Methods for identifying spatially referenced conservation needs and opportunities

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Abstract

Protected area coverage is expanding rapidly in response to threats such as habitat degradation, resource overexploitation, and climate change. Given limited resources, conservation scientists have developed systematic methods for identifying where it is most efficient to protect biodiversity. To improve the outcomes of protected areas, planners have also sought to incorporate non-ecological data into protected area design, including data on conservation opportunity. Our study expands this literature using expert elicitation, participatory mapping, and a case study of the Southern Ocean to identify areas of conservation need and opportunity. We consider the spatial variation between need and opportunity, examine how socioeconomic and political factors influence the selection of areas, and investigate barriers to reaching consensus and establishing marine protected areas along the Western Antarctic Peninsula. We found that, while experts readily identified areas of conservation need and opportunity, most did not easily distinguish between the different types of opportunity proposed in the literature (existing, potential, and fleeting). Geographically, there were significant areas of overlap between need and opportunity, but areas of need were more restricted and specific, whereas areas of opportunity were more expansive and general. Biophysical and socioeconomic factors were most important in motivating the selection of areas of opportunity, followed by geopolitical and then scientific factors. Our approach to data collection and planning can provide insights into tradeoffs between ecological needs and opportunities for taking action, and therefore aid in identifying and reducing barriers to designating effective marine protected areas.

Resumen

La cobertura de áreas protegidas está creciendo rápidamente en respuesta a amenazas tales como la degradación de hábitats, la sobreexplotación de recursos y el cambio climático. Debido que los recursos disponibles para la conservación son limitados, los científicos han desarrollado métodos para identificar sitios en donde es posible proteger biodiversidad de forma eficiente. Asimismo, los planeadores para la conservación han buscado incorporar datos no biológicos para mejorar el diseño y resultados de áreas protegidas, incluida información sobre oportunidades de conservación. Nuestro estudio extiende nuestros conocimientos sobre el tema utilizando métodos para recolectar el conocimiento de expertos y técnicas de mapeo participativo para identificar áreas que es necesario proteger y aquellas en donde existen oportunidades de conservación, utilizando el Océano Austral como estudio de caso. En particular, estudiamos tres aspectos: la distribución espacial y similitud entre las áreas que requieren protección y las áreas de oportunidad; también examinamos cómo los factores socioeconómicos y políticos influyen en la selección de dichas áreas; y, finalmente, investigamos las barreras para llegar a un consenso y establecer áreas marinas protegidas a lo largo de la Península Antártica Occidental. Nuestros resultados indican que, si bien los expertos identificaron fácilmente las áreas de necesidad y oportunidad, la mayoría no distinguió fácilmente entre los diferentes tipos de oportunidades propuestas en la literatura (existentes, potenciales y efímeras). Asimismo, encontramos que existe un traslape importante entre las áreas de necesidad y de oportunidad. Sin embargo, notamos que las áreas de necesidad son más específicas y están restringidas geográficamente, mientras que las áreas de oportunidad son más genéricas y extensas. Los factores biofísicos y socioeconómicos fueron los aspectos más comúnmente utilizados en la selección de áreas de oportunidad, seguidos por factores geopolíticos y luego científicos. Nuestro enfoque para la recopilación de datos y planificación espacial puede: proporcionar información sobre el balance entre los requerimientos ecológicos de protección y las oportunidades para tomar medidas y, por lo tanto, ayudar a identificar y remover las barreras que previenen la designación de nuevas áreas marinas protegidas de forma efectiva.

1. Introduction

Over the past several decades, marine protected areas (MPAs) have become one of the primary conservation tools used in response to biodiversity loss stemming from overexploitation, habitat loss and degradation, and climate change (IPBES, 2019; UNEP-WCMC, IUCN and NGS, 2021; Watson et al., 2014). Given the limited resources available for the designation and implementation of protected areas, scientists have focused on developing methods for prioritizing where it is most cost-effective to protect biodiversity and reduce threats to its persistence (Groves and Game, 2016; Kareiva and Marvier, 2010; Kukkala and Moilanen, 2012). While early approaches recognized the economic and political constraints on conservation efforts (e.g. Groves et al., 2002; Margules and Pressey, 2000), they have continued to evolve to be more inclusive of stakeholders (as illustrated by Pressey and Bottrill's (2009) revised conservation planning framework), and more recent works have sought to better understand and incorporate social, economic, and political factors into conservation planning to account for how they shape outcomes for people and nature (Ban et al., 2013; Guerrero and Wilson, 2016; Levin et al., 2013). However, the best ways to consider and account for non-ecological factors in conservation planning are unresolved and context-dependent (Ban et al., 2019; Bennett et al., 2017; Naidoo et al., 2019).

One theoretical construct that has evolved for considering the role that these factors play in shaping conservation investments and outcomes is that of conservation opportunity (Knight et al., 2010; Mills et al., 2013), which Moon et al. defined as an "advantageous combination of circumstances that allows goals to be achieved" (Moon et al., 2014). In their 2014 framework, Moon et al. proposed three types of conservation opportunities: 'Existing opportunities', in which no barriers preclude actors from taking action to achieve a desired conservation outcome; 'Potential opportunities', in which actors are capable of identifying barriers to implementing conservation actions, the removal of which permits forward progress; and Traction opportunities (renamed 'Fleeting opportunities' in this paper to better reflect their ephemeral nature), in which actors can identify windows of opportunity that might arise from unpredictable or stochastic events such as a political election, pandemic, or catastrophic tsunami, wildfire, oil spill, or ice shelf collapse.

While previous studies have made significant contributions to improving our understanding of the factors that could influence conservation opportunities, they have been criticized for lacking sufficient clarity and methodological structure in how these are framed and used in conservation applications (Guerrero et al., 2020; Lechner et al., 2014; Raymond, 2014). In particular, conservation researchers and professionals have struggled to move beyond conceptual formulations to operationalizing the systematic collection of spatially referenced data on opportunity in ways conducive to planning efforts (Raymond, 2014). This paper endeavors to address this contemporary methodological gap in the field of conservation planning by developing a practical/operational approach to identifying areas of conservation opportunity to guide conservation planning.

Importantly, understanding opportunities requires identifying complementary 'conservation needs', which we define broadly as 'areas that require the implementation of some type of conservation action' to allow individuals the flexibility to identify needs based on a wide range of characteristics that they believe warrant protection. We purposely used a broad definition to accommodate the diverse values that people hold about nature in conservation planning (Álvarez-Romero et al., 2018; Wallace et al., 2021; Whitehead et al., 2014). Under this definition, areas of need can be characterized by any of the following: ecological characteristics such as species richness, endemicity, abundance, genetic or functional diversity; perceived spiritual, philosophical, recreational, cultural, or aesthetic values; the presence of important historical sites; unique geophysical characteristics such as mountain ranges or channels; resilience to climate change; or their potential to prevent the adverse effects of human activities such as fishing or mining. Without considering information about conservation needs, pursuing conservation opportunities would lead to protected areas being residual to extractive uses of the land and sea, which have questionable value for conservation (Cockerell et al., 2020; Devillers et al., 2015; Pressey et al., 2015). Consequently, we argue that an integrated understanding of conservation need and opportunity can improve the implementation and outcomes of conservation actions, which has been described as 'informed opportunism' (Arponen et al., 2010; Game et al., 2011; Pressey and Bottrill 2008).

Given their broad and multidisciplinary approach, we built upon Moon et al.'s (2014) conceptualization of conservation opportunity to develop an operational framework that can help conservation planners identify, understand, and map both areas of conservation need and opportunity to guide planning. Our proposed operational framework also builds on expert elicitation (Martin et al., 2012) and participatory mapping (Wahle and D'Iorio, 2010) literatures to operationalize the identification and mapping of areas of conservation need and opportunity. The proposed framework aims to link spatially referenced areas of opportunity with data on socioeconomic, geopolitical, and scientific factors that could influence the location of new MPAs. Here we contribute to advancing the theory and methodological application of conservation opportunity by pursuing the following research objectives:

1) Assess whether Moon et al.'s (2014) conceptualization of conservation opportunity and its three distinct sub-categories are cognitively accessible to participants and facilitate the collection of conservation opportunity data and exploration of spatial variations within it;
2) Identify areas of perceived conservation need and conservation opportunity, and assess the extent to which conservation needs can overlap with opportunities;
3) Examine the factors motivating participants' delineation of areas of opportunity to further understand the concept of conservation opportunity and its application to conservation planning; and
4) Identify barriers to taking conservation action and develop a series of recommendations regarding how data on conservation need and opportunity can provide additional information to guide negotiations in conservation planning.

To achieve these objectives, we use the Southern Ocean as a case study. We chose this particular region because the international environmental regime that governs the Southern Ocean has been working to establish a large-scale network of MPAs for the past decade. Besides seeing this as an opportunity to help develop useful approaches to inform an ongoing planning process, we also believe it provides an opportunity to understand the different social, economic, and political factors that can influence the selection and configuration of new conservation areas that underpin these types of real-world negotiations. Recently, there has also been significant interest in the international environmental agreements that govern the Southern Ocean because of their potential to provide broader insights into high seas area-based management (De Santo, 2018), the factors leads to successful political/diplomatic outcomes in high seas governance (Sykora-Bodie and Morrison, 2019), and how this particular regime might co-exist with a new instrument focused on managing biodiversity in areas beyond national jurisdiction (Gardiner, 2020).

We also adopted a 'process'-focused principle to guide our inquiry given the highly political nature of the case study that we present in the following section. In recognition of its highly political nature and the fact that our findings could negatively affect the negotiations, we sought to present them in such a way that avoids interfering in the discussions while still providing information that can be useful and complementary to existing and ongoing conservation efforts in the region. We focus our discussion on the topics of conservation needs and opportunities in conservation planning, and thus avoid discussing the actions of any specific actors or the politics surrounding these negotiations, which are outside the scope of this study.

2. Methods and data analysis

2.1 Case study

The Southern Ocean, which surrounds the Antarctic continent, encompasses nearly 10% of global oceans, and plays a crucial role in regulating global climate (Constable et al., 2014; Doney et al., 2012; Rintoul, 2018). Although it remains one of the most intact marine ecosystems on earth, it faces numerous threats, including fishery expansion and a rapidly changing climate (Chown and Brooks, 2019; Chown et al., 2015; Halpern et al., 2015). The region is governed by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), an international environmental regime that entered into force in 1982 (De Santo, 2018; Gardiner, 2020; Press et al., 2019). CCAMLR uses consensus-based decision-making, practices precautionary, ecosystem-based management, and is guided by a mandate for conservation, which is enshrined in Article II (1) and states that the primary 'objective of this Convention is the conservation of Antarctic marine living resources' (*Convention on the Conservation of Antarctic Marine Living Resources*, 1982).

