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Understanding the effects of different social data on selecting priority conservation areas

Authors:

Azadeh Karimi[1, 2*], Ayesha I.T. Tulloch [1], Greg Brown[1, 3], Marc Hockings[1]

1. School of Earth and Environmental Sciences, University of Queensland, Brisbane, QLD, 4072
2. Department of Environmental Sciences, Faculty of Natural Resources and Environmental Sciences, Ferdowsi University of Mashhad, 9177948974, Iran
3. Present address: Natural Resources Management & Environmental Sciences Department, California Polytechnic State University, San Luis Obispo, California, 93407, USA

Author for correspondence: Azadeh Karimi

Address: School of Earth and Environmental Sciences, University of Queensland, Brisbane, QLD, 4072

Email: azadeh.karimi@uq.net.au; azkarimi81@gmail.com

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Abstract

Conservation success is contingent on assessing social as well as environmental factors so that cost-effective implementation of strategies and actions can be placed in a broad social-ecological context. Until now, the focus has been on how to include spatially-explicit social data in conservation planning, whereas the value of different kinds of social data has received limited attention. In a regional systematic conservation planning case study in Australia, we examined the spatial concurrence of a range of spatially-explicit social values and preferences collected using public participation GIS (PPGIS) methods with biological data. We then integrated the social data with the biological data in a series of spatial prioritization scenarios using Zonation software to determine the effect of the different types of social data on spatial prioritization vis-à-vis biological data alone. We found that the type of social data included in the analysis significantly affected spatial prioritization outcomes. The integration of social values and land-use preferences under different scenarios was highly variable and generated spatial prioritizations that were 1.2% to 51% different from those based on biological data alone. The inclusion of conservation-compatible values and preferences added relatively little new area to conservation priorities while in contrast, including non-compatible economic values and development preferences as costs significantly changed conservation priority areas. The multi-faceted conservation prioritization approach presented herein that combines spatially-explicit social data with biological data can assist conservation planners in identifying the type of social data to collect for more effective and feasible conservation actions.

Introduction

The overriding goal of conservation planning is to identify priority areas that ensure the persistence of ecological components (Knight et al. 2008). To conduct spatial conservation planning planners typically include data on the distribution of biodiversity features and conservation costs, to find areas that are complementary, representative and adequate for protecting or managing target biodiversity (Pressey & Margules 2000). There is an enormous variety of data available to inform conservation planning, and typically planners do not have the time or resources to collect it all (Tulloch et al. 2014). Much of the traditional literature on conservation planning data focused on which biodiversity data might be most informative for prioritizing the right places (Van Jaarsveld et al. 1998). This historical focus on biodiversity features in conservation planning did not account for the importance of the landscape for a wide variety of non-biodiversity-related reasons. The inclusion of social dimensions in conservation planning, in addition to biological information, is now recognised as a more effective way to achieve conservation success, as social support is often essential for conserving ecological components of the landscape (Cowling & Wilhelm-Rechmann 2007; Knight et al. 2010).

The last decade has seen a rise in research attention to collecting meaningful social data in addition to biodiversity data to inform spatial conservation planning (Mascia et al. 2003). There are many different ways to measure socio-economic aspects of a landscape that have implications for conservation. For example, social data can represent opportunity costs for conservation-incompatible economic activities such as fishing or farming (Naidoo et al. 2006; Carwardine et al. 2008), can identify human capital to support conservation activity (Knight et al. 2010), and can distinguish cultural ecosystem services such as aesthetics, recreation, and spiritual value (Brown et al. 2012). A number of studies have incorporated social data into conservation planning to identify conservation opportunities and constraints and evaluate the cost-effectiveness of strategies and actions that include socio-economic aspects of the conservation landscape. For example, biophysical and economic data are frequently combined to identify priority areas of high biodiversity value and low cost (Cabeza & Moilanen 2006; Naidoo & Ricketts 2006). More recently, models of conservation opportunity were integrated with biophysical factors to compare the costs and benefits of integrating social data when allocating conservation actions across a highly modified human-use landscape (Tulloch et al. 2014). Conservation opportunity and feasibility can vary considerably depending on political and social settings (O'Connor et al. 2003; Mills et al. 2013), history of human use of the landscape (Knight et al. 2010) and characteristics of individuals (Moon et al. 2014). Knowing the range of variability in these characteristics and preferences across the landscape can enhance our understanding of how different types of social data explicitly support or hinder the effectiveness of conservation actions (Moon et al. 2014). However, there has been limited research on the value of incorporating different kinds of social data compatible or incompatible with conservation.

Public Participation Geographic Information Systems (PPGIS) provide opportunities to collect spatially-explicit social data including the specific values people associate with places and land-use preferences indicating their support for the locations of different uses (Brown 2004). Previous studies have shown the potential of using PPGIS data along with biological data to examine spatial concurrence of social and biodiversity values (Brown et al. 2015), and to identify social-ecological hotspots as valuable areas from both human and environmental perspectives (Karimi et al. 2015). These studies examined the extent to which social data were associated with biological data, but did not incorporate these data into spatial conservation planning and hence they were unable to explore trade-offs between social and biodiversity values when identifying conservation priorities in a systematic and quantitative way. Recently, Whitehead et al. (2014) explicitly integrated place-based values and preferences into a landscape prioritization process to identify socially acceptable conservation priorities; however, the social values were limited to three types and the level at which different types of social values are compatible with conservation was not considered.

