Report from the Expert Panel (EP) on the evaluation of the ARK VRZ commitment during the 2020/21 fishing season

Executive Summary and Recommendations

This is an update on the operation and compliance of the ARK commitment during its third year of function. The EP completed the evaluation, based on communication through video conferences and e-mails. EP carried out its work with a slightly reduced team compared to last year (Appendix 1) based on its objectives and requests from the Review Panel (RP) (Appendix 2) . The EP had access to fishery data up to the end of July 2021 and based its evaluation on this information, combined with CCAMLR reports and recent publications related to the Antarctic ecosystem. The report also includes responses to comments and requests from the ARK Review Panel (RP). The EP based its discussions on the input from the participants as given in the Appendices 3-7. The pandemic has limited access to new scientific information both due to reduced CCAMLR activity and restrictions on field research. The krill fishing fleet associated with ARK agreed to avoid fishing in an area of up to 40 km from penguin colonies in Subarea 48.1 during the penguin breeding season as well as in the new year-round protection zone around Hope Bay (Figure 1).

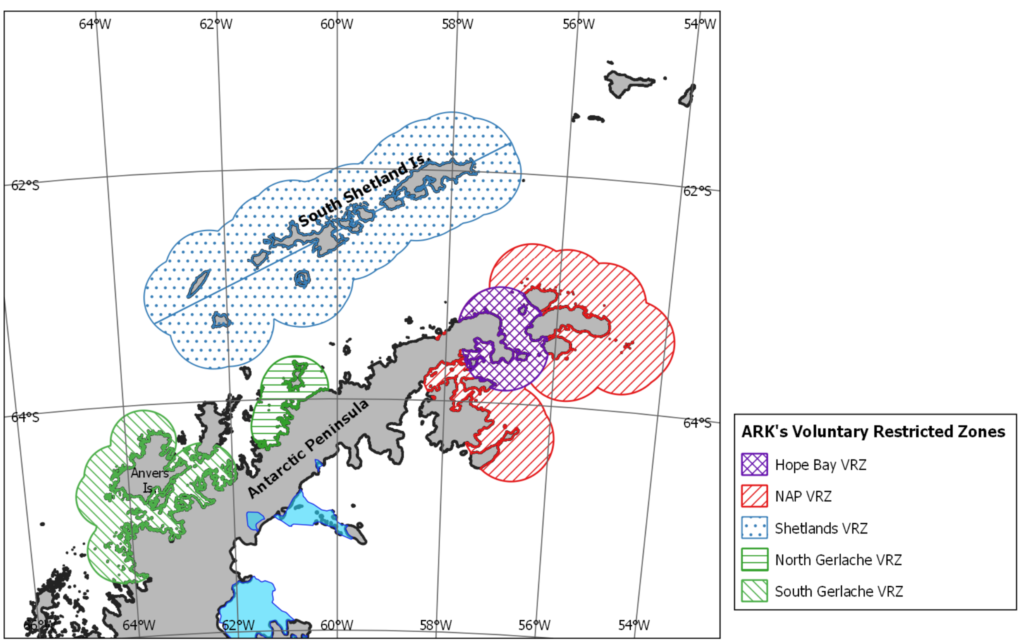

Figure 1. Map depicting the size and duration of the seasonal closure of Voluntary Restricted Zones (VRZs) around the South Shetland Islands (*blue*), the northern tip of the Antarctic Peninsula (NAP)(*red*), and northern and southern areas of the Gerlache Strait (*green*). The year-round VRZ at Hope Bay is also shown (purple).

1. Response to RP-2020

The EP appreciates the constructive talks with the RP which were held this year, in relation to the 2020 EP report. The issues discussed included the lack of clarity in the objectives of the ToRs of the EP (Appendix 2). This lack of clarity has been a source of confusion in the past, but we hope that the risk of such confusion in the future has been reduced as a result of improved communication between the EP and the RP. A second issue was the occasional gap between the expectations of the RP and what the EP considers scientifically viable, given the limited resources and information available to the panel. The EP considers it important that future communication ensures precise understanding of the ambition of RP requests, enabling the EP to respond appropriately. For example, it may be possible to address some questions using simplified qualitative evaluations instead of comprehensive statistical methodologies.

Based on the interactions between the RP and EP during 2021, the EP is satisfied that both panels are interested in an open and transparent process that might enhance the impact of the ARK Commitment in the long run.

In 2020 the EP proposed a Science-Industry Communication Forum (SICF) as a tool for efficient utilisation of the potential of the ARK Commitment. This year the EP further developed this initiative by detailing the organisation of such a forum (Appendix 3). The EP still considers this a constructive way of strengthening the ARK Commitment.

The EP recommends that:

a) Annual meetings among the two panels should be scheduled early in the reporting period (no later than March), to ensure that the aspirations of RP requests are within the capability of the EP.
b) The Science – Industry Communication Forum, SICF, is brought into operation under the principles outlined in this report to ensure that the ARK contribution is efficiently utilized.

2. Assess the compliance with the VRZs by ARK 's fishing vessels

All vessels affiliated with ARK complied with the seasonal and year-round VRZs during the 2020/21 fishing season (see Appendix 4). Thus, ARK has fulfilled its commitment for the third successive year.

Eleven ARK-affiliated vessels (from a total of 12), belonging to seven companies, participated in the krill fishery in 2020/21. The season had a slow start due to the late arrival of vessels from Korea and China, following delays at home ports related to COVID restrictions. As in preceding years, the fleet started operations in Subarea 48.2, but undertook several excursions into Subarea 48.1 during December-January. The fleet moved into Subarea 48.1 in mid-March (11-27 March) and remained there until the Subarea catch limit (155 kt) was reached on 4 June 2021. After this, half of the fleet moved into Subarea 48.2 and the other half to Subarea 48.3. The complete absence of catches in Subarea 48.3, for the first time since 2008/09, forced vessels to move back to Subarea 48.2, while 4 vessels left the fishery for the season.

As in past years, four companies representing seven vessels provided catch and effort data for the season. The remaining vessels provided maps with their tracking information, which confirmed they arrived at the fishing ground in Subarea 48.1 during March or later.

The EP notes that, as in previous years, the same ARK member companies restricted their reporting, thus degrading the accuracy and consistency of the EP analysis. Data held by ARK represents ~23-75% of catches in Subarea 48.1 (67% in 2021). The EP is concerned about the impact of this inconsistency in reporting for the quality of the upcoming 5-year evaluation.

Preliminary analysis of fishing displacement suggests a change in behaviour in the krill fleet. Since 2019, catches in Subarea 48.2 have increased in summer and decreased in winter; the opposite had occurred in Subarea 48.1. However, these changes in catch distribution are not statistically significant (Appendix 5).

The EP recommends -

c) The RP works with ARK and its members to resolve the recurring difficulties in data delivery (see Appendix 4).

3. Update krill population status

CCAMLR does not conduct formal assessments of krill stock status on a regular basis. The two large-scale surveys of Subareas 48.1 to 48.4 conducted in 2000 and 2019 produced similar total biomass estimates (60.3 and 62.6 Million tonnes, respectively). The estimated biomass for Subarea 48.1 was 15.9 and 19.1 Million tonnes, respectively. These results are not directly comparable because of methodological differences between surveys but they both indicate a substantial biomass of krill.

Smaller-scale surveys give some information on interannual variation in biomass. Chinese surveys within Subarea 48.1 conducted in 2018, 2019 and 2020 showed a modest, but not statistically significant, increase in the mean estimated biomass over this time. Nonetheless, current values remain below the peak values observed in 1997 and 2007 (Kinzey et al. 2015[1], Krafft et al. 2021[2]). Again, these results are not directly comparable because of methodological differences between surveys. Although a survey was conducted in this subarea in 2021, the results are not currently available to the EP.

[1] Kinzey D., Watters G.M., and Reiss C.S. 2015. Selectivity and two biomass measures in an age-based assessment of Antarctic krill (*Euphausia superba*). Fisheries Research, 168:72-84. https://doi.org/10.1016/j.fishres.2015.03.023

[2] Krafft B.A., Macaulay G.J., Skaret G., Knutsen T., Bergstad O.A., Lowther A., Huse G., Fielding S., Trathan P.N., Murphy E.J., Choi S.-G., Chung S., Han I., Lee K., Zhao X.Y., Wang X., Ying Y., Yu X., Demianenko K., Podhornyi V., Vishnyakova K., Pshenichnov L., Chuklin A., Shyshman H., Cox M.J., Reid K., Watters G.M., Reiss C.S., Hinke J.T., Arata J.A., Godø O.R., and Hoem N. 2021. Standing stock of Antarctic krill (*Euphausia superba* Dana, 1850) (Euphausiacea) in the Southwest Atlantic sector of the Southern Ocean, 2018–19. Journal of Crustacean Biology 41 (3):1-17. https://doi.org/10.1093/jcbiol/ruab046

The Expert Panel has previously reported on the difficulties with assessing change in the krill population based on current data streams and the lack of any new data or analysis designed to assess the effects of the ARK VRZ commitment. This situation remains unchanged, and there is therefore no basis for concluding whether the VRZs have a positive or negative effect on the availability of krill to predators compared to areas open to fishing all year around.

Nonetheless, two different initiatives highlighted potential benefits of protection of areas included in the VRZs:

- Members of SKAG[3] raised concerns about the potential effect of fishing the effective spawning stock, which concentrates north of the South Shetland Islands in summer (Meyer et al. 2020). They suggest a "seasonal closure" to protect spawning areas. This area overlaps with the VRZ off the north coast of the South Shetland Islands.
- As part of the new strategy for krill fisheries management, CCAMLR working groups are developing a Risk Assessment to spread the catches based on spatial information about the distribution of krill biomass, krill predation and fishing. One layer in that process is the krill consumption by penguins during summer. This layer uses similar data to that which informed the establishment of the VRZs and identifies many of the VRZ areas as important penguin foraging grounds.

Recent developments in krill research and fishery management include:

- SKAG held a workshop in April 2021 to evaluate change in the Antarctic krill population and identify approaches for monitoring the krill population into the future. On the first of these points, the workshop reported on the difficulty of reaching definitive conclusions about change based on current sampling methods, none of which provide regular data covering the full extent of krill's distribution at either the regional or circumpolar scale. On the second point, the workshop supported the use of krill fishing vessels as a platform for gathering data on krill populations.

- In 2021 CCAMLR's scientific working groups continued their work to develop a revised management approach for the fishery of Antarctic krill in Subareas 48.1 to 48.4, with initial work focused on Subarea 48.1. This work included the compilation of all acoustic time series from regional krill monitoring programmes, which is a potentially useful resource for understanding past krill dynamics. Nonetheless, no new conclusions about stability, change or population processes were reached on the basis of these data. The work also included the initial Risk Assessment results for Subarea 48.1. This Risk Assessment is a potential means of assessing the conservation benefit of initiatives such as the Voluntary Restricted Zones.

The EP recommends that:

d) The RP contacts the research organisations conducting krill surveys in Subarea 48.1 to arrange for the EP to have timely access to results.

