Full length article

Planning marine protected areas under the CCAMLR regime – The case of the Weddell Sea (Antarctica)

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A B S T R A C T

Currently, almost 8% of the world's oceans are designated marine protected areas (MPAs), the majority of which are relatively small and under national jurisdiction. Several initiatives are presently underway in international waters to establish large-scale MPAs, such as for the Southern Ocean under the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). By reviewing the MPA initiative in the Weddell Sea (WSMPA), we aim to guide through the planning steps involved in developing an MPA in the high seas of the Southern Ocean in the context of an international organisation, i.e. CCAMLR. We focus also on the associated science-policy discussion process. To this end, we examine the WSMPA roadmap retrospectively from its beginning in 2013 until today. We discuss the individual planning steps and how these have been designed in detail. Throughout, we show that the planning of the WSMPA was based on a collaborative, science-based process that exemplified best practice in applied science. Lastly, we also provide an outlook on the current situation regarding the establishment of CCAMLR MPAs and point out that scientific best practice may not be sufficient to achieve the consensus and political drive ultimately required for the designation of MPAs in the Southern Ocean.

1. Introduction

The Convention on Biological Diversity's [1] Strategic Plan for Biodiversity 2011–2020 and the United Nations Sustainable Development Goal 14 (UN SDG 14) set global targets for the designation of at least 10% of coastal and offshore marine areas as Marine Protected Areas (MPAs) by 2020. Currently, 7.56% of the world's oceans are designated MPAs (www.protectedplanet.net/marine). The majority of these MPAs are, however, relatively small and within national jurisdiction. Only 1.18% of the high seas are designated MPAs, although the high seas represent 61% of the world's oceans.

Several initiatives are currently underway to establish MPAs in the high seas of the Southern Ocean under the Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention). The Convention originated from the Antarctic Treaty and contains provisions binding Contracting Parties to a number of obligations deriving

from the Antarctic Treaty (www.ccamlr.org/en/organisation/convention). The Convention aims to conserve Antarctic marine living resources including their rational use. It does so using precautionary, ecosystem-based, and science-led decisions; an approach for which it has been applauded internationally (e.g. [2]).

The CAMLR Convention is different from Regional Fisheries Management Organisations in that it has firm linkages to other political treaties, such as the Antarctic Treaty and its associated Environmental Protocol, and is therefore an integral part of the Antarctic treaty system (https://www.ccamlr.org/en/system/files/e-linkages_0.pdf). It is also different because of the conservation principles enshrined in the Convention itself. The Convention is implemented through the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), under whose auspices Contracting Parties negotiate the measures to be implemented.
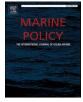
In 2002, CCAMLR officially recognised the World Summit on

Sustainable Development's commitment to establish an MPA network, and added MPAs as a standing agenda item. In the following years, several MPA workshops (e.g. [3]) were carried out in order to facilitate and support the work of CCAMLR on MPAs. In 2009, CCAMLR committed itself to the establishment of a representative system of MPAs within the Convention Area by 2012 [4]. CCAMLR has achieved several important milestones in efforts to do so and meet the targets set by the 2010 CBD and the UN SDG 14, namely:

1. The designation of the Southern Shelf Area of the South Orkney Islands MPA in 2009, the first MPA beyond national jurisdiction [5, 6] (Fig. 1);

2. the adoption of a general framework for the establishment of CCAMLR MPAs, Conservation Measure 91-04 in 2011 [7];

3. the division of the Convention Area into nine MPA planning domains (Fig. 1) to ensure that the system of MPAs developed in the Convention Area is representative and comprehensive [8,11].

4. and the implementation of the Ross Sea MPA, the largest MPA in the world [9,10] (Fig. 1).

Additional CCAMLR MPAs have been proposed but their approval is still pending, despite several years of discussion. Proposals have been submitted for MPAs in Domain 1 Fig. 1 [12,63] in East Antarctica [66] and for the Weddell Sea [13].

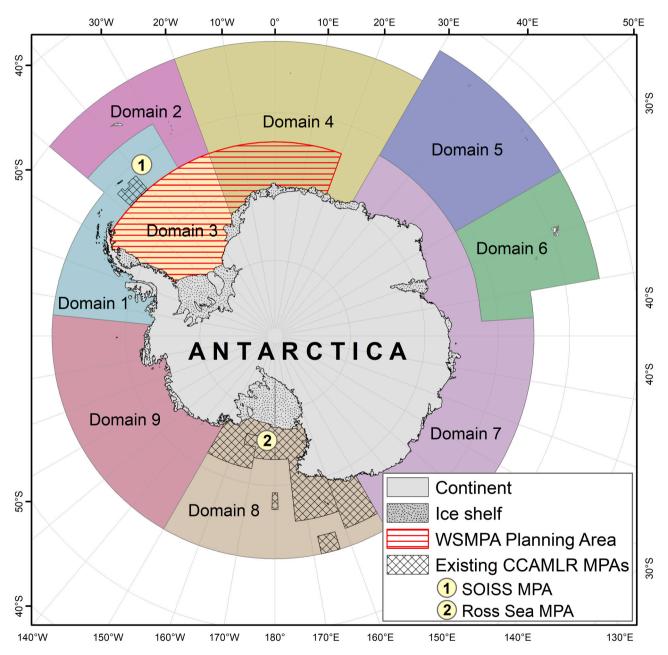The Weddell Sea represents the southerly part of the Atlantic Sector

