zone, that is, "the boundaries of the coastal zone extend as far inland and as far seaward as necessary to achieve the policy objectives, with a primary focus on the land/sea interface" (CoA, 1992, p. 2).

In this paper we use the term 'coastline' for the broader coastal zone, and 'shoreline' to refer to where the ocean meets the land (cf. Short and Woodroffe, 2009). The shoreline is taken to be Mean High Water Mark (MHWM) (AGGA, 2016a). In Western Australia, as in many other jurisdictions, high water mark is used to delineate the landward margin of marine protected areas.

1.4. Using PPGIS to collect social data

Participatory mapping methods provide a means of identifying and assessing cultural ecosystem values and services (Brown et al.,

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2012; Brown and Fagerholm, 2015). Participatory mapping is a key element of public participation GIS (PPGIS) (Brown and Kyttä, 2014), which relies on individuals mapping values that matter to them, with respondents asked to place markers onto a digital or hard copy of a map of a study area.

The types and locations of cultural values may be emergent through an interview or small group process (e.g., Klain and Chan, 2012) or through the use of *a priori* determined categories. The study reported herein used an online PPGIS with *a priori* value categories that were selected based on previous qualitative research in the region that used field-based, semi-structured interviews to identify values (Strickland-Munro et al., 2015).

There is ongoing interest in incorporating values into management processes (Murray et al., 2016). The environmental values literature typically classifies human values as 'held' or 'assigned'. Held values represent enduring personal beliefs about the importance of a specific mode of conduct or an end state of existence (Rokeach, 1973) while assigned values express the importance of an object relative to other objects (Brown, 1984). Assigned values are "values that people attach to things, whether they are goods such as timber, activities such as recreation, or services such as education" (Lockwood, 1999, p. 382). Assigned values enable values to be specified and spatially located.

For policy makers, values are important as they describe how people perceive a place, including their concerns and aspirations for the place. Mapped values are empirically related to both spatial and non-spatial land use preferences (Brown, 2013) and thus may be indicative of how the public and other stakeholders would potentially respond to planning and management options in a given location. Mapped values, also called social values for ecosystem services (Sherrouse et al., 2011), are a type of *relationship* value that bridges held and assigned values (Brown and Weber, 2012) and can help managers identify potential land use conflict (Brown and Raymond, 2014; Moore et al., 2017; Karimi and Brown, 2017; Brown et al., 2017b), assess the compatibility of management area allocations (e.g., marine protected areas) (Brown et al., 2016), and provide broad public input to managing public lands and waters (Brown and Reed, 2009; Strickland-Munro et al., 2016). Although not exclusive to nature, values can be used to describe relationships between people and nature including interactions with nature (Chan et al., 2016). Values mapping can capture place attributes ranging from objective location features (e.g., biological/conservation value) to subjective perceptions of place and importance, including place attachment (Brown and Raymond, 2007; Raymond et al., 2009; Brown et al., 2015). Importantly, a place can give rise to multiple values, for example, a waterfall can be valued for its aesthetics, recreation and cultural heritage values for Aboriginal people.

1.5. Research aim and questions

The aim of this paper is to analyse the distribution of cultural ecosystem values generated from a participatory mapping process implemented in the Kimberley coastal region in Australia to identify significant relationships (or not) with administrative, demographic, and physical landscape features. Specifically, the following research questions were examined:

Research Question 1. What is the distribution of specific cultural ecosystem values (e.g., wilderness, Aboriginal culture and heritage, recreation, scenic/aesthetic) in the coastal zone and seaward to 200 km offshore?

Research Question 2. How is the distribution of cultural ecosystem values in the coastal zone related to:

a) Tenure of the coastal hinterland.
b) Tenure of the sea.
c) Density of access roads and tracks (unsealed roads) in the coastal hinterland.
d) Geomorphology of the shoreline.
e) Population density of the coastal hinterland.

Research Question 3. What are the implications of these empirical findings for land use policy development in the coastal zone with a particular emphasis on marine spatial planning?

2. Methods

2.1. Study area and data collection

2.1.1. Study area

The Kimberley region, vast, remote and encompassing 423,500 km^2, occupies the northwest of the Australian continent (Fig. 1). Its ecotourism and wilderness experiences are largely built on its remoteness, rich biodiversity and living cultural heritage, offered in a largely unspoiled coastal and marine environment. Its highly crenulated coastline extends 13,296 km. With a population of only 34,794 people, 43.5% of whom identify as Indigenous, the Kimberley is sparsely populated. Most people live in the towns of Broome, Derby, Wyndham and Kununurra (Fig. 1). A limited number of sealed roads connect these centers, with the coastline generally inaccessible except by boat.

The coastline is acknowledged as one of the world's biodiversity hotspots (Wilson, 2013) and one of the most ecologically diverse and intact tropical marine ecosystems (Mustoe and Edmunds, 2008). The Kimberley Regional Planning and Infrastructure Framework (WAPC, 2015) commits the Western Australian government to generating and sustaining population growth in the regional centers of Broome and Kununurra, as well as preserving Aboriginal culture and heritage. The Framework advocates additional infrastructure development including boating facilities and roads, and port and airport upgrades. In response to these values and potential for pressure from economic activities such as oil and gas extraction and processing, the Western Australian Government committed to designating five marine parks in State waters (Fig. 1). A number of marine reserves have also been designated in Commonwealth waters off the Kimberley coast.

2.1.2. Data collection

Social values data were collected via an online PPGIS survey with values mapping as the central activity. Questions regarding participants' socio-demographic characteristics and their stakeholder affiliation were also included. Participants were asked to drag and drop markers representing 14 different values onto a Google® Maps interface of the study area (Fig. 2). To implement the PPGIS survey, we used the Google® Maps JavaScript Application Programming Interface (API), a software development platform for designing custom map applications. A growing number of commercial vendors now provide the ability to develop and implement custom PPGIS surveys without the knowledge of programming languages and internet databases. We choose to implement the PPGIS survey using the Google Maps platform because of widespread public familiarity with using Google Maps. The values were mapped as point features rather than polygons because points are easier for participants to map and because points and polygon features can potentially yield similar spatial results with a sufficient quantity of point data (Brown and Pullar, 2012). These values were derived from earlier interview-based research in the Kimberley by the authors (Strickland-Munro et al., 2015; Brown et al., 2017a) and were generally consistent with value typologies used in previous PPGIS studies (Brown and Kyttä, 2014). The survey was open to all