To achieve the principles outlined in the Convention, the CAMLR Commission has embarked on a process to designate a representative network of MPAs. In 2011, CCAMLR agreed upon Conservation Measure (CM) 91-04, a 'General framework for the establishment of CCAMLR Marine Protected Areas,' which set up a structure and process for establishing a representative network of MPAs based on the best available science (Gjerde et al., 2016; Grant, 2012; Wenzel et al., 2016). Since that time, CCAMLR has established two MPAs—one on the South Orkney Islands Southern Shelf marine protected area (SOISSMPA; 2009) and a second in the Ross Sea region marine protected area (RSRMPA; 2016)—with additional proposals by Australia, the European

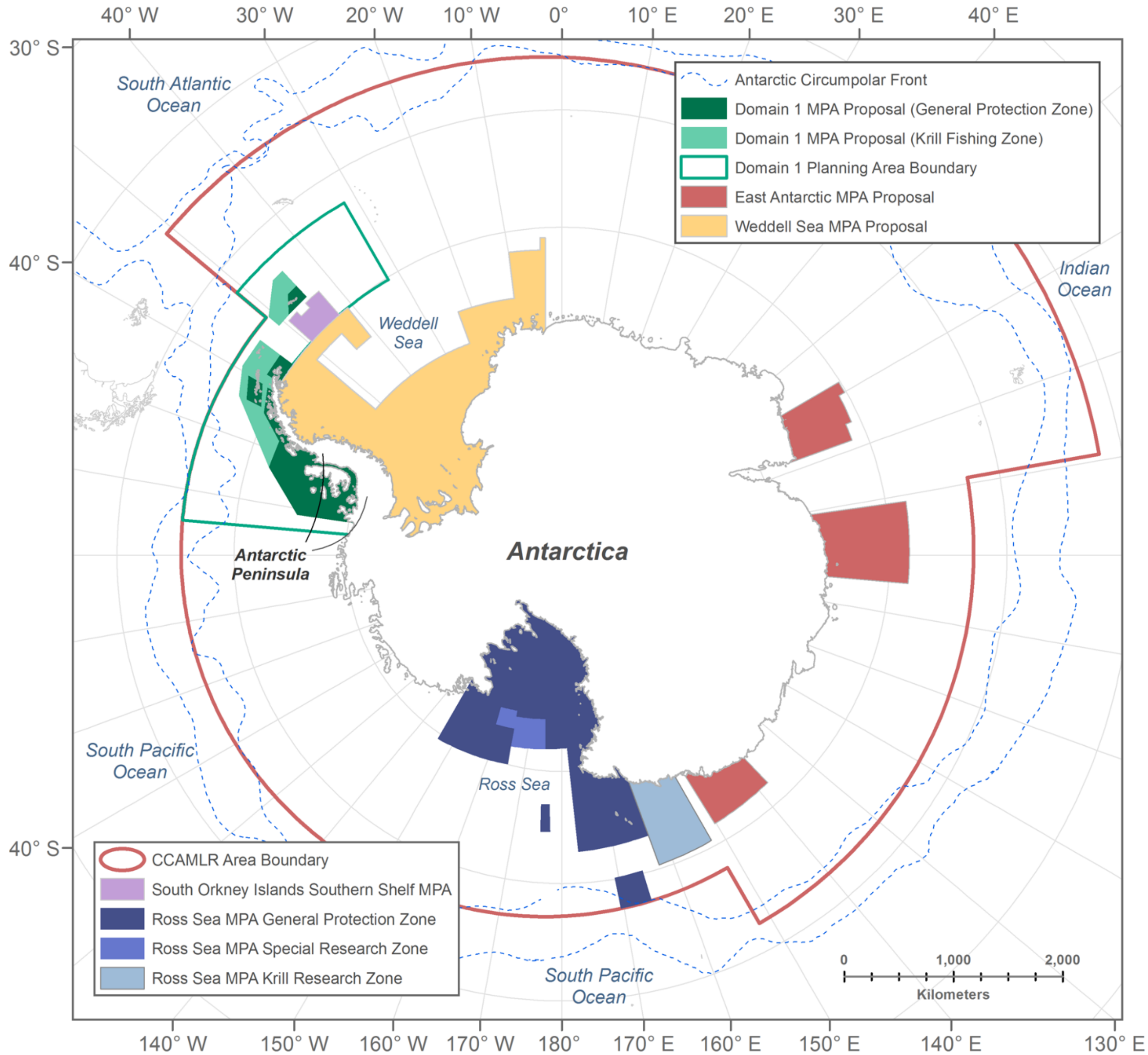

Figure 1: *Case study area - The red outline identifies the area under management by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) surrounding the Antarctic continent. Shaded areas show existing and proposed marine protected areas, where different activities are regulated. The South Orkney Islands Southern Shelf MPA and the Ross Sea MPA's General Protection Zones are areas where commercial fishing is prohibited, while the Special Research Zones allow limited fishing for scientific research purposes and the Krill Research Zone permits limited scientific fishing of krill species.*

Union, France, Germany, Argentina, Chile, and others currently under consideration (CCAMLR, 2011).[1] Here, we focus on the Western Antarctic Peninsula (Figure 1) and Domain 1 planning area,

[1] For more background on the history, politics, and policies of CCAMLR see: Cordonnery et al., 2015; Everson, 2015; Hemmings et al., 2018; Miller and Slicer, 2014; or Sykora-Bodie and Morrison, 2019. We have not included a discussion of these due to space constraints and the scope of this paper.

for which Argentina and Chile have proposed an additional MPA (the Domain 1 MPA) that would promote multinational monitoring of and scientific research on marine living resources, assess the impacts of the krill fishery on dependent predators, and 'ensure a sustainable development of the Antarctic krill fishery' (Delegations of Argentina and Chile, 2019; Sylvester and Brooks, 2019).

The Commission's ongoing work shares many similarities with the broader trajectory of conservation planning, because the organization is considering how to incorporate non-ecological data into designing a representative network of MPAs. While Argentina and Chile have integrated hundreds of ecological data layers into a Marxan-driven spatial prioritization analysis to delineate areas to be considered for new MPAs (Delegations of Argentina and Chile, 2019), there have been calls by parties with concerns about the proposed MPAs to incorporate socioeconomic considerations into the Domain 1 MPA proposal (the Domain 1 planning area encompasses the Western Antarctic Peninsula and South Scotia Arc). In response, Argentina and Chile (the lead proponents of the proposal) have incorporated a fisheries 'cost' layer to address concerns about potential economic losses, which is critical because significant krill fishing (and tourism) occurs along the Western Antarctic Peninsula and around many of the sub-Antarctic islands contained within Domain 1. Yet, this approach does not account for the broader range of underlying geopolitical, socioeconomic, and scientific concerns and considerations shaping the negotiations (e.g. existing scientific research programs, global conservation pressures, tourism, etc.) , which current conservation planning practices consider to be critical (Álvarez-Romero et al., 2018; Ban et al., 2013; Pressey and Bottrill, 2009). As a result, discussions around the Domain 1 MPA proposal will benefit from new and complementary approaches to identifying and incorporating Members' varied interests as CCAMLR works to establish additional MPAs.

The Western Antarctic Peninsula is a particularly useful case study for a number of reasons. First, as noted above, CCAMLR is considering how to incorporate non-ecological data into designing a representative network of MPAs. Second, CCAMLR's mandate to manage human activity and protect the Southern Ocean's marine living resources allows us to focus directly on a pre-determined set of actors with significant interests, knowledge and authority over the ecosystem in question. Third, the geographic isolation of the region and the comparatively low level of current human activity limit the number of actors and factors causing change, thereby reducing the overall complexity of the system. Finally, CCAMLR is active in high seas conservation, having established two high seas MPAs—the SOISSMPA and RSRMPA (Figure 1) (Everson, 2015; Miller, 2011; Wenzel et al., 2016). In short, CCAMLR's record of implementing conservation and management measures through a consensus-based process can provide relevant insights on the role of opportunities and barriers in enabling global efforts to protect biodiversity in areas beyond national jurisdiction (Coetzee et al., 2017; De Santo, 2018; De Santo et al., 2019; Smith and Jabour, 2017). At the same time, it also offers an opportunity to study how socioeconomic, geopolitical, and scientific considerations can shape MPA design and inform investments of limited resources to achieve desired conservation outcomes.

2.2 Structured expert elicitation protocol

We used expert elicitation and participatory mapping techniques to collect spatially referenced data on conservation need and opportunity (Hemming et al., 2017; Levine and Feinholz, 2015; Martin et al., 2012; Wahle and D'Iorio, 2010). Expert elicitation and participatory mapping techniques are widely used in conservation planning where socioeconomic and/or ecological data are scarce or insufficient and urgent decision-making is required (Burgman et al., 2011; Martin et al., 2012).

We selected experts (also referred to as 'participants') using a modified purposive sampling method, based on their participation in the Domain 1 MPA expert working group that, at that time, consisted of 29 individuals from CCAMLR member countries who were nominated by delegations to participate in and advise on the development of the Domain 1 MPA. We say "modified" because discussions with some members of the working group helped identify members who were not currently active in the planning process, so inactive members were removed. Further, members not on the working group were added if they were perceived by peers as having high levels of knowledge about, and influence on, development of the Domain 1 proposal (e.g. observer delegation members who play external roles such as rallying broader political support, even if they do not participate in formal working group meetings). This resulted in a final list of 42 individuals from 11 country delegations, who were sent an invitation to participate that included a short project description, confidentiality statement, and consent agreement (Supplementary Material A; XYZ IRB #2018-0072). We received qualitative responses from 24 of the 42 individuals and spatial data from 19 of the 42 for response rates of 60% and 45%, respectively. Our expert respondents represented multiple member states including Argentina, Australia, Chile, the European Union, France, Germany, the United Kingdom, and the United States, and observer delegations including the Association of Responsible Krill harvesting companies (ARK), the Antarctic and Southern Ocean Coalition (ASOC), Oceanites, and the Scientific Committee on Antarctic Research (SCAR).