[3] SKAG: SCAR (Scientific Committee on Antarctic Research) Krill Action Group

4. Provide an update on population trends of krill-dependent predators

Due to COVID-19 restrictions that limited access to monitoring platforms, little to no additional information for predator population trends for the 2020-21 season was produced. Some compilations of penguin population data indicated, consistent with previous reporting, the following: 1) The majority of chinstrap penguin populations in Subarea 48.1 are declining, but there is high variability with some populations apparently remaining stable and some increasing; this difference is not clearly related to proximity to fishing grounds; 2) Gentoo penguin populations are generally increasing throughout the Western Antarctic Peninsula (WAP); 3) Adelie penguins are declining throughout the WAP, but populations appear stable south of Adelaide Island on the WAP and in the Weddell Sea (see Appendix 6).

A number of lines of evidence from studies published in the previous year increasingly suggest that population-level induced competition between fisheries and penguins may not be limited to the breeding season. For example, fledglings appear to incur their highest mortality in the earliest weeks post-fledging, and their foraging may take them considerable distances from breeding sites, into potential conflict areas with fisheries in both time and space. If this is the case, a protection regime that relies solely on reducing conflict in foraging areas associated with breeding colonies alone may not be robust enough to offer buffering from impacts that result in poor recruitment in subsequent breeding seasons.

With respect to marine mammals, there is new information forthcoming that will provide updated and quite different estimates of daily consumption rates of krill by baleen whales in Antarctic waters. These, along with new abundance estimates will likely challenge the existing notion of not only how many whales feed on krill around the Antarctic Peninsula area, but how much they consume. Further, Cade et al.[4] provide novel insights regarding how whales perceive prey patches and how their foraging, when relativized to spatial scales of dives and the engulfment capacity of individuals, allows for a more robust and accurate estimation of the densities of krill that humpback whales target in the Antarctic. In sum, while little direct field work was conducted, significant advances in our knowledge of how whales forage, the density of prey they require, how many whales currently occupy waters surrounding the Antarctic Peninsula, and the amount of krill that these whales consume is being published in the scientific literature and will have great impact and value for managing the krill fishery.

The EP recommends that:

e) The RP should work with SICF to stimulate combining krill biomass and catch distribution data with MAPPPD penguin distribution data, which could be used together to analyze differences in predator population response;

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[4] Cade, D. Fahlbusch, J., Oestreich, W., Ryan, J., Calambokidis, J., Findlay, K., Friedlaender, A., Hazen, E., Seakamela, M., and J. Goldbogen. In Press. Social exploitation of extensive, ephemeral, environmentally controlled prey patches by super-groups of rorqual whales. Animal Behavior

f) The RP considers requesting an update on whale consumption based on recent published information.

5. Harmonize current VRZs with other initiatives

This issue has been on the agenda of the EP for two years. Last year the EP concluded that they had no basis to discuss the issue and delayed it for the 2021 report. The pandemic has limited the work in CCAMLR's working groups where a major focus has been the development of a new krill fishery management approach to replace CM 51-07, which expires in 2021.

In 2021 the EP held video conferences to discuss harmonization with representatives of two other initiatives: The proponents of the Domain 1 MPA and the coordinator of CCAMLR activities towards the replacement of CM 51-07.

A constructive meeting with the lead proponents of the current Domain 1 MPA (D1MPA) proposal (Mercedes Santos, Argentina, and Cesar Cardenas, Chile) was held on March 25 2021.

The EP emphasised that the ARK Commitment is a provisional action pending the declaration of a D1MPA.

Regarding the data that are being collected through the VRZ initiative, the D1MPA proponents showed limited interest in adding new information to the proposal since the D1MPA proposal has come close to the final version. On the other hand, they considered the EP a potential bridge builder between the D1MPA proponents and the industry, which could be an important factor during the implementation of D1MPA.

The D1MPA proponents made constructive recommendations regarding VRZs boundaries and closure periods, in line with the full reproduction cycles of the penguin species in consideration. Evaluation of these recommendations requires substantial effort and will not be done without a request from the RP. These observations seem appropriate for consideration in the upcoming 5-year evaluation process.

The EP chair met with Dr. Chris Darby (UK). Dr Darby has been appointed by the CCAMLR Scientific Committee to coordinate the activities within CCAMLR that aim at developing a new krill fishery. management regime.

There have been multiple initiatives from CCAMLR Members on krill fishery management approaches that could replace CM 51-07. Dr. Darby informed the EP chair about the approach he is coordinating and emphasised that this will be an open model system that can include relevant krill biomass data. Regarding the several ARK-led initiatives for collecting data to contribute to managing the fishery, Dr Darby underlined the positive outcomes of scientist-industry collaboration, as exemplified by interactions between scientists and the krill industry to collect data around South Georgia, the South Orkneys and the South Shetland Islands. These positive examples have convinced Dr. Darby that industry involvement might become an important element in the approach he is coordinating. Dr. Darby thus welcomed the EP proposed initiative for a SICF.

The EP chair underlined that the operation of the ARK initiative includes collection of scientific quality data at a large scale and that the EP recommends making these data available for assessment and management. The outcome of this communication suggests that the RP and EP should follow the proposed initiative for a SICF to ensure an efficient flow of information from the fleet to the CCAMLR scientific community.

The EP recommends that:

g) The RP considers whether and how to include the suggestions from the D1MPA proponents (reviewing VRZ spatial and temporal limits in relationship to the full reproductive cycle of penguin species) in the coming 5-year review process of the ARK Commitment;

h) The RP uses its influence through ARK to improve data flow from the fleet (acoustic data during fishing, oceanographic data, etc) to CCAMLR scientists to support the risk assessment process.

6. Provide additional advice to the RP

The RP requested the EP to provide some additional advice this year, including on the value of the VRZs and the overall quality of the D1MPA proposal (Appendix 2). Some of these requests created uncertainty in the EP regarding the objectives and the degree of detailed analysis required to respond adequately to the request. A meeting between both panels for clarifying these and related concerns took place on 23 September 2021. The EP is grateful for this opportunity and is looking forward to the possibility of more regular meetings with the RP in the future.

Response to the 2021 specific requests from the RP:

i. "*Provide an in-depth review of the effectiveness (conservation value) of the VRZ in terms of (i) fishing displacement and (ii) conservation benefits*"

The VRZs were originally defined based on penguin colony distribution and the foraging range of the various species during the breeding phase. As such, any analysis of VRZs benefit should include a review of penguin performance. The EP considered whether it is possible to assess a quantifiable benefit to penguin populations arising from the initiation of the VRZs. Briefly, such analysis is not possible at this time for the following reasons:

- Penguins are long-lived species. Along with variability from year to year in breeding numbers and among breeding locations, any changes will likely be masked until significant population shifts have occurred, which may take a number of years (possibly a decade or more) to observe.
- The VRZs were not designed to test hypotheses regarding the removal of fishing pressure during the breeding season (e.g., there are no control areas, there was no pre-treatment baseline established,

there was no randomized treatment plan). A historic baseline that could be used to compare pre and post treatment is largely unavailable over the range of the treatment area.

- Other relevant measures of life history (fledgling rates, chick weights, prey composition, recruitment indices, adult return rates) that could reflect post-treatment change are only available for a limited number of sites due to the expense and time of obtaining such data; in addition, these sites are not replicated sufficiently to provide any meaningful statistical analysis.

Regarding the requests about fishing displacement, Appendix 5 presents a preliminary analysis that describes the impact of the ARK Commitment on the displacement of fishing. The analysis showed changes in the behaviour of the fleet, with an increased use of Subarea 48.2 in summer and reduced use in winter. In Subarea 48.1, summer catches had reduced, although winter catches had remained similar, with a decreasing trend in the use of VRZs even during winter; however, differences are not significant.

ii. *Give technical advice on:*

  - *"The objective conservation values of the D1MPA proposal (each protected area), to have their feedback on the general "quality" of the proposal itself"*

The current D1MPA proposal represents a major investment of effort from the proponents and their co-workers, and it has been scrutinised within CCAMLR's scientific working groups. This process has not been concluded and CCAMLR has not taken a decision on the implementation of the proposal. Nonetheless the proposal is supported politically by an alliance of CCAMLR member countries and by most eNGOs with an interest in the protection of the Southern Ocean. A new detailed evaluation of the D1MPA proposal or a specific review of each protected area in the proposal requires an effort beyond the current capacity of the EP. It is therefore not feasible for the EP to respond further to this request in the current reporting period.

  - *"Other areas worth protecting, not necessarily for implementing next season, but in coming years"*

The EP supports the intention of the RP to continue identifying other areas worth protecting, as such changes must be well prepared and introduced over time. The EP received constructive inputs from the D1MPA proponents that should be included in this discussion.

As noted in section 3, the VRZs comprise areas that provide seasonal protection of spawning krill females during summer. It also coincides with important foraging areas of penguins during breeding, in line with the Risk Assessment framework underway at CCAMLR. Further, new research has identified Important Bird Areas[5] (IBA's) for penguin species around the South Shetland Islands, Gerlache Strait and

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[5] Handley J, M-M Rouyer, EJ Pearmain, V Warwick-Evans, K Teschke, JT Hinke, H Lynch, L Emmerson, C Southwell, G Griffith, CA Cárdenas, AMA Franco, P Trathan, MP Dias. 2021. Marine Important Bird and Biodiversity Areas for Penguins in Antarctica, Targets for Conservation Action. Frontiers in Marine Science 7, 1190. https://www.frontiersin.org/article/10.3389/fmars.2020.602972. DOI=10.3389/fmars.2020.602972

the northern tip of the Antarctic Peninsula. Fortunately, these are all included in the VRZs except the IBA around Elephant Island.

The additional advice requests from the RP caused uncertainty within the EP this year, particularly regarding conservation benefits. The discussions in EP covered several issues of importance for a constructive evaluation of this issue as reflected in Appendix 7.

iii. "*Evaluate the impact if the expiring CM 51-07 is not renewed or replaced, and what actions by ARK could reduce negative influence*".

Conservation Measure, CM 51-07, which caps the catch limit for Subarea 48.1 at 155,000t per year, is due to expire at the end of the current 2020/21 fishing season. If CM 51-07 expires and no alternative is agreed, the full trigger level (620,000t, as per CM 51-01) could be exploited at any single location. Under such a scenario, the ARK Commitment would be the only measure in operation that provides spatial regulation of catches in Subarea 48.1. In the case that CM 51-07 expires without a scientifically based replacement, ARK should consider whether new voluntary measures should be included in the Commitment to help maintain the precaution which underpins sustainable fisheries certification. One way is to maintain the precaution included in CM 51-07, by ensuring that catches in Subarea 48.1 do not exceed 155,000t per year (and those in other subareas do not exceed the relevant caps defined in Conservation Measure 51-07).

The EP recommends that:

i) The RP provides clarity on the scope of the ARK Commitment, particularly on the relationship between existing and future VRZs and the development of the D1MPA proposal.

j) The RP, at an early stage in the annual working cycle, provides a clear and well-defined list of special requests.

k) The RP provides a thorough framework with clear objectives for the 5-year review of the ARK VRZ Commitment. Issues which require clarification include the scope of the required "in-depth review of the effectiveness of the VRZ", the definition of "conservation value" and the criteria for identifying "other areas worth protecting" (see also recommendation g).

l) The RP identifies how additional scientific capacity can be achieved to deliver the objectives of the 5-year review.

m) The RP works with ARK to ensure a functional Science Industry Communication Forum providing efficient data flow from krill vessels to the new krill fisheries management framework.

n) The RP advises ARK members to continue observing the catch limit caps specified in Conservation Measure 51-07 until such a time as CCAMLR implements a revised management approach.