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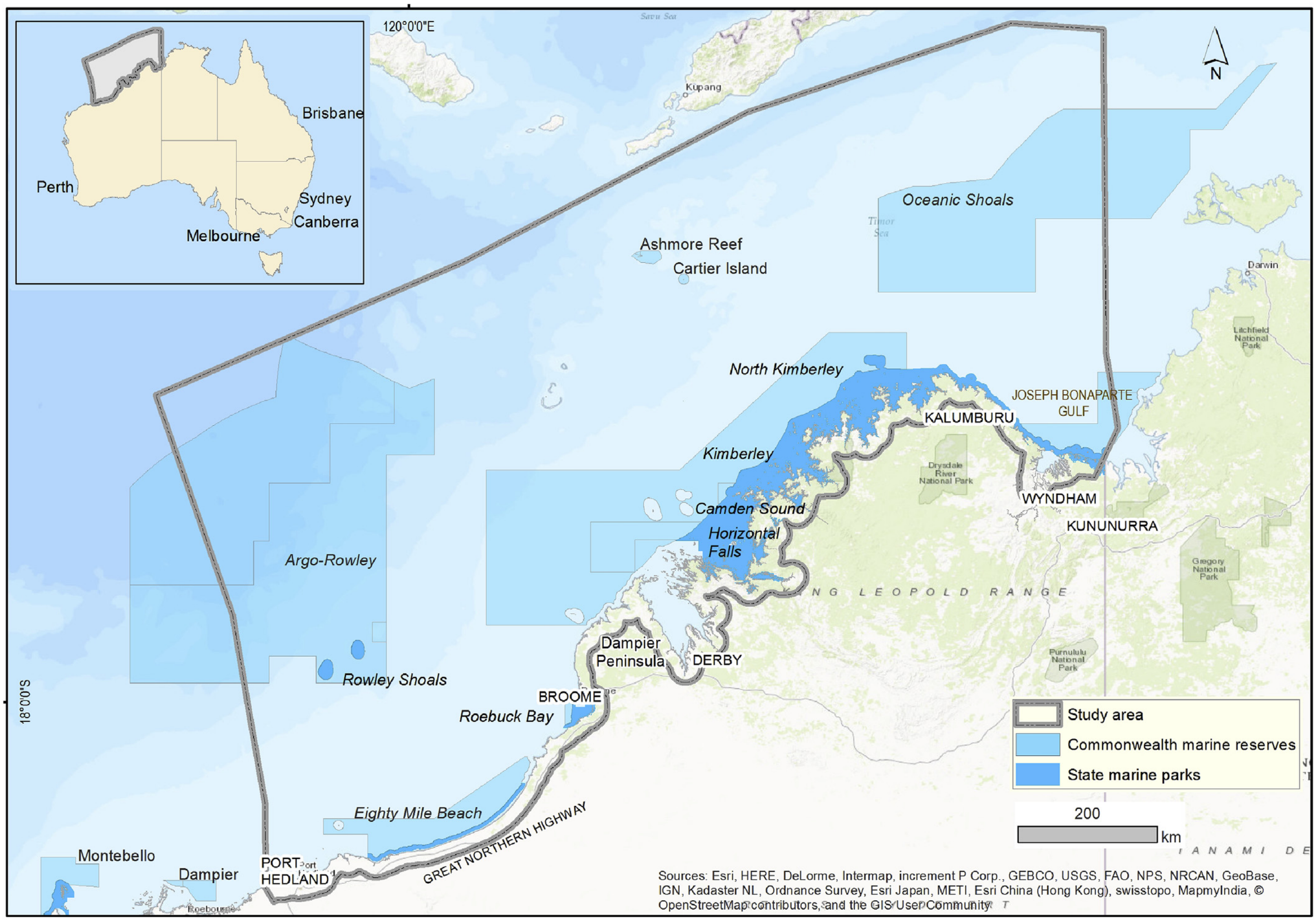

Fig. 1. Kimberley coastline study area (source for marine protected area boundaries: Geoscience Australia 2014, Department of Parks and Wildlife Sept 2015).

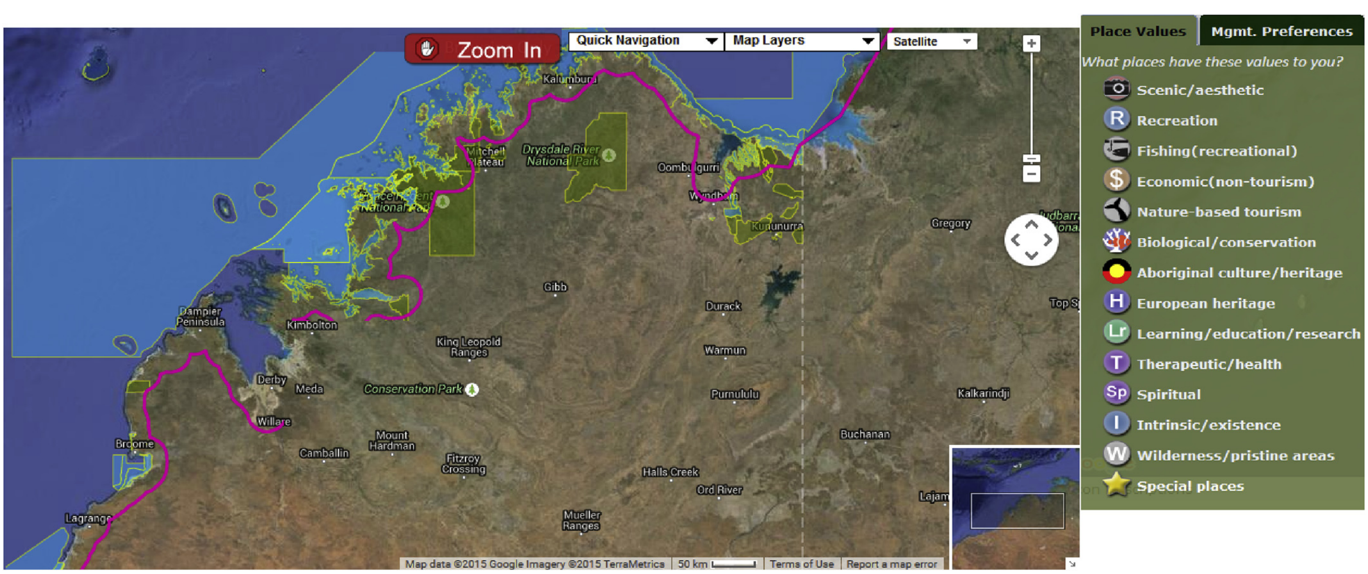

Fig. 2. PPGIS mapping interface showing values associated with the Kimberley coast. The custom web application was implemented with Google Maps JavaScript Application Programming Interface (API).

participants in the community and they were free to identify any value within the value set. To ensure a reasonable level of mapping accuracy, participants had to zoom into a minimum scale of 10 km before placing markers. Marine protected area and national park boundaries were available as extra layers to assist with place identification and map navigation.

Respondents were targeted from diverse groups including Aboriginal Traditional Owners; Kimberley residents; industry (mining, oil, gas and tidal energy interests); marine transport and aviation; recreational and commercial fishing; aquaculture; tourists and the tourism industry; independent sailors; scientists; federal, state and local government; and environmental non-government organisations. Over 120 official and informal groups were engaged through eight public recruitment approaches: social media; personal referral; direct personal contact with researchers; email invitation; direct postal invitation; local newspapers; organizational newsletters; and printed invitation cards (Brown et al., 2016; Strickland-Munro et al., 2016; Munro et al., 2017). The survey was pilot tested and minor changes made prior to data collection. Respondents were also recruited via a commercial research company and their online panel. The research company was requested to provide a representative sample of Western Australian residents (Brown et al., 2016; Munro et al., 2017).

2.2. Spatial data preparation and analyses

2.2.1. Defining the coastal zone for this study

The coastal zone for this study was defined as a band 20 km seaward and 20 km inland of MHWM, a definition derived from a focus on cultural ecosystem values. Thus, the extent of recreational and tourism use, and Aboriginal heritage associated with the coast (all values found in the study area), provided the seaward extent. Campsites, sealed and unsealed roads, and historic and cultural features near and accessing the shoreline, but inland, provided a landward boundary. The Kimberley has some of the largest tides in the world with ranges of up to 12 m (BOM, 2016). This means that tidal, and hence coastal influences extend well inland, as well as seaward. For example, around Derby (Fig. 1) tidal influences extend up to 20 km inland while on very low tides, the shoreline can be many kilometers out to sea.

2.2.2. Spatial distribution of values in the coastal zone and seaward to 200 km

Analysis was undertaken at two scales. The first broader scale analysis extended seaward to 200 km (with 40 km increments) to capture values evident well offshore, such as oil and gas development, fisheries, and ecological values of Commonwealth marine reserves. The inland boundary was extended for this broader approach to 40 km inland from MHWM to complement the 40 km offshore increments. The second, finer scale analysis identified the frequency distribution of values up to 20 km landward and seaward of the shoreline using 1 km distance increments (bands). Using GIS software, value markers were spatially intersected with the multiple distance increments to generate frequency distributions and percentages for each distance increment. The percentages of markers were then plotted with distance from shoreline on the x-axis and percentage of the value on the y-axis to show the spatial abundance of mapped values as a function of distance both offshore and onshore.

2.2.3. Spatial influences on the distribution of values in the coastal zone

To determine the potential influence of land and sea tenure, density of roads and tracks, population density and geomorphology (shoreline type), 4 × 4 km grid cells were placed over the 40 km wide band of the coastal zone (20 km landward and 20 km seaward of MHWM).

