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From spatial prioritization to conservation management in the Southern Ocean using the marine IBAs approach

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ABSTRACT

Implementing effective conservation action requires spatial prioritization exercises to be functionally integrated with a process for developing an implementation strategy. There is great potential for animal tracking data to inform marine management in the Southern Ocean. Using information on penguin distribution, a set of marine Important Bird Areas (mIBAs) has recently been identified around Antarctica. Large-scale spatial analyses like this are key to guide resources and the attention of decision-makers towards areas of significant value. Yet, protecting marine resources requires translating prioritization exercises into legally-binding conservation measures. Here we use one of the largest gentoo colonies in Antarctica as a case study to explore pathways for the utilization of the mIBAs approach in the design and implementation of conservation measures in the Southern Ocean. For scientists and organizations willing to have a policy impact, there are two main routes to contribute to Antarctic Treaty System (ATS) decision-making: through Parties' National Delegations, or through Experts and Observers. We provide three main recommendations for incorporating the results of spatial prioritization analyses into the agenda of ATS governance bodies using the mIBAs approach: 1. Differentiate the potential contribution of mIBAs to spatial prioritization from the potential contribution to conservation planning, two different stages in the conservation process; 2. Use methods, criteria and data for delineating boundaries of potential conservation areas according to the stage of the conservation process that the outputs are expected to contribute to; 3. Understand how Antarctic mIBAs might fit into the ATS conservation measures framework and ongoing deliberations.

1. Introduction

Antarctica and the Southern Ocean provide a variety of ecosystem services of global scope and play an important role in the regulation of climate, sea level, and heat balance (Wauchope et al., 2019). In recent decades, this region has been strongly affected by climate change and pressures derived from human activity, that generate biodiversity loss, alien species introduction, contamination, overexploitation of marine resources, and physicochemical changes in the marine ecosystem (Lee et al., 2022; Wauchope et al., 2019). Due to its remoteness, size and extreme conditions, the identification of ecologically relevant areas in the Southern Ocean depends on the extrapolation of information from spatially scattered data sets (e.g., Hindell et al., 2020). Animal tracking is often the only way to determine species overlap with threats and thus to assess potential impacts of those threats for species that range widely in the oceans (Hays et al., 2019). Thus, there is great potential for animal tracking data to inform marine management (e.g., Bestley et al., 2020; Hindell et al., 2020; Ropert-Coudert et al., 2020). Penguins have been identified as valuable indicators for the identification of areas of ecological relevance in the Southern Ocean (e.g., Handley et al., 2021). Tracking data from *Pygoscelis* penguins have revealed predictable feeding areas and highlighted areas of potential competition with the regional fishery at the Antarctic Peninsula and at nearby archipelagoes (Hinke et al., 2017; Trathan et al., 2018; Watters et al., 2020; Machado-Gaye et al., 2024, among others). For instance, tracking data from Adélie penguins (*Pygoscelis adeliae*) were used to help create the South Orkney Islands southern shelf MPA (Hays et al., 2019; Trathan and Grant, 2020).

The Important Bird and Biodiversity Area (IBA) program was established by BirdLife International in 1979 with the aim of identifying sites of importance for bird conservation at a global scale (note there are also similar proposals for mammals in the Southern Ocean). The Key Biodiversity Areas Programme (KBA) an initiative promoted by a partnership of thirteen global organizations including BirdLife International, IUCN and WWF, among others, takes the concept of "important areas", and applies it to all taxa, providing common criteria for identifying, mapping, monitoring, and preserving areas that play an important role in the persistence of biodiversity. Given that the designation of KBAs is based on the IBA framework, the latter also constitute KBAs by definition (KBA Programme, 2016). The delimitation of IBAs was initially focused on terrestrial sites and only began to consider IBAs in marine areas as recently as 2004 (Donald et al., 2019). The identification of ma-

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rine IBAs (mIBAs) was greatly enhanced by the proliferation of scientific studies providing information about the at-sea distributions of seabirds, especially those based on tracking individual birds (Dias et al., 2018). As a consequence, a standardized method (the mIBAs protocol) was developed to define important areas for marine conservation based on tracking data (Lascelles et al., 2016).

