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Using expert informed GIS to locate important marine social-ecological hotspots

Pouyan Mahboubi [a], Margot Parkes [b], Craig Stephen [c], Hing Man Chan [d,*]

[a] University of Northern British Columbia, 353 5th Street, Prince Rupert, British Columbia, V8J 3L6, Canada
[b] Canada Research Chair in Health, Ecosystems and Society, School of Health Sciences, University of Northern British Columbia, 3333 University Way, Prince George, British Columbia, V2N 4Z9, Canada
[c] Canadian Cooperative Wildlife Health Centre, University of Saskatchewan, 52 Campus Drive, Saskatoon, SK, S7N 5B4, Canada
[d] Canada Research Chair in Toxicology and Environmental Health, Centre for Advanced Research in Environmental Genomics, University of Ottawa, 30 Marie Curie, Ottawa, Ontario, K1N 6N5, Canada

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ABSTRACT

The marine environment provides significant benefits to many local communities. Pressure to develop coastal waterways worldwide creates an urgent need for tools to locate marine spaces that have important social or ecological values, and to quantify their relative importance. The primary objective of this study was to develop, apply and critically assess a tool to identify important social-ecological hotspots in the marine environment. The study was conducted in a typical coastal community in northern British Columbia, Canada. This expert-informed GIS, or xGIS, tool used a survey instrument to draw on the knowledge of local experts from a range of backgrounds with respect to a series of 12 social-ecological value attributes, such as biodiversity, cultural and economic values. We identified approximately 1500 polygons on marine maps and assigned relative values to them using a token distribution exercise. A series of spatial statistical analyses were performed to locate and quantify the relative social-ecological importance of marine spaces and the results were ultimately summarized in a single hotspot map of the entire study area. This study demonstrates the utility of xGIS as a useful tool for stakeholders and environmental managers engaged in the planning and management of marine resources at the local and regional levels.

1. Introduction

Coastal communities often rely on the marine environment for, among others, natural resources to help maintain livelihoods (Brotherston and White, 2006), meet nutritional needs, advance scientific learning (Molnar et al., 2009), and practice traditional knowledge (see Assembly of First Nations, 2003; Chan et al., 2011; CRIFC, 2010). Current projects and new proposals involving development and use of coastal waterways, such as, the shipping of crude oil, the construction of natural gas plants, the expansion of ports and many others (see examples for northern British Columbia, Canada in Carleton Ray and McCormick-Ray, 2013) could result in significant marine environmental impacts.

A major challenge facing natural resource managers and environmental decision-makers is to plan for these impacts, with the objective of minimizing adverse effects to both human and ecosystem health. Such decisions require an understanding of the locations of marine spaces associated with important social or ecological values (e.g. economic opportunities), and the degree to which those spaces are important. With such an understanding, anticipated impacts could be spatially distributed with the objective of avoiding spaces with the highest social-ecological values. This begets several challenging questions: what criteria should be considered as a measure of importance? How do we measure those criteria? How do we integrate and analyze those measurements in order to draw inferences and make environmental management decisions? This paper proposes expert informed geographic information systems (xGIS) as a tool to help answer these questions by drawing on local environmental knowledge expertise to identify important social-ecological marine spaces.

Insufficient data and a limited understanding of the complex

* Corresponding author.
E-mail addresses: pmahboubi@nwcc.bc.ca (P. Mahboubi), parkesm@unbc.ca (M. Parkes), cstephen@ucalgary.ca (C. Stephen), Laurie.Chan@uottawa.ca (H.M. Chan).

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cross-linking relationship between human and environmental health (Birley, 2002; Braveman et al., 2011; Noble and Bronson, 2005) have posed challenges to answering the questions posed. The challenges were partially addressed by the early works of (Tuan, 1974, 1977) and Relph (1976), and the more recent works of Bechtel and Churchman (2002), who recognized a relationship between people and their environment. They described people as active participants in the landscape -thinking, feeling, acting and receiving information from both observation and experience. In doing so, they gain ‘perception’ and thereby attribute ‘meaning’ to landscapes, ultimately developing a ‘sense of place’. Zube (1987) and others (Brown, 2005) further build on this phenomenon and describe the human–landscape relationship model; proposing that individuals who develop such place attachments are often capable of associating a quantifiable range of values to places (Brown, 2005). Rolston and Coufal (1991) and others (see Landscape Values PPGIS Institute, 2013) proposed an iterative list of landscape value attributes (see Appendix A) to reflect the human–landscape relationship. Brown (2012a) described these landscape value attributes, as “layers of human perceptions” that can be spatially referenced and overlaid on the physical landscape. Brown and Reed (2012a) asserted that the “human process of valuing landscapes results in structural and distributional patterns on the landscape that, although not directly observable, constitute latent patterns of social and psychological complexity that can ultimately be measured and quantified”. Therefore, in the fields of natural resource and environmental management, the sense of place can help bridge the gap between the science and the management of ecosystems (Brandenburg and Carroll, 1995; Brown, 2005; Eisenhauer et al., 2000; Mitchell et al., 1993; Williams and Stewart, 1998) and help predict resource conflicts (Brown and Raymond, 2007).