We collected spatial data by using SeaSketch, a web-based participatory planning platform that permits remote data collection and participant interaction and has been used successfully in collaborative design of MPAs (Goldberg et al., 2016; Johnson et al., 2020; *SeaSketch Training Manual*, 2014). We then provided participants with clear definitions of conservation need and conservation opportunity, step-by-step instructions on how to complete the mapping exercise and (within the SeaSketch platform) spatial reference data (e.g., management boundaries, research stations, bathymetry) to help participants orient themselves along the Western Antarctic Peninsula. We then asked participants to delineate areas of the Domain 1 planning area along the Western Antarctic Peninsula (Figure 1) that represented areas of conservation need (i.e. areas identified by experts as requiring some type of conservation action, in this case, designation as an MPA), and areas that matched the definitions of the three types of conservation opportunity outlined by Moon et al. (2014)—existing, potential, and fleeting (Supplementary Material B).

We followed standard questionnaire guidelines (Bernard, 2006; Fowler, 2013) to develop a series of questions that elicited information on the underlying biophysical, socioeconomic, and geopolitical factors that motivated participants to identify those locations as areas of either conservation need or opportunity (see Supplementary Material C). Participants were permitted to skip questions, and a final question prompted them to consider any other factors that might potentially influence the designation of MPAs in Domain 1 that had not yet been considered.

2.3 Data analysis

2.3.1 Qualitative data

We coded and analyzed responses to open-ended questions in QSR NVivo 12.6.0 to address research objectives one, three, and four. Based on earlier research findings reported in XYZ (2019) about the key factors in negotiated outcomes in CCAMLR, we used a pre-determined coding structure and then added to it throughout the process as additional themes emerged from the data (Supplementary Material D). The four main categories of influences on participants' spatial delineations were biophysical, geopolitical, scientific, and socioeconomic (Supplementary Material D). Additional coding accounted for case-specific variation (e.g. the potential for catastrophic events to shape conservation efforts).

To analyze our data, we began by focusing on our first objective, which consisted of determining whether the framework was cognitively accessible to participants and facilitated data collection, i.e., delineating areas of conservation opportunity. We assessed this by analyzing whether participants were able to identify areas of conservation opportunity with qualitative attributes that matched the three categories proposed by Moon et al. (2014). We coded the data into three response types: 1) non-responses; 2) responses that provided spatial data where the defining characteristics of the three opportunity types were indistinguishable to participants; and 3) responses that provided spatial data where the characteristics of the three opportunity types were clearly interpreted.

Because our second objective was associated with the spatial data (discussed in the next section), we next focused on our third objective, which consisted of investigating factors underpinning participants' delineation of areas of opportunity. Pre-determined root nodes (categories used for coding in NVivo 12.6.0 software) corresponded to motivations that were biophysical (e.g. the natural environment, wildlife, and areas facing threats), socioeconomic (e.g. fisheries, tourism, and shipping), geopolitical (global politics, territorial claims, and the global conservation movement) and scientific (e.g. lack of data, existing research programs), with some of the sub-categories emerging during coding.

Finally, we focused on the fourth objective, which consisted of identifying barriers to taking conservation actions. We used the same coding structure as for the third objective to review responses to questions about barriers that participants thought were blocking progress on proposed MPAs (Supplementary Material D). We also reviewed responses to other questions (Supplementary Material C) containing relevant information and supplemented these with data from interviews completed for related research (see XYZ, 2019; XYZ IRB #2018-0072). All of these data were synthesized for recurring themes and patterns.

2.3.2 Spatial data

Turning our attention to our second objective, ESRI shapefiles representing need and opportunity and the corresponding attribute data were exported from SeaSketch and processed using ArcGIS Desktop 10 software package (ESRI, 2019). We analyzed existing, potential, and fleeting categories of opportunity separately, and also pooled them into a single 'combined opportunity' category. We then summarized the data at the level of individually drawn polygons with spatial statistics (e.g. area, perimeter), calculated areas of convergence and spatial variation between need and opportunity for each individual respondent (Supplementary Material E) and created polygon hotspot maps that represented areas of higher and lower selection frequency.

Initial data exploration suggested that the areas of conservation need were much smaller than areas of conservation opportunity. To investigate this further, we ran a Welch's two sample t-test on the areas of polygons for conservation need and opportunity. However, because the dataset contained a few extremely large outliers (one participant delineated a 'need' polygon covering the entire planning area), we chose to trim it. Rather than completely removing these outliers, as some methods advocate (Cook et al., 2014; Lechner et al., 2014; Tulloch et al., 2014), we took a more conservative approach and used Winsorization to cap the dataset at the 95^{th} percentile by removing outliers beyond that cutoff point and replacing them with the value at that point (Raymond, 2014). This approach ensured that participants' responses were not discarded, and that the means of the conservation need and conservation opportunity areas were less impacted, but that the most extreme outliers were adjusted back to the 95^{th} percentile.

To determine the extent to which the conservation need and opportunity datasets clustered and overlapped, we used the Generate Tessellation tool to create a 100 km^2 hexagonal mesh, which we then overlaid on the polygons. Polygons were counted within a hexagon if they covered more than 50% percent of that hexagon. The resulting attribute data attached to each hexagon was a count of the number of times that hexagon had been included in polygons representing need and/or opportunity.

We used two spatial autocorrelation tests to assess the extent to which areas of need and opportunity overlapped. To test for spatial clustering within both conservation need and opportunity, we ran a Moran's global autocorrelation test, which is a measure of similarity between objects expressed as a coefficient between -1 (perfect clustering of dissimilar values) and +1 (perfect clustering of similar values). We then used a Spearman's correlation test, which is a non-parametric measure of the relationship between two continuous datasets expressed as a coefficient ranging from -1 to +1, to test whether there was a relationship between the count values in the conservation need dataset and the count values in the conservation opportunity dataset.

We used two approaches to gauge overlap between areas of need and opportunity. For this analysis, we recognized coincidence only if both types of areas had been selected by at least 33% or 50% of participants.

3. Results

3.1 Cognitive accessibility and utility of Moon et al.'s conceptualization of conservation opportunities

Qualitative analysis showed that Moon et al.'s framework presented some difficulties for structuring the collection of spatially referenced conservation opportunity data. Although interpretations of existing opportunity appeared generally to match its definition, participants frequently mislabeled polygons as representing 'potential' or 'fleeting' opportunities even though the associated attribute data did not accurately reflect the definition of those specific types of opportunities. As shown in Figure 2, non-responses and inaccuracies in the use of definitions increased consistently from existing to potential to fleeting opportunity, which is discussed further in section 4.1.

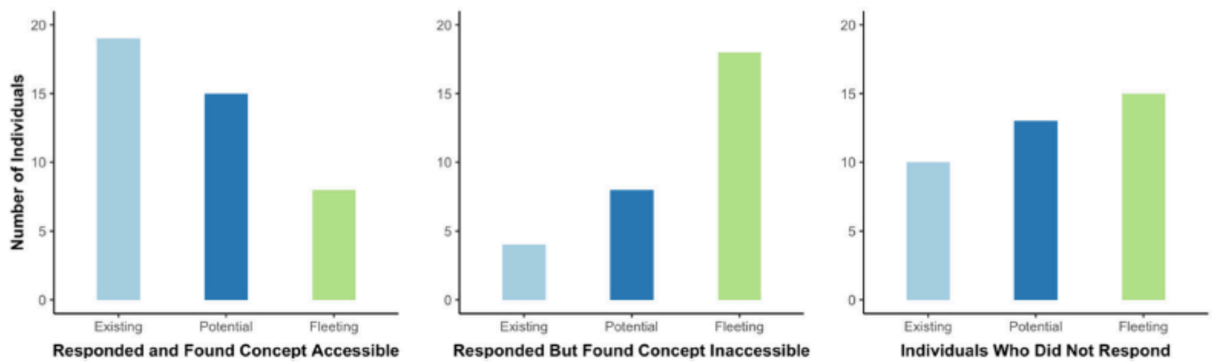

Figure 2: *Participants' responses to the questions that followed spatial data elicitations and collected qualitative data on the motivations for selecting these geographic locations.*

3.2 Spatial relationships between areas of opportunity and need

Our second research objective focused on identifying areas of perceived conservation need and opportunity along the Western Antarctic Peninsula and assessing the extent to which needs overlap with opportunities. In total, participants drew 111 individual polygons representing conservation need (59) and opportunity (52) in ArcGIS (Figure 3).

Welch's two sample t-test indicated that polygons representing areas of conservation need (mean area = 65,673 km^2; mean perimeter 1003 km) were significantly smaller than those representing areas of conservation opportunity (mean area = 205,410 km^2; mean perimeter = 1,897 km) (Welch's two sample t-test results: $t = -3.7559$; $df = 63.113$; p-value = 0.000379; Figure 4). Overall, areas of conservation need tended to be more restricted (spatially) and specific (in the attribute data), whereas areas of conservation opportunity tended to be more expansive and general. Typical illustrations of how areas of need were qualitatively described include 'Low Island', 'the Gerlache Strait and Palmer Deep Trough', and the 'western side of the South Shetlands'. Qualitative descriptions associated with areas of opportunity were generally less specific, e.g. 'the northern areas in D1', referring to the entire of Domain 1 offshore and northwest of the peninsula.