A recent study has identified a set of mIBAs around Antarctica that might contribute to marine resources management in the region (Handley et al., 2021). However, to advance in the protection of Southern Ocean resources there is a need for translating prioritization exercises like this into conservation actions. To move from science advice into actual conservation action it is useful to recognize three different stages in the conservation process: 1) conservation assessment (i.e., spatial prioritization), a short-term activity for identifying spatially explicit priority areas for conservation action; 2) conservation planning, a long-term process that complements a conservation assessment with a process for collaboratively developing an implementation strategy; and 3) conservation management, the activities and actions undertaken to achieve the objectives of the conservation initiative (Knight et al., 2006; Moilanen et al., 2011; Tallis et al., 2021). As IBAs boundaries are often identified with the aim of delineating discrete manageable units that are expected to provide the requirements of the trigger species (Donald et al., 2019), there is a risk of confusing the output of a spatial prioritization exercise like this (stage 1), with the output of a planning process (stage 2). Examples abound within the Antarctic Treaty System (ATS) on the challenges for moving from prioritization exercises into the adoption and effective implementation of legally binding conservation measures (e.g., Brooks et al., 2020; Goldsworthy, 2022; Sylvester and Brooks, 2020; Soutullo et al., 2022; Burrows et al., 2023). The geographic areas ultimately affected by these measures result from negotiations and are usually not the ones proposed in the initial conservation assessments.

Spatially explicit conservation measures within the ATS include, among others, MPAs adopted by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), and specially protected and managed areas (ASPAs and ASMAs) designated by the Antarctic Treaty Consultative Meeting (ATCM) (Hughes et al., 2023). Here we analyze a case study to discuss possible pathways towards the translation of large-scale spatial prioritization exercises into local-scale conservation measures that can be adopted and implemented under the ATS legal framework. We focus on two aspects of this process: 1) the need to improve the boundaries derived from coarse, large-scale, spatial analyses, incorporating locally generated information, and 2) the need to complement the spatial prioritization exercise with an implementation strategy that explicitly engages ATS Parties.

The case study focuses on Ardley Island, an ASPA located in the southern tip of King George Island, in the South Shetland Archipelago, which has also been designated as a terrestrial IBA (BirdLife International, 2024; Soutullo et al., 2022) and is surrounded by three mIBAs proposed by Handley et al. (2021). Ardley Island was designated an IBA because it hosts one of the largest breeding colonies of gentoo penguins (*Pygoscelis papua*) in Antarctica, meeting the A4ii IBA criteria, which includes sites that hold ≥1 % of the global population of a congregatory species on a regular basis (BirdLife International, 2024). On the West Antarctic Peninsula (WAP), the populations of this species are increasing, while the numbers of the other Pygocelid species are decreasing. The reasons behind these tendencies are still debated, although they are likely associated to life history traits that give gentoo penguins an advantage in changing environments, including a more flexible diet, foraging behavior and phenology, a lower degree of site fidelity, and the ability to relay eggs if they are lost early on in the incubation stage (Miller et al., 2009; Herman et al., 2020; Juáres et al., 2013).

Specifically, here we 1) assess the effects of using locally generated high-resolution data and alternative criteria to estimate individual penguins home ranges, on the boundaries of the conservation proposal; 2) frame the outputs of this analysis as inputs for a planning process to update the ASPA management plan; 3) discuss possible ways of generalizing this case study to other mIBAs in Antarctica. We expect this exercise to shed light on how to move from large-scale prioritization exercises in the Southern Ocean, into the policy process of creating and then implementing spatially explicit conservation measures on smaller scales.