There is, however, no definite consensus on how to specifically measure sense of place; especially in the context of diverse sociocultural conditions (Kaltenborn and Bjerke, 2002) and few techniques that explicitly provide for the inclusion of this form of knowledge into the planning and analysis (Brown et al., 2004). Much of the work that has been done focuses on collecting qualitative data about the connections of people with special places (Brandenburg and Carroll, 1995; Mitchell et al., 1993); data that are not easily integrated with existing biophysical inventories (Brown, 2005).

The field of public participatory GIS (PPGIS) addresses one aspect of this need for measurement by tapping the knowledge of the ‘general’ public to quantifiably and spatially detect a range of social and ecological hotspots (Brown, 2012a). The PPGIS survey instrument is sent to every household in the community (Brown and Reed, 2009) and the data collected are assumed to represent the views of the “silent majority” (Alessa et al., 2008), the broad views of the entire local population (Brown and Reed, 2012b). While many approaches (e.g. Valipour, 2014) are generally applicable to large regional or national scales, PPGIS occurs at a scale that is useful for local planning.

xGIS builds on the PPGIS approach but focuses on the knowledge of local experts, rather than the general public, as a means of improved spatial accuracy. In such instances, the public is not viewed as one homogenous group to be randomly surveyed, but rather consisting of individuals with specific areas of knowledge expertise. In such cases, a stakeholder–participant transition process is required. Parkes (2011) described this process as beginning with the determination of existing knowledge strengths and deficits across multiple stakeholders, followed by a transitioning phase when stakeholders are invited to become research participants; thus establishing the ‘participatory research community’.

While xGIS appears to be a promising tool, there have been few related studies demonstrating how it can be applied in the context of environmental management or its challenges and limitations. This paper explores the use of xGIS as an innovative approach to detecting and quantifying the spatial distribution of important social-ecological hotspots in the marine ecosystem based on expert social-ecological knowledge from the local community. We use this case study to demonstrate the usefulness of xGIS in the field of marine resources management. The specific objectives of the study include: 1) to determine the feasibility of recruiting expert participants; 2) to apply xGIS to detect important marine social-ecological hotspots; 3) to critically evaluate the methodology and results. In an era of increasing inclusion of civil society in environmental decision-making (Janicke, 2008), we propose that xGIS can serve as timely and useful tool to help bridge the gaps.

The region of northwest BC where this case study was applied is broadly consistent with many small coastal communities. It has a relatively small population (less than 20,000) and is comprised of residents of a wide range of ethnic origins, including Aboriginal peoples (37.5%) (Statcan, 2010). Socio-economic conditions (10.7% unemployment) and levels of education (57% with no post-secondary education and 28% aged 25–64 with high school as their highest educational attainment) all lag behind the BC average (In Stantec, 2014), as do most health indicators (Fang et al., 2010). The region is comprised of a mountainous temperate rainforest ecosystem and a highly productive and bio-diverse marine ecosystem (PNCIMA, 2011). The economy is based largely on natural resources, including fishing, forestry, energy, transportation and tourism (BC Stats, 2012). The general region includes a small central community and a number of outlying First Nation's villages. Subsistence living is common, especially in outlying communities.

2. Methods

Four major components were involved in the development of the xGIS tool: selecting who to survey, applying the survey instrument, determining the extent of surveying, and analyzing the data. These components are described below. Human research ethics approval was obtained from the Research Ethics Board of the University of Northern British Columbia.

2.1. Selecting expert participants

The knowledge categories ‘specialized’ and ‘individual’ proposed by Brown (2007) were deemed the most reflective of the range of local expertise in the study region and were, therefore, used in this study. These two categories were further sub-divided as shown in Table 1. The initial selection of experts was based on individuals known to the primary investigator as being widely recognized and accepted in the region as having significant marine spatial knowledge. These individuals were contacted and invited to

Table 1
Categories of knowledge expertise considered relevant to the study region.

Specialized	Individual
Independent consultant/scientist	Politician with a marine portfolio
Government marine scientist	Longtime resident
Government marine administrator	Marine leisurist
Marine watchmen or patrolmen	
Commercial fisher	
Food fisher	
Traditional knowledge	
Sport fishing or Ecotourism guide	
Marine-based NGO[a] staff	
Community health worker	

[a] Non-governmental organization.