Fig. 1. CCAMLR Convention Area, showing the planning domains, the existing MPAs (black-crosshatched area) and the MPA planning area in the wider Weddell Sea (red-shaded area). SOISS refers to South Orkney Islands Southern Shelf and WSMPA refers to Weddell Sea MPA. Planning Domains: 1 = Western Peninsula - South Scotia Arc; 2 = North Scotia Arc; 3 = Weddell Sea; 4 = Bouvet Maud; 5 = Crozet - del Cano; 6 = Kerguelen Plateau; 7 = Eastern Antarctica; 8 = Ross Sea; 9 = Amundsen - Bellingshausen. (CCAMLR MPA planning domains and existing MPAs are from CCAMLR GIS, 2019; available from: https://gis.ccamlr.org. Ice shelf and continent are from Norwegian Polar Institute, Quantarctica2; available from: https://www.npolar.no/quantarctica/). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

of the Southern Ocean. About one quarter of the Weddell Sea's entire marine area lies over the continental shelf, stretching along the eastern contour of the Antarctic Peninsula and the Antarctic continent up to 20°E (Planning Domain 3 and parts of Domain 4; Fig. 1). The latter is defined as a non-topographic delineation. Water depths range from 100 m at the edge of the ice shelf to about 5300 m in the central Weddell Sea. In the eastern Weddell Sea, the shelf and shelf slope are relatively narrow and complex in structure, whereas the southern Weddell Sea is characterised by a very wide shelf and the Filchner Trough.

The Weddell Sea is worthy of protection because it is unique in several respects. It plays an important role in driving global thermohaline circulation and ventilating the global abyssal ocean because it generates a considerable part of the Antarctic Bottom Water (e.g. [14]). The formation of those dense water masses in the Weddell Sea is facilitated by the large-scale cyclonic Weddell Gyre.

The Weddell Sea is also unique because of the sheer size of its sea ice extent, which is marked by extreme seasonal dynamics. At the end of the Antarctic winter, sea ice covers more than 75% of the area, which shrinks to only one third of the maximum winter extent during the short summer. Multi-year sea ice occurs predominantly in the south-western Weddell Sea and covers approximately 13% of the Weddell Sea. Because of the ice cover and ocean currents, the Weddell Sea is expected to be one of the last regions of the Southern Ocean where the consequences of climate change will manifest. Until then, this region may serve as a retreat for those Antarctic species which either directly depend on sea ice (e.g. krill, emperor penguin, Weddell seal) or have developed such strong adaptations to the polar temperatures during the past millennia that their heat tolerance is low (e.g. most notothenioid fishes).

Another reason for protecting the Weddell Sea is that it contains several areas of ecological significance for birds and marine mammals, such as important breeding and foraging areas [15]. Almost one third of all emperor penguin chicks hatches on the sea ice of the Weddell Sea [16], and almost half of the Antarctic petrel's population hunts there [17]. In addition, the area's sea floor is home to large and unique forest-like sponge and filter-feeder assemblages, which are particularly numerous on the continental shelf in the eastern part of the Weddell Sea. These species assemblages are very similar to tropical coral reefs in that they create a structurally complex and diverse habitat for thousands of species (e.g. [18,19], [62]).

The Weddell Sea also requires special protection as it is one of the last pristine areas in the Antarctic. There have been historical whaling activities 9 [60] and, in the 1970–1990s, occasional Antarctic krill fishing in some parts of the Weddell Sea region (www.ccamlr.org/en/fisheries/krill). However, the international fishing fleet has spared this region thus far. Currently, there are no Antarctic krill fishery activities in the Weddell Sea region (as opposed to the extensive krill fishery in the Scotia Sea in the north of the Weddell Sea); it is a "closed area" for krill fisheries with no catch allowance for this region. However, this may change in forthcoming decades. Projected long-term effects of climate change may shift the most favourable krill habitats further south into the Weddell Sea [20], which may mean the krill fishery would have to follow. Fisheries in the Weddell Sea region are currently limited to exploratory fishing for Antarctic toothfish (*Dissostichus mawsoni*), which takes place in the eastern part of the region within CCAMLR research blocks, i.e. restricted management areas with specific catch limits [21]. The western Weddell Sea region, on the other hand, is a "closed area" where directed fishing for Antarctic toothfish is prohibited [22].