2. Material and methods

For this study, we used tracking data from adult gentoo penguins (*P. papua*), collected during the austral summer seasons of 2019/2020, 2020/2021, and 2021/2022 on Ardley Island. Ardley Island (62°13′ S, 58°56′ W), in the southwest of King George Island/25 de Mayo Island, South Shetland Islands (Fig. 1), is an Antarctic Specially Protected Area (ASPA N°150), a CEMP site (CCAMLR Ecosystem Monitoring Program), and nesting site of one of the largest colonies of gentoo penguins in Antarctica (7704 breeding pairs in the 2023/24 season; this study).

Two main approaches have been used to delineate mIBAs in Antarctica using data on penguins: 1) estimating the at-sea distribution of birds based on the application of a modified foraging radius approach (Handley et al., 2021); 2) using a modified version of the mIBA protocol for its application to penguins (Dias et al., 2018). Following Handley et al. (2021), we focused our analysis on breeding birds during the chick-rearing stage. This is a critical phase of the annual cycle in terms of the requirement of provision to offspring, being the period when birds tend to aggregate most at sea. With a smaller foraging area accessible during that stage, the overlap between different individuals is necessarily higher, facilitating the identification of areas consistently used by a significant fraction of the tracked population (Dias et al., 2018). We studied the colony during three consecutive years, in line with suggestions by Beal et al. (2023). Approximately 20 individuals per season were tagged with Axy-Trek (70 × 40 × 15 mm, 69 g; TechnoSmart, Italy) loggers including GPS and other sensors. The recorders were attached on the birds' lower back feathers using Tesa® 4651 tape (Wilson et al., 1997). The loggers used represent <1 % of the body mass of an adult gentoo penguin (mean for Ardley Island 5604 ± 902.1 g; this study). They were programmed to record a position every 5 min. The tagged birds were recaptured in the nest after 5–8 days and the loggers were recovered to access recorded data. All penguin handling procedures were reviewed and approved by the Honorary Commission of Animal Experimentation of Uruguay (CHEA protocol N° 1312).

GPS data was analyzed using the R software (version 4.1.3; R Core Team, 2022). Excessive points recorded before departure and after arrival at the colony were manually removed, retaining only five points located at the colony in each case. To filter possible erroneous location estimates we removed points leading to horizontal speeds above 10 km.h^{-1}. This velocity threshold was chosen based on our data: <1 % of the records were above that value (Appendix S1). We linearly interpolated the raw GPS location data at regular 5 min intervals using the *interpolateTime* function of the 'move' R package.

For each individual, foraging trips were defined from the time birds moved >50 m from the colony to the sea until the time they were within 50 m of the colony again. Detailed methods for foraging trips identification are described in Machado-Gaye et al. (2024).

To translate the tracking data into areas delimited by their relevance to the colony, we used the R package 'track2KBA' (Beal et al., 2021), developed to implement the mIBA protocol. The process implies 3 stages: a) estimating individual core areas, b) assessing sample representativeness and c) quantifying spatial overlap among individuals and scaling up to the population level. However, our approach differs from that developed by Lascelles et al. (2016) and the modification introduced by Dias et al. (2018) for its application to Antarctic penguins in two main aspects:

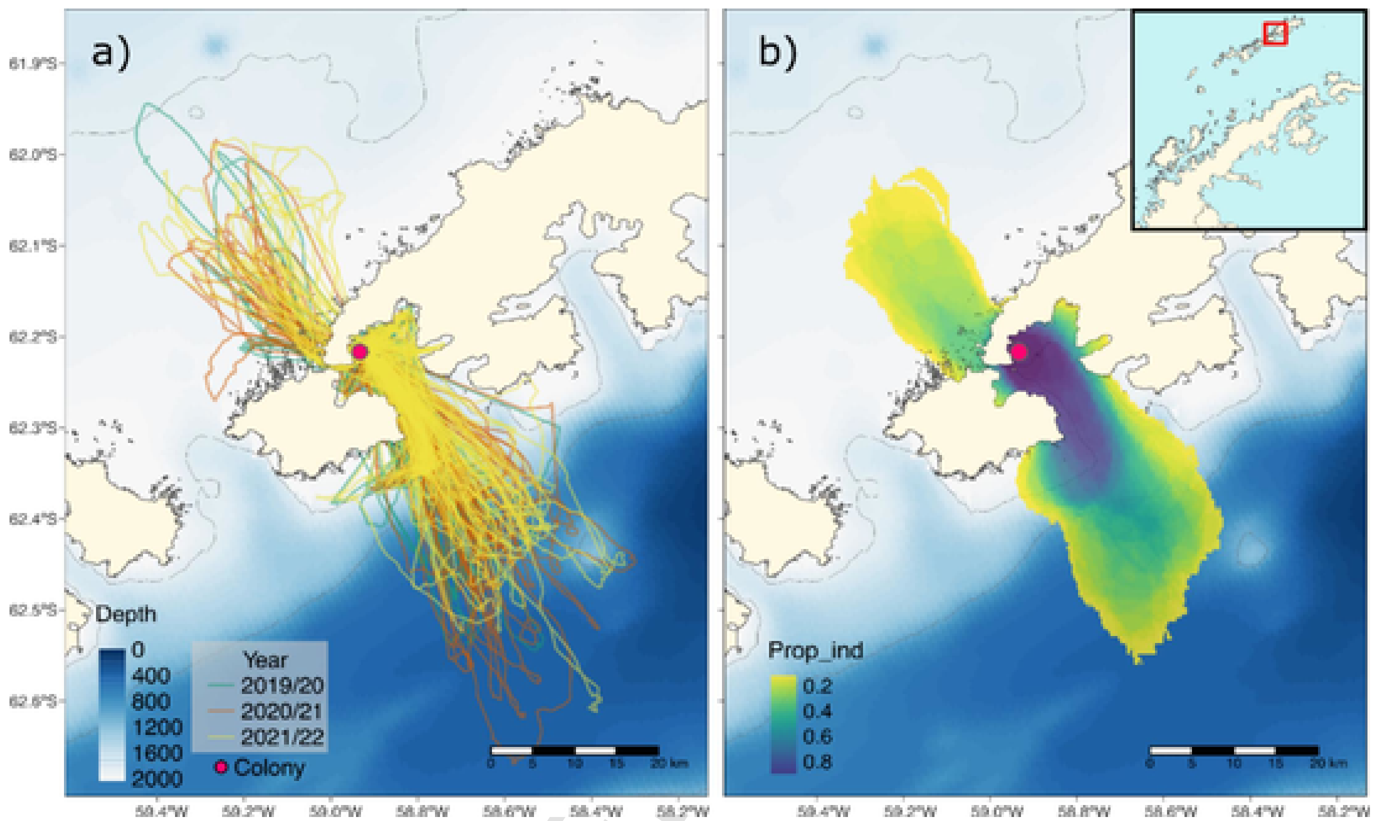

Fig. 1. a) Foraging trips of gentoo penguins (*P. papua*) from the colony on Ardley Island (red dot) during the chick-rearing stage of the 2019/2020, 2020/2021 and 2021/2022 breeding seasons; b) marine area used by at least 10 % of the individuals breeding in Ardley Island. Prop_Ind refers to the proportion of the population that used the area across the three seasons. Inset panel in b) shows the location of the study area (red square) in the northwest of the Antarctic Peninsula. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