Despite a clear understanding that including social data can influence conservation decisions and support conservation success (Tulloch et al. 2014; Whitehead et al. 2014), it is still unclear what types of social information best identify conservation opportunities and constraints. Identifying the type of information with the highest utility in terms of informing (and changing) decisions has been shown to deliver better conservation outcomes (Canessa et al. 2015). Learning what types of social data are important to include in conservation planning in different situations based on (a) compatibility or (b) influence on conservation priority will increase the reliability and long-term effectiveness of conservation decisions. Unlike the previous studies which integrated social data with biodiversity data to find optimal places for conservation actions (Whitehead et al. 2014), our study aims to a very different information-based objective of exploring the value of collecting different kinds of social data through the use of a spatial conservation planning tool. We examine the effect of different social values and land-use preferences collected by PPGIS method in a conservation prioritization analysis using the Baffle Basin in Queensland on the east coast of Australia as a case study. The Baffle Basin region is a highly modified landscape containing a number of national parks as well as urban coastal communities, and is likely to be subject to considerable development pressures from proposed mining and associated development in coming years (Great Barrier Reef Marine Park Authority 2012) (See Appendix S1 for more details). To address the knowledge gap in the context of incorporating social data in conservation planning, we use both qualitative (expert elicitation) and quantitative (gap analysis) techniques to identify the relationships between different types of social values and conservation. We use an expert elicitation method to understand the compatibility of 13 different types of social values with conservation. We then perform a gap analysis to explore how much these social values overlap with biodiversity features prioritised using the systematic conservation planning software Zonation. Finally, we determine the effects of different types of social data on conservation prioritization outcomes. Our study addresses key research gaps of understanding how different kinds of conservation-compatible social values and land-use preferences might change conservation prioritization decisions, and more importantly, which kinds of social data to collect when resources are limited.

Methods

Social data mapping

We implemented a mixed-methods PPGIS survey to collect spatially-explicit point data on 13 perceived social values (biological, wilderness, spiritual, scenic, historic, intrinsic, learning, future, life-sustaining, socialising, land-and water-based recreation, and economic value) and six land-use preferences (conservation, agriculture, residential, industrial, mining and tourism development) in the

Baffle Basin (see Appendix S2 for operational definitions). We provided the option of completing an internet-based or mail-based survey for participants. Invitation letters were sent to 2200 residential addresses provided by a marketing company (Yell123 2014). The study sample size was 1835 households as 365 invitation letters were undeliverable. Each letter included the website address, a unique access code, and instructions explaining how to complete the survey. Detailed information about different steps of social data collection can be found in Karimi et al. (2015). Participants were asked to place markers in the internet version (or sticker dots in paper version) on the map locations that corresponded to each value and land-use preference as binary data. The participation rates for the internet-based and paper versions of the PPGIS survey were 11.7% and 44.6% respectively. We digitized the locations of the sticker dots in ArcGIS and merged them with internet-based spatial data resulting in a total of 4865 points for the analysis. For the purpose of this study we aggregated the preference points for agriculture, residential, industrial, tourism and mining development, hereafter called development preferences. Continuous surfaces were then generated for all value, conservation preference, and development preference points using a kernel density method and a 500m grid cell size and 3-km search radius. Higher values in these density maps of either social values or preferences indicate higher numbers of co-occurring values or land-use preferences.

In the next step, we identified the extent to which different types of values appear compatible with conservation. In a similar study that integrated social and biodiversity values in spatial prioritization, Whitehead et al. (2014) used three types of values—intrinsic, biodiversity and natural significance. In our study we performed expert elicitation using convenience sampling (Suri 2011) to assess the relative compatibility of 13 social values with conservation. The 16 expert participants were academics with either a degree in environmental management or were enrolled in a doctorate degree program. Participants were asked to score the compatibility of each social value with conservation on a scale of -5 (highly incompatible with conservation) to +5 (highly compatible with conservation). The mean scores were calculated for each value and used as the basis for weighting values in different prioritization scenarios in the next analyses. Social values with compatibility scores greater than four were defined as conservation-compatible values.

Biological input data

We used Species of National Environmental Significance (SNES) data to represent biodiversity features and evaluate the biodiversity value of the Baffle Basin (Department of Environment 2015). These data comprised the range maps of 162 nationally important (i.e. listed on the Environment Protection and Biodiversity Conservation Act 1999) threatened and migratory species, and encompassed 53 bird, 43 fish, 22 plant, 20 mammal, and 24 reptile species. To account for the information on highly valuable habitats in the prioritization, we used the National Vegetation

Information System (NVIS) (Australian Government 2015) to represent the distribution of native vegetation as an additional layer. This resulted in 163 biodiversity feature layers in total for use in conservation prioritization.