Recognising these unique Weddell Sea characteristics and the necessity for their protection, experts paved the process for MPA planning in the Weddell Sea after discussions at the MPA Workshop in Brest, France in 2011. As a result of these discussions, experts provided advice to the CCAMLR Scientific Committee (and its working groups) and the Commission [67] that the possibility of MPA planning in the Weddell Sea should be further explored, in particular to support the region's potential role in serving as a climate change refugia and to monitor

changes in the ecosystem. In the following year, the CCAMLR Circumpolar Gap Analysis MPA Technical Workshop (Brussels, Belgium) identified available data and developed draft conservation objectives for CCAMLR Planning Domains 3, 4 and 9 (see Fig. 1) in which (at that time) conservation planning was not underway (see [23]). The outcome of the Workshop was presented at the CCAMLR Scientific Committee meeting in 2012, during which Germany offered to take the lead in MPA planning in the Weddell Sea [24], as the Alfred Wegener Institute (AWI) has been undertaking scientific research in this area since the early 1980s.

Here, we discuss the MPA conservation planning process in the Weddell Sea as a case study to outline the applied conservation planning steps necessary for developing a large-scale international MPA proposal. The case study also provides a specific focus on the context and associated science-policy process under the CCAMLR conservation regime. Starting with a brief review of the stakeholders involved in the Weddell Sea MPA (WSMPA) development process, we provide an insight into the necessary scientific working steps, such as the development of conservation objectives and their specific features, the identification of priority areas for protection and the management approach. Lastly, we discuss the current situation regarding the establishment of CCAMLR MPAs and outline the requirements we believe are necessary for the successful implementation of the proposed MPA in the Weddell Sea.

2. Conservation planning outlined along the steps undertaken as part of the WSMPA initiative

2.1. Structure of decision network

The German Federal Ministry of Food and Agriculture (BMEL) provides the German commissioner at CCAMLR and is the lead ministry for the WSMPA initiative. The BMEL asked the Alfred Wegener Institute (AWI) to handle the scientific work necessary for the development of a WSMPA. For this purpose, a small project team was formed at the AWI in 2013. The overall WSMPA proposal was developed by a larger German WSMPA working group consisting of representatives from the AWI, the BMEL, the Federal Ministry of Education and Research, the Federal Foreign Office, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety with its subordinate authorities, the German Environment Agency, the Federal Agency for Nature Conservation as well as from the German Oceanographic Museum. The draft WSMPA proposal and the underlying scientific work developed by this working group was discussed at the European level and subsequently at the international level in several workshops and within CCAMLR and its working groups.

CCAMLR applies a multi-stage process for discussion of all science and management related issues. The main route for scientific advice in CCAMLR is through the Scientific Committee and its working groups. The Scientific Committee creates advice on harvest levels and other management issues (e.g. establishment of MPAs) and then provides that advice to the Commission. The Commission's decisions based on the scientific advice, ultimately establish the regulatory framework (in form of conservation measures) applied to the respective management issue in the Convention Area. The annual meetings of the Scientific Committee and the Commission are open to CCAMLR's current 26 members (i.e. 25 Member States plus the European Union) and to observers, representatives of inter- and non-governmental organisations (e.g. Scientific Committee on Antarctic Research (SCAR), Association of Responsible Krill harvesting companies (ARK), Coalition of Legal Toothfish Operators (COLTO), Antarctic and Southern Ocean Coalition (ASOC)).

Following this CCAMLR process, we started out by presenting on and discussing the topic of developing a scientific basis for the WSMPA in the relevant CCAMLR scientific working groups (most of our work fell within the remit of the Working Group on Ecosystem Monitoring and Management, WG-EMM). The revised scientific papers were then presented to CCAMLR's Scientific Committee. Afterwards, the European

Union and its Member States submitted a draft conservation measure for the WSMPA (including the management regime and the priority elements for the research and monitoring plan) to the Commission.

2.2. Definition of planning area

At the meeting of CCAMLR WG-EMM in 2013, discussions revolved around the planning area to be considered in the scientific data collection and analysis needed to develop a WSMPA proposal [25]. The German WSMPA working group emphasised the fact that the boundary between the CCAMLR MPA Planning Domain 3 (Weddell Sea) and Planning Domain 4 (Bouvet-Maud) cuts through the middle of a biogeographically homogeneous region, particularly on the Antarctic shelf (see Fig. 1). The group therefore proposed to extend the WSMPA planning area into Planning Domain 4. WG-EMM recognised these concerns, but asked for a meaningful and clear definition of the extended planning area [25]. Accordingly, Germany informed the CCAMLR Scientific Committee at the 32th annual meeting in 2013 that the extension of the WSMPA planning area (beyond Planning Domain 3 into the southern part of Planning Domain 4) would ensure that the specific oceanography, ecological conditions and biological communities of the Weddell Gyre system are considered as one entity in the spatial planning procedure (Fig. 1). The total WSMPA planning area thereby proposed would cover approximately 4.2 million km^2 (of which about 665,000 km^2 are covered by shelf ice). The Scientific Committee noted that the report on the WSMPA scientific data collection and analysis adequately described the boundaries of the planning area [68].