The influence of land tenure to 20 km inland and 20 km seaward was examined. For land tenure, the proportion of the cell occupied by a tenure category was calculated. Tenure was then classified as present/absent in a cell based on any non-zero proportion found in the cell. Land tenure categories included Indigenous Protected Areas, defense lands, State protected areas (national parks and nature reserves), unallocated Crown land, pastoral leases, and Ramsar wetlands.

We examined the distribution of values using both chi-square/residual analyses and proportional analyses. The chi-square test evaluates whether two categorical variables are independent, or alternatively stated, whether there is a statistical association between the two categorical variables (in this case, value type by land tenure category). The larger the chi-square statistic, the greater the difference between the observed and expected number of value markers in the land tenure categories (the chi-square statistic sums these differences). Given that chi-square results for value distributions are likely to be statistically significant because mapped values are not uniformly or evenly distributed on the landscape, chi-square residuals are generated to reveal which value/tenure pairings are the principal driving sources contributing to the overall significant chi-square result. The magnitude and direction of the chi-square residuals reveal which values have the greatest or least association with specific tenure categories. Residual values greater than +2.0 indicate there were significantly more value markers than expected in the land tenure category while residual values less than −2.0 indicate there were significantly fewer value markers than expected.

A second, proportional analysis was also performed which differs from chi-square analysis. In chi-square analysis, the test is whether there is an association between two categorical variables. Proportional analysis tests whether the observed proportion of values found in a given land tenure category is similar or different to the proportion that would be expected given the size of the area occupied by the land tenure category. For example, if 10% of the study area were tenured as national parks, the null hypothesis would be that 10% of values should be mapped in national parks. The deviation from the null condition (difference in proportions) is calculated as a z-score. Similar to a chi-square residual, z-scores that are greater than +2.0 or less than −2.0 are considered statistically significant.

Classification and analysis of sea tenure was conducted as for land tenure. Sea tenure categories included State marine protected areas, Commonwealth marine protected areas, and other marine (Commonwealth and State) waters.

Density of access roads and tracks comprised three categories: major roads (sealed bitumen surfaces); minor roads (gravel surface navigable by two-wheel drive vehicles); and tracks (unconstructed, unformed roads created by off-road vehicles). The results are presented in two categories as main roads (includes major and minor roads) and tracks. Roads and tracks were digitised from high resolution imagery from a variety of sources. The length of roads and tracks per grid cell provided the basis for analysis where each cell containing any length of road or tracks was counted as present (containing roads or tracks), otherwise, the cell was counted as absent (no roads or tracks).

Population density was estimated for each 4 × 4 km cell based on data from the Australian Bureau of Statistics 2011 census (ABS, 2016). As the Kimberley has a sparse population, density was classified as either low, medium, or high.

Geomorphology analysis involved selecting all 4 × 4 km cells that intersected the coastline. The geomorphic category allocated to each cell was based on that cell's dominant geomorphic feature, i.e., the geomorphic category occupying the longest length of coastline in each cell. Geomorphic categories were beach, beach/rocky shore, mangal, mud/salt marsh, rocky shore, rocky shore/mangal, and unclassified island (no geomorphology allocated) (AGGA, 2016b).

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Shoreline type, as listed above, influences coastal access, with beach, or rocky shore being most accessible.

3. Results

There was a total of 692 completed surveys, 372 by the public (16,448 markers placed) and 320 by panel members (2667 markers placed).

3.1. Distribution of cultural ecosystem values by distance from the shoreline

The percentage of mapped values in the coastal zone decrease as a non-linear function of distance from the shoreline, both offshore and onshore (Figs. 3–5). These values were particularly concentrated in the 0–20 km offshore and 0–20 km onshore bands (i.e., the coastal zone as defined in this study). Over 40% of the recreational fishing, scenic and therapeutic values were mapped immediately seaward of the coastline to 20 km offshore. Over 50% of heritage values, and over 40% of Aboriginal, learning, economic values and special places mapped across the study area were located landward within 20 km of the coastline. Importantly however, many values were mapped up to 80 km seawards, in particular, biological, wilderness, nature tourism, and special place values (Fig. 3).

Finer scale analysis revealed that values were disproportionately located 0–2 km onshore. Almost 30% of recreation values were mapped in the band 0–2 km onshore. Other highly mapped values in this band included scenic, economic, heritage and special place values. Biological values were more widely dispersed offshore, while spiritual and Aboriginal cultural values were more widely dispersed onshore (Fig. 4).

3.2. Distribution of cultural ecosystem values by land tenure

Pair-wise chi-square residual analysis revealed that a number of values were more abundant than would be expected if the distribution was independent of land tenure. Most notable was the abundance of values mapped in national parks and unallocated Crown land (Table 1). Values consistently more abundant on these tenures included scenic, nature-based tourism, biological, Aboriginal culture, spiritual, wilderness and special places.

Conversely, defense lands and pastoral leases had fewer mapped values than expected (Table 1). This lack of values (relative to other land tenures) was more significant for pastoral leases than defense lands (significant at $p < 0.001$ compared to $p < 0.01$–0.05 for defense lands). Indigenous protected areas and Ramsar sites had a greater than expected number of mapped values, but for a limited value set (Table 1).

Indigenous protected areas had significantly more *and* less of a number of values mapped relative to other land tenures (Table 2, Fig. 6). More abundant values included Aboriginal culture, scenic, special places, spiritual, and wilderness. Less abundant values included biological, economic, learning, recreational fishing, general recreation, and therapeutic. Recreational fishing, recreation, and economic values were mapped significantly less in parks/reserves. National parks/reserves had the largest positive residual score (much greater abundance than expected) for all analyses with 11.0 for wilderness values. In contrast, the largest negative residual score (much less abundant than expected) was −8.2 for recreational fishing in Indigenous protected areas (Table 2).

Pastoral leases and defense lands contain disproportionately fewer cultural ecosystem values than would be expected—for all values (Fig. 7). Conversely, 'other' tenures such as freehold land exhibit disproportionately more ecosystem values than would be expected—for all values. Both national parks/reserves and Ramsar had disproportionally more ecosystem values for scenic/aesthetic, biological, intrinsic, and wilderness values. Additionally, recreation,