We converted all biodiversity layers to raster grids with an output cell size of 500m consistent with the spatial resolution of the social data layers. Qualitative data in the SNES maps were reclassified to raster layers representing relative probabilities of occurrence of each feature by applying the values of 0, 0.5, 0.75 and 1 to the initial values of no occurrence, may, likely, and known to occur respectively. The categorical NVIS layer was converted to a binary raster by assigning a value of 1 for all native vegetation and a value of 0 for all remaining categories (i.e. developed areas, cleared lands).

Spatial prioritization analysis

We used the conservation prioritization software Zonation v.3.1.1 (Moilanen et al. 2012) to identify the top priority areas in the Baffle Basin that might be considered valuable under different input data sets (Table 1). Zonation is a freely available tool that uses information about the relative distributions of features to generate a hierarchical prioritization of the landscape that maximises the complementary representation of all conservation features (Moilanen et al. 2012) (see Appendix S3 for more details).

We examined seven prioritization scenarios (Table 1) in Zonation in a way that allow us to determine how different types of social data can be informative for conservation prioritization. We did this by comparing alternative social-data scenarios against a prioritization based only on biodiversity data and measuring the unique areas identified in the priority locations. We first prioritized the landscape based only on biodiversity data (scenario1: biodiversity-only), then based only on the conservation-compatible values (scenario 2: conservation-compatible social values-only). In scenarios 3 and 4, we incorporated either all the conservation-compatible values (scenario 3: Biodiversity and conservation-compatible social values) or the single layer of conservation preferences (scenario 4: biodiversity and conservation preferences) with biodiversity data as conservation features for prioritization. Next, we built on scenario 3 to include economic value and development preferences as cost layers in three different ways: first, using only economic value as a cost layer (scenario 5: biodiversity and conservation-compatible social values with economic value); second, using only the development preference layer as a cost layer (scenario 6: biodiversity and conservation-compatible social values with development preferences). Finally, we defined a comprehensive multiple objective prioritization (scenario 7) aiming to maximise representation of both social and biodiversity features in the landscape whilst minimising cost. To achieve this we included all conservation-compatible social values and biodiversity information in the spatial prioritization. Due to the limitation for including only one layer as a cost in Zonation software, we aggregated the economic value and development preference layers together by multiplying the values associated with these two layers in ArcGIS to set the cost layer for this scenario. According to the results of expert elicitation, the conservation-compatible and conservation neutral values were given weights of 1 and 0, respectively (Table 2). All biological features were assigned a weight of 1 in all scenarios.

[Insert Table 1]

We performed a gap analysis to identify the differences in the representation of social values based on kernel density rasters and the conservation prioritization made using biological features alone, i.e. biodiversity-only scenario (Pressey & Margules 2000). We used the results of the expert elicitation to select the eight social values compatible with conservation. We then identified the top 25% of the landscape with the highest values from the density raster of each social value, and the best-ranked 25% of biodiversity-only prioritization. We used the top 25% because a higher percentage (e.g. 30%) resulted in the inclusion of grid cells with a value of 0 for some social values. We overlaid each density-value raster with biodiversity-only prioritization to identify where, and by how much, social values spatially coincide with areas valuable for biological conservation.

Next, we investigated similarities in the scenarios outputs including or excluding social data in conservation prioritization. We measured the pairwise similarity of each cell's priority in the biodiversity-only scenario with its priority in other scenarios using Pearson's correlation coefficients to determine the strength of the relationships in each pair of outputs.

In the next step, we identified the top 30% of all seven prioritization outputs and compared them with the top 30% of biodiversity-only priority map to identify the extent to which prioritization decisions changed when incorporating different types of social data. The results of this analysis allowed us to identify and compare the extent of area unique to prioritizations incorporating different types of data. Using the results of multiple scenarios, we also identified the representation levels of all eight social values compatible with conservation in the top 30% and 10% of the landscape. For scenarios 3, 4, 5, 6 and 7, we explored the sensitivity of the representation of different taxonomic groups to the inclusion of different kinds of social data in conservation prioritization.

Results

Social value compatibility with conservation

Using the results of our expert elicitation, we categorized the compatibility of social values with conservation based on the mean score given to the compatibility of each value with conservation (Table 2) (see the representation of the range of scores given to the relationships of values with conservation in Appendix S4). Eight values were classified as conservation-compatible, whereas four (social, historic, and two recreation values) were judged conservation-neutral. Economic value was considered conservation-incompatible and considered a cost rather than conservation benefit. (See Appendix S5 for more details about survey results).

[Insert Table 2]

Gap analysis

Using only biodiversity features as the basis for setting conservation priorities would decrease the representation of the highly valuable places for certain types of conservation-compatible social values. Overlaying the top 25% of density rasters of each conservation-compatible value with top 25% of biodiversity-only priority map revealed important similarities and differences (shared and unique areas) between the spatial coverage of the two sets of data (Table S2). The extent and spatial configuration of the differences between the two layers depended on the specific value (Fig. 1, Appendix S6). The largest shared area (43.16%) was observed in the overlap of each of intrinsic and spiritual values with high priority cells from the biodiversity-only scenario, followed by learning (41.58%) and scenic (41.49%) values. Life-sustaining value had the smallest spatial coincidence (38.17%) with the biodiversity-only priority area, and correspondingly, the highest unique area compared with biological priorities.