2.3. Compilation of database

All sources of environmental and ecological data collected by the end of 2016 and further processed in the context of the WSMPA planning process are systematically described in Teschke et al. [26]. The compilation of data sources comprises data produced by scientists / institutions from more than twenty countries and were either available within the authors` institutes, downloaded via data portals, or transcribed from the literature. This compilation of data sources includes abiotic data ranging from daily satellite observations (e.g. sea ice) to oceanographic model outputs (e.g. finite element sea ice ocean model) and continuous oceanographic measurements. Ecological data sources were also diverse and covered e.g. ship-based data collections of zooplankton, benthos and fish, satellite tracking data of penguins and airborne counts of seals (see Fig. 2).

2.4. Definition of conservation objectives, features and targets

The WSMPA conservation objectives and features were developed in a two-step procedure via (1) basic definition by the German WSMPA working group and (2) discussion and refinement through two international expert workshops [27] plus a CCAMLR workshop [72] and annual CCAMLR working group meetings (e.g. [29]).

General and specific conservation objectives for the long-term protection of the Weddell Sea ecosystem were formulated in accordance with Article II and IX of the CAMLR Convention (www.ccamlr.org/en/document/publications/basic-documents-december-2011) and paragraph 2 of Conservation Measure 91-04 [7]. The six general WSMPA objectives were based on and derived directly from objectives set out in Conservation Measure 91-04 [7]. They were formulated to express the
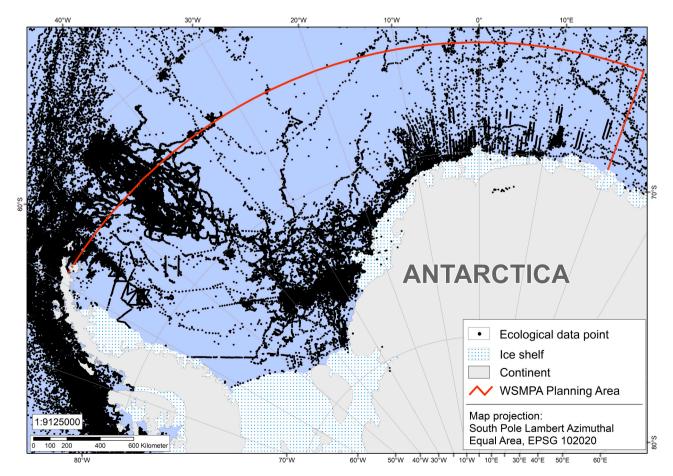

Fig. 2. Distribution of all ecological data points across the Weddell Sea region compiled in the context of the WSMPA planning initiative. (Ice shelf and continent are from Norwegian Polar Institute, Quantarctica2; available from: https://www.npolar.no/quantarctica/).

general conservation needs in the Weddell See planning area. In addition, scientific data and expert opinion on the vulnerable marine ecosystems, species and habitats present in the WSMPA planning area led to the identification of a set of 12 specific conservation objectives. For example, the specific objective for the conservation feature Antarctic toothfish reads: "Protection of Antarctic toothfish (*Dissostichus mawsoni*) as key species of the upper trophic level in the Antarctic food web including all life history stages and their habitats". All proposed WSMPA conservation objectives are listed in the Supplement.

Based on the conservation objectives, a set of 18 ecological and 57 environmental conservation features was identified (see Table S1). In order to ensure that a representative proportion of each conservation feature would be protected, targets for each conservation feature were discussed at the 2nd WSMPA International Expert Workshop. There, the experts identified the lowest and highest target values for each conservation feature. The target values were given as a proportion of the area of the total distribution of the respective conservation feature to be protected (0% ≤ target value ≤ 100%). In general, lower target values were chosen for common conservation features, while higher target values were used for unique, rare or sensitive conservation features. For example, a medium target value of 20% was set for most of the environmental conservation features (e.g., geomorphic features). To cover larger areas for highly mobile species with less predictable distribution patterns, medium target values between 30% and 50% were used. Target values of 100% were set for unique geomorphic or ecological features, e.g. for areas with highly sensitive sponge associations and nesting sites of demersal fish.

2.5. Mapping of conservation features

Each of the 18 ecological and 57 environmental features was mapped in order to comprehend its spatial distribution across the WSMPA planning area. For each conservation feature, all methodological-analytical steps are described in detail in [26]. The maps (including metadata description) are also freely available from the data publisher PANGAEA [30–35].