1) As proposed by Lascelles et al. (2016) we used fixed kernel density estimation (KDE) to define an utilization distribution (UD) for each tracked individual. A critical parameter for kernel estimation is its bandwidth, or h-value, which controls the spread of each kernel around each recorded location (Péron, 2019) and hence, reflects the probability distribution of finding individuals in the vicinity of the recorded locations, as the distance from the locations increases. From a biological perspective, it reflects the spatial scales at which individuals interact with their environment (Dias et al., 2018). Here we explore the effect of 4 alternative h-values on the mIBA delimitation: a) we used the 7 km h-value used and suggested by Dias et al. (2018) to delimit mIBAs for penguins in the Southern Ocean; b) we calculated the reference smoothing parameter (href) on the basis of the location of all individuals taken together; the href reflects the number of positions and their spatial variance in longitude and latitude, and is a typical smoother used for identifying important sites for biodiversity (e.g., Beal et al., 2023); c) we calculated a h value using the 'ad-hoc' method (Schuler et al., 2014), which has been suggested to outperform other smoothers, and provide the smallest value for h consistent with a contiguous home-range estimate (Kie, 2013); initial estimation of an UD considering the locations of all individuals together, was calculated using the href value; a sequence of UDs was then calculated by reducing the h-value by 5 % in successive steps until the contour fractured into two or more polygons; d) we calculated a h-value estimated on the basis of the maximum horizontal speed of gentoo movements while in water (calculated from our own data), and the average interval between consecutive locations in our study; this value represent the maximum distance the species is able to move in the timespan between two consecutive locations, thus, the probability of locating an individual beyond that distance from the previous location should be zero; we contend this is a reasonable criterion to define a biologically meaningful h-value that reflects the spatial scales at which individuals interact with their environment at the temporal scale considered in the study.

2) UDs reflect the probability of use throughout an animal's home range, allowing calculation of home-range area within any desired probability contour (i.e. isopleth) (e.g., Gitzen et al., 2006). Börger et al. (2006) have shown that the 90 % isopleth can provide unbiased home range estimates even with relatively little data, and that inner isopleths tend to be more biased than outer isopleths. Actually, these authors explicitly caution against the use of home range core areas as a quantitative tool for habitat conservation plans. Therefore, here we opted for using 90 % UD when estimating individuals home ranges, instead of the values suggested by Dias et al. (2018). Actually, previous studies in the study area have shown that some of the key foraging sites for penguins in the vicinity of Ardley Island are not located within animals' UD inner isopleths (e.g., Machado-Gaye et al., 2024). This is not surprising, as being central-place foragers, a large proportion of the locations obtained are concentrated around the colony, a sector of the home range consistently used at the beginning and end of the foraging trips, irrespective of where the animals are actually foraging. With central-place foragers, using inner isopleths to identify areas of ecological relevance might restrict the mIBA boundaries to areas regularly used as transit areas, but not necessarily the most relevant ones in terms of food acquisition.

Representativeness of the sample (i.e., the degree to which the tracked animals represent the whole population) was obtained using the function *repAsses* from the 'track2KBA' R package. For the estimates

100 iterations were used, as it is the minimum number recommended by the authors (Beal et al., 2021).

3. Results

A total of 301 foraging trips from 60 gentoo penguins were obtained over three breeding seasons: 2019/2020, 2020/2021 and 2021/2022. Roughly 100 trips per season were recorded, with an average of 5 trips per individual. Trips duration and distances covered are summarized in Table 1. Movements were registered both in a northwest and southeast direction from the colony (Fig. 1a). For the space use estimation, the value obtained for href was 2.2 km, 2.4 km for h ad hoc, and 0.8 km for the h-value estimated on the basis of the maximum horizontal speed of gentoos. The mean size of the areas obtained for each individual using h ad hoc for the 50, 90, and 95 kernels was 124.7 ± 52.44 km^2, 414.2 ± 163.9 km^2, and 518.1 ± 199.6 km^2, respectively. The href and h ad hoc values obtained were similar to those calculated by Dias et al. (2018) for chinstrap penguin colonies with similar maximum foraging trip distances, using the ARS (area-restricted search behavior) method.

Fig. 1b shows the area where the UDs of at least 10 % of the colony overlap. Representativeness of the sample was 99.1 %. Fig. 2 compares the boundaries of the areas used by the gentoo penguin's colony in Ardley Island estimated using different h values, with the boundaries of Antarctic Marine IBAs 9, 11 and 12 proposed by Handley et al. (2021). The size of the estimated areas was 2335.2 km^2 (h = 7 km), 910.98 km^2 (h = 2.2 km), 972.56 km^2 (h = 2.4 km) and 524.54 km^2 (h = 0.8 km).