[Insert Figure 1]

Comparing different prioritization scenarios

The rankings of cell priorities under different scenarios were positively correlated (Table 3). The lowest similarity in cell rankings was between the complete multiple objective prioritization and biodiversity-only scenario (Pearson's correlation r = 0.639). The two most similar scenario outputs to biodiversity-only prioritization occurred when conservation preference data were included (scenario 4; r=0.995), followed by the use of conservation-compatible values (scenario 3; r=0.985). A prioritization based on conservation-compatible social data only as conservation features (ignoring biodiversity data and costs) was also positively correlated with the biodiversity-only scenario, although only to a moderate degree (r=0.681).

Including social values or preferences with biodiversity data in the conservation prioritization generated a solution overlapping with 91-98% of the high priority locations of the biodiversity-only prioritization (Table 3). Spatial analyses overlaying the top 30% of cells from each prioritization indicated that including conservation-compatible values in biodiversity-only prioritization resulted in

4.6% unique priority areas. In contrast, adding conservation preference data to a biodiversity-only prioritization resulted in only 1.2% of unique areas compared with the baseline (scenario 4).

[Insert Table 3]

Incorporating social data as both features and costs dramatically changed the biodiversity-only prioritization. Including economic value and development preference data as cost layers separately in the solutions (scenario 5 and scenario 6), resulted in 48.2% and 47.4% unique areas in the top 30% priority cells compared with the top 30% of the biodiversity-only scenario. The biggest difference occurred in the complete multiple objective prioritization, with approximately 51% unique priority locations compared with the biodiversity-only scenario. About 15% of areas with high priority in biodiversity-only prioritization (e.g., adjacent to Baffle Creek, Turkey beach, the town of Seventeen Seventy and Agnes water; Fig. 2) decreased in priority when social values and preferences for conservation-incompatible objectives were included as costs in the prioritization. Conversely, according to the complete multiple objective scenario, areas located in the middle of the region with higher social values, lower value for biodiversity, and lower cost received higher priority compared with the scenarios that did not consider costs (Fig. 2). Pairwise comparisons of the Zonation prioritizations when including conservation preferences as features (scenario 4), economic value as a cost (scenario 5) and development preferences as a cost (scenario 6) relative to biodiversity-only prioritization are presented in Appendix S7.

[Insert Figure 2]

Including conservation-compatible values in conservation prioritization with no costs (scenario 3) resulted in very little change to the average proportions of species distributions represented under the biodiversity-only prioritization, despite the locations of protection changing by 4.6%. Integrating all social values and development preferences with biological data in scenario 7 resulted in the greatest changes to the average representations of all taxonomic groups (Appendix S8), with plants the most affected (44% reduction in the representation of species' distributions, on average). Figure S4 represents the range of distributions protected for individual species in the top 30% of the landscape (Appendix S9).

Protecting the top 30% of the landscape in complete multiple objective prioritization would result in changes in the representation of socially valuable areas compatible with conservation, compared with conservation-compatible social values-only scenario (Fig. 3). The greatest reduction in average representation of social values in the top 30% of the landscape was related to learning value (52.8%), followed by life-sustaining value (52.2%) and wilderness value (51.9%). Comparing scenarios 5 and 6 that included either economic value or development preferences revealed that the reduction in the extent of all conservation-compatible values was greater when including development preferences in scenario 6 (Fig. 3).

[Insert Figure 3]

Discussion

The goal of this study was to evaluate how different types of social data might change conservation prioritization decisions by providing unique information to identify conservation opportunities and constraints. The findings highlighted different levels of trade-offs between biodiversity values and social objectives across the landscape, which we used to assess the utility of different kinds of social data in conservation prioritization. The determination of social value compatibility with conservation through expert elicitation in this study provided a way of understanding which social values should be incorporated as benefits rather than costs in conservation prioritization, leading to more robust decisions and reducing uncertainty in outcomes resulting from heterogeneity in human values for landscape attributes. By incorporating the enhanced knowledge of the relationships between social data and conservation into the prioritization framework, we found that the type of social data included, and the way the data are incorporated into the prioritization (i.e. as a constraint or an opportunity), can significantly affect the outcome of spatial prioritization for conservation. Individual values were similar in the amount of unique locations they offered to supplement biodiversity priorities, although the spatial configuration of these locations sometimes differed (Fig. 1).

This is the first study that determined the relationships between single social values with conservation and their effects on the biological prioritization using both gap analysis and expert elicitation approaches. In the absence of collecting a full range of social values, our results suggest some degree of social value substitutability. Our conservation compatibility findings were consistent with those of Brown et al. (2015) who found that the majority of social values were related to modelled conservation priorities for public lands in Victoria, with the exception of economic value which was least compatible with conservation. The inclusion of aggregated conservation-compatible values and conservation preference-only data in scenario 3 and 4 added relatively little new areas to conservation priorities and made small changes to the protection of different taxonomic groups (Table 3). However, these data provide an important planning function by indicating areas that have strong support from local communities and therefore higher social feasibility, acceptability, and effectiveness of implementation (e.g., Bryan et al. 2011; Whitehead et al. 2014).