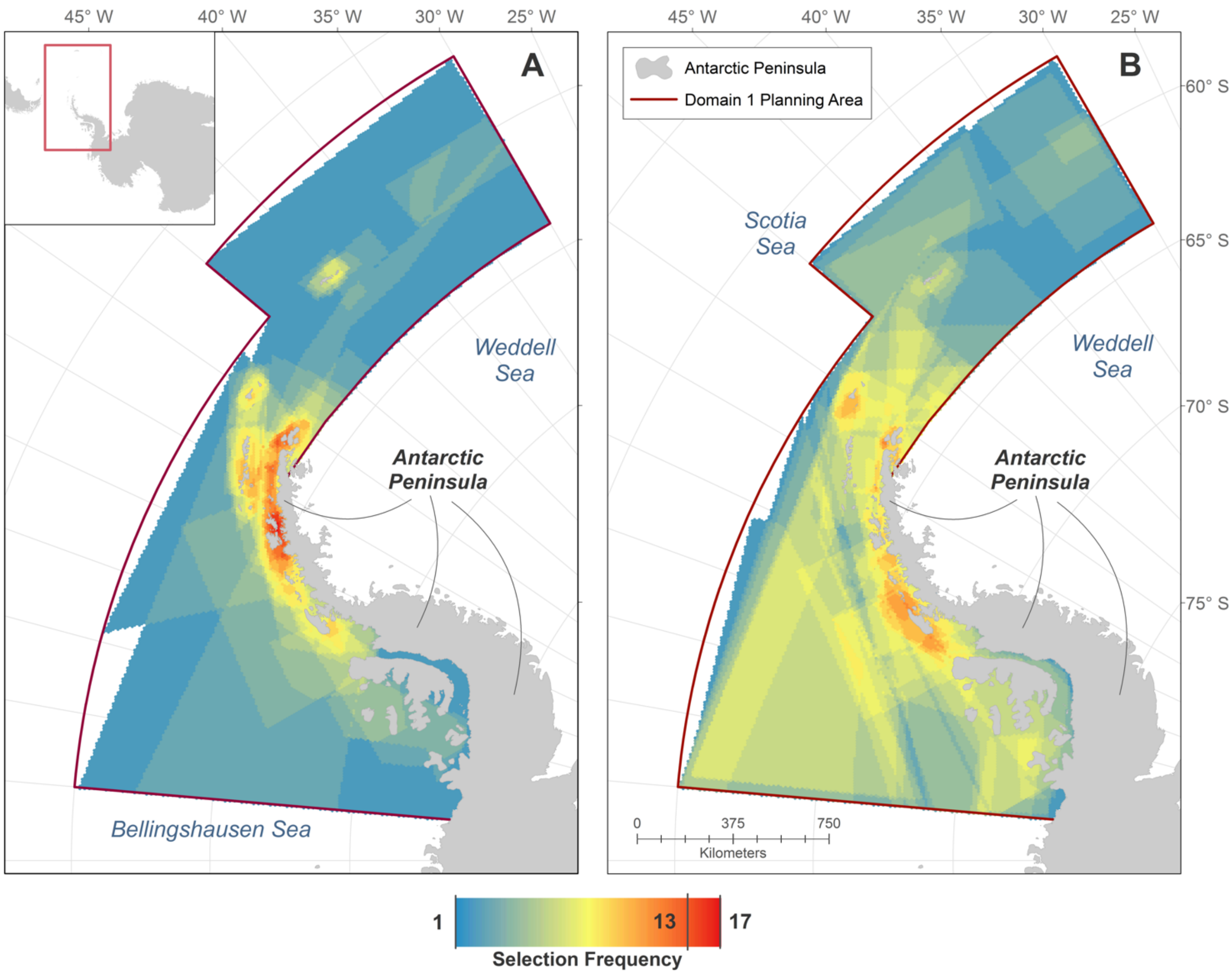

Figure 3: *Selection frequency of areas of conservation need (A) and combined conservation opportunity (B) standardized across 100 km² hexagons using drawn polygons from the 19 participants who provided spatial data, represented here using a South Pole Lambert Azimuthal Equal Area Projection. The highest selection frequency for conservation need was 17 (based on the 59 polygons) and the highest for combined opportunity was 13 (based on the 52 polygons). The area outlined in red on the main map (not the inset) identifies the Domain 1 study area along the Western Antarctic Peninsula.*

Areas of conservation need were almost exclusively inshore, and nearly all offshore areas delineated by participants were areas of conservation opportunity (Figure 3). The only exception were offshore seamounts (located along the Scotia Arc) identified as areas of conservation need, which were also spatially restricted and qualitatively specific. Areas of conservation need tended to be situated closer to the northeastern tip of the Peninsula, whereas areas of opportunity showed higher concentration further southwest (Figure 3). There was also a higher level of spatial overlap within the conservation need data than within the conservation opportunity polygons, which were more geographically diverse (Figure 3).

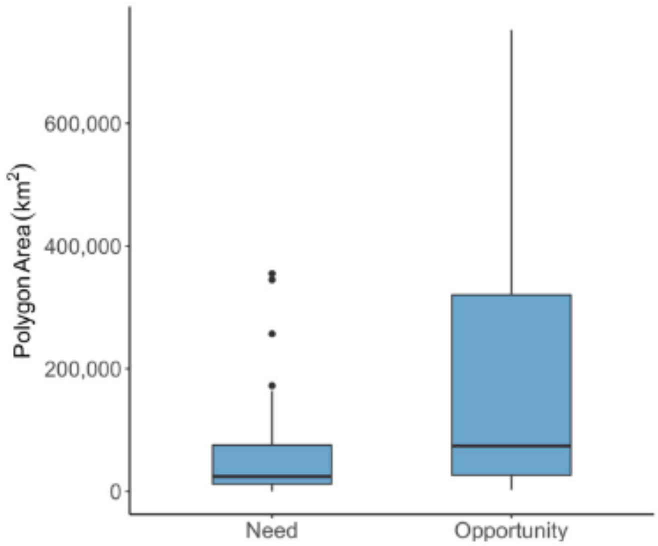

Figure 4: *Comparison of polygon areas for conservation need and combined opportunity. Outliers were capped and replaced at the 95th percentile according to standard Winsorization techniques.*

The Moran's global autocorrelation test results confirmed that both datasets exhibited high levels of non-random clustering (conservation need: Moran's *I*: 0.9373; p-value = 2.2^{-16}; and conservation opportunity: Moran's *I*: 0.9114; p-value = 2.2^{-16}). Participants frequently drew polygons around the same geographic areas when thinking about areas that would benefit from designating no-take MPAs (conservation need) but they were also relatively consistent in identifying areas where they perceived there to be greater conservation opportunities. Similarly, the Spearman's correlation test showed a strong positive relationship between the areas of conservation need and opportunity (S = 8.7418^{11}; p-value = 2.2^{-16}; Spearman's Rho = 0.661), indicating that many areas of high selection frequency for conservation need corresponded with areas of high selection frequency for conservation opportunity (Supplementary Material F).

Finally, our analysis of areas of overlap between conservation need and opportunity based on threshold functions (33% and 50%) further indicate there were notable areas of coincidence (Figure 5). As expected, the higher threshold value resulted in smaller areas of need, opportunity and coincidence, with the latter shrinking to the areas further north along the peninsula (highlighted in Figure 3). Further, it is noteworthy that using the higher threshold resulted in a particularly large reduction in the total area of conservation opportunities. In other words, conservation opportunities were much more widespread, but there was less agreement on where they were or might arise. Additionally, the areas of agreement between needs and opportunities around the South Orkney Islands and along the Southwestern Antarctic Peninsula disappeared when using the 50% threshold value. Regardless of the threshold value, the areas of need remained centered around the Gerlache and Bransfield Straits and South Shetland Islands along the Northwestern Antarctic Peninsula.

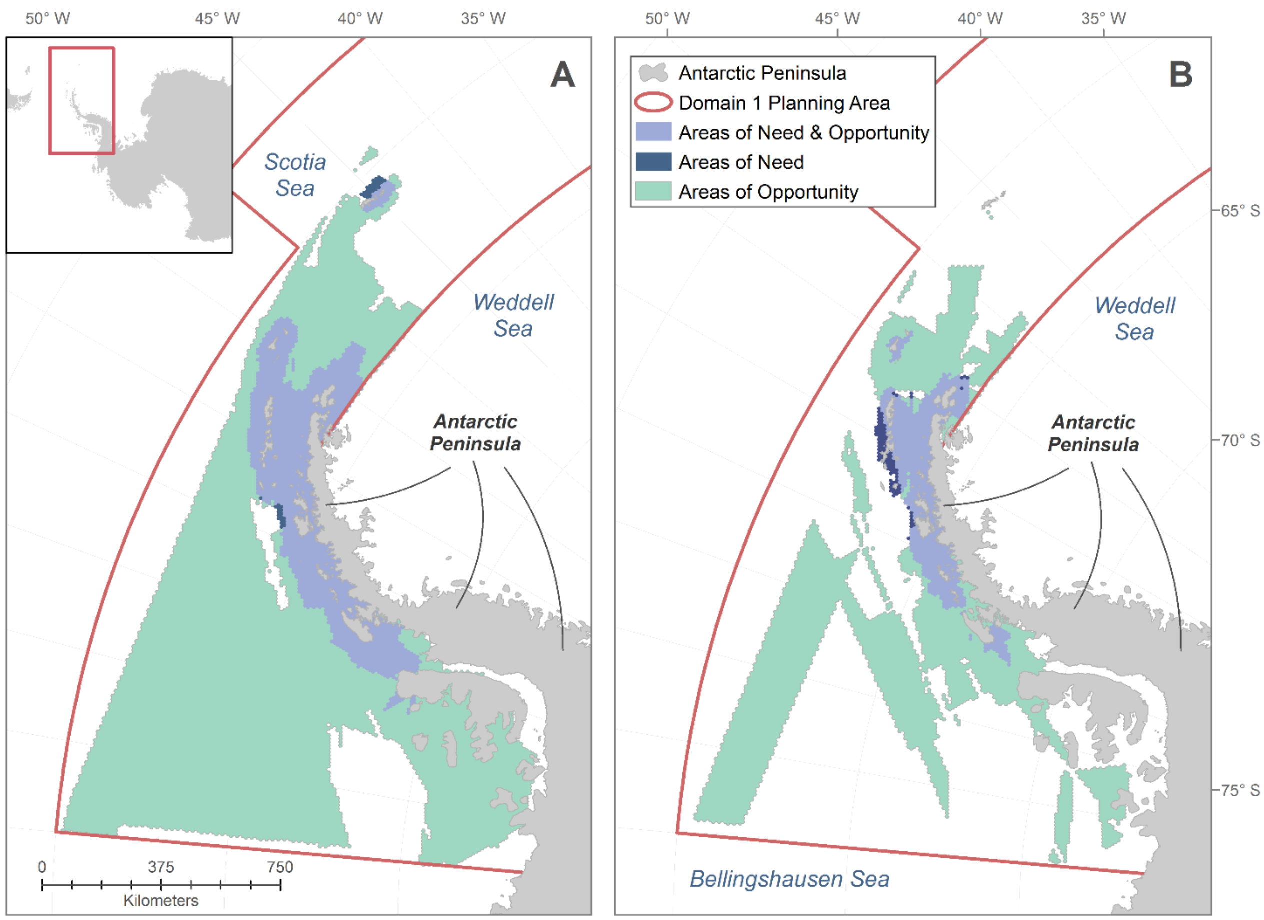

Figure 5: Areas of conservation need (dark blue), areas of conservation opportunity (green), and areas of overlap between the two (lavender). Two separate threshold functions were used—those areas that were selected by at least one-third (33%) of participants (A), and those areas that were selected by at least half (50%) of participants (B).