The analytical methods that we used to present the spatial distribution of species and environmental variables in the WSMPA planning area varied between features and depended on the evidence available for each (i.e. data quality and quantity). For example, almost exclusively expert knowledge was available for the conservation feature "juvenile Antarctic toothfish". On the basis of expert information of juvenile fish records presented during the CCAMLR Workshop for the Development of an Antarctic toothfish (*Dissostichus mawsoni)* Population Hypothesis for Area 48 (Berlin, Germany, 2018), we were able to produce a map with polygons highlighting identified potential habitats of juvenile Antarctic toothfish. In contrast, the ecological conservation feature "sponge presence", was based on spatially clustered semi-quantitative data on the shelf (i.e. abundance categories such as rare, regular, abundant occurrence). These data were represented by applying the inverse-distance weighting method, one of the most commonly used deterministic models in spatial interpolation (e.g., [36]), over a buffer of 10 nautical miles around each data record. Finally, there were also conservation features, such as "adult Antarctic krill (*Euphausia superba*)", for which more solid scientific records (i.e. many, relatively homogeneously distributed data) existed in the WSMPA planning area. For those conservation features we developed species distribution models using the renowned shareware biodiversity modelling package biomod2 [37, 38] that combines predictive results from different models ([39] and references therein).

2.6. Priority areas for protection

In order to identify priority areas for protection within the WSMPA planning area, we used the spatial planning software Marxan (www.marxan.org). Marxan is the most widely used conservation planning software [40] and was explicitly endorsed by CCAMLR as a tool for planning CCAMLR MPAs [41]. Marxan delivers decision support for the design of protected area systems [42]. It attempts to meet user-defined biodiversity targets at the smallest possible cost within the planning area. To do so, the entire planning area is divided into planning units. Each planning unit is then assigned a cost (e.g. opportunity cost in catch tonnage for fisheries) and the conservation feature amounts (e.g. the sum of the area of each feature occurring within the planning unit). Marxan seeks to achieve all conservation feature targets by selecting a configuration of planning units that contains sufficient amounts of each conservation feature target whilst minimising the overall cost. Marxan uses an iterative algorithm to proceed from an initial solution towards a near-optimal solution.

Although Marxan tries to find spatially efficient solutions, the selected configurations of planning units should only be interpreted as possible solutions to the defined problem, not as the final answer [42]. Therefore, Marxan should be run several times under different scenarios (e.g. with different user-defined targets for the conservation features) to generate a range of possible solutions. These solutions should then be carefully interpreted by experts during a review process involving stakeholders, as the objective Marxan solution outputs should be assessed from a variety of standpoints. Marxan outputs are presented as "best" and "summed" solutions. In summed solutions, each planning unit is evaluated according to how many times it has been included in a solution from a series of runs, while in the case of best solutions each planning unit is scored solely according to the best run from a series of runs.

We calibrated Marxan's internal parameters according to the Marxan Good Practices Handbook [43]. In addition, we took into account costs (assigned to each planning unit) through two separate cost layers to reflect the two major fishing interests present in the region: one cost layer for Antarctic toothfish (*Dissostichus mawsoni*) and one for Antarctic krill (*Euphausia superba*). The cost layers reflected which areas were both accessible to fishing vessels on the basis of sea ice cover and presented potentially suitable habitats for toothfish (based on a model combing catch per unit effort data and depth data) or for krill (based on a habitat suitability model for adult krill). Planning units that are accessible to fishing vessels and contain potentially suitable habitats for toothfish or krill received highest costs.

We then prepared the Marxan input files by merging all the ESRI files of the conservation features and cost layers with the planning unit file. We developed different Marxan scenarios, each with one of the two cost layers and with different user-defined targets for the conservation features, to assess whether the priority areas for protection selected by Marxan showed patterns or similarities under the different scenarios. For example, we ran a scenario with medium target values for all conservation features and compared these solution outputs with the outputs of a Marxan scenario with low target values for all features (see Table S1 and Fig. 3).

The calibration results, the final cost layer analysis as well as the solution outputs of all Marxan scenarios were presented and discussed at the CCAMLR Workshop on Spatial Management held in Cambridge in 2018 [28].

The Marxan solution outputs guided the decision making regarding the demarcation of the proposed WSMPA boundaries. Additional factors that were considered as part of the process were: (a) the minimisation of the WSMPA area and simultaneous achievement of the medium target values for all 75 conservation features and (b) the easy identification and navigability of the boundaries. The proposed WSMPA boundaries resulting from this analysis (see Fig. 3b) represented the best compromise between both principles. Nevertheless, the boundaries are currently still subject to agreement of all CCAMLR Member States.