Our evaluation of multiple scenarios helps illustrate that the changes made by different social data can inform planners about the extent of trade-offs between social and biological objectives need to be made when prioritizing areas for conservation. The strength of the changes to prioritised areas in our study when social preferences were incorporated as costs (Table 3, Figure 2) indicate there are situations where socio-economic objectives are incompatible with conservation. Including economic value and development preferences separately in different scenarios added almost the same extent of unique prioritized areas, but these were in different parts of the landscape. Because of this, accounting for development preferences necessitated a greater trade-off between social and biodiversity objectives than accounting for economic values, reducing the average representation of some taxonomic groups – fish and reptiles – by up to 37.25% and 19.2% (compared with a reduction of only 30% and 7.2% for these groups in the economic value scenario) (Appendix S8). Including both economic value and development preferences as costs in scenario 7 considerably changed the average representation of species distributions in the top priority areas, decreasing the level of protection of different taxonomic groups by a maximum of 44% for plants and a minimum of 8.5% for birds, on average. It is important to note that placing too much reliance on social data (i.e. through incorporating multiple social layers, or incorporating multiple social needs as a cost) may lead to planners prioritising conservation in areas that have high values compatible with human perceptions of biodiversity value and/or low values for development preferences, but may actually have little true biodiversity value.

The heterogeneity of social and biodiversity values in human-use landscapes means that there are multiple possible protected area networks, each of which results in slightly different outcomes for biodiversity versus social needs. Our study focused on a Western post-industrial landscape that is associated with particular social values. In some places social and economic needs may be more important for alleviating poverty and maintaining the cultural needs of the population (Ferraro et al. 2011), while in other places, biodiversity will have higher weighting (e.g. a location where one of the few remaining populations of an endangered species resides). We suggest that future studies explore a wider range of possible protected area network options through changes to the number, type and weighting of biodiversity and socio-economic data layers, then identify Pareto efficient protected area network options that might provide “win-win” solutions for both biodiversity and social objectives (e.g., Bode et al. 2015). A protected area network is Pareto inefficient if another network performs better according to one objective and as well or better according to the other objective, and the shape of the Pareto frontier between the two objectives can be used to understand the trade-off between biodiversity and another objective that is made unavoidable by the patterns of biodiversity and human use in the landscape. Analyses that trade off multiple objectives against one another would enable better transparency of decisions to choose social outcomes over biological outcomes, or vice versa (Ferraro et al. 2011, Bode et al. 2015).

The approach presented in this study can help inform planners and decision makers about the type of social data that need to be collected and incorporated in conservation prioritization. Due to limited resources available to conservation efforts, decision makers are required to make cost-effective decisions when prioritizing areas for protection or management (Naidoo et al. 2006). Conservation planners could spend less funding on data collection (leaving more for management) if they knew which types of social data would lead to the biggest change in conservation priorities (indicating the greatest trade-offs between social and biological objectives), thus avoiding collecting redundant data that do not change priorities (Canessa et al. 2015). We believe that conservation planners should present to stakeholders the effects of incorporating data that radically change priorities (such as through a Pareto-efficiency analysis of multiple proposed protected area networks). If conservation resources are limited and biodiversity protection is the primary objective, planners could collect social values and development preferences that appear incompatible with conservation by both local people and experts as these data are most likely to indicate spatial trade-offs in conservation prioritization. However, the value of identifying conservation-compatible social values and preferences for political leverage in conservation efforts may far exceed their analytical value for conservation prioritization. The results of gap analysis and expert elicitation methods used in this study can also guide future research to choose a shorter list of social values which needs to be identified during data collection.

In this study all biodiversity features had equal value to one another and were therefore assigned equal weighting in the prioritizations. Future studies could use expert elicitation or stakeholder analyses to identify weightings for both social and biodiversity features (e.g., by assigning species relative weights based on their status in threatened species legislation at regional and national scales, or defining the degree of their endemism based on the proportion of species' national distributions that occur in the study area (Whitehead et al. 2016)). We also note that biodiversity data used in this study (i.e. SNES layers) were coarse representations of species occurrence. In the absence of modelled species distributions to measure the likelihood of species occurrences, we reclassified probabilities of occurrences based on qualitative information to prepare these data for prioritization analyses. This added uncertainty to the ranking outcomes, but the assumption was deemed acceptable for the purposes of this hypothetical study focussed on the value of social rather than biological data.

The challenges of collecting social data with PPGIS are those of any social survey, and include participation rate and the potential influences of participants' locations on the type and spatial distributions of mapped attributes (Brown & Kytta 2014). Our study was able to achieve a typical PPGIS sampling response rate compared with the response rates of other PPGIS studies in developed countries (Brown & Kytta 2014) using both internet and mail-based survey to collect representative social data. In this study, we examined the compatibility of social values with conservation through expert elicitation, but our social value results are only relevant to the population of the study area at the time of sampling. Landscapes and communities can be highly dynamic and predicting the future values of the landscape based on changes to the community would be very useful. One way to do this would be to gather data on the people who are providing the social value data (e.g. occupations, family history in the area), and build models relating these data to the people's values, that might then be used to predict future social needs across the landscape when community dynamics change (Tulloch et al. 2014). Future studies could also validate the relationships between perceived social values and conservation by defining a more detailed value typology (i.e. smaller categories of economic values based on the context of the study area) and using the approach presented in this paper.