APPENDICES

Appendix 1. Affiliation of the members of the Expert Panel 2021

MEMBER	AFFILIATIONS & POSITIONS (last 5 years)
Olav Rune Godø 	• Advisor Norwegian Research Centre (2018 -) • Scientific Advisor AkerBiomarine (2018 -) • SC-CCAMLR Representative for Norway (2012-2017) • Senior Scientist Institute of Marine Research, Bergen, Norway – 2017
Simeon Hill 	• British Antarctic Survey
Rodolfo Werner 	• Senior Advisor of The Pew Charitable Trusts and Antarctic and Southern Ocean Coalition (2003 -) • SC-CCAMLR Representative for ASOC (2003 -) • Science Advisor of Antarctic Wildlife Research Fund (AWR) (2015 -)
Ari S. Friedlaender 	• Associate Researcher, Institute for Marine Sciences, University of California Santa Cruz (2017 -) • Associate Professor, Marine Mammal Institute, Department of Fisheries and Wildlife, Oregon State University, Newport, OR (2013 – 2017)
Steve Forrest 	• Antarctic Resource Inc, Truckee CA (2017 -) • Research Associate of the Antarctic Site Inventory (Oceanites Inc.)
Javier A. Arata 	• Executive Officer of ARK (2018 -) • General Manager of CRC IDEAL (Research Center on Dynamics of High Latitude Marine Ecosystems) from University Austral of Chile (2016 - 2018). • Science Advisor for the Chilean Institute for Antarctic Research, INACH (2014 - 2015). • SC-CAMLR Representative for Chile (2009 - 2015).

Appendix 2. Objectives of the Expert Panel

The objectives of the EP, as outlined in the ToRs, are the following:

1. Assess the compliance with the Voluntary Restricted Zones (VRZ) by ARK's fishing vessels.
2. Provide an update on krill and krill predator status and population trends in the areas subject to the ARK's Commitment.
3. Review the required changes to modify the seasonal VRZs into a year-round protection measure and the size of such protection.
4. Harmonize current voluntary measures with other initiatives discussed in CCAMLR (i.e., D1MPA, FBM, CM 51-07).
5. Provide advice on complementary, operable industry measures to provide adequate ecosystem protection while waiting for equivalent CCAMLR regulations to be adopted.

In addition, this year the EP was asked to provide advice to the RP on the following issues:

a. Provide an in-depth review of the effectiveness (conservation value) of the VRZ in terms of (i) fishing displacement and (ii) conservation benefits.

b. Give technical advice on:

i. the objective conservation values of the D1MPA proposal (each protected area), to have their feedback on the general "quality" of the proposal itself.

ii. Other areas worth protecting, not necessarily for implementing next season, but in coming years.

c. Evaluate the impact if the expiring CM 51-07 is not renewed or replaced, and what actions by ARK could reduce negative influence.

The EP further considered the organization of explicit requests from the Review Panel: the proposed Science – Industry Communication Forum.

Appendix 3. The Science – Industry Communication Forum (SICF)

Introduction

Constructive discussion among stakeholders with conflicting standpoints is a prerequisite for compromised agreements. The ARK commitment is an example of such a compromise, obtained through discussions among NGOs and the industry outside the CCAMLR formal management processes.

The Expert Panel (EP) proposed a science–industry communication forum in its 2020 report to the Review Panel (RP). Such a communication channel between ARK and CCAMLR scientists was presented to foster and enhance scientific data collection by the fishing fleet and improve the collaborative atmosphere in discussions related to CCAMLR management of the krill fishery.

The proposal has two main purposes:

1. **Reduce tension and increase understanding** between major stakeholders and prepare the ground for political consensus on krill fishery management.
2. **Enhance information flow from the fishing fleet to CCAMLR science bodies**. Antarctic research suffers from a lack of data due to limited access to vessel time. The fishing industry operates highly capable and well-equipped vessel capacity year-round. In its 2020 report, the EP underlined the potential and demonstrated the industry's willingness to fill this data gap. To ensure appropriate data collection and efficient operation, the EP suggested that the proposed communication forum organizes discussions on objectives, technology, routines, and procedures associated with such data collection.

Overarching goal:

- Develop a constructive communication and exchange of information between CCAMLR scientists and the industry to foster joint actions that will improve the krill fishery management.

Specific Objectives:

- Organize periodical discussions between industry and CCAMLR scientists to identify research priorities with the contribution of the industry.
- Identify specific tasks and technologies with associated procedures and routines.
- Establish specific joint projects to achieve the agreed objectives.

Organization:

ARK would be responsible for coordinating and supporting the Science – Industry Communication Forum.

EP suggests that the Science-Industry Communication Forum operates on two levels:

(1) **An annual meeting** (the *Science-Industry Communication Forum*, SICF), where the main objectives, activities and results would be discussed; this forum will be open to CCAMLR scientists, members of ARK's Expert and Review panel, SKAG Committee, ARK members.

(2) **Year-round activities,** including e-groups and workshops.

a. E-groups would work on challenges identified at the SICF, such as sensor/monitoring technologies, routines and procedures, and report their outcome to next year's SICF meeting.

b. Workshops will clarify specific issues associated with fishing practices and new management initiatives that require discussion among the different stakeholders.

The first Science-Fishery Communication Forum is scheduled for 2022, pending the approval of this initiative.

Annual Meeting

The SICF will meet once a year during the weekend between EMM or ASAM meetings or during the CCAMLR annual conference in Hobart. This scheme will ensure appropriate participation with minimum extra travelling. The agenda will include three main subjects:

- Short presentation of the outcome of recent workshops/e-groups; results of ongoing research and data collection projects, with a feedback discussion
- Short presentation of selected issues for new joint projects or groups formation
- Making decision and commitments for the oncoming year's activity

Reporting

All activities by the e-groups and workshops will be reported during the SICF annual meeting as a basis for decisions. Further reporting:

- ARK will present a summary of the SICF activities and outcomes through a background paper to SC-CCAMLR.
- Participating CCAMLR scientists will present the outcomes of research and technology testing to CCAMLR WGs and SC for further evaluation and potential inclusion in CCAMLR processes.

Structure of the Science-Industry Communication Forum

Javier/Olav discussed two models for organizing the SICF:

A simple ad-hoc approach with a minimum of new organization structure (Figure A3.1):

The SICF is organized by ARK, which receives input from the EP and the RP on the status of key questions and challenges. The ARK president will communicate with the EP chair and be responsible for establishing an agenda covering important themes from both groups, including inviting experts to cover the selected issues.

An independent SCIF body (Figures A3.2-A3.3)*:*

The SICF and associated activities are organized and coordinated by a Science-Industry Communication Forum Board. Members of this Board are agreed at the SICF meeting and could include the chair of relevant CCAMLR Working Groups, particularly EMM, ASAM, FSA; scientists actively engaged in krill population studies; fishery representatives; representatives from ARK's Expert and Review Panels.

The Science-Industry Communication Forum will meet once a year to:

- Support two-way communication between the industry and scientists:
    - Update on the development of management-related research, including data and operational challenges that might require action by the SICF.
    - Update from the industry on the research-support efforts conducted throughout the year and the results obtained during the last fishing season, including the report of fishermen's experience on, i.e., changes in krill distribution and availability, occurrence and activity of whales, and other unquantified subjective anomalies from the fishers' point of view.
- Review the priority research needs best suited to be undertaken by the fishing industry.
- Discuss a work plan to implement the priority technology and research objectives.
- Identify issues that require further interaction between scientists and the industry during the coming years.
- Based on the above discussions, organize follow-up activities, including the establishment of subgroups/e-groups to tackle specific activities, or propose workshops. Such subgroups could include:
    - Technology and operation subgroups:
        - Discussions on potential technologies for implementation on fishing vessels
        - Specification of associated operation routines and procedures
        - Analysis of the impacts of specific regulations on the activity pattern of the fleet.
    - New fisheries management proposals
        - Implication on industry
    - Etc.

Recommendation of themes for the first year of SICF

Based on discussions and recommendations at EP 2020 and 2021 meetings, the EP suggests that the SICF should start working on how the fleet may support ongoing science and monitoring programs with adequate data. In the first year, the forum could specify what is available, i.e., what vessels, where and when they operate and what their capability is in terms of sensors and technology infrastructure. Also, a clarification of visiting scientists' requirements is needed (e.g., travel to/from ports, appropriate certificates (and insurance?), and a plan for analysing the data and reporting the results. Further, a request to EMM and SKAG to identify priority projects that are tangible given the constraints should be formulated.

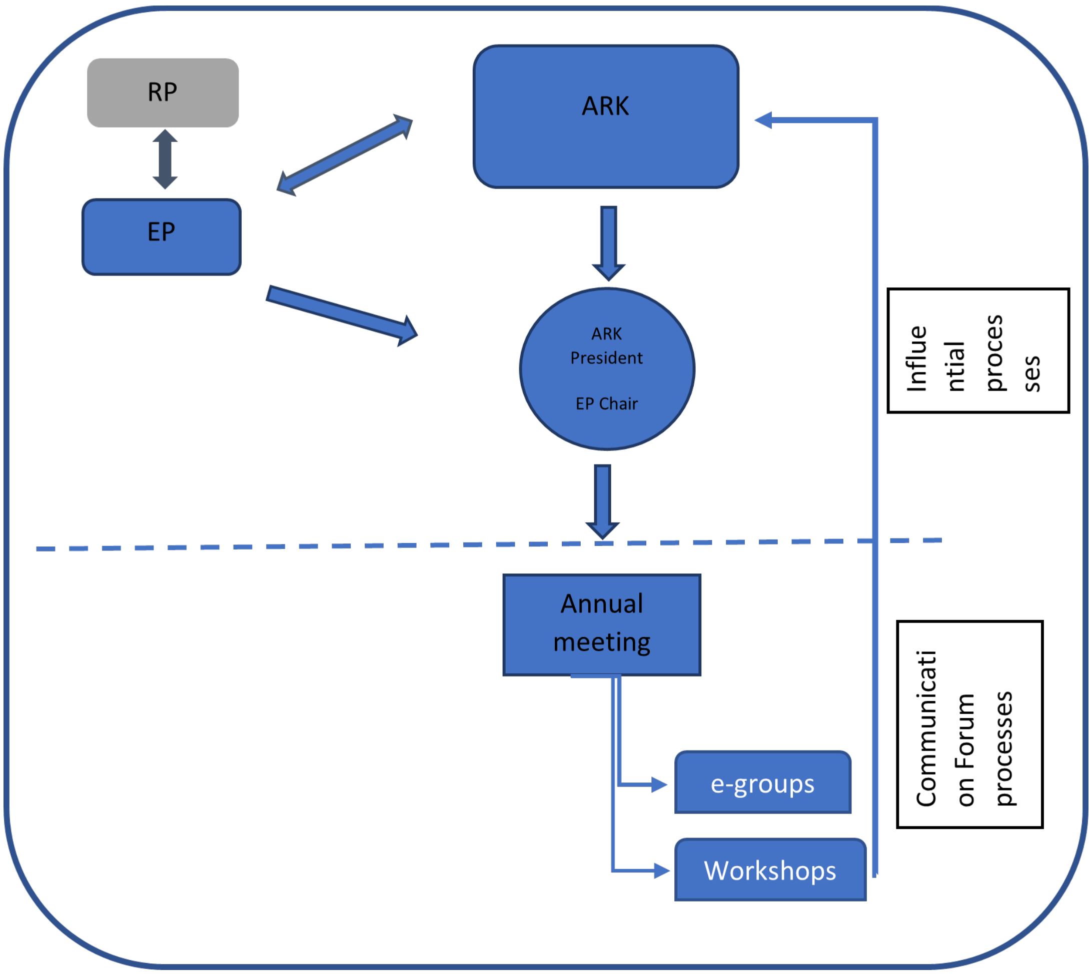


Figure A3.1. A simple ad-hoc organisation. Illustration of the function and operation of the Science - Industry Communication Forum, SICF. Hatched line separates the influential processes taking place as prerequisite for the SICF (upper panel) and the activity within the SICF (lower panel), The idea is that ARK, as the owner of the process, coordinates activities of the SICF through interactions with the RP and EP.