3.3 Motivations for the selection of areas of opportunity

We identified four categories of factors that motivated participants to identify specific geographic areas of opportunity and describe them here in the order of the frequency with which they were cited by participants (Table 1).

Biophysical factors

Biophysical factors were one of the two most important categories shaping participants' identification of areas of opportunity. In total, 80% of respondents made 99 individual references to biophysical factors that influenced their selections. Spatially, these responses were generally further north along the Western Antarctic Peninsula, inshore and proximate to sub-Antarctic islands, and more restricted in size. They also reflected three major subcategories: those related to wildlife, threat-based concerns, and the natural environment. In terms of wildlife, participants considered that areas with higher levels of biodiversity would be more likely to attract support for their protection. As for threat-based concerns, many participants were concerned that fishery interactions pose a significant threat to predators and suggested that areas vital for certain life stages, such as breeding or foraging areas, could be easier to include in any arrangements to establish new MPAs along the Western Antarctic Peninsula. Finally, numerous respondents referenced the natural environment, highlighting sea ice as a compelling factor, both its current extent, which renders some areas unfishable, and the likelihood that climate change will open new areas to exploitation, which encourages some Convention Members to resist designating these areas as MPAs.

Socioeconomic factors

Around 84% of participants reported that their identified areas of opportunity were influenced by socioeconomic factors. The 87 individual references were primarily related to existing or potential fisheries, with evident differentiation between areas where fishing currently occurs and areas of conservation opportunity. Many responses highlighted a general sense that fisheries and MPAs were incompatible, with one participant even justifying one of their opportunity selections by writing, "*This area, proposed by Argentina-Chile, is far from any conflict zone (fishing)*." Respondents also noted that market changes such as decreases in price or boycotts of krill products would likely play a major role in shaping MPA proposals and proponents' ability to successfully include areas in MPAs. Similarly, there was a broad consensus that the very act of designating new MPAs will change the economic calculus and likely lead the fishing industry to consider operations in areas that have previously been less lucrative. In short, participants generally agreed that areas that are inaccessible (ice-covered), without fisheries, or with a low potential for fishery development, have a greater likelihood of being designated as MPAs.

Geopolitical factors

The third most frequently cited motivation for selecting specific areas of opportunity was geopolitical, with 76% of the respondents making 61 individual references. The clearest message in the data was significant pessimism about the current approach to negotiating MPAs and a general perception that the success or failure of CCAMLR to designate MPAs does not depend on current scientific knowledge or future discoveries, but rather largely on politics. Many individuals felt that, unlike other CCAMLR topics, ongoing debates over MPAs are driven by traditional power politics concerned with national identity, historic territorial claims, and preserving access to resources. Many areas were deemed to be 'off-limits' because of historical claims, national research programs operating in the area, or countries' interest in establishing exploratory fisheries. Participants also noted the existence of a multi-level game in which developments at the U.N. and within the Antarctic Treaty System play a major role in shaping discussions and outcomes at CCAMLR.

Scientific factors

Scientific factors were the fourth most commonly mentioned, with 25% of participants making 19 individual references, suggesting that specific areas are more likely to be included in proposals or successfully negotiated if they have scientific value. Some of these references to 'scientific value' suggested that specific areas warranted protection because little is known about the benthic communities contained within them, or that protection should be afforded to areas with high levels of biodiversity as scientific reference areas. Several respondents also cited the importance of continuing existing long-term monitoring projects and research programs, and raised Antarctic Specially Protected Areas (ASPAs) or Antarctic Specially Managed Areas (ASMAs) to suggest that expanding or reinforcing them seemed to be a natural next step for CCAMLR (ASPAs and ASMAs are small spatial designations authorized under the Antarctic Treaty that can be established for scientific, cultural, or other purposes). Several participants also highlighted the importance of zoning MPAs to permit experimental fishing as a way to disentangle the effects of fisheries on the natural environment.

Table 1: *Reasons why participants identified areas as conservation opportunities. The columns represent: the four primary categories of motivating factors, along with the sub-codes that were used for coding purposes; the number of participants who referenced this factor or sub-code (note, numbers for the sub-codes are not intended to be added together, as some statements matched multiple codes); the total number of references for each factor and sub-code; and example quotes that illustrate the diversity of comments from participants.*

Factors motivating selection	Participants referencing	Total coding references	Example quotes
Biophysical factors	20	99	
Natural environment	17	35	• "Marguerite Bay: Recognized area of biological significance." • "Connectivity to existing South Orkneys and proposed Weddell Sea MPAs."
Wildlife	14	48	• "Home to the vast majority of Adelie penguins on the peninsula, as well as the only emperor penguin colony." • "Area of significant biophysical value (predators and benthic communities)." • "It does protect feeding areas for southern Fin whales, fur seal rookeries, and numerous breeding populations of seabirds that are currently declining."
Threat-based concerns	9	15	• "It is important to have some buffer zones in proximity of predator colonies to manage interaction between fisheries and predators." • "Climate change-induced biological changes (e.g. changes in population distribution and abundance; changes in the food chain; introduction of new species and pathogens)."
Socioeconomic factors	21	87	
Existing fisheries	15	27	• "These are regions where there is high krill fishing activity." • "In the South Orkneys, political/economic disagreements come from the proposed closure of the area west of the South Orkneys, where most of the krill fishery concentrates."

Factors motivating selection	Participants referencing	Total coding references	Example quotes
Potential fisheries & markets	9	18	• "This area is now being considered for some fishing. It is likely that this fishing activity is a response to the desire to implement the [Domain 1] MPA." • "If exploratory fishing discovers a resource in these areas, that would make a GPZ [General Protection Zone] more difficult."
No fisheries	12	26	• "It is also an area that is likely to remain more "Antarctic" in climate and should see considerable interannual availability in ice, meaning it is unlikely to be economically viable for the foreseeable future." • "This could be negotiated as a GPZ [General Protection Zone] as it doesn't contain areas of significant fishing interest."
Tourist operations	4	5	• "Tourism is an activity whose potential increase in the near future could impact decision making in this respect."
Geopolitical factors	19	61	
External – domestic & global politics	11	22	• "High level political engagement such as occurred between the U.S. and Russia over the Ross Sea may lead to more favorable conditions for negotiating GPZs [General Protection Zones]." • "There are higher level pressures at the level of the ATS [Antarctic Treaty System] and global politics that further inhibit progress on most conservation measures, including GPZs." • "There would need to be political instructions from high-level officials to a number of CCAMLR delegations that they need to agree to establish no-take MPAs in the Peninsula or negotiate in good faith to do so."
Global conservation pressure	5	5	• "All is related to access of fisheries resources but also about the negotiations at the UN about the high seas." • "While also being obvious, actions and motivations in the ATS [Antarctic Treaty System] are also driven more broadly by global interactions and tensions between parties. It's worth noting that the Ross Sea MPA was only progressed in CCAMLR as it was taken to the highest political levels by the US and given a global prominence that MPAs in Antarctica are unlikely to achieve again."
Objections to proposed MPAs	11	23	• "A primary concern among some members (particularly China and Russia) is the degree to which GPZs [General Protection Zones] may limit future fishing ambitions." • "I note here that current opportunities and challenges to establishment of MPAs and GPZs are politically, not ecologically-based. While proposals put forward by various proponents have a varying degree of evidence-base (including those established in poorly understood areas), debate within CCAMLR relates to political motivations to parties." • "A few nations (e.g. Russia, Republic of China), expressed several times in the past general and clearly economically motivated reservations against MPAs in the Southern Ocean. These states advocate a separation of exploitation/ management and protection of marine resources and consider MPAs in general to be an obstacle that makes fishing more difficult or even impossible."

Factors motivating selection	Participants referencing	Total coding references	Example quotes
Territorial claims	2	2	• "Clear political reasons, such as territorial claims in the Southern Ocean." • "Thus, pressure on fishing nations to come to the table and agree, and or a desire to protect future geopolitical claims may be the necessary driver to increase the desirability of protection."
Scientific factors	6	19	
Lack of data	4	8	• "All features are a problem with inadequate science - we need to categorically show the krill fishery has an impact - without this nothing will happen. This is why experimental fishing is so important." • "It is critical to provide new knowledge on the relationship between fishery and krill dependent predators."
Research programs/ Antarctic Specially Protected/Managed Areas (ASPAs/ASMAs)	3	6	• "[There is] Less fishing pressure [in this area, and an], existing ASPA No. 153 off Brabant Island." • "The footprint of human activities including tourism, fishing and scientific research is higher in this region than in any other similarly sized region in the CCAMLR convention area."

3.4 Barriers to designating MPAs

In addition to gaining insights into the key factors motivating participants' views about areas of conservation opportunity, we also sought to understand important barriers to action. Specifically, we wanted to identify the barriers preventing Members from agreeing to the proposed Domain 1 MPA in the Western Antarctic Peninsula or parts thereof. We categorized barriers in the same way that we categorized motivations for identifying opportunities—as biophysical (none identified), socioeconomic, geopolitical, and scientific. Here, we report our findings in the same order as the previous section and do not report frequencies because these data were both sparse and interspersed throughout the answers to nearly all of the questions.

Socioeconomic barriers: Participants' comments about economic barriers emphasized the need to find ways to account for existing fisheries and their potential displacement. The general opinion was that there will not be a successful agreement to set aside parts of the Western Antarctic Peninsula for conservation purposes as long as opponents of MPAs feel that their access to fisheries is threatened by MPAs that are entirely no-take. Some participants also suggested that, while consumer pressure is keeping the krill industry honest and cooperative, any boycotts of krill products might backfire and cause some companies to cease participating in the Association of Responsible Krill (ARK) harvesting companies. This is seen as a potential barrier because participants generally view ARK as a reasonably cooperative partner that, because of its representation of the industry, has the ability to speak on its behalf. Therefore, if ARK is weakened, some currently cooperative countries might feel the need to more actively or aggressively protect the industry's access to fisheries.