2.7. Management measures

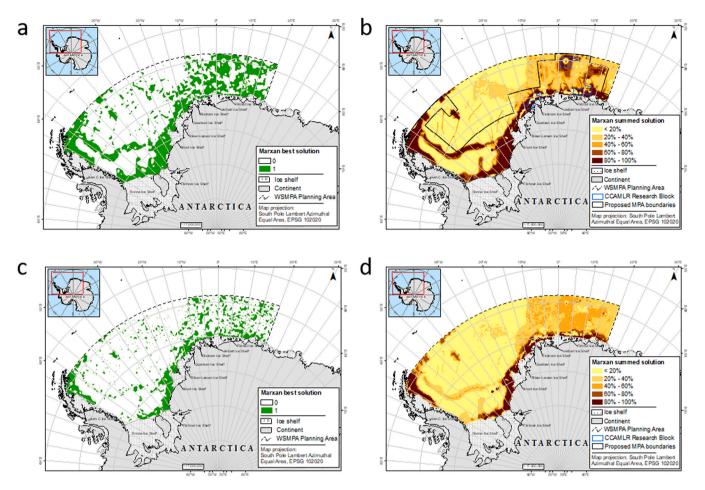In order to achieve the conservation objectives, the proposed

Fig. 3. Best (a, c) and summed solutions (b, d) of the Marxan scenarios with medium target values (a, b) and with low target values for all conservation features (c, d) and the cost layer of the Antarctic toothfish. Green areas indicate areas selected by Marxan as potential areas for protection (a, c). Dark brown areas indicate areas with the highest selection frequency by Marxan, and yellow areas indicate areas of a low selection frequency (b, d). (CCAMLR research blocks are from CCAMLR GIS, 2019; available from: https://gis.ccamlr.org. Ice shelf and continent are from Norwegian Polar Institute, Quantarctica2; available from: https://www.npolar.no/quantarctica/). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

WSMPA was divided into three management zones: (i) the General Protection Zone (GPZ), (ii) the Special Protection Zone (SPZ) and (iii) the Fisheries Research Zone (FRZ) (Fig. 4).

The GPZ was designed to provide a general level of protection, e.g. for representative examples of pelagic and benthic ecosystems, biodiversity and habitats, including relevant ecosystem components such as key species and top predators. In addition, the GPZ aims to increase the region's resilience to climate change and to support the research and monitoring furthering our understanding of the Antarctic ecosystems and the effects of climate change and human activities. The SPZ was created to provide enhanced protection to known vulnerable marine ecosystems and unique, rare or biodiverse and/or endemic habitats and features. The FRZ was designed specifically to contribute to the science-based management of the toothfish stock through ongoing research conducted by fishing vessels. In addition, the FRZ includes a scientific reference (unfished) area to analyse possible wider ecosystem effects and trophic impacts of longline fishing on Antarctic toothfish.

In the GPZ, scientific research on toothfish taxa, irrespective of gear type, would be limited to a catch of five tonnes per vessel per year and the catches for all other finfish and non-finfish taxa (such as krill) would be limited to one tonne per vessel per (according to Conservation Measure 24-01; [45]). For other scientific research in the GPZ, the use of any towed gear that physically interacts with the seafloor, such as trawls and dredges, would be limited to one square kilometre per vessel per season. In the SPZ, all fishing activities and scientific research using towed gear that physically interacts with the seafloor would be

prohibited. In the FRZ, which includes an existing CCAMLR research block for exploratory fishing for *Dissostichus mawsoni* (see Fig. 4), fishing on toothfish taxa would be allowed in accordance with established CCAMLR procedures and conservation measures [21,46]. For directed fishing for all other finfish and non-finfish taxa, as well as for other scientific research conducted in the FRZ and the scientific reference area, the same provisions as in the GPZ should apply.

2.8. Priority elements for research and monitoring

The inclusion of priority elements in a research and monitoring plan (RMP) is not only good practice and essential for the effective implementation of MPAs, but also a mandatory step under CCAMLR Conservation Measure 91-04 [7]. The purpose of identifying such priority elements is to facilitate the development of a multidisciplinary RMP following the adoption of an MPA. The priority elements for research and monitoring in the WSMPA were formulated based on three main objectives: (i) the assessment of whether the areas protected by the WSMPA are suitable to meet the specific conservation objectives and the extent to which the specific objectives are met; (ii) the contribution to the review evaluating the effectiveness of management provisions; (iii) the evaluation of the contribution of the WSMPA to Article II (3) and Article IX (1–2) of the CCAMLR Convention. In addition, under the priority elements, we have identified several research questions that should be addressed as part of research and monitoring activities. For example, it should be studied whether the WSMPA actually protects an
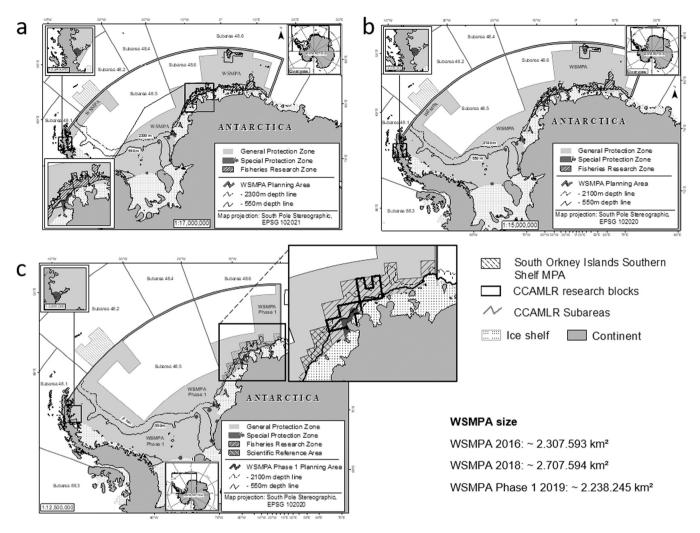
Fig. 4. The WSMPA as proposed in 2016 (a) and 2018 (b) and the current 2019 proposal of WSMPA Phase 1 with the different management zones (c). The size of each proposed WSMPA (rounded up to decimals) includes the areas under the ice shelves. (CCAMLR MPA boundary of South Orkney Islands Southern Shelf Area, research blocks and statistical subareas are from CCAMLR GIS, 2019; available from: https://gis.ccamlr.org. Ice shelf and continent are from Norwegian Polar Institute, Quantarctica2; available from: https://www.npolar.no/quantarctica/. Depths are derived from IBCSO Version 1.0; available from: [44]).