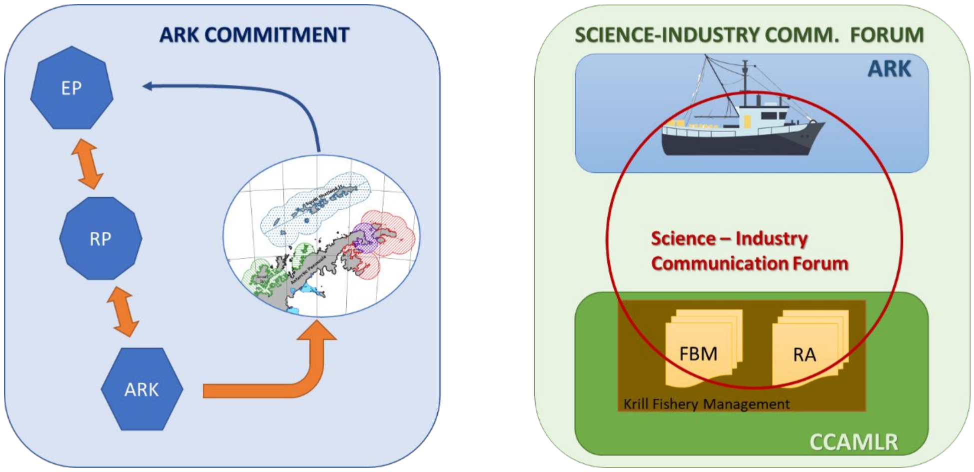


Figure A3.2. The Science-Industry Communication Forum will have other goals than the ARK Commitment. As such, it should function as an independent organization. FBM: Feedback Management [of krill]; RA: Risk Assessment.

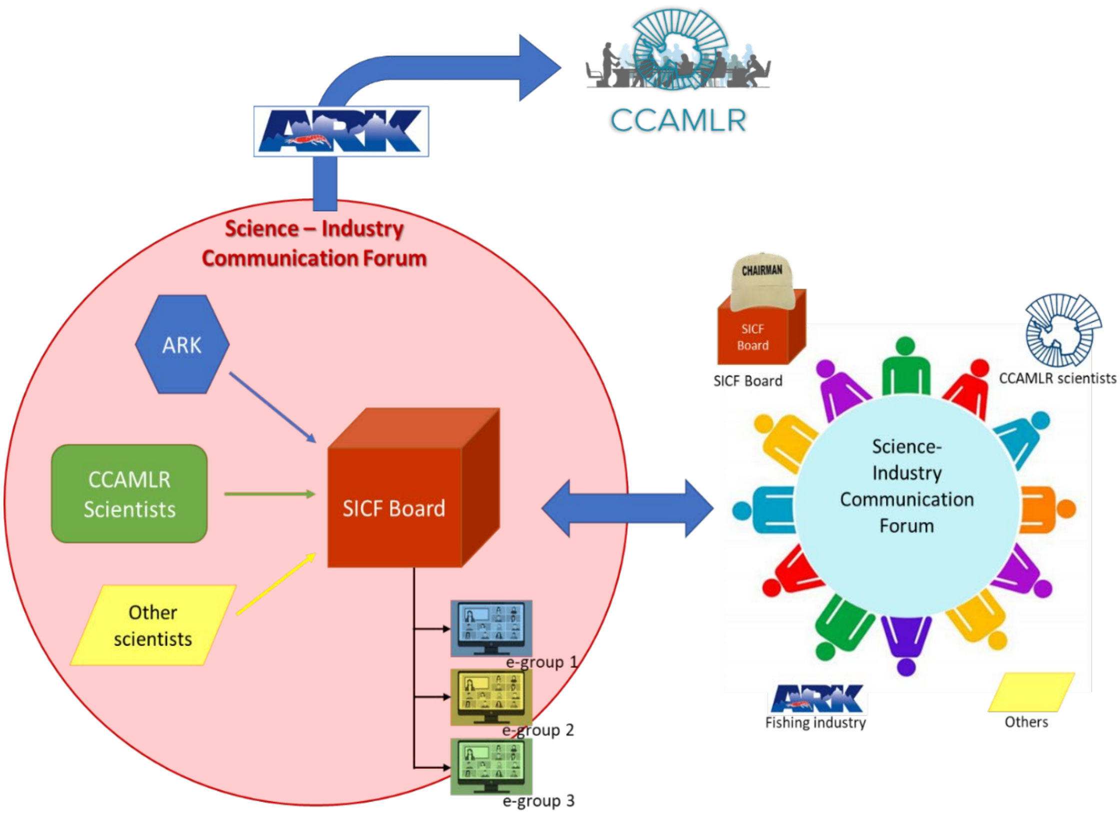


Figure A3.3. A more formal structure. The Science-Industry Communication Forum (SICF) Board will coordinate and discuss the main issues among stakeholders. Propositions and results will be presented at the annual SICF meeting to obtain feedback from all interested parties. Results will be presented to CCAMLR through ARK via a background paper.

Appendix 4. Analysis of the krill fleet distribution during season 2020/21

Dr. Javier A. Arata, Executive Officer, ARK

Summary

- Twelve krill fishing vessels operated in the 2020/21 season; only one vessel is not affiliated to ARK.

- Four out of the seven companies affiliated to ARK and actively fishing during this season, representing 7 vessels, provided haul-by-haul data.
- The other three companies, representing 4 vessels, provided maps with the distribution of their vessels during the fishing season.
- According to the information available, the whole krill fishing fleet complied with the seasonal VRZ and the year-round VRZ at Hope Bay during the 2020/21 fishing season.

Krill catches

Krill catches by subarea were obtained from the official CCAMLR monthly reports. Subarea 48.1 quota was reached on June 4th (Table A4.1). Low catches in Subarea 48.2 at the beginning of the season motivated several vessels to move into Subarea 48.1 during December and January, although most returned to Subarea 48.2 in late January (Fig. A4.1). The fleet moved into Subarea 48.1 on 11-15 March, a week earlier than last season. After the closure of Subarea 48.1, the fleet moved initially into Subarea 48.2, but absence of fishing motivated the fleet moving back into Subarea 48.2 in 6-10 June (Fig. A4.1).

Table A4.1. Synopsis of the krill fishing season 2020/2021 (1 December 2020 to 30 June 2021).

	Subarea 48.1	Subarea 48.2
Max No. fishing vessels	12	8
Subarea closure	4 June	NA
Total Catch (tons)	161,771.72	139,241.36
% Subarea quota	104.37%	49.9%

Distribution pattern of the fleet

Distribution of the fleet was described using (i) haul-by-haul data provided by the companies, (ii) vessel track maps provided by companies and, (iii) AIS positions, as obtained from www.MarineTraffic.com (Table A4.2).

Haul-by-haul data

Four companies affiliated to ARK, representing 7 vessels, provided haul-by-haul data (Table A4.2).

Data was no catches (NA) were removed. Hauls positions were filtered and corrected when obvious (-420.6 instead of -42.06), using positions for preceding/following 3 hauls; when only the start or end position was missing, the start/end position was duplicated. Distribution of hauls was estimated as the middle point between the start and end of each tow.

Distribution Maps provided by Companies

CNFC, Liaoning and Fujian Zhengguan Fish. Dev. Co. did not provide haul-by-haul data, but maps depicting the distribution of their vessels for the season.

These maps indicate that all Chinese vessels arrived at Subarea 48.1 on mid-March or later (Figures A4.3-A4.6), after the end-date of the seasonal VRZs.

Compliance with seasonal VRZ

A total of 12 vessels operated during the fishing season 2020/21. Different from last year, 4 Vessels operated in Subarea 48.1 during the summer period, all of which provided their haul-by-haul data. According to the haul-by-haul data, all ARK vessels complied with the seasonal VRZs during 2020/21 season (Table A4.3).

During the winter (March-June) period, none of the vessels which provided haul-by-haul data fished within the Hope Bay VRZs (Table A4.3). The other 4 vessels which provided maps of their tracks, did not engage in fishing activities near the Hope Bay VRZ either (Figs. A4.3-A4.6).

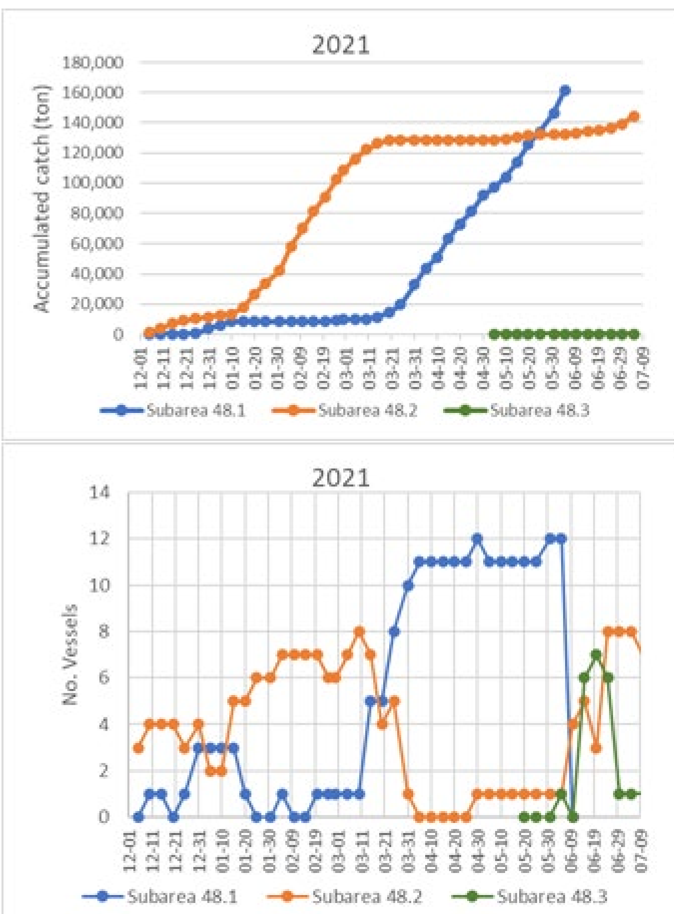


Figure A4.1. Accumulated krill catches (top) and number of fishing vessels operating (bottom) as reported to CCAMLR Secretariat.