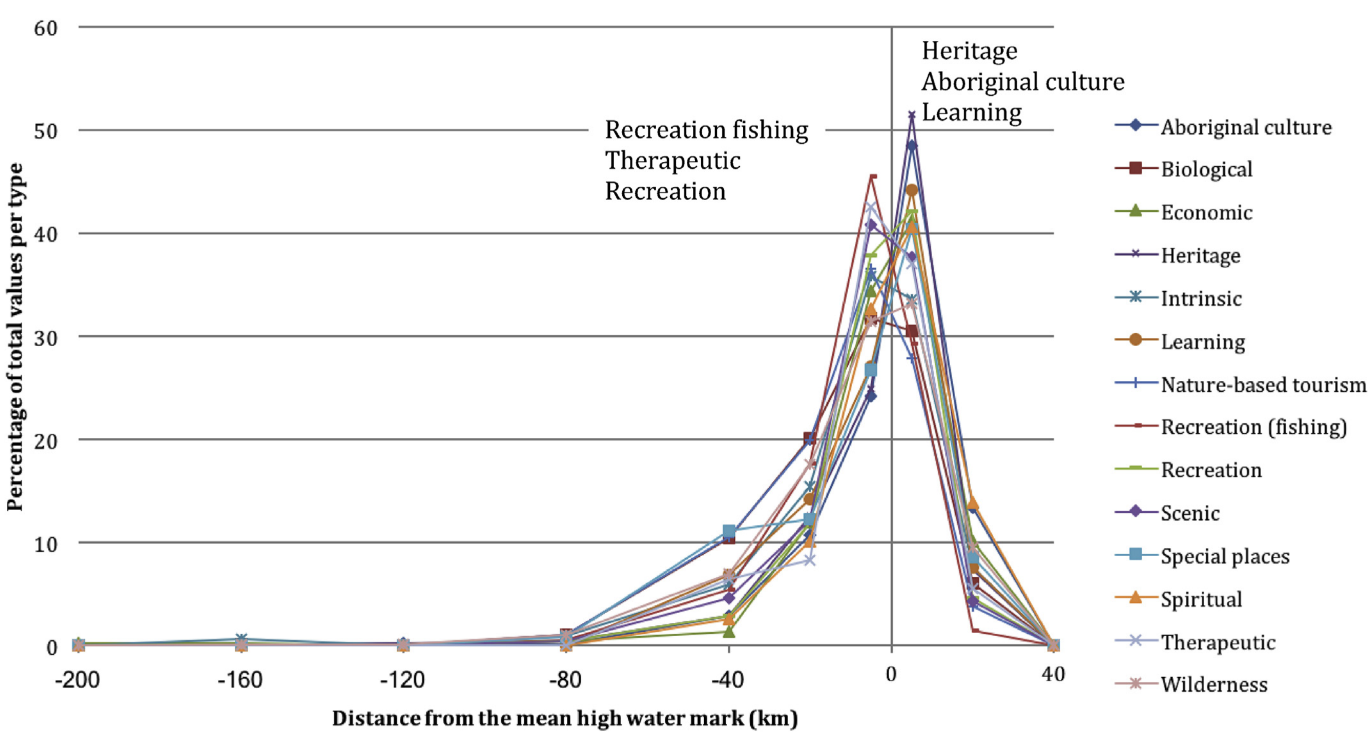

Fig. 3. Percentage of total values per type plotted against distance from the coast (−200 km offshore to +40 km onshore).

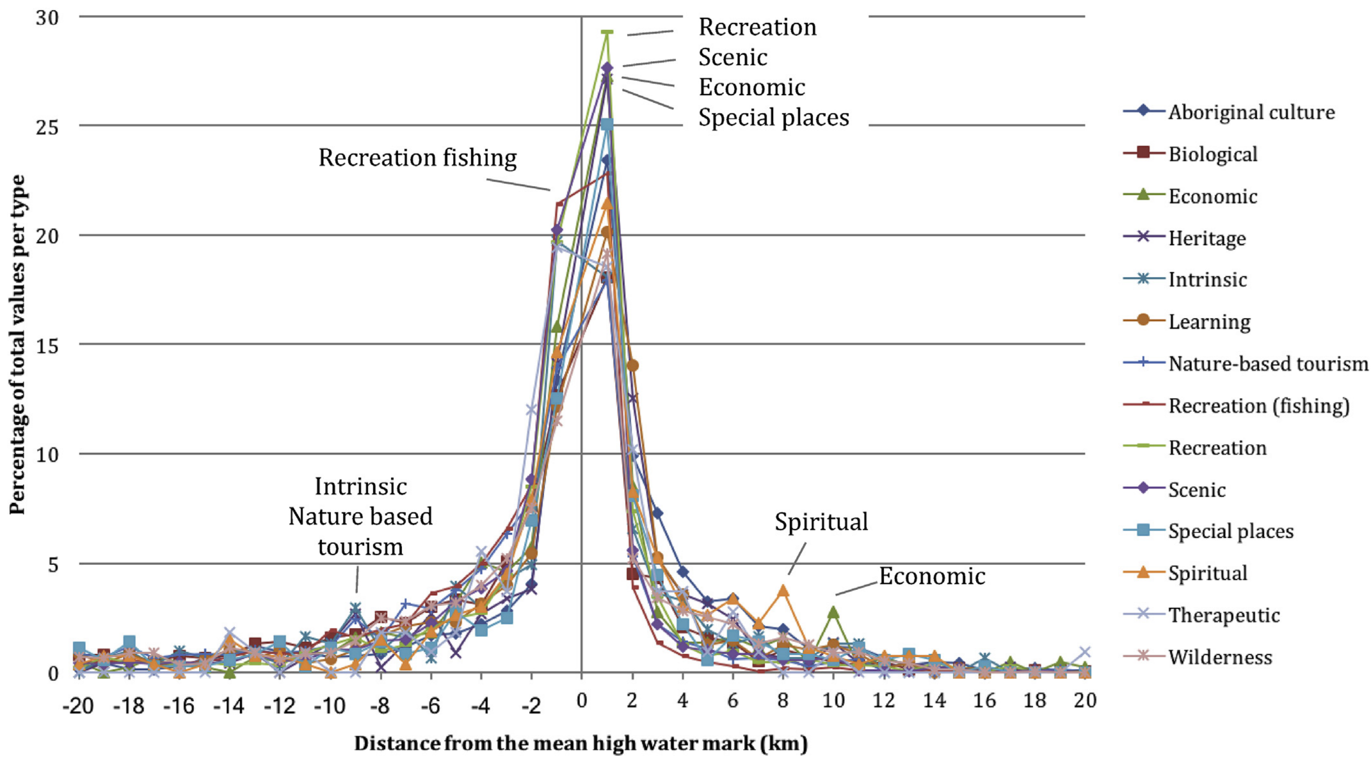

Fig. 4. Percentage of total values per type plotted against distance from the coast (−20 km offshore to +20 km onshore).

recreational fishing, nature tourism, learning, and special place were disproportionally valued in Ramsar areas. Ramsar wetlands in the study area include Eighty Mile Beach and Roebuck Bay (Fig. 1).

3.3. Distribution of cultural ecosystem values by sea tenure

Analysis was conducted to explore whether mapped cultural ecosystem values were related to sea tenure. Most notable was the abundance of values allocated to 'other marine (non-protected)' tenure (Table 3). More abundant values included Aboriginal culture, economic, heritage, learning, recreation and special place. Commonwealth marine protected areas had fewer values relative to the other two tenures.

State and Commonwealth marine protected areas had significantly fewer Aboriginal cultural, and more biological and intrinsic value markers placed than 'other marine'. State marine protected areas also had significantly more scenic/aesthetic and wilderness value markers placed than the other tenure categories. The largest adjusted negative and positive residuals were a residual score of −11.1 for Aboriginal cultural values in State marine protected areas, and a residual score of +11.6 for Aboriginal culture in 'other marine' (Table 3).

3.4. Distribution of cultural ecosystem values by access

Analysis was conducted to explore whether mapped cultural ecosystem values were related to access type, that is, main roads or tracks. Particularly prominent was the abundance of values associated with tracks (Table 1). Values that were consistently significantly more abundant in association with coastal tracks were recreation, economic, Aboriginal culture, heritage, learning, therapeutic, and spiritual values. As expected, tracks had a lower abundance of values than expected for scenic/aesthetic, biological and wilderness values. Economic and heritage values were the only values mapped significantly more than expected in relation to roads.

3.5. Distribution of cultural ecosystem values by population density

Chi-square analysis for the three population density categories indicated all values were more abundant in more densely populated areas than would be expected if allocation of values was independent of population (Table 1).

3.6. Distribution of cultural ecosystem values by geomorphology of the coastline

Chi-square and residual analysis revealed that a number of values were more abundant than would be expected if allocation of values was independent of coastal geomorphology. Most notable was the abundance of values allocated to mangal, namely economic, heritage, learning, and recreational fishing (Table 4).

Islands had more abundant biological and wilderness values, while beaches were favoured for recreation and therapeutic values. Rocky shores had significantly fewer values mapped relative to other geomorphic categories including economic, learning, recreational fishing and recreation. The largest positive residual score was for beaches and recreation (11.0) while the lowest score was for islands and recreation (−7.4) (Table 4).