adequate proportion of all benthic and pelagic ecosystem components. We also need to evaluate to which extent the ecosystems, habitats, or species included within the WSMPA are affected by e.g. human activities including climate change and/or fishing. All formulated research questions are listed in the Supplement.

3. Discussion under CCAMLR

3.1. WSMPA discussion process

The comprehensive scientific work carried out in the context of developing the draft WSMPA boundaries (excl. work on a management regime and priority elements for research and monitoring), to which the German WSMPA working group and numerous national and international researchers contributed, was recognised by the 35th Scientific Committee Meeting of CCAMLR as the "best science currently available" [69]. However, Norway questioned whether best available science was used, due to a procedural issue (i.e. specific information on the fisheries research zone requested was not submitted to the Scientific Committee for consideration) and the exclusion of existing datasets in the WSMPA analysis [70]. Norway reiterated its view [47] following the presentation of the first draft WSMPA proposal [48] (see Fig. 4a) at the subsequent meeting of the CAMLR Commission. Although Germany reflected the recommendations made by Norway at SC-CAMLR-XXXV and

presented a background paper accordingly at the subsequent Scientific Committee meeting in 2017 [49], Norway still refused its support and made further new recommendations, which had not been mentioned at the prior Scientific Committee meeting of CCAMLR (see [50]). Norway based its criticism in particular on the limited availability of data and information in the eastern part of the WSMPA planning area and their assumption that Marxan is not suitable for use across both data-rich and data-poor areas within one analysis [51]. At the Commission meeting in 2018, the European Union and its Member States then submitted a revised WSMPA proposal based on intersessional discussions with several CCAMLR Member States [52]. The revised WSMPA now also included areas in the western part of the Weddell Sea along the Antarctic Peninsula, thus linking the two separate WSMPA areas proposed in 2016 to ensure full achievement of the conservation feature target of the Antarctic toothfish (see Fig. 4b). Following up intersessional discussions, Norway withdrew the reservations expressed in 2016 regarding "best available science" for the scientific basis of the WSMPA proposals [53], while at the same time still noting a contrast in data availability, moving from the western to the eastern part of the WSMPA planning area, and the implications of such on the modelling efforts. Norway proposed to split the contrasting parts of the WSMPA planning area at the zero meridian [53] and suggested to extend the eastern part of the WSMPA planning area (up to 30°E and 60°S). They highlighted that an eastward extension up to 30°E would allow the inclusion of the priority areas for

protection identified by German scientists in the WSMPA proposal, while also putting more emphasis on increasing connectivity with other areas further east, supporting the creation of a representative system of MPAs in the CCAMLR Convention Area. Norway announced that an MPA in the eastern part of the WSMPA planning area should be prepared in the coming years (until 2022/23) in cooperation with other CCAMLR Members, Germany in particular. Many Members supported Norway's suggestion as a useful way forward to achieve consensus on the WSMPA proposal.

Following this discussion, at the 38th Commission meeting (CCAMLR) in 2019, the European Union and its Member States and Norway proposed that the WSMPA should be adopted by CCAMLR in two phases: WSMPA Phase 1 (west of the zero meridian) and WSMPA Phase 2 (east of the zero meridian) [54]. At this meeting, the new proposal for the western part - WSMPA Phase 1 - was presented [55] (Fig. 4c). The WSMPA Phase 1 proposal included (in addition to the new eastern boundary) a scientific reference area as part of the proposed Fisheries Research Zone (FRZ), which shall remain unfished and serve as an area for the analysis of potential ecosystem effects of longline fishing for Antarctic toothfish. The scientific basis for the development of this scientific reference area was discussed at various CCAMLR meetings in 2018 ([73] and references therein). Moreover, the proposed boundaries of the FRZ were amended to follow straight lines instead of depth contours for better navigability. The WSMPA Phase 1 proposal, however, could not be adopted unanimously by CCAMLR in 2019. Although a large majority of CCAMLR Member States were in favour of adopting WSMPA Phase 1, Russia and China expressed reservations [71]. Russia noted inter alia that a WSMPA proposal needed to be complemented by information on the commercial potential and future rational use of the dominant fish species and krill. China, on the other hand, wanted the WSMPA proposal to include an analysis of the mechanism and the extent of potential threats to Antarctic marine living resources.