Table A4.2. List of krill fishing vessels operating in the 2020/21 season and information available to describe their distribution. Haul-by-haul data was provided by some ARK Members (under 'haul-by-haul data'). AIS information was obtained from www.MarineTraffic.com.

AIS information was obtained from www.MarineTraffic.com.

COMPANY	VESSEL NAME	Haul-by-Haul data	Distribution Map	AIS information	First entrance to Subarea 48.1*
PescaChile	Antarctic Endeavour	YES		YES	06-DEC-2020
JEONG-IL	Sae In Leader	YES		YES	23-MAR-2021
	Sae In Champion	YES		YES	03-APR-2021
AKER BIOMARINE	Antarctic Sea	YES		YES	21-DEC-2020
	Saga Sea	YES		YES	27-MAR-2020
	Antarctic Endurance	YES		YES	29-DEC-2020
DONGWON	Sejong	YES		YES	18-FEB-2021
CNFC	Long Teng	**NO**	YES	YES	21-MAR-2021
	Long Fa	**NO**	YES	YES	15-MAR-2021
LIAONING	Fu Rong Hai	**NO**	YES	YES	15-MAR-2021
Fujian Zhengguan	Fu Yuan Yu 9818	**NO**	YES	YES	27-APR-2021
IKF Ltd	More Sodruzhestva	**NO** (Not part of ARK)		YES	13-MAR-2021

*Data corroborated through MarineTraffic.com.

Table A4.3. Distribution of catches inside and outside of the VRZs during Summer (Dec-Feb) and Winter (Mar-June), as reported to ARK.

	Summer (ton)	Winter (ton)	Subtotal (ton)
Inside VRZs	0	23,176.32	23,176.32
Inside Hope Bay VRZ	0	0	0
Outside VRZs	9,374.95	75,833.54	85,208.49
Data reported to ARK	9,374.95	99,009.86	108,384.8
Subtotal for Subarea 48.1 (CCAMLR Secretariat)	9,782.75	151,463.82	161,771.72
ARK/total data	*95.83%*	*65.37%*	*67.00%*

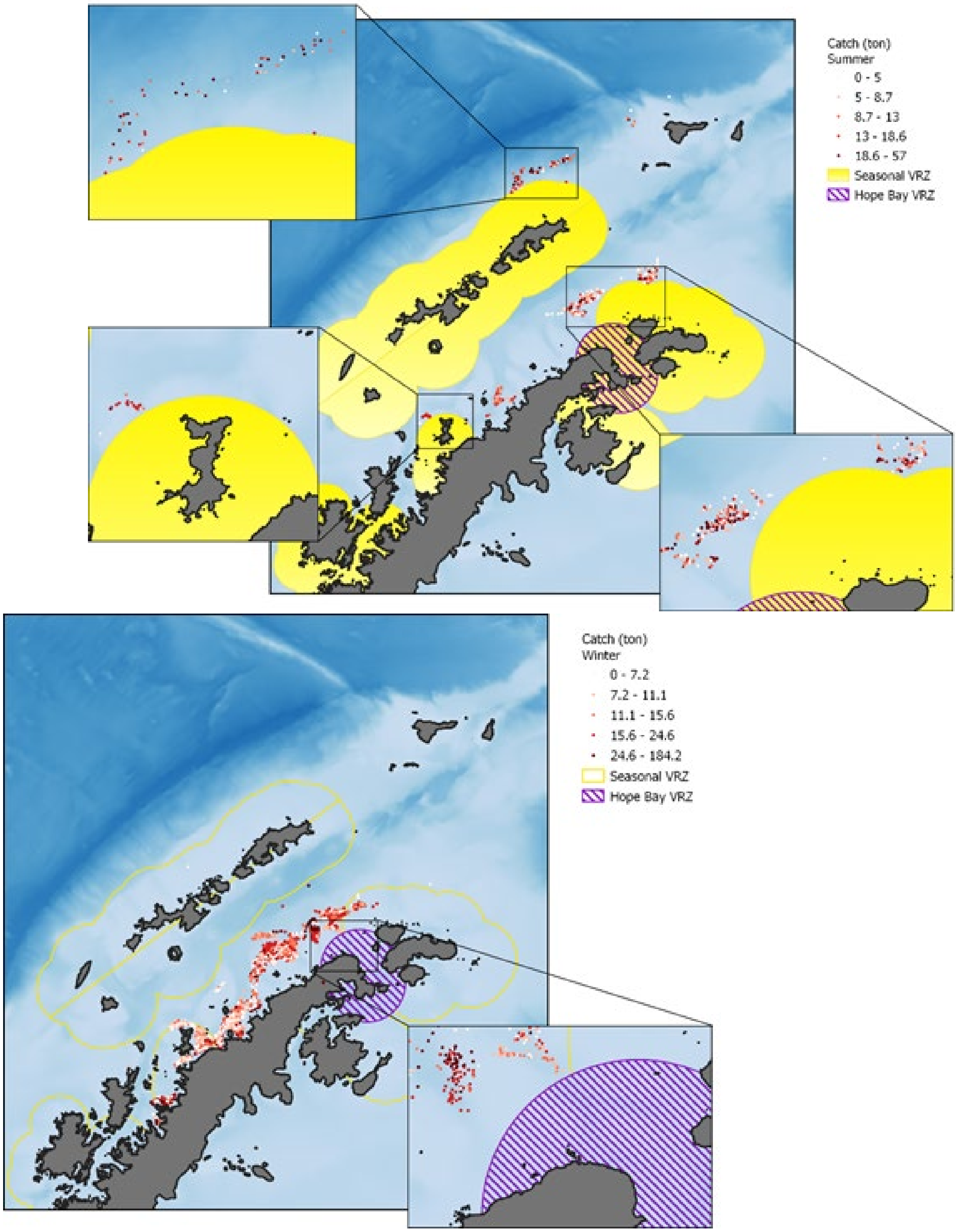


Figure A4.2. Distribution of accumulative krill catches of 7 ARK vessels during the 2020/21 fishing season (see Table A4.2 for a list of vessels). Top: December 2020 to February 2021; Bottom: March to June 2021. Source: ARK database.

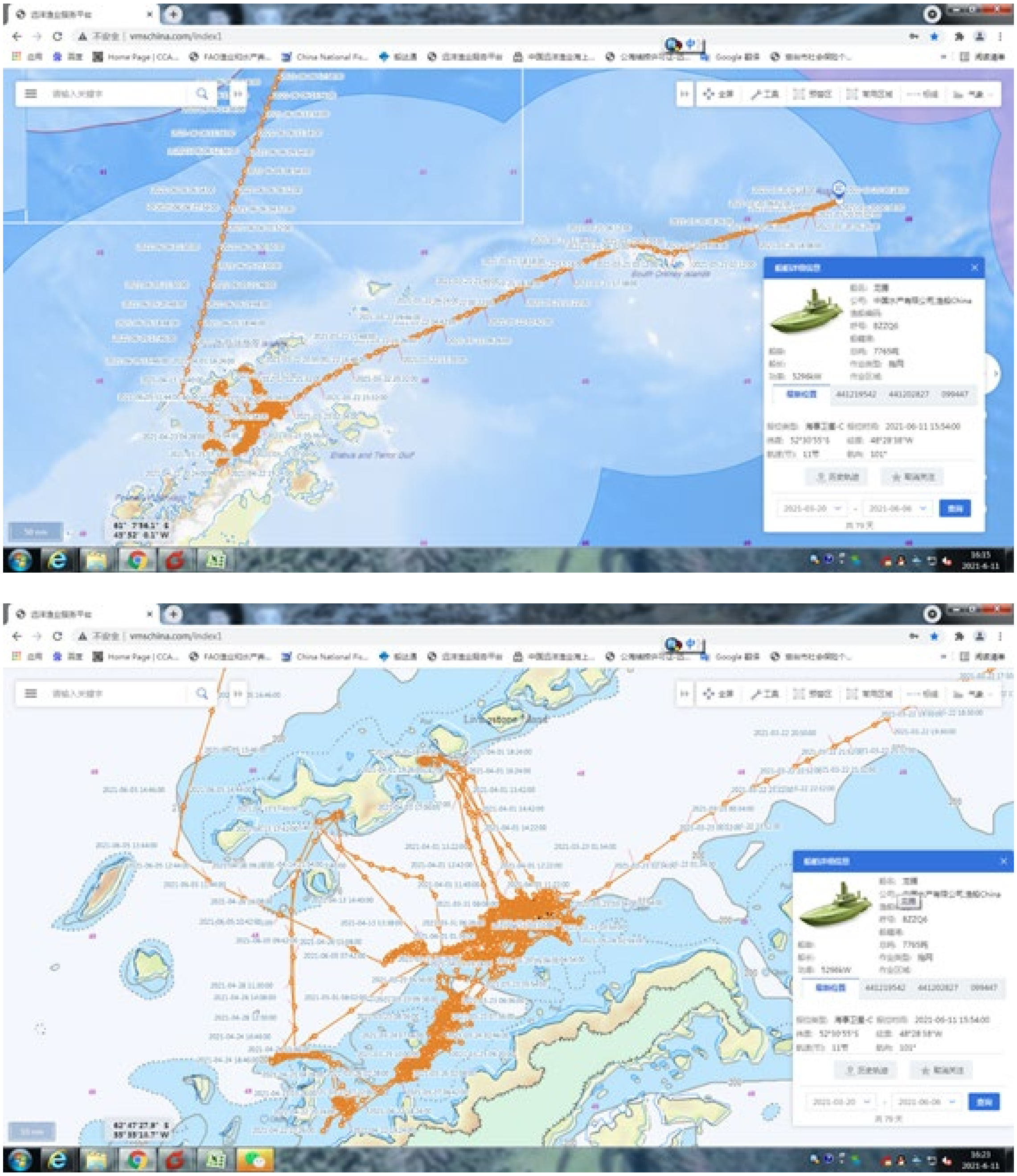


Figure A4.3. Distribution of FV LONG TENG during the 2020/21 krill fishing season, as provided by CNFC.