4. Discussion

Robust, defensible planning efforts require careful consideration and inclusion of social values in deliberations and resultant plans. The spatial analyses applied to PPGIS data in this study shows the coastal zone as highly valued, with these values disproportionally located 0–2 km onshore (Figs. 4–5). Key findings from the results are discussed below, accompanied by implications for land (and

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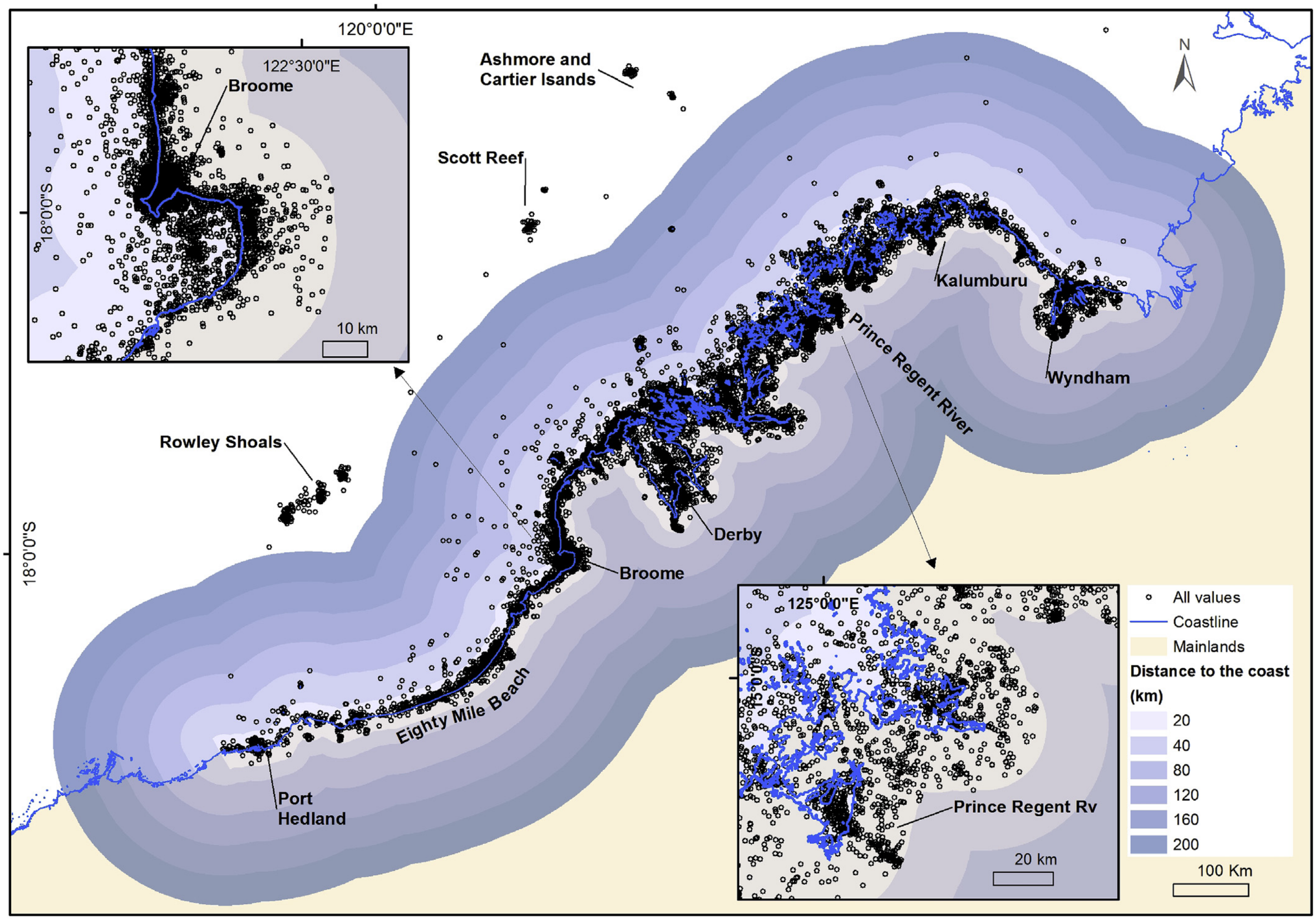

Fig. 5. Distribution of all value markers plotted across the study area with the distance to shore zones indicated in 20 km bands.

Table 1
Presence/absence analysis of the distribution of mapped values in 4 × 4 km cells using pairwise chi-square analysis for land tenure, roads/tracks, and population density from coastline to 20 km landward. Significant associations ($p < 0.05$ = "+"; $p < 0.01$ = "++" and $p < 0.001$ = "+++") are indicated by colour with greater than expected counts (green) and fewer than expected counts (pink). NR = no relationship.

Value Category	Indigenous Protected Area	Defense lands	National parks/ reserves	Unallocated Crown	Pastoral leases	Ramsar	Main roads	Tracks	Population density (low, medium, high)
Scenic/aesthetic	+++	++	+++	+++	+++	+++	+++	++	+++
Recreation	NR	++	+++	+++	++	+++	NR	+++	+++
Recreation (fishing)	NR	+++	NR	+++	+++	+++	+++	NR	+++
Economic	NR	NR	NR	+++	NR	NR	+++	+++	+++
Nature-based tourism	+++	+++	+++	+++	+++	+++	+	NR	+++
Biological	++	+++	+++	+++	+++	+++	+++	+	+++
Aboriginal culture	+++	NR	+++	+++	+++	NR	++	+	+++
Heritage	NR	++	NR	+++	++	NR	+	+++	+++
Learning	NR	+	+++	+++	+++	++	NR	+++	+++
Therapeutic	NR	NR	+	+++	NR	NR	NR	+++	+++
Spiritual	+++	+	+	+++	+++	NR	NR	+	+++
Intrinsic	NR	++	+++	+++	+++	++	NR	NR	+++
Wilderness	+++	++	+++	+++	+++	+++	+++	+++	+++
Special places	++	+	++	+++	+++	NR	NR	NR	+++

sea) use planning and management.

4.1. Distribution of cultural ecosystem values in the coastal zone and seaward

A disproportionate number of values were mapped in the coastal zone and particularly 0–2 km inland from the shoreline. Moore et al. (2017) have showed, using PPGIS data, that places where diverse values are mapped are likely to experience greater potential for conflict, a finding supported by Brown and Raymond (2014) land use conflict model where potential conflict derived from differences in values and preferences. The abundance of values in this narrow band suggests greater attention in planning efforts to understand the compatibility and incompatibility of values in these areas.

This abundance of values in near shore areas helps explain the

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Table 2
Chi-square and residual analysis by land tenure. Significant residuals are highlighted in green (more values relative to other tenure categories) and pink (fewer mapped values than expected).

		National Park/reserve	Indigenous Protected Area	Unallocated Commonwealth	Pastoral lease	Ramsar	Defense	Other	Total
Aboriginal culture	Count	92	374	292	108	25	35	578	1504
	%	12.4%	21.2%	15.4%	15.0%	4.3%	29.4%	11.7%	14.0%
	Adj. Resid.	-1.3	9.6	2.0	.8	-6.9	4.9	-6.3	
Biological	Count	146	189	254	95	133	13	563	1393
	%	19.7%	10.7%	13.4%	13.2%	22.9%	10.9%	11.4%	12.9%
	Adj. Resid.	5.7	-3.0	.6	.2	7.4	-.7	-4.5	
Economic	Count	2	31	67	29	8	4	195	336
	%	0.3%	1.8%	3.5%	4.0%	1.4%	3.4%	3.9%	3.1%
	Adj. Resid.	-4.6	-3.6	1.1	1.4	-2.5	.2	4.5	
Heritage	Count	18	51	43	33	1	1	201	348
	%	2.4%	2.9%	2.3%	4.6%	0.2%	0.8%	4.1%	3.2%
	Adj. Resid.	-1.3	-.9	-2.6	2.1	-4.3	-1.5	4.5	
Intrinsic	Count	21	42	29	13	12	0	82	199
	%	2.8%	2.4%	1.5%	1.8%	2.1%	0.0%	1.7%	1.8%
	Adj. Resid.	2.1	1.8	-1.1	-.1	.4	-1.5	-1.4	
Learning	Count	16	41	54	27	17	4	175	334
	%	2.2%	2.3%	2.8%	3.7%	2.9%	3.4%	3.5%	3.1%
	Adj. Resid.	-1.5	-2.0	-.7	1.0	-.2	.2	2.4	
Nature-based tourism	Count	62	158	132	56	48	4	436	896
	%	8.4%	9.0%	6.9%	7.8%	8.3%	3.4%	8.8%	8.3%
	Adj. Resid.	.0	1.1	-2.4	-.5	.0	-2.0	1.7	
Recreation (fishing)	Count	32	121	275	87$_{b}$	122	9	740	1386
	%	4.3%	6.9%	14.5%	12.1%	21.0%	7.6%	14.9%	12.9%
	Adj. Resid.	-7.2	-8.2	2.3	-.7	6.0	-1.7	5.9	
Recreation	Count	49	129	176	89	65	6	566	1080
	%	6.6%	7.3%	9.3%	12.3%	11.2%	5.0%	11.4%	10.0%
	Adj. Resid.	-3.2	-4.1	-1.2	2.2	1.0	-1.8	4.5	
Scenic/ aesthetic	Count	121	328	323	89	83	19	833	1796
	%	16.3%	18.6%	17.0%	12.3%	14.3%	16.0%	16.8%	16.7%
	Adj. Resid.	-.3	2.4	.4	-3.2	-1.6	-.2	.4	
Special place	Count	15	58	47	11	12	3	97	243
	%	2.0%	3.3%	2.5%	1.5%	2.1%	2.5%	2.0%	2.3%
	Adj. Resid.	-.4	3.2	.7	-1.4	-.3	.2	-1.9	
Spiritual	Count	13	46	40	15	4	4	83	205
	%	1.8%	2.6%	2.1%	2.1%	0.7%	3.4%	1.7%	1.9%
	Adj. Resid.	-.3	2.4	.7	.4	-2.2	1.2	-1.6	
Therapeutic	Count	4	5	9	7	2	0	51	78
	%	0.5%	0.3%	0.5%	1.0%	0.3%	0.0%	1.0%	0.7%
	Adj. Resid.	-.6	-2.4	-1.4	.8	-1.1	-.9	3.5	
Wilderness	Count	151	188	160	62	48	17	355	981
	%	20.4%	10.7%	8.4%	8.6%	8.3%	14.3%	7.2%	9.1%
	Adj. Resid.	11.0	2.5	-1.1	-.5	-.7	2.0	-6.4	
Total		742	1761	1901	721	580	119	4955	10779
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