Geopolitical barriers: Participants identified a number of political barriers to successfully designating one or more MPAs in Domain 1. In particular, they argued that proponents will need to change the political calculation and incentives for China, Russia, Norway, and others, either by curtailing their current access to fisheries, or through higher-level political engagement that links CCAMLR's MPAs to other topics such as fisheries, climate change, or biodiversity beyond national jurisdiction. Many agreed that the debate is currently missing both a carrot and a stick: opponents either need to lose or be lured in by something of value (which might even be the same thing, e.g., fisheries access). For example, some proponents of MPAs have begun to consider refusing to permit exploratory fisheries or even to refuse consenting to re-opening existing fisheries until Russia and China agree to negotiate in good faith on MPA proposals. Although this is considered to be a significant escalation, many thought it is one of the few remaining courses of action and the only strategy likely to shift the boundaries of the debate. Finally, there were numerous suggestions that MPA negotiations would benefit from an improved process that authorizes and tasks working groups to solve specific problems, conducting more work intersessionally, and encouraging all parties to engage in good faith.

Scientific barriers: While participants did not suggest that specific scientific unknowns were acting as barriers and slowing progress on CCAMLR MPAs, they noted that improved knowledge about the natural environment could improve MPA proposals and alleviate some countries' objections. For example, they suggested that CCAMLR would benefit from a better understanding of krill dynamics and from clearly identified biodiversity hotspots that are particularly sensitive to human activities such as fishing and/or tourism. They also highlighted the need for down-scaled climate models that can help understand how a changing climate will affect the distribution of both sea ice and species. Respondents saw scientific knowledge as providing opportunities to circumvent barriers by answering these questions and/or by implementing more complex and effective fishery management mechanisms, expanding Antarctic Specially Protected/Managed Areas (ASPAs and ASMAs), or setting aside smaller, more discrete inshore areas of exceptional biodiversity such as Wilhelmina Bay.

4. Discussion

Despite widespread interest and efforts in understanding conservation opportunities to improve planning (Moon et al., 2014), there has been little recent progress on developing a methodological structure for collecting and integrating such data into protected area planning (Brown et al., 2019; Guerrero and Wilson, 2016; Karimi et al., 2017). Our research sought to address this key gap by developing a methodological framework to structure data collection for use in spatial analysis in support of MPA planning. We used the framework to collect spatially referenced conservation need and opportunity data, to compile information on the biophysical, socioeconomic, geopolitical, and scientific factors that motivated participants to delineate these areas, and to identify key barriers impeding further progress on establishing MPAs along the Western Antarctic Peninsula.

4.1. Conservation opportunity framework

As a reminder, Moon et al.'s (2014) framework defines **existing opportunities** as those opportunities to which no barriers currently exist and action can be taken, and **potential opportunities** as those in which barriers need to be overcome for action to be taken. Realistically, there will be no clear line between these categories. The potential for conservation action lies on a spectrum from a few minor barriers to many major barriers.

Although our results show that Moon et al.'s (2014) framework is useful for identifying spatially referenced areas of conservation opportunity, participants frequently mislabeled polygons and were only able to reliably identify two broad types of opportunities—those that currently exist and those that might one day exist—from the three categories of opportunity (existing, potential, and fleeting) proposed in the framework. This suggests that additional definitional clarity is needed prior to future applications of the framework and efforts to collect spatially referenced conservation opportunity data. Interrogating the framework also emphasized some of the difficulties that conservation practitioners might encounter when delineating spatially referenced conservation opportunities (Brown and Kyttä, 2018; Fauna & Flora International, 2013; Goldberg et al., 2016). Asking them to identify areas of potential opportunity requires practitioners to: 1) identify a potential factor or event that could shape future opportunities (e.g. political events, changes in market values, new scientific discoveries); 2) consider how and when these events could occur (e.g. shape countries' policies or increase demand for fish); and then 3) identify the geographic spaces that will be affected by them. Considering that there are many biophysical, socioeconomic, geopolitical, or scientific phenomena that could shape potential opportunities (e.g. changes in sea ice distribution, armed conflict, market price of fished species), it is comprehensible why distinguishing three types of opportunity can be cognitively challenging and could be simplified to facilitate data collection. Despite this difficulty, the framework has the potential to underpin a more structured collection of conservation opportunity data if it is used to carefully design methods for collecting data in a narrowly defined situation. For example, future studies could be restricted to geopolitical considerations or potential opportunities rather than all factors or types of opportunities.

4.2. Areas of conservation need and opportunity

We collected spatially referenced data on areas of conservation need along the Western Antarctic Peninsula to: 1) assess the feasibility of doing so in the same expert elicitation and qualitative data collection instrument that we were using to collect opportunity data; and 2) investigate the potential overlap between areas of need and opportunity. Our results indicate that participatory mapping tools such as SeaSketch can be useful for simultaneously collecting complementary datasets, which facilitates the identification and comparison of overlapping areas (Figure 5), further suggesting that using need and opportunity in tandem can help identify areas that are ecologically important, socially acceptable, and economically feasible (Brown et al., 2019; Whitehead et al., 2014).

Additionally, spatial data on conservation needs represented geographic locations that participants thought required protection and, although it was not our original intent, were broadly similar to those included in the original Domain 1 MPA proposal, with the primary hotspots located along the Northwestern Antarctic Peninsula (Delegations of Argentina and Chile, 2019). In 2018 and 2019, the delegations of Argentina and Chile submitted revised proposals to address concerns raised by a number of Members including how the proposed Domain 1 MPA would account for the distribution of the krill fishery (Delegations of Argentina and Chile, 2019). The 2019 revised proposal shifted the General Protection Zones (GPZs—areas prohibiting commercial fishing) southwest along the peninsula into areas that were more closely aligned with those we identified as representing conservation opportunities. This updated proposal suggests that the Domain 1 expert working group has also found these areas to have fewer barriers to designation and offer opportunities for progress.

Our approach to identifying spatially referenced conservation opportunities and operationalizing the concept of informed opportunism provides a mechanism for incorporating social, economic, and political considerations into protected area planning efforts. However, planners should be aware of the risk of selecting areas based solely on their lack of perceived barriers rather than their conservation value. 'Residual reserves' occur when planners focus on minimizing costs to human communities and fail to establish protected areas that achieve underlying conservation objectives (Devillers et al., 2014; Pressey et al., 2015). As a result, we must be clear that opportunity data cannot be used in isolation to identify conservation areas and that it must be combined with ecological data during the design phase using spatial prioritization methods (Guerrero and Wilson, 2016; Thiault et al., 2017). Conducting a planning process using only opportunity data will most likely result in residual reserves.

4.3. Motivations for selecting areas of opportunity

Our finding that socioeconomic factors shape perceptions of opportunity is consistent with other studies that have highlighted the influence that (for example, but not limited to) stakeholder engagement, indigenous rights/ownership, tourism, the potential loss of fisheries, and perceived restrictive government regulations have played in shaping and establishing MPAs in the Mediterranean Sea (Giakoumi et al., 2011), Hawaii (Levine and Feinholz, 2015; Rossiter and Levine, 2014), the Philippines (Ban et al., 2009), Fiji (Gurney et al., 2015), Australia (Day et al., 2019; Fernandes et al., 2009) and California (Fox et al., 2013; Gleason et al., 2013). This study adds to that list and echoes other literature that has noted the importance that countries such as China, Russia, Japan and others place on retaining access to marine resources in the Southern Ocean (Constable et al., 2000; Jacquet et al., 2016; Miller and Slicer, 2014). Despite participants' hesitancy to discuss how higher level geopolitical objectives shape Members' policy positions on MPAs, fisheries, or other issues for which CCAMLR has responsibility, many countries' Antarctic strategies are heavily shaped by the continent's strategic value (CCAMLR, 2019; 2018).

Many respondents also directly stated or indirectly suggested that fishing and MPAs are incompatible in the Southern Ocean context, although there is no scientific evidence in the literature to support this claim. This perception of incompatibility is likely the result of several years of contentious debates during which China and Russia in particular have sought to reinterpret the CAMLR Convention as a mechanism intended to facilitate resource extraction. Despite this, the Convention's text, the context within which it was signed, and legal analyses all agree that its original purpose was to implement an ecosystem-based management system that adheres to the precautionary principle in order to conserve Antarctic marine living resources (*Convention on the Conservation of Antarctic Marine Living Resources*, 1982; Everson, 2015; Fabra and Gascón, 2008; Miller and Slicer, 2014).

4.4. Barriers to establishing MPAs

Because the difference between 'existing' and 'potential' opportunities depends on the existence of barriers, we identified a number of perceived obstacles preventing the expansion of Southern Ocean MPAs. Some participants indicated that Members will need to address and/or ensure access to existing fisheries before consensus is reached on the proposed Domain 1 MPA, even though this need is inconsistent with the principles and rules of the Convention. Nonetheless, this perceived need is reflected in Argentina and Chile having twice revised the Domain 1 proposal in response to delegations raising concerns about access to fisheries (Delegations of Argentina and Chile, 2019). A number of countries have opposed designating additional MPAs because earlier iterations of proposals have restricted some access to currently fished spaces along the Northwestern Antarctic Peninsula, and individual scientists and diplomats are now confirming that finding a compromise is the primary barrier to reaching consensus.

4.5. Limitations of the study

Although we assembled a group of key individuals who could help us gain an understanding of the range of expert judgments and interpretations, and thus provide a diverse range of perspectives (Krueger et al., 2012; Tversky and Kahneman, 1974), the relatively small number of experts means that it would be wise to consider the data informative of, but not necessarily exhaustive or generalizable to, the larger population of individuals engaged in designing and negotiating the Domain 1 MPA (Morgan, 2014). Our group consisted of 24 key respondents primarily drawn from the Domain 1 MPA expert working group representing 11 key delegations, which is larger than is commonly recommended for expert elicitations of this type (Kuhnert et al., 2010; McBride et al., 2012). Similar expert elicitations in conservation typically range from having 8-20 participants (Aspinall, 2010; Burgman et al., 2011a; Burgman et al., 2011b; Hemming et al., 2017). This method is not intended to capture a representative sample, and we did not extrapolate our results to a larger population.