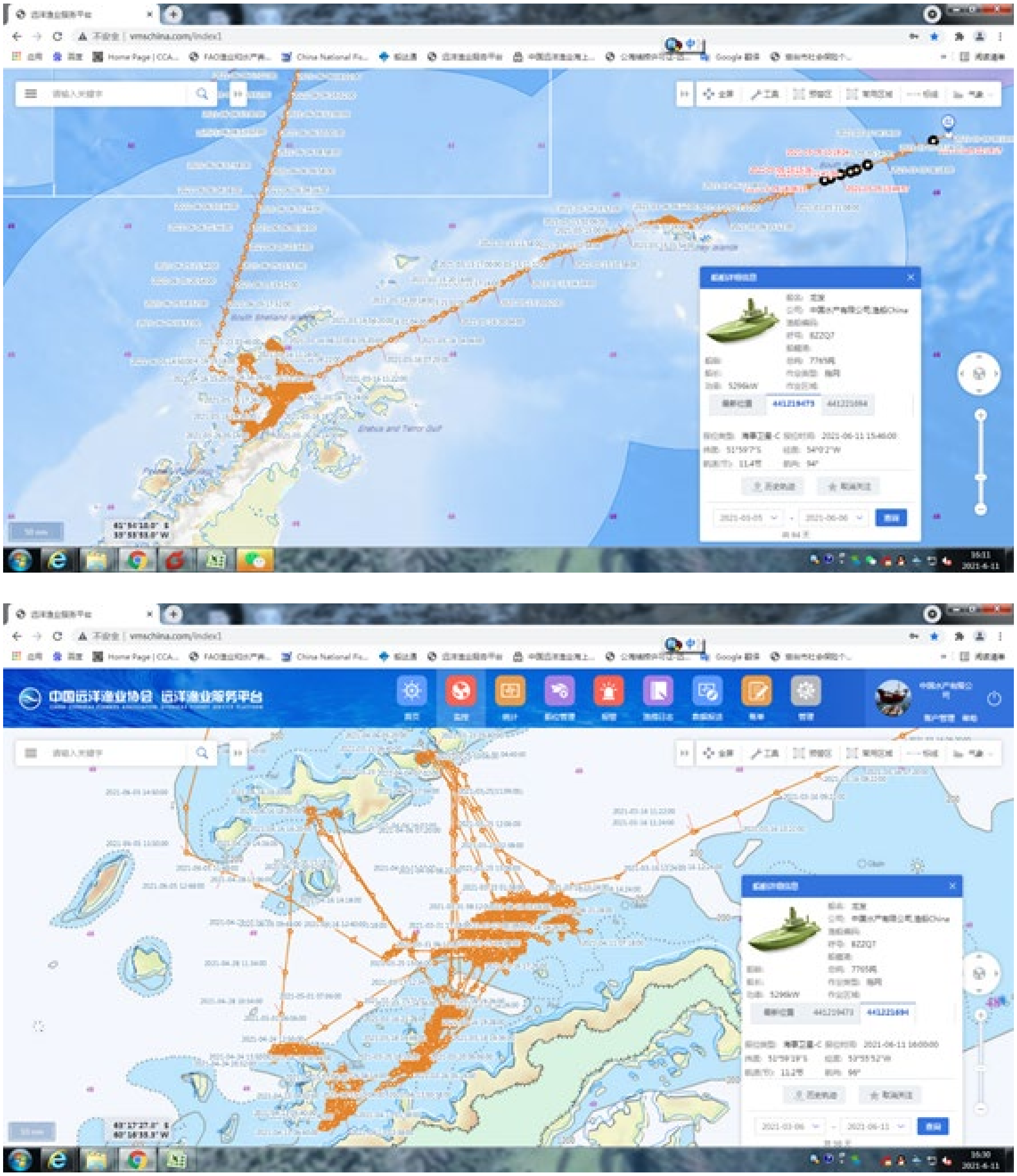


Figure A4.4. Distribution of FV LONG FA during the 2020/21 krill fishing season, as provided by CNFC.

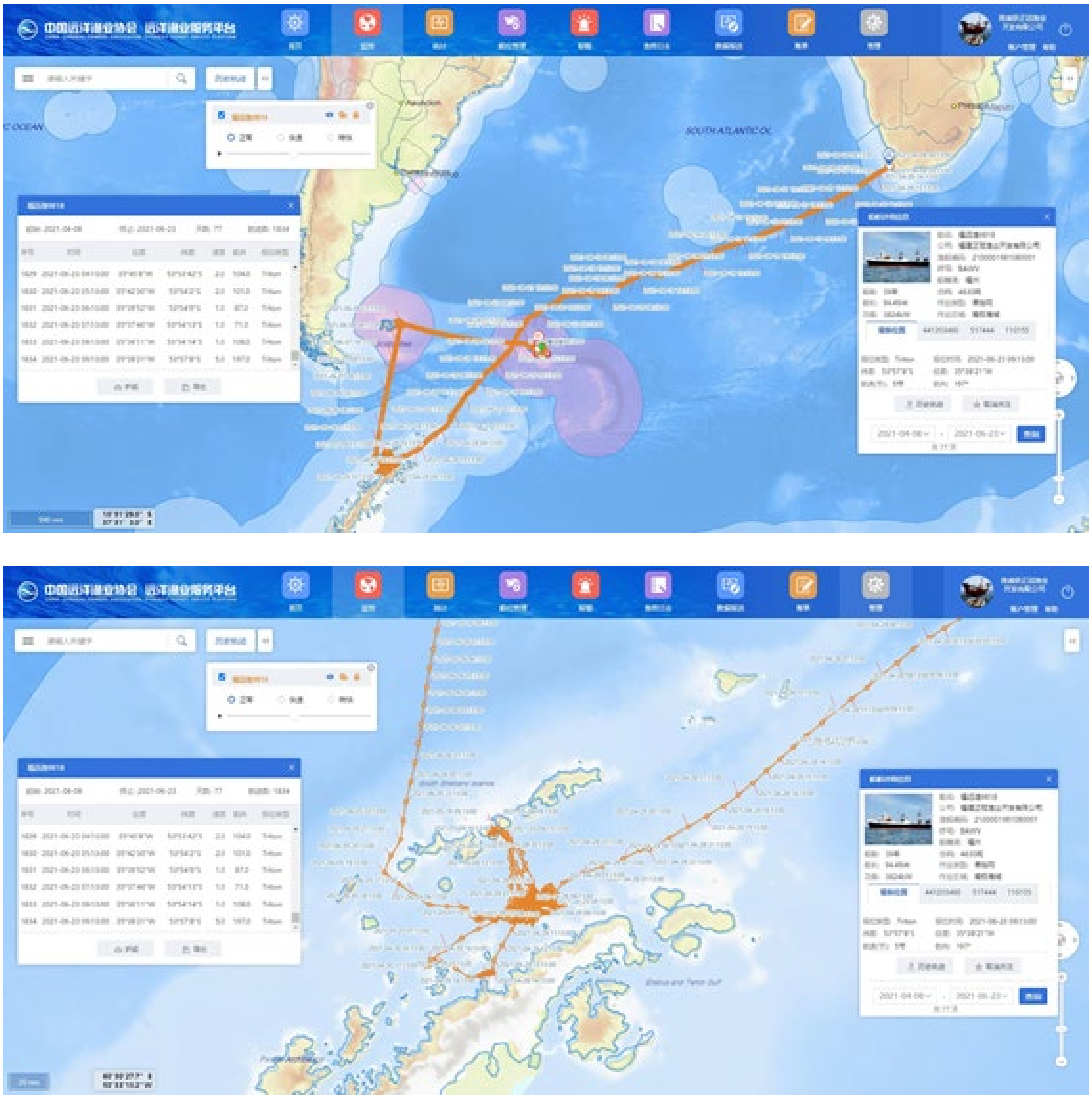


Figure A4.5. Distribution of FV FU YUAN YU 9818 during the 2020/21 krill fishing season, as provided by Fujian Zhengguan Fish. Dev. Co.

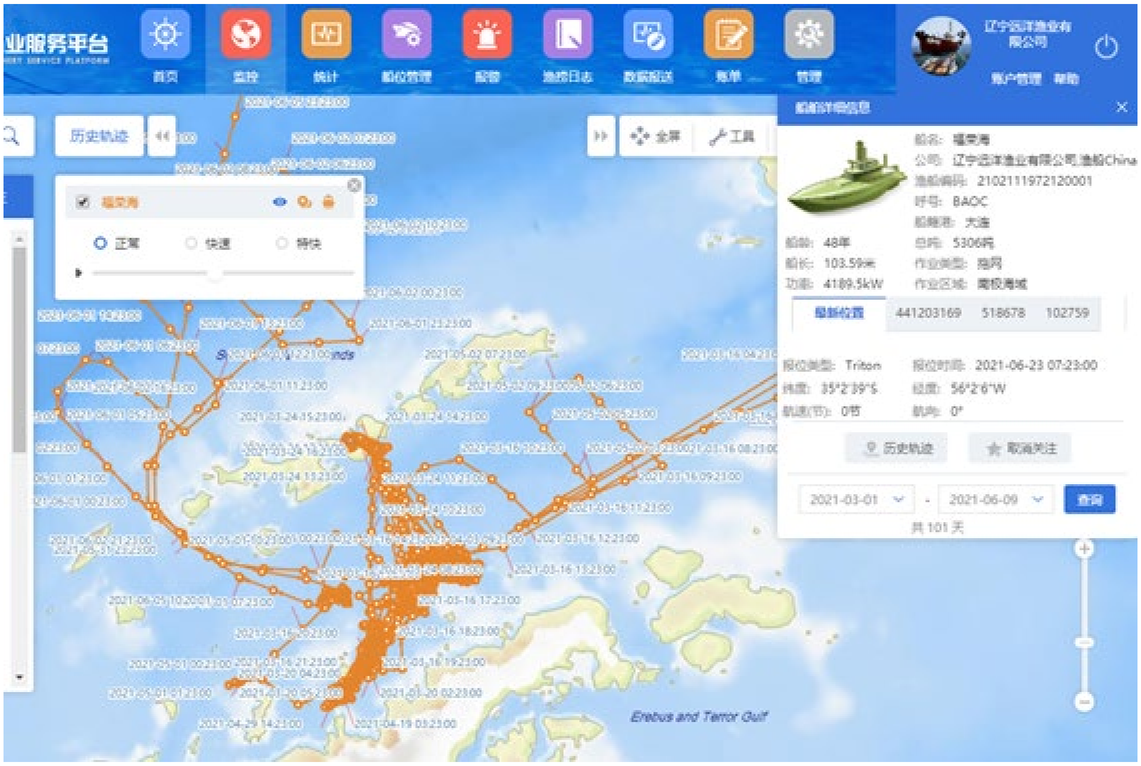


Figure A4.6. Distribution of FV FU RONG HAI during the 2020/21 krill fishing season, as provided by Liaoning Pelagic Fish. Dev. Co.

Appendix 5. Impact of the VRZ in the fleet behaviour

Dr. Javier A. Arata, Executive Officer, ARK

Summary

- ARK has collected haul-by-haul data from 2009 to 2021. Current data available to ARK represents 23-75% of total krill catches for Subarea 48.1
- Implementation of VRZ in 2019 had an impact on the spatial and temporal distribution of the fleet. Since the implementation of the VRZ –
  - The fleet had increased its catches in Subarea 48.2 during summer
  - Summer catches in Subarea 48.1 had decreased, and non occurs within the VRZ
  - Conversely, catches in Subarea 48.2 during winter had decreased
  - Winter catches in Subarea 48.1 had remain similar, but a significant reduction of catches from inside VRZ is evident
  - However, differences are not significant

Introduction

The EP considered in 2019 the need to assess the potential effect of the introduction of the VRZs in the krill fishing fleet. The two main questions raised were:

(i) Does the introduction of the VRZs generated any detectable change in the fleet operation?