Rather than contesting the procedures used by Dias et al. (2018) and Handley et al. (2021) to delimit mIBAs, with the adjustments we introduce here we expect to extend the mIBA protocol for its application in the next stage of the conservation process. That is, from using the approach to identify spatial priorities for conservation actions, to produce inputs for a conservation planning process incorporating local-scale data. We understand these modifications better reflect the change of scale of the question at hand and the resolution of the data, while retaining the general approach for the analysis and synthesis of the data. Hence, taking advantage of the widespread use of the mIBAs approach and the experience accumulated with its application across the globe.

4. Discussion

We showed how the mIBA approach can be extended to generate inputs for a conservation planning process aimed at providing protection to one of the largest gentoo colonies in Antarctica using high-resolution locally generated tracking data. In doing so we introduce a series of modifications to the approaches used to delineate mIBAs boundaries that we believe can help moving from the spatial prioritization stage

Table 1
Summary of the foraging trips (mean ± SD) of gentoo penguins (*P. papua*) breeding in Ardley Island during the 2019/2020, 2020/2021 and 2021/2022 seasons. For each season the following parameters are shown: number of individuals tracked (N), total number of trips (N° trips), trips mean duration (h), maximum distance from colony (km), total distance (km), and 50 and 90 % UDs (h = 2.4 km).

Season	N	N° trips	Duration (h)	Max. distance (km)	Total distance (km)	Home range (50 % UD) (km^2)	Home range (90 % UD) (km^2)
2019/20	19	102	9.23 ± 3.46	16.3 ± 9.96	37.4 ± 20.3	101 ± 42.5	336 ± 129
2020/21	20	84	13.1 ± 11.8	22.8 ± 11.5	53.1 ± 26.2	138 ± 44.6	457 ± 136
2021/22	21	115	12.1 ± 4.41	18.6 ± 10.9	44.8 ± 23.3	134 ± 61.5	444 ± 195

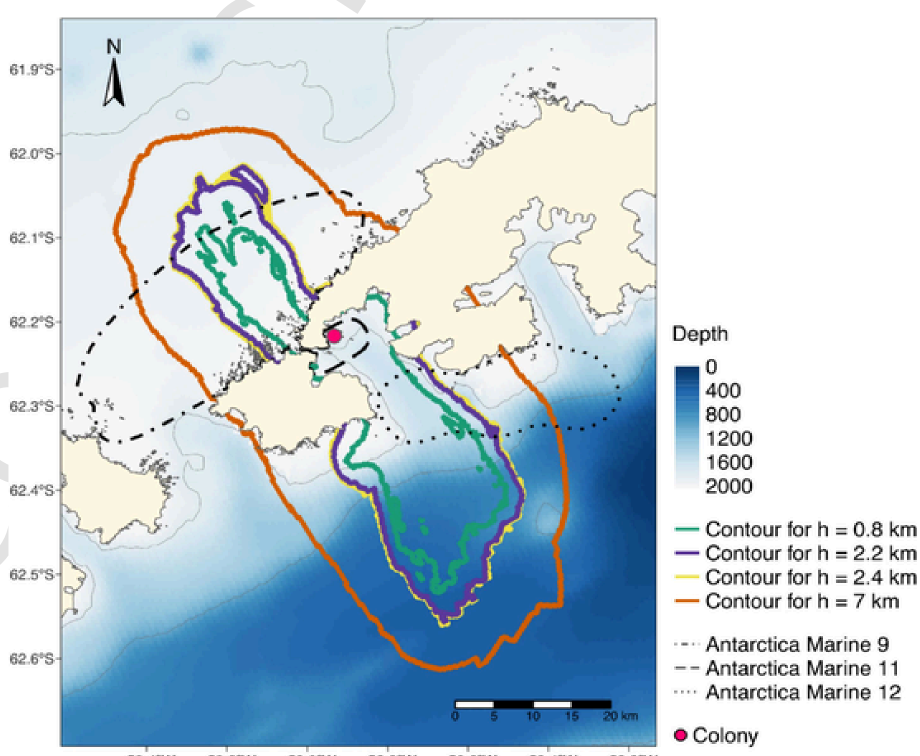

Fig. 2. Limits of the area used by the gentoo penguin (*P. papua*) colony in Ardley Island estimated using different h-values: h = 0.8 km, h = 2.2 km (h ref), h = 2.4 km (h ad hoc) and h = 7 km. The limits of the mIBAs Antarctica Marine 9, 11 and 12 are also shown.