Incorporating social values and preferences—whether complementary or conflicting to conservation—may lead to more realistic conservation decisions in practice by representing explicit trade-offs between biological and social objectives. This study examined the use of social data for conservation planning by evaluating the utility of different types of social data for informing conservation prioritization decisions. The comprehensive multiple objective prioritization approach presented in this study provides a framework for incorporating social opportunities and constraints to achieve both social and biological objectives. This approach enables conservation planners to assess the value of collecting and incorporating different kinds of social data with respect to different planning objectives and available resources. Embracing such a framework may lead to more realistic conservation prioritizations underpinned by the social-ecological landscape (Ban et al. 2013) that account for the importance of both social and biodiversity values.

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Supporting Information

Details of Study area (Appendix S1), operational definitions of social values and land-use preferences used in the Baffle Basin (Appendix S2), details of prioritization process in Zonation (Appendix S3), representation of the range of compatibility scores (Appendix S4), details of social survey results (Appendix S5), gap analysis results showing similarities and differences between social values and biodiversity-only prioritization (Appendix S6), Pairwise comparisons of the resulting prioritizations for scenarios 4, 5 and 6 with baseline scenario (Appendix S7), sensitivity of taxonomic groups to different conservation planning inputs (Appendix S8), representation of the range of distributions protected for individual species in the top 30% of the landscape (Appendix S9) and comparison of the proportion of socially valuable areas protected in top 10% of the landscape when integrating social and biological data for prioritization (Appendix S10) are available on-line. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Table 1: Seven scenarios for incorporating biodiversity and social data into conservation prioritization for the Baffle Basin

Scenario	*Conservation feature layers*	*Cost layer*
Scenario 1: Biodiversity only	162 species + vegetation	None
Scenario 2: Conservation-compatible social values only	8 social values	None
Scenario 3: Biodiversity + conservation-compatible social values	162 species + vegetation + 8 social values	None
Scenario 4: Biodiversity + conservation preferences	162 species + vegetation + 1 preference	None
Scenario 5: Biodiversity + conservation-	162 species + vegetation + 8	Economic value

compatible social values + economic cost	social values	
Scenario 6: Biodiversity + conservation-compatible social values + preference cost	162 species + vegetation + 8 social values	Development preferences
Scenario 7: Comprehensive multiple objective prioritization (biodiversity + conservation-compatible social values + cost)	163 species + vegetation + 8 social values	Economic values + development preferences

Table 2: Mean compatibility scores resulting from expert elicitation process used for modelling social value/conservation relationships and the weighting used in Zonation priority analysis. See Appendix S2 for definitions of these values.

Social Value	*Mean score value*	*Standard error*	*Compatibility with conservation*	*Feature/cost*	*weighting*
Perceived biological	4.93	0.062	Conservation-compatible	Feature	1
Life-sustaining	4.93	0.062	Conservation-compatible	Feature	1
Wilderness	4.86	0.058	Conservation-compatible	Feature	1
Future	4.8	0.136	Conservation-compatible	Feature	1
Scenic	4.66	0.198	Conservation-compatible	Feature	1
Intrinsic	4.33	0.256	Conservation-compatible	Feature	1
Learning	4.2	0.25	Conservation-compatible	Feature	1
Spiritual	4.13	0.344	Conservation-compatible	Feature	1
Historic	3.8	0.256	Conservation-neutral	Feature	0
Land-based recreation	2	0.693	Conservation-neutral	Feature	0
Socialising	1.93	0.515	Conservation-neutral	Feature	0
Water-based recreation	1.4	0.763	Conservation-neutral	Feature	0
Economic	0.26	0.823	Conservation-incompatible	Cost	---

Table 3: Comparisons of spatial distribution of top 30% of high-priority areas in biodiversity-only scenario with scenario 3, 4, 5, 6 and 7

	Correlation with biodiversity-only prioritization (scenario 1)	*Area unique to either top priorities (top 30 %)*
Scenario 3: Biodiversity + conservation-compatible social values	0.985**	4.6
Scenario 4: Biodiversity + conservation preferences	0.995**	1.2
Scenario 5: Biodiversity + conservation-compatible social values + economic cost	0.794**	48.2
Scenario 6: Biodiversity + conservation-compatible social values + preference cost	0.655**	47.4
Scenario 7: Comprehensive multiple objective prioritization (biodiversity + conservation-compatible social values + cost)	0.639**	50.9

** Significant at 0.001 level.

List of Figures

Figure 1: Spatial distribution of shared and unique area valuable for conservation resulting from overlaying biodiversity-only prioritization with each conservation-compatible value layer at the top 25% of the landscape.