(ii) Does the introduction of the VRZs generated an increase in fishing concentration?

In 2021 the RP requested a review of the effects of the VRZs, including on the fishery. For the purpose of this report, these effects are assessed through the analysis of potential changes in:

- Fishing displacement, considered as temporal and spatial changes in effort and catches associated with the implementation of the VRZs.

Data and methods

Data availability

Four ARK companies, out of seven, provided haul-by-haul data (CCAMLR C1 Forms) for their vessels, from 2009 fishing season forward (fishing seasons start on 1 December and ends 30 November; seasons are named by the year they finished). The actual number of vessels and catches reported, divided by Subarea 48.1 and 48.2, are presented in figures A5.1-A5.4.

Data provided by ARK was compared to the total krill fishery by estimating the percentage of vessels and total catches informed by ARK, in relation to the overall statistics provided by the CCAMLR Secretary (Tables A5.1-A5.2).

SUBAREA 48.1

Table A5.1. Percentage of fishing vessels ('ARK vessels') and catches ('ARK catches') from Members that reported back to ARK, relative to total numbers provided by CCAMLR Secretariat for Subarea 48.1.

Season	ARK vessels (%)	ARK catches (%)
2009	12%	28%
2010	14%	47%
2011	15%	113%
2012	27%	23%
2013	33%	53%
2014	42%	60%
2015	36%	64%
2016	63%	30%
2017	63%	73%
2018	67%	67%
2019	70%	75%
2020	58%	67%
2021	58%	67%

Figure A5.1. Number of vessels fishing for krill in Subarea 48.1 as reported by CCAMLR Secretariat ('Total vessels') and vessels from Members that reported back to ARK ('ARK vessels') for each fishing season.

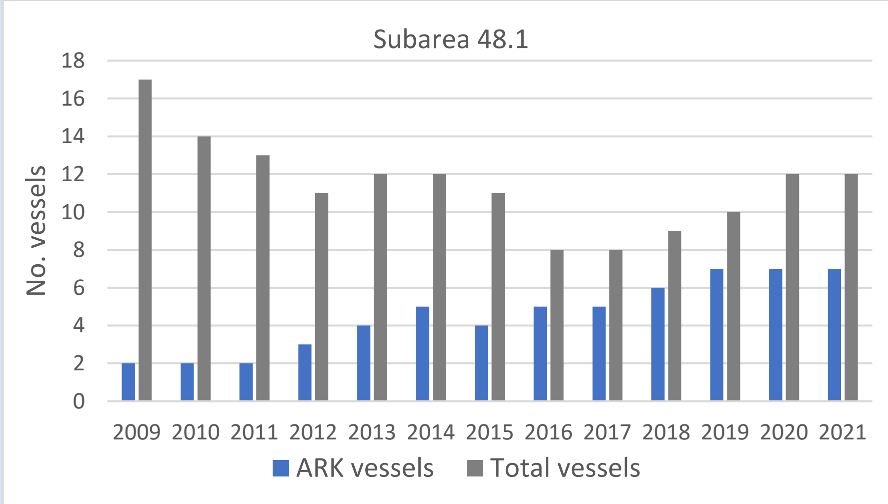
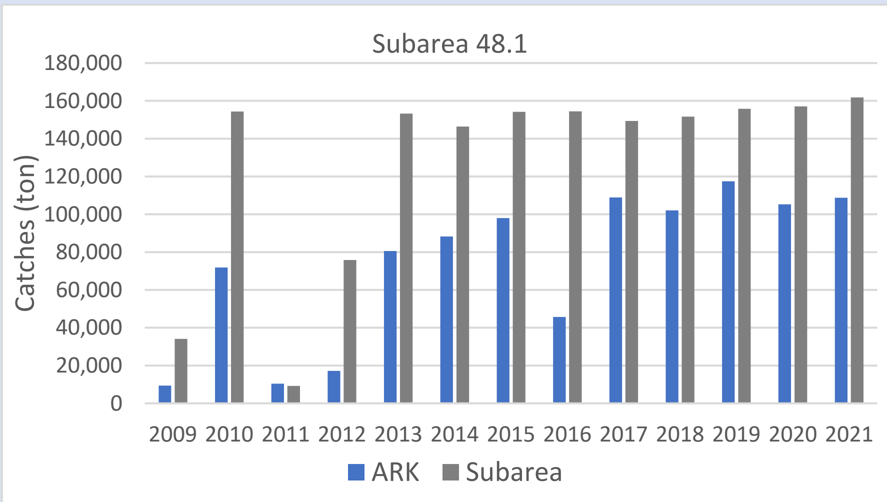


Figure A5.2. Krill catches for Subarea 48.1 for each fishing season, as reported by CCAMLR Secretariat ('Subarea'), and partial catches from Members that reported back to ARK ('ARK').



SUBAREA 48.2

Table A5.2. Percentage of fishing vessels ('ARK vessels') and catches ('ARK catches') from Members that reported back to ARK, relative to total numbers provided by CCAMLR Secretariat for Subarea 48.2.

Season	ARK vessels (%)	ARK catches (%)
2009	12%	52%
2010	14%	72%
2011	15%	34%
2012	9%	68%
2013	27%	45%
2014	33%	81%
2015	20%	96%
2016	17%	96%
2017	25%	87%
2018	50%	71%
2019	58%	83%
2020	88%	65%
2021	56%	68%

Figure A5.3. Number of vessels fishing for krill in Subarea 48.2 as reported by CCAMLR Secretariat ('Total vessels') and vessels from Members that reported back to ARK ('ARK vessels') for each fishing season.

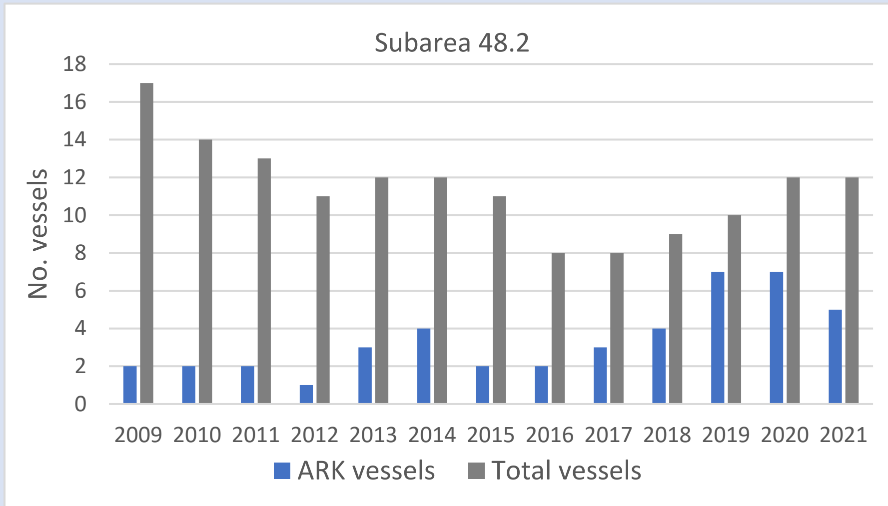
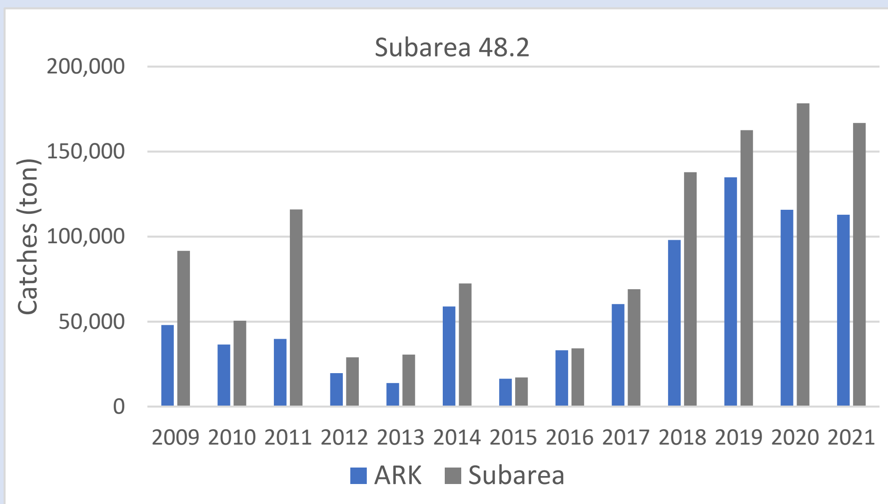


Figure A5.4. Krill catches for Subarea 48.2 for each fishing season, as reported by CCAMLR Secretariat ('Subarea'), and partial catches from Members that reported back to ARK ('ARK').



Distribution of catches

Spatial and temporal distribution of the fleet was analysed with the available data provided by ARK, thus reflecting 23-75% of total catches for Subarea 48.1 (Table A5.1-A5.2). Location of each haul was determined by the middle position between the start and end of each haul. Positions were transformed to South Pole Lambert Azimuthal Equal Area projection, centred at 51°W, 61°S. Data was filtered out by using the following criteria: absent of catch data, a combination of speed (>30 knots) and distance (>20 nm) from previous haul. A total of 124,914 hauls were analysed, corresponding to 99.63% of total hauls informed to ARK.

Fishery displacement

Distribution of fishing effort before and after the implementation of the VRZ were compared considering the following:

-First, a temporal subdivision of data (Year and Season):

- Time period: before and after the implementation of VRZ in December 2019
- Seasonality: summer (October-February) and winter (March-September); although VRZs have different durations, the fleet has operated with a standard end-period of 1 March for all of them.

-Second, the response variable:

- Distribution of catches during each period, measure as % of catches coming from inside and outside VRZ spatial zones, for each temporal (year/season) combination.

All analyses were conducted using R (R Core Team 2020) under GUI RStudio version 1.2.5042.

Results

Description of data made available to ARK

The annual variation in fishing effort and catches accounted by ARK vessels, subdivided by fishing method and Subarea, is presented in figure A5.5. Fishing effort and catches at each subarea present a high interannual variation, but the trend at each Subarea differs.

Fishing effort, measured by number of hauls, has remained relatively stable in Subarea 48.1, within 2000-4000 hauls per season per fishing method, from 2013 onwards. Likewise, catches, although with high interannual variability, are relatively stable within each fishing method during the same period. The latter figure also indicates the significance of the catches by the 'other' vessels (data not available to ARK), which all correspond to traditional trawlers.

Available data for Subarea 48.2 indicates an increasing trend in effort (no. hauls) from 2016 onwards for the continuous fishing fleet. This increase is also in the catches by the continuous fleet from 2018 onwards. This could in part be explained by the incorporation of a third vessel in 2019. For the traditional fleet, fishing effort and catches in Subarea 48.2 increased significantly since 2019, with the implementation of the VRZs. Catches not accounted in the ARK database indicates a peak in 2011, when several fishing vessels appeared and then disappeared from the fishery; from 2018 onwards, these catches increased significantly again, this time driven by Chinese vessels (part of ARK). The significant increase since 2019 it is at least in part associated with the implementation of the VRZs.