Spatial clustering of polygons around the Northwestern Antarctic Peninsula suggest some level of anchoring. Anchoring is a common phenomenon in expert elicitations whereby individuals base their estimates, predictions, or answers on known or initial starting points (Krueger et al., 2012; Kuhnert et al., 2010; Tversky and Kahneman, 1974). For example, when asked to provide a population estimate for Bengal tigers, an expert might start from published numbers and then adjust up or down based on their own personal judgment and knowledge. Thresholds or benchmarks, such as those in the IUCN Red List assessments, also influence experts' estimates based on their perception of whether or not the species should be designated as endangered or critically endangered (McBride et al., 2012). In this study, polygons for conservation need clustered inshore along the Northwestern Antarctic Peninsula in proximity to many research stations and projects, which might represent a possible cognitive bias towards geographic locations with which researchers are more familiar or knowledgeable.

The structure and format of the data collection also created a number of challenges. For example, although the logistics and cost were prohibitive given available resources, a workshop setting would have provided more opportunities for participants to ask questions, gain clarification, and engage in more discussion than was possible with remote data collection (Levine and Feinholz, 2015; Wahle and D'Iorio, 2010). For example, handful of individuals indicated that they only provided qualitative data because they found the participatory mapping component to be too onerous and confusing. It is possible that an in-person, interactive collaborative setting might have provided more clarity, but this was not possible for our study. However, other problems arise in group settings (e.g. groupthink, dominance, social influence, and overconfidence) and should be further considered if this approach is employed in other studies and settings (Burgman et al., 2011; Hemming et al., 2018; Sutherland and Burgman, 2015).

Although we provided our respondents with clear definitions of conservation need and the three sub-categories of conservation opportunities, detailed step-by-step instructions, and several spatial examples, one limitation of our study is that participants may still have interpreted these concepts differently. Therefore, planners should be careful when integrating our results, and more generally when using conservation opportunity data (like all data derived from elicitations or other measurements) into various planning and decision-making processes.

4.6. Future Research

Pursuing these research objectives provided a number of lessons for future consideration, particularly with regards to using conservation opportunity as a framework to understand the complex factors that shape the design and negotiation of MPAs. While some factors influencing the distribution of opportunity are unlikely to be mapped or made 'legible' (Martin and Hall-Arber, 2008), a properly articulated set of research objectives, and a framework tailored to them, could permit scientists to assemble datasets with a greater level of detail than has been done in the past (Guerrero and Wilson, 2016; Karimi et al., 2017; Martin et al., 2012). This could be accomplished by using potential changes in the market value of fished species or the distribution of sea ice to develop a range of values representing proxies for some of the factors identified as important in shaping conservation opportunity across space. Similarly, properly designed expert elicitations could produce sophisticated spatial datasets that characterize opportunities for conservation given historic territorial claims and national areas of influence in Antarctica. For example, geographic locations claimed or dominated by MPA proponents (e.g. Chile, New Zealand, France) might have a higher potential to be designated than those in locations where scientific and exploratory activities have been historically led or dominated by those opposing or less supportive of MPAs (e.g. Russia, Norway).

Additional research should build upon our initial efforts by utilizing questionnaires that further structure the theory and concept of conservation opportunity in practical ways that permit its inclusion in decision-support tools. In particular, it will be important for future research to consider the temporal and spatial aspects of conservation opportunity, in addition to effective ways to communicate the concept to participating individuals with questionnaires that can effectively capture the meaning of their responses. The remote aspect of the elicitation made it difficult to understand how conservation planners and practitioners interpret and define conservation opportunities. Future research should focus on developing and defining a clearer typology of 'conservation opportunities.'

5. Conclusion

Although conservation scientists developed the concept of conservation opportunity to help guide conservation actions and resource investments, it can also be used to consider and analyze the some of the social, cultural, and economic factors that could shape or motivate conservation planning, decision-making, and outcomes. This research project contributes to bridging the gap between theory and practice by assessing the potential for using conservation opportunity as a theoretical concept upon which to build an operational framework for data collection and analysis. In particular, we attempted to account for the role that biophysical, socioeconomic, geopolitical, and scientific factors play in shaping spatial prioritizations and protected area design using the case of the Southern Ocean, as well as barriers to establishing a representative network of MPAs in the region.

Most importantly, this research explored the potential of conservation opportunity theory to integrate social and ecological data into efforts to achieve positive conservation outcomes in real world planning settings. Connecting theory and practice is becoming more important as global environmental challenges grow in both scale and complexity.

Author Contributions

SSB, JGAR, GGG, RLP, and NCB conceived of the study, SSB and RLP secured funding for the project, SSB, JGAR, VMA, GGG, JC, RLP, and NCB designed the survey and mapping exercise, SSB collected the data, SSB analyzed the data with input from JGAR, GGG, JC, and NCB, SSB created the figures and led the writing of the manuscript, and JGAR, VMA, GGG, JC, RLP, and NCB provided edits and revisions to the final manuscript.

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Supplementary Materials

A. Supplementary Methods

Creating Reference Layers

The first step in building the participatory mapping tool was to develop spatial reference data for participants to use to orient themselves within SeaSketch. Data layers consisted of bathymetric data (the polar front and 200, 500, and 1000m isobath lines), management boundaries and areas (the Convention Area, Domain 1 planning area, and existing MPAs), CCAMLR Research Blocks, CCAMLR Ecosystem Monitoring Program (CEMP) sites, and research stations. These data were obtained from the General Bathymetric Chart of the Oceans (GEBCO) database and two online geographic information systems (GIS): CCAMLR's GIS (https://gis.ccamlr.org) and the Scientific Committee on Antarctic Research (SCAR)'s Antarctic Digital Database (https://www.add.scar.org) – both developed and maintained with support from the British Antarctic Survey. After sourcing these shapefiles, they were cleaned and hosted on ArcGIS Online as a map service that was referenced from within the SeaSketch portal.

Participatory Mapping Effort

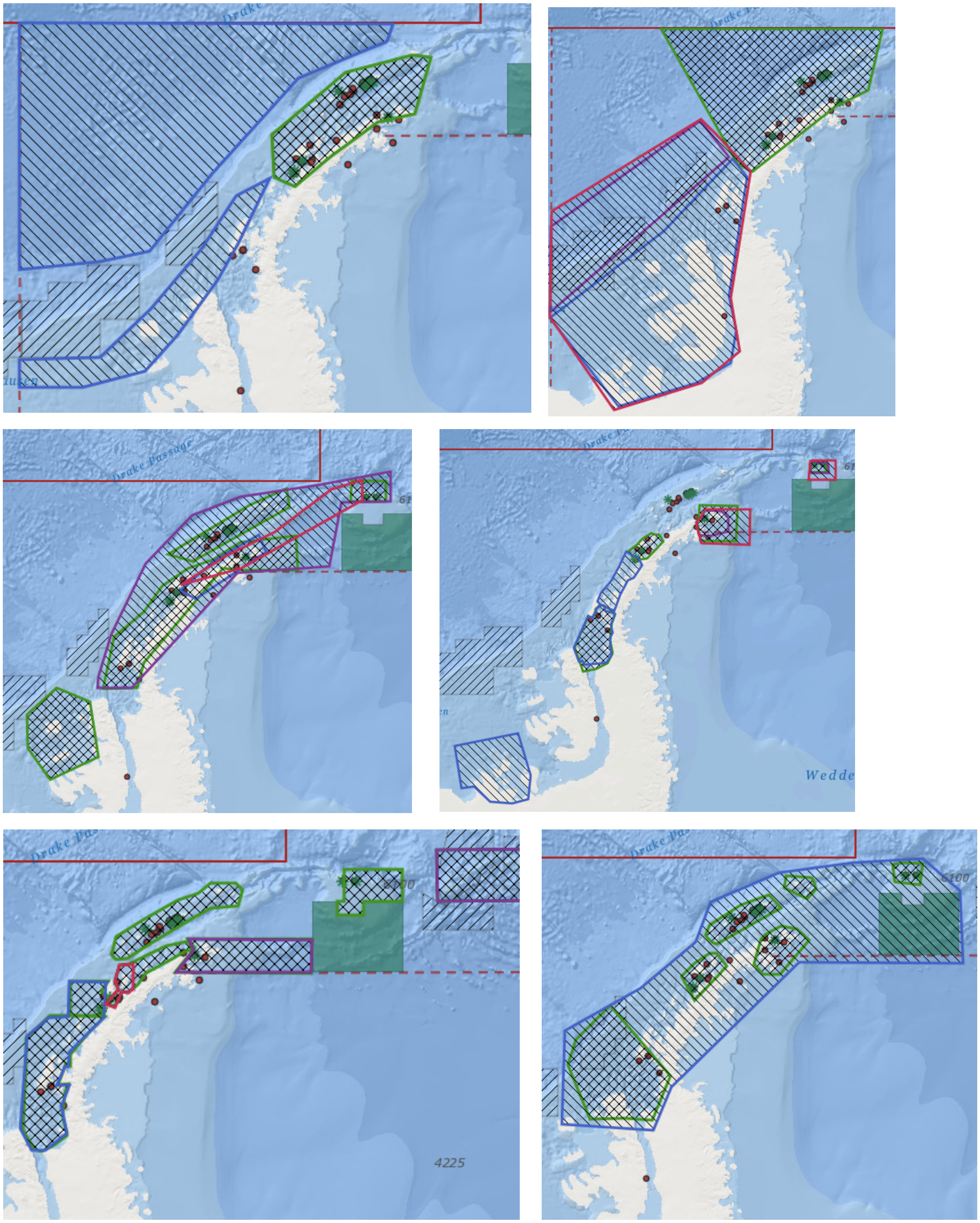
The study relied on participatory mapping techniques to elicit spatially-referenced socioeconomic and political data (Sykora-Bodie and Morrison, 2019). Data were derived by using SeaSketch, a web-based participatory planning platform developed by the McClintock Lab at the University of California, Santa Barbara with support from the Environmental Systems Research Institute (ESRI). Common qualitative survey techniques informed a series of questions (Supplementary Material C) on conservation needs and opportunities (Bernard, 2006).

Earlier qualitative research into the key factors influencing negotiations and agreement on the Ross Sea Region MPA suggested that participants are primarily motivated by conservation concerns, resource access, national identity, or scientific investigation (Sykora-Bodie and Morrison, 2019).