into the conservation planning stage of the conservation process. Specifically, when using tracking data to set the boundaries of spatially explicit conservation measures for central-place foragers, we suggest using a 90 % UD to define individual home ranges, and a smoothing parameter (h-value) that explicitly considers both the movement characteristics of the species of interest and the study's data acquisition schedule. In the case of Ardley Island, using this approach we identified important areas for gentoo penguins around the island that were not included within the areas proposed by Handley et al. (2021) as mIBAs. This difference is likely a consequence of the different methodological approaches and data resolution used to define the boundaries of the area of interest, highlighting the relevance of considering these differences when using the outputs of spatial analyses to inform policy.

One of the early criticisms to the Key Biodiversity Areas (KBA) approach (also applicable to mIBAs) is that identifying local-scale areas for conserving species using large-scale data sets has the potential to produce significant errors of omission and commission, highlighting the need of incorporating more accurate local-scale data provided by local stakeholders in the analyses (Knight et al., 2007). Actually, it is noteworthy that current estimates of >7000 breeding pairs in Ardley Island (Soutullo et al., 2023) more than doubles the median value used by Handley et al. (2021) in their analysis. Coarse analysis for identifying potential areas of conservation value at a continental scale (e.g., using a foraging radius approach) are not meant to provide the detailed information needed for the delimitation of legally binding local-scale conservation measures and hence, the outputs of large-scale and local-scale analyses should not be used interchangeably. Large-scale analyses as Handley et al. (2021)'s are extremely valuable in the Southern Ocean because they help prioritizing funding and research efforts over an extensive area that because of its size and remoteness demands strategic decisions when allocating efforts. This is part of the first stage in the implementation process described by Knight et al. (2006). Further analysis of these areas to define the spatial extent of the conservation measures is part of the second stage of this process, conservation planning, which requires engaging relevant stakeholders in order to advance towards actual conservation measures on the ground (Knight et al., 2006). The mIBAs approach can provide valuable contributions to both stages, but in order to be useful, outputs of the analyses must be used according to the stage they were designed to inform.

Implementing effective conservation action requires spatial prioritization exercise to be functionally integrated with a process for developing an implementation strategy and processes for stakeholder collaboration (Knight et al., 2006). This requires establishing conservation planning capacity in priority regions and engaging local stakeholders (Knight et al., 2007). In the Antarctic Treaty System, key stakeholders include Parties of the Antarctic Treaty (AT) and the CCAMLR, Observers and Expert organizations that provide advice to the governance bodies (Hughes et al., 2023). For scientists and organizations undertaking policy-relevant research willing to have policy impact there are two main routes to contribute to ATS decision-making: either through Parties' National Delegations, or through Experts and Observers officially invited to participate of the ATS fora, including SCAR, the Scientific Committee on Antarctic Research (Hughes et al., 2018, 2022). Conservation measures are adopted by Parties on the advice of the AT Committee for Environmental Protection (CEP) and CCAMLR Scientific Committee (SC-CCAMLR). In order to move from spatial prioritization exercises to concrete conservation proposals, there is a need to incorporate the results of analyses as Handley et al. (2021)'s and ours into the agenda of these governance bodies. That is, there is a need to develop an implementation plan that explicitly involves Parties in the design of an operational model for conservation action.