preferential reservation of large offshore marine areas as they are regarded as less conflicted, with Devillers et al. (2015) critiquing this 'residual' approach as an easy option to make do with what is 'left over' after other marine uses, such as oil and gas development, commercial fishing, tourism, and wind power generation, have received their spatial allocations. This approach is evident in Fig. 1 showing large offshore marine protected areas proposed by the Commonwealth Government. Such an approach has long been a characteristic of terrestrial reservation of protected areas globally (Devillers et al., 2015).

Conflict is not inevitable where there are multiple values. Careful spatial and temporal zoning can separate incompatible uses in space and/or time and cluster compatible uses (Brown and Hausner, 2017). This is an established approach in land use planning but a much more recent development for marine planning (Douvere and Ehler, 2009; Verutes et al., 2017). MSP recognizes the presence of often conflicting values and management preferences in coastal and marine environments, and advocates an ecosystem-based approach and integration across sectors (Jentoft and Knol, 2014; Vince, 2014). Both these features of MSP explicitly address conflict, with a number of researchers noting the importance of such planning for resolving conflict in often highly contested marine spaces (e.g., Douvere and Ehler (2009) analysis of MSP efforts in the North Sea). The values identified in studies such as that reported here provide spatially explicit data that can be readily incorporated into MSP.

4.2. Administrative, demographic, and physical landscape influences on the distribution of cultural ecosystem values in the coastal zone

Different abundances in mapped values were strongly associated with land and sea tenure. National parks, Ramsar sites, unallocated Crown lands and 'other' lands had disproportionally more values mapped than pastoral or defense lands. The reasons for this are likely twofold. First, national parks, Ramsar sites, and 'other' lands (includes freehold land and reserves for purposes other than protection of ecological values; only 4% of coastal zone), have been established due to them being valued, often for more than one value. For example, national parks are valued for their scenery, biological, recreational, and wilderness values. Second, access may be prohibited, or at least difficult and discouraged, to defense and pastoral lands. Due to the phenomenon of spatial or geographic discounting, places that are known and closer to domicile tend to be more highly valued than places more distant (Norton and Hannon, 1997; Pocewicz and Nielsen-Pincus, 2013).

There was a significant relationship between scenic/aesthetic values and national park, Ramsar and 'other' land tenures. In

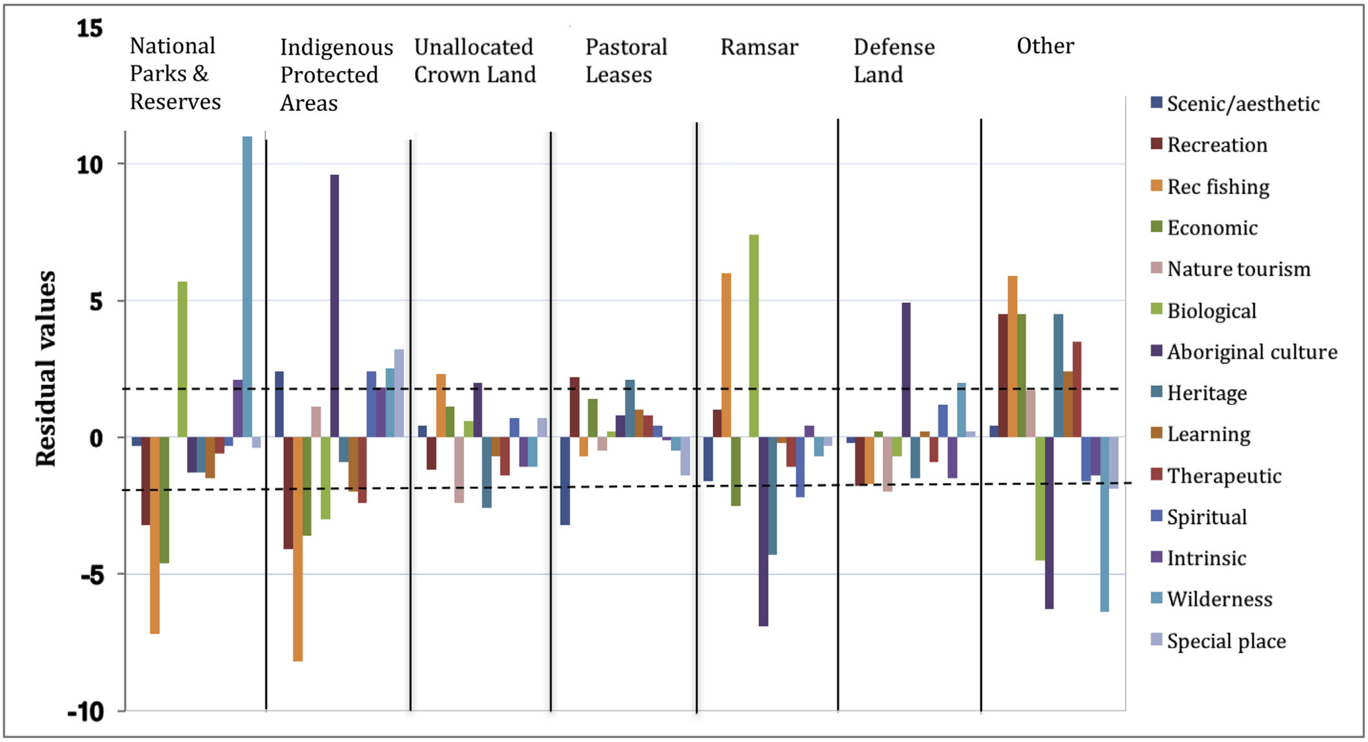

Fig. 6. Plot of chi-square residual scores that measure the strength of the difference between observed and expected counts of values in the coastal zone by land tenure category. Chi-square residual scores greater than +2.0, or less than −2.0 (dashed lines), indicate significant deviation from expected counts.