3.2. Current situation and outlook of MPA establishment

So far, the CAMLR Commission has not reached consensus on the WSMPA Phase 1 proposal and any other Southern Ocean MPA proposal currently under consideration by the Commission. The experts at CCAMLR have discussed most of these MPA proposals and their underlying data for years (the East Antarctica proposal for nearly a decade). Throughout the proposal processes, as described above for the WSMPA, the various MPA proponents have taken up suggestions and requests by other CCAMLR members and revised the proposals accordingly. The overwhelming majority of CCAMLR Member States - even most of the fishing members - can now agree on the proposals and regard the establishment of MPAs as an essential part of their duties and obligations to conserve the Antarctic marine living resources under the CAMLR Convention.

However, there are two CCAMLR Members that do not recognise the necessity for and role of MPAs in the Southern Ocean and try to delay or even to halt the process of implementing Antarctic MPAs at all levels of CCAMLR. Apparently, the core issue here is that these members regard their long-distance fisheries - globally and hence also in the Antarctic - as a matter of national significance or even sovereignty, which would thus be restricted by an MPA. In the Weddell Sea, the highly priced Antarctic toothfish, sometimes also referred to as "white gold", seems to be the main problem (see e.g. [56]). These two CCAMLR fishing member states view toothfish, krill, and other fish species as resources that are or may become suitable for commercial exploitation. The majority of other fishing member states (e.g. the United Kingdom, New Zeeland) and in particular non-fishing states emphasise a more precautionary approach while recognising that MPAs are the most effective instrument for marine conservation, and have positive effects on commercially used fish stocks. They are aware and concerned about the vulnerability of the Antarctic ecosystems to fishing pressure, especially regarding krill dependent species or toothfish stocks, the latter of which due to the

species' longevity (up to 50 years), its slow growth, and gaps in scientific knowledge concerning its life stages.

The discussions at the 2020 meeting of the CCAMLR Commission - held online for the first time due to the COVID-19 pandemic - showed that there is very little, if any, hope for a solution to be found within the structure of CCAMLR itself. This year's negotiations demonstrated that the Commission has become unable to enforce its own measures when controversial issues arise (e.g. conservation versus exploitation), even when measures had already been implemented [57]. Those discussions also showed that CCAMLR needs to reinforce both its objective and its members' cooperation in order to fulfil its obligations for the conservation of Antarctic marine living resources and ecosystems. There is also a mismatch between the scientific work demanded to underpin MPA proposals on the one hand and the fisheries proposals on the other hand. The burden of proof currently lies with the MPA proponents, as the opponents demand sufficient data to show negative fishing impacts on the ecosystem; only then do they see MPAs justified. For fishing activities the CCAMLR principle „best available science" applies while no further studies on impacts are required. CCAMLR needs to rebalance toward its objective and precautionary approach.

With CCAMLR negotiations stuck in a deadlock, a breakthrough might need to be sought at much higher political levels. Discussions under the Antarctic Treaty will not be sufficient, as the members' representatives blocking progress in CCAMLR will also prevent discussions within the Antarctic Treaty on CCAMLR related issues such as MPAs. Talks between the foreign ministers of the USA and Russia paved the way for the adoption of the Ross Sea MPA in 2016. Requests for a similar high-level political engagement in support of further Antarctic MPAs, including the WSMPA, are increasing in forums such as the German Parliament [58] and in the European Parliament. We hope that, as political pressure and will are increasing, the issue of safeguarding the seas around Antarctica might find its way onto the agenda of future political exchanges, e.g. in the context of the G7/8 or G20 deliberations.

In the meantime, we will continue our scientific work, focusing in particular on the preparation, organisation and implementation of a WSMPA research and monitoring plan (RMP) to ensure that implementation can commence as soon as the necessary political agreement on the WSMPA has been reached. This involves elaborating on the currently formulated priority elements of a WSMPA Phase 1 RMP and developing them into a robust and comprehensive RMP. In this context, an international workshop is planned to take place in Berlin (probably in 2022). Implementation of the RMP will then ultimately be a joint project across all CCAMLR Member States and will require the support from their respective national Antarctic programmes to be brought to life.

CRediT authorship contribution statement

KT, HP, TB compiled the data, mapped the conservation features and identified priority areas for protection with input from PB, SH, HH and AL. PB and AL developed the management measures with input from KT, SH, HH, HP and TB. SH and HH developed the priority elements for research and monitoring with input from KT, BP, AL and TB. KT initiated the writing with contributions from all co-authors.

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Competing interests

The authors declare that they have no conflict of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2020.104370.

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