Identifying and Contacting Participants

A list of participants was developed by starting with the Domain 1 Group of Experts that is advising Argentina and Chile's development of the D1MPA proposal. After checking with key individuals, members who do not actually participate were removed, and additional suggestions of knowledgeable individuals were solicited, including from key nations not yet represented in the list. These were then cross-checked with other group members to validate nominated participants. This approach combined systematic stratified and snowball sampling methods to ensure sufficient coverage (Bernard, 2006). We then approached 42 individuals from 20 delegations during the 2018 CCAMLR negotiations to propose the idea and ask that they consider participating. Many agreed on the spot, but all were re-contacted shortly after the meeting (Dec. 2018) with a formal invitation, a short information sheet, the link to the survey, and a set of instructions for completing it. Of those invited to participate, 19 responded to the spatial questions and 24 responded to the qualitative questions (from 11 delegations), for response rates of 45% and 60%, respectively. Although we sought to incorporate a wide range of views, members of the Chinese and Russian delegations turned down repeated invitations to participate.

B. Spatial Responses Examples



C. Survey Questions

1) Areas in Need of Conservation Action

Directions: Please draw polygons around areas within Domain 1 planning area of the Western Antarctic Peninsula that you think require the implementation of some type of conservation action.

Q: Each time you 'Add a Feature,' please explain what your underlying reason was for doing so.

2) Existing Opportunity

Directions: Please draw polygons around the areas within Domain 1 where you believe that CCAMLR parties could immediately agree to establish GPZs tomorrow, given the current biophysical, socioeconomic, and political environment.

Q: Why have you selected these specific areas? Are there specific biophysical, socioeconomic, and/or political reasons (please specify type of reasons)?

Q: What changes or events might cause a reconsideration of these areas and reduce the opportunity of establishing GPZs?

3) Potential Opportunity

Directions: Please draw polygons around the areas within Domain 1 where barriers currently exist but could be readily removed to reach agreement on GPZs. *(Examples of 'barriers' include political disagreement, existing fisheries, insufficient scientific data, etc.)*

Q: What are the current barriers that could be removed to reach agreement on the placement of GPZs in each of the areas that you have selected? *(Please continue thinking in terms of political, socioeconomic, and/or biophysical events and specify which ones you are describing.)*

4) Fleeting Opportunity

Q: Please describe any changes or events that might open a window of opportunity for implementing conservation actions along the Western Antarctic Peninsula? *(Please continue thinking in terms of political, socioeconomic, and/or biophysical events and specify which ones you are describing.)*

Directions: Imagining that these changes or events happen, can you think of any areas where General Protection Zones could be quickly established? Please draw polygons around these areas within Domain 1 on the map to the left.

5) Are there any other socioeconomic or political considerations that you haven't yet mentioned in your previous responses?

6) Please indicate how much you agree or disagree with the statements below (Likert scales).

a) Fisheries should be prioritized above all else.

b) MPAs interfere with the 'rational use' of the Southern Ocean.

c) Threat assessments identifying specific threats are needed to justify the implementation of MPAs.

d) MPAs should be carefully designed to achieve clearly articulated scientific and research objectives.

e) The conservation of biodiversity should be prioritized above all else in the Southern Ocean.

f) Additional MPAs should be established to achieve conservation objectives.

g) I support my country's positions on MPAs.

h) My opinions and actions at CCAMLR are strongly influenced by and aligned with my country.

7) Please identify your areas of expertise. *(These could be areas of study, species, etc. For example, international law, diplomacy, conservation biology or planning, benthic ecology, polar ecology, biogeography, marine invertebrates, seabirds, penguins, krill, etc.)*

8) Do you have any advice on how this data collection method might be improved in the future? Please provide any feedback on the survey/web platform itself.

D. Coding Structure for Qualitative Data Analysis

We utilized a thematic assessment in which some categories were pre-conceived, and others were emergent.

<u>Cognitive Accessibility of the Moon et al. Framework</u>:

1) Existing
   a) Did not respond
   b) Responded and found accessible
   c) Responded and did not find accessible
2) Potential
   a) Did not respond
   b) Responded and found accessible
   c) Responded and did not find accessible
3) Fleeting
   a) Did not respond
   b) Responded and found accessible
   c) Responded and did not find accessible

<u>Factors Motivating the Selection of Conservation Needs and Opportunities</u>:

Four initial categories:

1) Biophysical
   a) Natural environment
      i) Biophysical features (productivity, oceanographic features, connectivity)
      ii) Important habitat
   b) Threat-based concerns
   c) Wildlife
      i) Cetaceans
      ii) Fish or benthic organisms
      iii) Krill
      iv) Penguins
      v) Pinnipeds

vi) "Predators"

vii) Seabirds

2) Geopolitical

   a) External to CCAMLR—domestic and global politics

   b) Global conservation pressure

   c) Objections to proposed MPAs

   d) Territorial claims

3) Scientific

   a) Research programs (ASPAs & ASMAs)

   b) Scientific uncertainty/lack of data

4) Socioeconomic

   a) Existing fisheries

   b) No fisheries

   c) Potential fisheries & markets

   d) Tourism

   e) Shipping

Three additional emergent categories:

5) Many competing interests

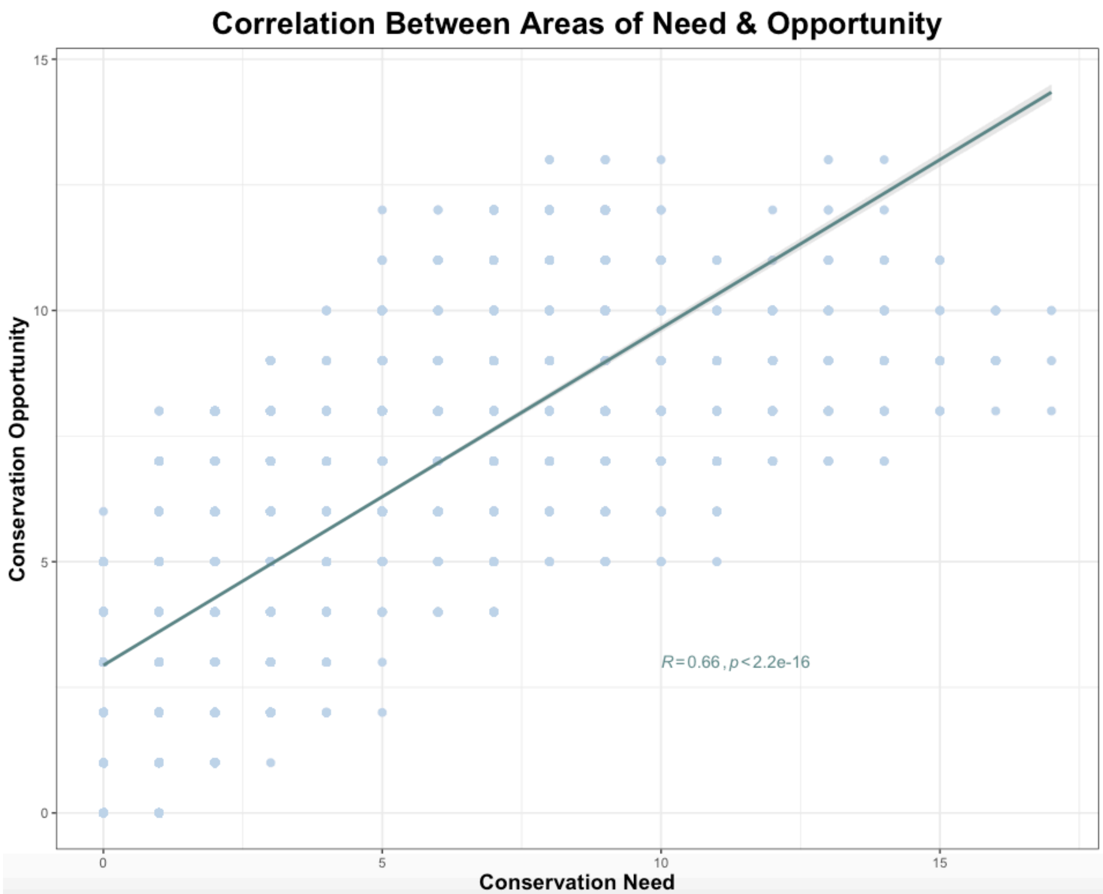
6) Few competing interests

7) Catastrophic event

E. Overlapping Area Calculations

Respondent	Need Total Area	Opportunity Total Area	Intersection Area	% of Need covered by Opportunity	% of Opportunity covered by Need
S12	247084.7903	27376.2489	7432.19674	3.01%	27.15%
S14	148247.6988	534630.8235	145976.8	98.47%	27.30%
S20	73693.42106	2291307.229	3820.69758	5.18%	0.17%
S18	294923.9416	0	0	0.00%	0.00%
S17	2829625.056	2550663.327	2546261.8	89.99%	99.83%
S22	286626.0841	511529.4639	225428.193	78.65%	44.07%
S1	479139.0952	1119870.868	1054.07573	0.22%	0.09%
S2	141410.5406	887732.6701	0	0.00%	0.00%
S6	5785.211951	730580.8154	0	0.00%	0.00%
S9	260930.4862	914625.3992	231867.1	88.86%	25.35%
S8	288959.8397	248099.3304	182161.4	63.04%	73.42%
S3	8096.359948	363304.3664	0	0.00%	0.00%
S4	108568.5718	183179.7671	64829.99	59.71%	35.39%
S15	774404.5349	443074.2836	0	0.00%	0.00%
S24	257118.41	181237.9144	121919.9	47.42%	67.27%
S10	4966.92982	209177.8453	0	0.00%	0.00%
S7	205562.1159	730945.4108	205562.12	100.00%	28.12%
S13	376281.61	362645.0931	304852.6	81.02%	84.06%
			12 of 18	39.75%	30.13%

F. Spearman's Autocorrelation Plot



Relationship between the selection frequency of hexagons containing conservation needs and opportunities (S = 8.7418^{11}; p-value = 2.2^{-16}; Spearman's Rho = 0.661). Note: that the data points are all evenly spaced, whole numbers because the standardization used a threshold function that included conservation needs and opportunities when they intersected > 50% of the hexagon. Therefore, the values for each hexagon are a whole number representing of the frequency with which each hexagon was selected when tabulating the polygons that intersected the hexagonal planning units.