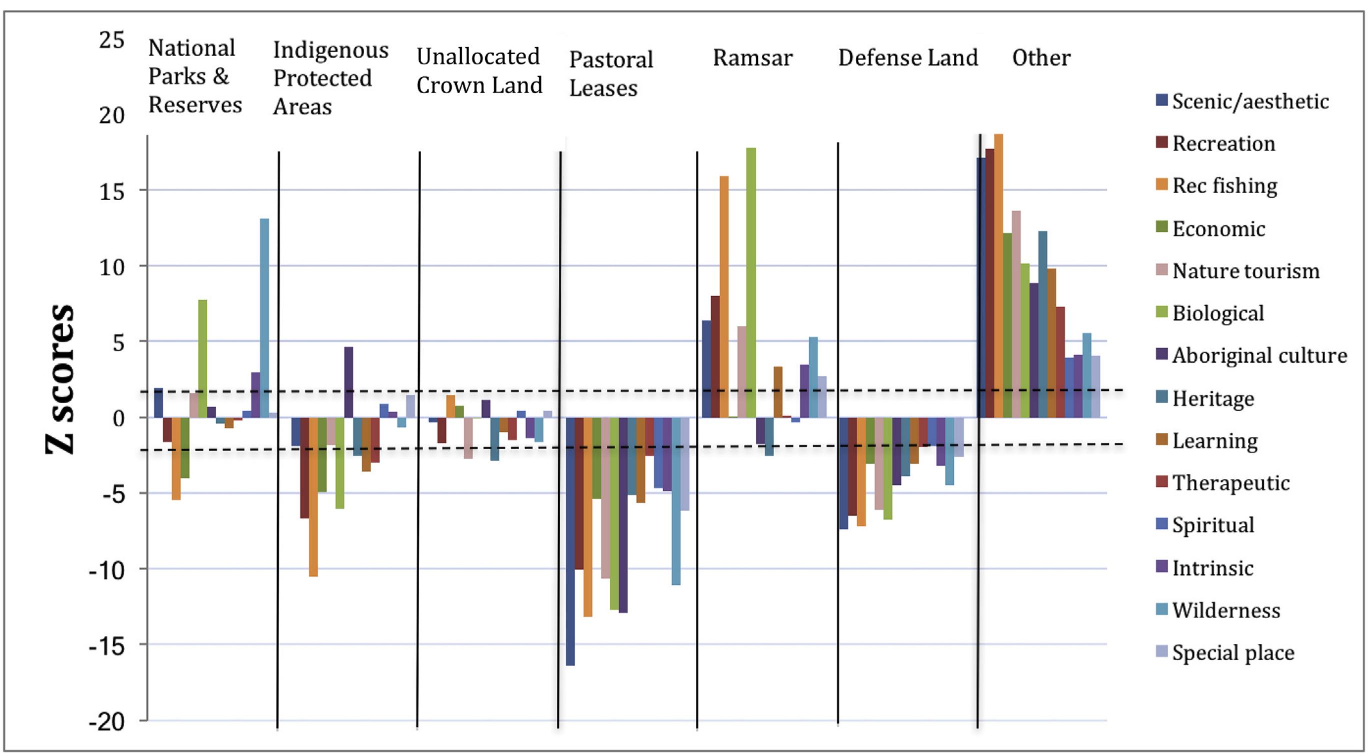

Fig. 7. Plot of z scores measuring the deviation between the observed, mapped proportions of values with land tenure categories and the expected proportion of values based on the area of the land tenure category as a proportion of total study area size. Z scores greater than +2.0 or −2.0 (dashed line) indicate significant deviation from expected proportion of values.

contrast, Hausner et al. (2015) found that these values were unrelated to land tenure and protected areas in their study in (inland) southern Norway. They suggest that the lack of relationship may be attributed in part to overlapping tenures that were in place before

Table 3
Chi-square and residual analysis by type of marine protected area (State, Commonwealth, other marine [non-protected]). Significant residuals are highlighted in green (more values relative to other categories) and pink (fewer values).

		State MPA	Commonwealth MPA	Other marine (non-protected)	Total
Aboriginal Culture	Count	258	6	1086	1350
	%	19.1%	0.4%	80.4%	100.0%
	Adj. Resid.	-11.1	-2.4	11.6	
Biological	Count	800	40	1040	1880
	%	42.6%	2.1%	55.3%	100.0%
	Adj. Resid.	10.0	4.7	-10.9	
Economic	Count	45	1	314	360
	%	12.5%	0.3%	87.2%	100.0%
	Adj. Resid.	-8.2	-1.5	8.5	
Heritage	Count	75	1	278	354
	%	21.2%	0.3%	78.5%	100.0%
	Adj. Resid.	-4.6	-1.5	4.9	
Intrinsic	Count	103	6	135	244
	%	42.2%	2.5%	55.3%	100.0%
	Adj. Resid.	3.2	2.1	-3.7	
Learning	Count	91	5	270	366
	%	24.9%	1.4%	73.8%	100.0%
	Adj. Resid.	-3.2	.5	3.0	
Nature-based tourism	Count	470	15	864	1349
	%	34.8%	1.1%	64.0%	100.0%
	Adj. Resid.	1.9	.1	-1.9	
Recreation (fishing)	Count	682	25	1326	2033
	%	33.5%	1.2%	65.2%	100.0%
	Adj. Resid.	1.0	.7	-1.2	
Recreation	Count	337	12	909	1258
	%	26.8%	1.0%	72.3%	100.0%
	Adj. Resid.	-4.6	-.5	4.7	
Scenic/aesthetic	Count	759	16	1430	2205
	%	34.4%	0.7%	64.9%	100.0%
	Adj. Resid.	2.0	-1.8	-1.6	
Special place	Count	67	3	197	267
	%	25.1%	1.1%	73.8%	100.0%
	Adj. Resid.	-2.6	.1	2.6	
Spiritual	Count	60	0	139	199
	%	30.2%	0.0%	69.8%	100.0%
	Adj. Resid.	-.7	-1.5	1.1	
Therapeutic	Count	22	0	67	89
	%	24.7%	0.0%	75.3%	100.0%
	Adj. Resid.	-1.6	-1.0	1.8	
Wilderness	Count	513	13	668	1194
	%	43.0%	1.1%	55.9%	100.0%
	Adj. Resid.	8.0	.0	-8.0	
		4282	143	8723	13148
		32.6%	1.1%	66.3%	100.0%

the designation of protected areas. The Kimberley region is subject to dramatic ongoing tenure changes as Aboriginal people acquire control of extensive areas of land and sea country, including national and marine parks. More complex relationships between tenure and values may be one unexpected result.

The strong relationship between terrestrial protected areas and wilderness values warrants careful consideration in planning. Wilderness is a contested concept in the Kimberley, which has a history of continuous occupation by Aboriginal people within the landscape. Given wilderness in its purist sense has no people in it, this definition does not hold in the study area. What does apply and is highly relevant to land use planning are those elements of wilderness related to vast, wild landscapes with little sign of human habitation or (European) modification. This suggests attention to the extent and location of infrastructure, including ports and marinas, eco-retreats, boat ramps and beach shelters, to ensure wilderness values are not compromised.

Analysis of sea tenure showed disproportionally more value markers placed in non-protected areas relative to State and Commonwealth MPAs. And within the MPAs, Aboriginal culture was valued proportionally less while biological and intrinsic were valued disproportionally more than in other marine (non-protected) areas. It is likely that the diversity of sea uses supported by non-protected areas (i.e., fishing, oil and gas, mining, tourism, recreation, aesthetics, biological), and associated abundance of values, is a function of such areas occupying more than a third of the study area (38%). As with terrestrial protected areas, there was a strong relationship between State MPAs and wilderness values with similar implications for planning. The strong negative relationship between State MPAs and Aboriginal culture probably reflects current uncertainties around joint management and Native Title determinations, both of which will clarify and in many cases, legally and administratively strengthen Aboriginal peoples' association with their sea country within MPAs.[1] However, while Native Title rights permit Aboriginal people to exercise traditional fishing practices and joint management arrangements allow for greater governance authority, much work remains to be done to ensure that Aboriginal culture is valued more highly. Future research and

[1] Joint management between the Government of Western Australia and Aboriginal Title holders is being negotiated for MPAs reserved in the Kimberley (Department of Parks and Wildlife pers. comm. 3 October 2016).

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Table 4

Chi-square and residual analysis by dominant shoreline type (geomorphic category). Significant residuals are highlighted in green (more values relative to other tenure categories) and pink (fewer values than expected).