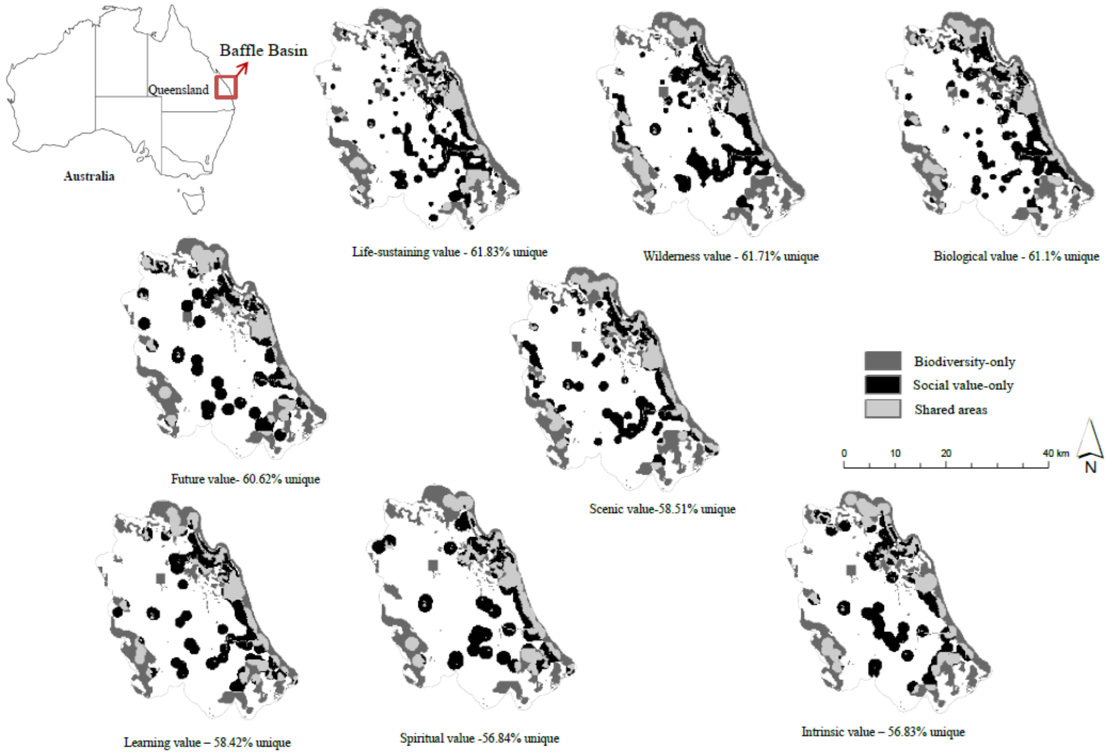

Fig. 1

Figure 2: Pairwise comparisons of the Zonation prioritizations when a) including conservation-compatible social values as features (scenario 3), and b) economic value and development preferences as cost layers (scenario 7) relative to biodiversity-only prioritization (scenario 1).