There are many barriers to using science to inform conservation policy and practice. Yet there is a growing body of evidence on how to better navigate this challenge, including proposals on institutional frameworks that can facilitate science-policy interfaces (Cook et al., 2013; Cvitanovic et al., 2015, 2016; Toomey et al., 2017). Across a range of fields, coproduction has been identified as a promising approach to deliver action based on scientific evidence (Beier et al., 2017; Chambers et al., 2021). Coproduction seeks to connect researchers with other stakeholders to produce knowledge, action and societal change (Chambers et al., 2021). Within the ATS, advancing in the implementation of conservation measures require integrating spatial prioritization analysis as Handley et al. (2021)'s into the process of creating ASPAs, ASMAs or CCAMLR MPAs, or updating their management plans. Scientists and organizations willing to promote conservation measures on areas identified as mIBAs should actively seek for opportunities to contribute to these processes. Investing time in promoting "spaces" of interactions (sensu Toomey et al., 2017) with ATS Parties (especially those conducting operations or with interests in areas close to mIBAs) and building trust are key components for achieving evidence-informed policy (Cvitanovic et al., 2021; Toomey et al., 2017).

In the case of Ardley Island, the current process of updating its management plan (ATS (Antarctic Treaty Secretariat), 2024) provides a unique opportunity for incorporating the results of analyses as the one we present here in a conservation planning process. Ardley Island ASPA boundaries currently encompass most of the island, yet they do not include a marine sector despite penguins being one of the values the ASPA seeks to protect (ATS (Antarctic Treaty Secretariat), 2009). Penguins dependence on marine resources for fulfilling their energetic needs highlight the relevance of incorporating relevant marine sectors in the surroundings of the island for the ASPA to ensure the conditions needed to maintain the breeding colonies. A detailed analysis of animals' distribution at sea, as provided by the mIBAs protocol, might provide an initial proposal of new boundaries for discussion. In the lasts ATCM Chile, Argentina, China, Korea, the Russian Federation and Uruguay expressed their will in engaging in the process of upgrading the Management Plan of ASPA N° 150, Ardley Island (ATS (Antarctic Treaty Secretariat), 2024). This seems a perfect opportunity for scientists and organizations willing to advance in the protection of mIBAs to engage in the process.

Overall, we identify three main recommendations for advancing in the incorporation of mIBAs in the design of spatially explicit conservation measures in the Southern Ocean:

1. Differentiate the potential contribution of the mIBAs approach to spatial prioritization from the potential contribution to conservation planning. Large-scale analyses enable identifying potential valuable areas that need to be prioritized in terms of further research to assess their actual value. Yet, systematic conservation planning techniques are needed when aiming at delineating management actions at the local scale (Smith et al., 2019).
2. Use methods, criteria and data for establishing mIBAs' boundaries according to the stage of the conservation process that the outputs are expected to contribute to. We agree with Critchley et al. (2018, 2019) that a foraging radius approach provides a pragmatic and rapid method that can be used as an initial tool to identify important areas for potential protection. Especially in areas with limited data on seabird distributions at sea and limited resources to collect these data. The method predicts a baseline distribution that can be further refined using data on species specific foraging behaviors or other ecological factors. This detailed information is not needed for prioritization at the seascape level, but it is crucial for informing management at a local scale (e.g., Machado-Gaye et al., 2024).
3. Understand how Antarctic mIBAs fit into the ATS conservation measures framework and ongoing deliberations in its governance bodies. Frame the exercise of assessing potential mIBAs within the larger policy and management process: 1) bear in mind extant normative tools (e.g., CCAMLR MPAs or AT ASPAs) and the

procedures by which decisions are taken; 2) approach and engage relevant stakeholders, most remarkably those that regularly operate in the surroundings of the mIBAs; 3) seek for ways of integrating the outputs of the analyses in planning process conducted by ATS Parties; 4) maintain long-term commitment with the conservation initiative to ensure approval and, most importantly, effective implementation once approved.

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CRediT authorship contribution statement

A. Soutullo: Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **M. Raslan:** Writing – review & editing, Visualization, Investigation, Formal analysis. **A.L. Machado-Gaye:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability

Data will be made available on request.

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