		Beach	Beach/ rocky shore	Mangal	Mud/Salt marsh	Rocky shore	Rocky shore/ mangal	Unclassified island	Total
Aboriginal culture	Count	321	92	360	20	120	29	258	1200
	%	12.3%	12.8%	10.8%	6.9%	11.0%	8.8%	12.6%	11.5%
	Adj. Resid.	1.5	1.1	-1.6	-2.5	-.6	-1.6	1.8	
Biological	Count	276	96	461	42	130	35	371	1411
	%	10.6%	13.3%	13.8%	14.5%	11.9%	10.6%	18.2%	13.6%
	Adj. Resid.	-5.1	-.2	.5	.5	-1.7	-1.6	6.8	
Economic	Count	64	21	125	7	17	12	71	317
	%	2.5%	2.9%	3.7%	2.4%	1.6%	3.6%	3.5%	3.0%
	Adj. Resid.	-2.0	-.2	2.9	-.6	-3.0	.6	1.3	
Heritage	Count	60	18	124	11	37	15	48	313
	%	2.3%	2.5%	3.7%	3.8%	3.4%	4.6%	2.4%	3.0%
	Adj. Resid.	-2.4	-.8	2.9	.8	.8	1.7	-1.9	
Intrinsic	Count	52	8	62	3	19	4	39	187
	%	2.0%	1.1%	1.9%	1.0%	1.7%	1.2%	1.9%	1.8%
	Adj. Resid.	.9	-1.4	.3	-1.0	-.2	-.8	.4	
Learning	Count	70	28	113	13	17	2	47	290
	%	2.7%	3.9%	3.4%	4.5%	1.6%	0.6%	2.3%	2.8%
	Adj. Resid.	-.3	1.9	2.6	1.8	-2.6	-2.4	-1.5	
Nature-based tourism	Count	250	66	282	8	104	34	166	910
	%	9.6%	9.2%	8.4%	2.8%	9.5%	10.3%	8.1%	8.7%
	Adj. Resid.	1.8	.4	-.7	-3.7	1.0	1.0	-1.1	
Recreation (fishing)	Count	358	119	561	84	126	42	227	1517
	%	13.8%	16.5%	16.8%	29.0%	11.5%	12.8%	11.1%	14.6%
	Adj. Resid.	-1.3	1.5	4.4	7.0	-3.0	-.9	-4.9	
Recreation	Count	403	66	316	28	90	18	113	1034
	%	15.5%	9.2%	9.5%	9.7%	8.2%	5.5%	5.5%	9.9%
	Adj. Resid.	11.0	-.7	-1.1	-.2	-2.0	-2.7	-7.4	
Scenic/ aesthetic	Count	472	134	495	33	253	92	373	1852
	%	18.2%	18.6%	14.8%	11.4%	23.1%	28.0%	18.3%	17.8%
	Adj. Resid.	.6	.6	-5.4	-2.9	4.9	4.9	.6	
Special place	Count	58	19	67	8	24	8	43	227
	%	2.2%	2.6%	2.0%	2.8%	2.2%	2.4%	2.1%	2.2%
	Adj. Resid.	.2	.9	-.8	.7	.0	.3	-.3	
Spiritual	Count	39	14	48	7	20	6	34	168
	%	1.5%	1.9%	1.4%	2.4%	1.8%	1.8%	1.7%	1.6%
	Adj. Resid.	-.5	.7	-1.0	1.1	.6	.3	.2	
Therapeutic	Count	28	7	26	0	6	0	11	78
	%	1.1%	1.0%	0.8%	0.0%	0.5%	0.0%	0.5%	0.7%
	Adj. Resid.	2.2	.7	.2	-1.5	-.8	-1.6	-1.2	
Wilderness	Count	149	32	299	26	130	32	240	908
	%	5.7%	4.4%	9.0%	9.0%	11.9%	9.7%	11.8%	8.7%
	Adj. Resid.	-6.2	-4.2	.6	.1	3.9	.7	5.4	
		2600	720	3339	290	1093	329	2041	10412
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

management would benefit from the use of research methodologies that integrate Aboriginal views and knowledge systems. Such methodologies offer an opportunity to promote and highlight the significance of Aboriginal culture within the context of joint management of marine protected areas in the Kimberley, and can build upon the existing body of knowledge held in documents such as Aboriginal healthy country plans (e.g., Yawuru Registered Native Title Body Corporate, 2011).

Disproportionally more values were associated with greater densities of access tracks (but not roads) and higher population densities. These results indicate that people are more likely to map all values in areas where they live or visit and show the effect of geographic or spatial discounting where values are mapped closer to the home location of study participants (Table 1) (Brown et al., 2002; Pocewicz and Nielsen-Pincus, 2013). In the Kimberley, the easiest way to visit a limited number of places is in a vehicle across the land. The values associated with higher densities of access tracks were largely intangible nature-based values including learning, therapeutic, and spiritual values as well as more instrumental values such as recreation. For roads, the only values disproportionally mapped were economic and heritage. This finding complements that of Brown and Hausner (2017) who found that, in their study of coastal values in five countries, constructed road access was associated with development-based values. They also found, similarly to this study, a greater number of values associated with higher population densities. They observed that road access and development are often closely related and influence the perceived mix of values from nature-based to social and economic values.

Mangal coast had a disproportionally high number of values mapped relative to other geomorphological types (Table 4). Mangroves provide numerous recreational fishing opportunities, plus have economic value as nurseries for fish harvested commercially. An expected finding was that beach areas were disproportionately valued for their recreation and therapeutic benefits. These general spatial associations, however, should be interpreted cautiously as the geomorphology data vary considerably in scale and detail on the Australian coast (AGGA, 2016a,b) and the heuristic choice of classification scale analysis (in this case, 4 km grids) can potentially influence the reported spatial associations.

5. Conclusion

Diverse efforts are currently underway to include cultural ecosystem services in coastal planning (e.g., Arkema et al., 2015; Gould et al., 2015; Gould and Lincoln, 2017). This paper has described and analysed the distribution of cultural ecosystem values in the coastal zone and their relationships to common planning elements such as land and sea tenure, infrastructure (e.g., roads), population density, and geomorphology. These mapped values are unlikely to capture and reflect the comprehensive spatial distribution of all cultural values in the region given the inherent limitations in sampling human populations using participatory mapping methods. Alternatively stated, places that were not mapped should not interpreted as the absence of values, but simply places that require greater research effort. However, places that were mapped provide direct evidence for the presence of cultural ecosystem services that appear to satisfy human value-based needs. As shown, values are particularly concentrated in the coastal zone 0–2 km onshore, suggesting special attention to coastal polices and future development in this narrow band. The location of values is influenced by tenure, access, and population density, all elements of policy and planning systems that are subject to human regulation and control.

Gathering information on the cultural ecosystem values offered by a coastline is only one of the first, but nevertheless critical steps in MSP or planned development in the coastal zone. Equally important is to have deliberative processes (Martin et al., 2016) that enable stakeholders to reveal and discuss shared values and deliberate over places and values where there is evidence of potential synergies or conflict. Such a deliberative approach is especially important in the 0–2 km band of the coastal zone inland from the shoreline where there is a disproportionally high concentration of values. This is also the part of the coastal zone where infrastructure such as new ports or the expansion of existing ports, boat-launching facilities, aquaculture, road construction, tourism infrastructure, and even urban development are most likely to occur. Any such developments would be wise to include a deliberative element in policy formulation and site-based planning that include spatially-explicit place values as described in this study.

Acknowledgments

We are grateful for the time, expertise and advice contributed by the individuals who made this research possible. The support of the Department of Parks and Wildlife and others who were involved in recruitment are also gratefully acknowledged. This research was supported by the Kimberley Marine Research Program, administered by the Western Australian Marine Science Institution. Finally, this research would not have been possible without the tremendous leadership and support of the project leader, Professor Sue Moore whose enthusiasm, dedication, passion and drive were exceptional.

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Please cite this article in press as: Kobryn, H.T., et al., Cultural ecosystem values of the Kimberley coastline: An empirical analysis with implications for coastal and marine policy, Ocean & Coastal Management (2017), http://dx.doi.org/10.1016/j.ocecoaman.2017.09.002

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