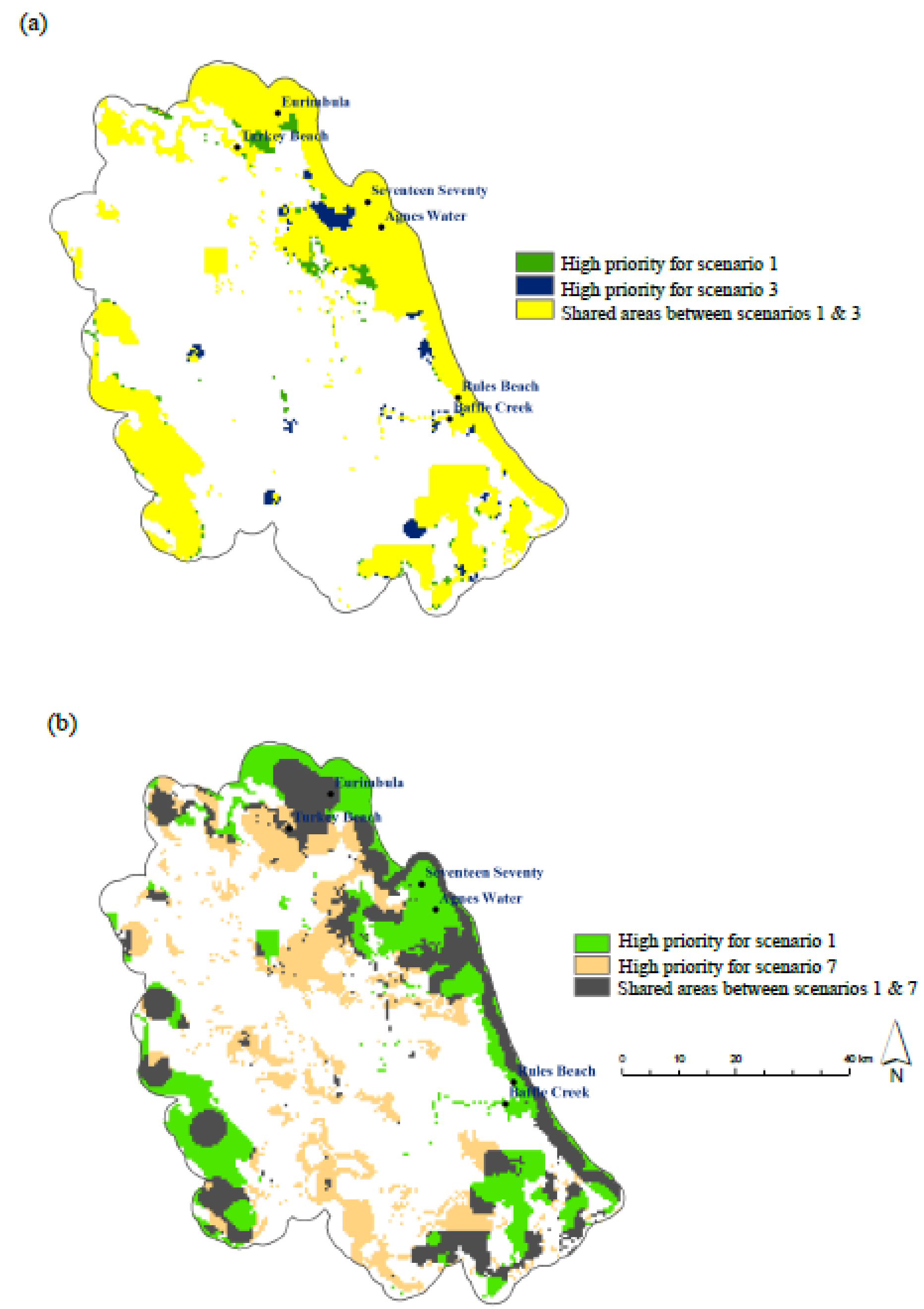

Fig. 2

Figure 3: Extent of valuable areas for conservation-compatible values remaining in the top 30% of the landscape under scenarios 3, 5, 6, and 7, compared with scenario 2. (Scenario 2= conservation-compatible social values-only, scenario 3= Biodiversity and conservation-compatible social values, scenario 4= biodiversity and conservation preferences, scenario 5= biodiversity and conservation-compatible social values with economic value, scenario 6= biodiversity and conservation-compatible

social values with development preferences, scenario 7= comprehensive multiple objective prioritization).

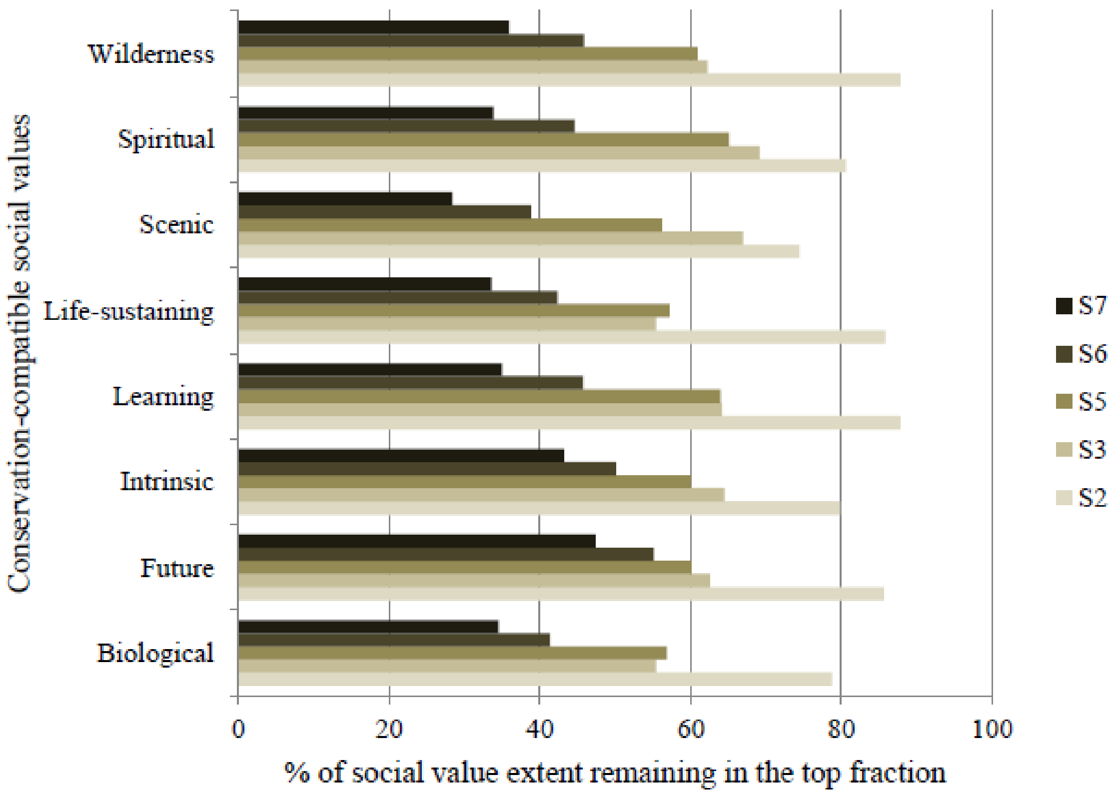

Fig.3