Fishery displacement

The introduction of the VRZ in the fishing season 2018/19 produced spatial and temporal changes in the spatial pattern of the fleet. The introduction of the VRZ produced an increase of catches at Subarea 48.2 during summer, as effect of avoiding the seasonal closed areas (Table A5.3). Before 2018/19, 11.77% of summer catches were obtained in Subarea 48.1 (6.46% inside a VRZ), and 22.28% were caught in subarea 48.2 (Fig. A5.6, left panel). Since the season 2018/19, the fleet has opted for fishing mainly in Subarea 48.2 during summer months (38.29% of catches), compared to 2.55% from Subarea 48.1 (all outside the VRZs) (Fig. A5.6, right panel); however, differences are not significant (Table A5.4).

The opposite happens during winter (March-June) after the seasonal VRZ restrictions are lifted. The fleet moves into Subarea 48.1 during March, after the seasonal closure, reducing the proportion of catches taken in Subarea 48.2 during winter (24.74% before vs 13.97% after; difference not significant). By contrast, winter catches in Subarea 48.1 remain similar between both periods (49.39% before vs 46.05% after; difference not significant), presumably due to the limited quota. Although the spatial distribution of catches changed between both periods: before the VRZ, 16.92% came from inside the VRZ in winter, compared to 7.95% after, differences are not significant (Table A5.4).

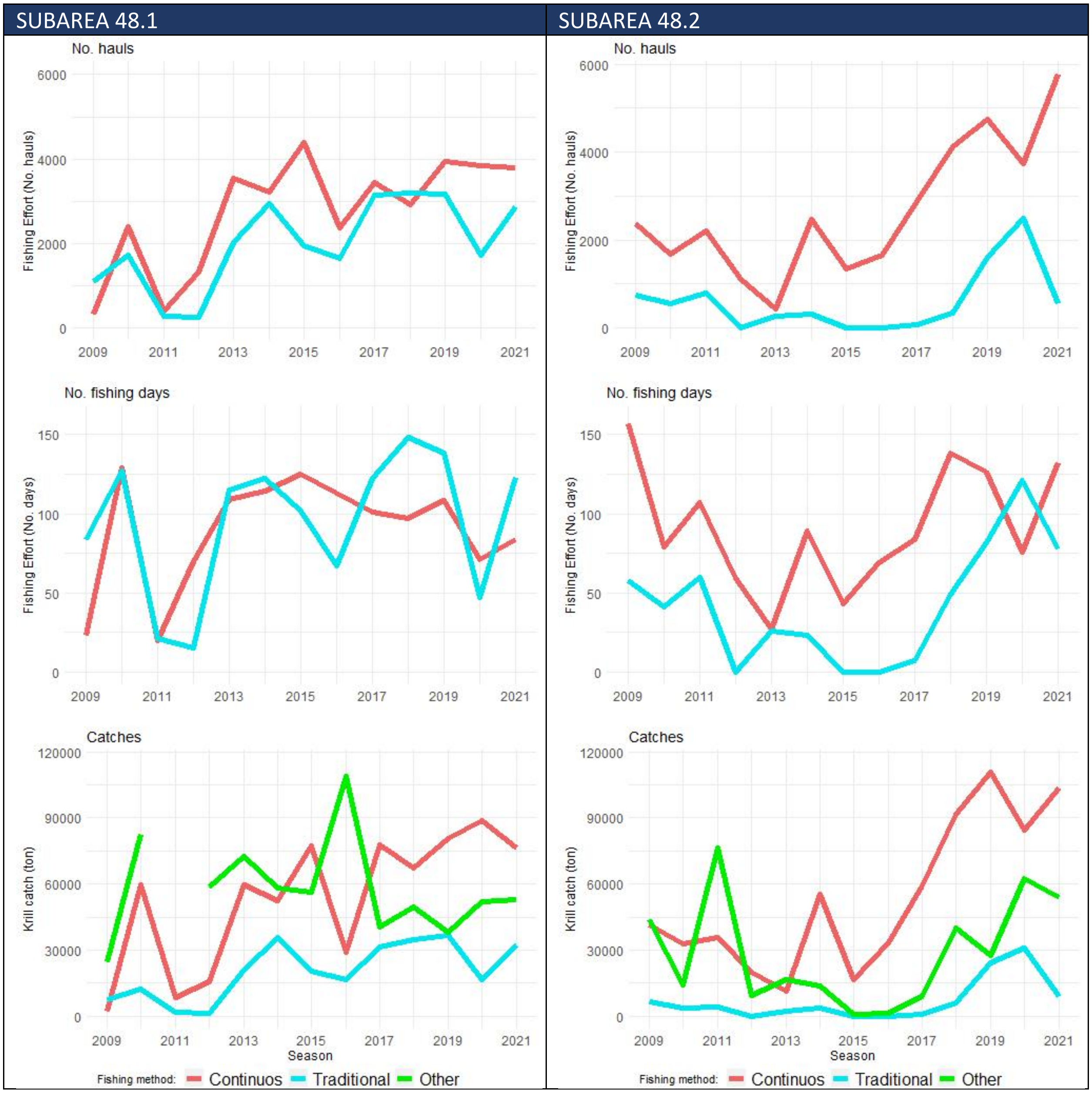


Figure A5.5. Annual fishing effort informed to ARK, divided by trawling method and Subarea. "Other" refers to catches conducted by vessels (all traditional trawlers) not affiliated to ARK.

Table A5.3. Percentage of annual catches (Mean, Q25, Q75) harvested from Subarea 48.1 (inside and outside the limits of VRZ) and Subarea 48.2, before and after the implementation of the VRZ in the 2018/19 fishing season. Period: before = 2009-2018, after = 2019-2021; Q25 and Q75: 25% and 75% quartiles.

Spatial Unit	Period	Season	Mean	Q25	Q75
Subarea 48.1 Inside VRZ	before	summer	6.46	3.91	9.58
Subarea 48.1 Inside VRZ	after	summer	0.00	0.00	0.00
Subarea 48.1 Inside VRZ	before	winter	16.92	3.71	25.97
Subarea 48.1 Inside VRZ	after	winter	7.95	6.70	10.11
Subarea 48.1 OUTside VRZs	before	summer	5.31	1.20	6.89
Subarea 48.1 OUTside VRZs	after	summer	2.55	1.62	3.48
Subarea 48.1 OUTside VRZs	before	winter	32.47	15.93	42.96
Subarea 48.1 OUTside VRZs	after	winter	38.10	35.15	40.05
Subarea 48.2	before	summer	22.28	14.04	34.82
Subarea 48.2	after	summer	38.29	36.59	39.28
Subarea 48.2	before	winter	24.74	10.16	27.28
Subarea 48.2	after	winter	13.97	12.38	16.32

Table A5.4. Two-way ANOVA tests of % catches between Period (before and after implementation of VRZ), Season (summer and winter), VRZ (inside and outside VRZ, only for Subarea 48.1). Interaction of variables is denoted by "*". Tukey post-hoc test results are indicated by "[T]". Significant difference in bold.

Comparisons	Subarea 48.1	Subarea 48.2
Period: Before vs After	$P = 0.663$	$P = 0.750$
Season: Summer vs Winter	**$P < 0.000$**	$P = 0.582$
Period*Season	$P = 0.540$	$P = 0.122$
Summer: Before vs After	$P = 0.887$	$P = 0.531$
Winter: Before vs After	$P = 1.000$	$P = 0.799$
VRZ: Inside vs Outside	**$P = 0.006$**	
Period*VRZ	**$P = 0.043$**	
[T] Inside VRZ: Before vs After	$P = 0.553$	
[T] Outside VRZ: Before vs After	$P = 0.562$	
Season*VRZ	**$P = 0.048$**	
[T] Inside VRZ: Summer vs Winter	$P = 0.205$	
[T] Outside VRZ: Summer vs Winter	**$P < 0.000$**	
Winter: Period*VRZ	$P = 0.313$	
[T] (winter) Inside VRZ: Before vs After	$P = 0.803$	

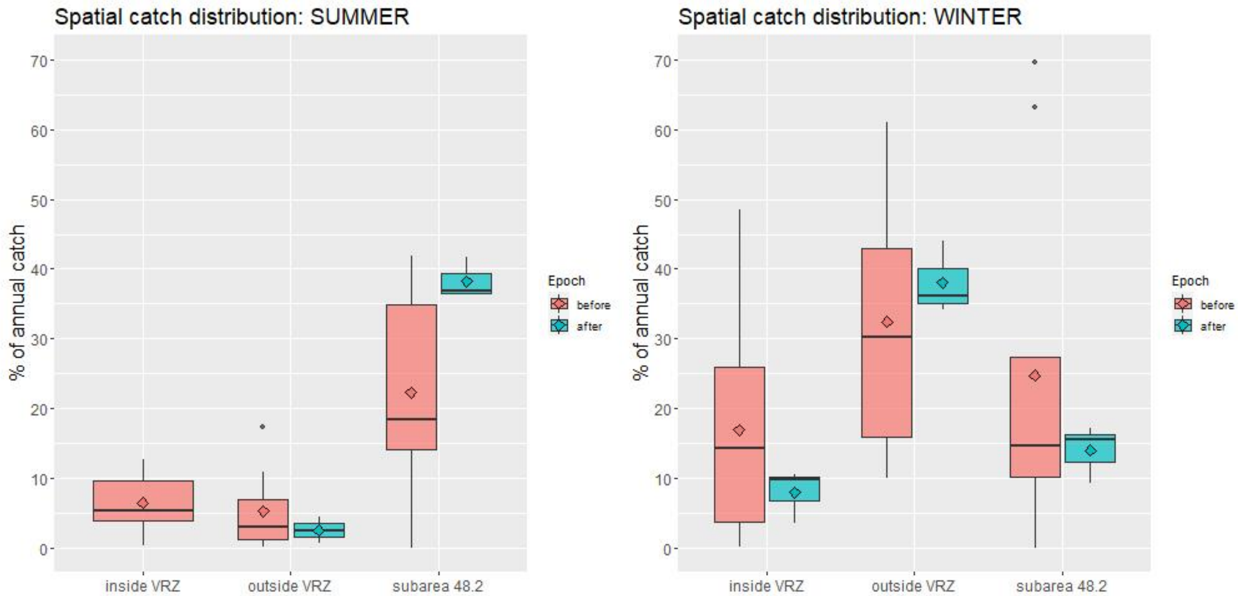


Figure A5.6. Boxplot of the effect of the introduction of the VRZ in 2019. Annual distribution of catches is presented by epoch (before: 2009-2018; after: 2019-2021) and seasonal closure (summer: closed; winter: open). Results for “inside VRZ” and “outside VRZ” correspond to Subarea 48.1. Boxplot: median, 25-75% quantiles; Diamond shapes = Mean.

Appendix 6. Penguin population trends

MSc. Steve Forrest, Oceanites

Reduced research activity during the field season 2020-2021 due to the global COVID-SARS 19 pandemic resulted in a lack of new information contributing to understanding trends for penguin species beyond our 2020 report. However, several studies and compilations for work conducted during the 2019-2020 seasons and earlier were published, elaborating on some details critical to our understanding of population trends.

Overview analyses

The most comprehensive review of chinstrap population trends to date was compiled by Strycker et al. (2020).[6] Table A6.3 of their review is reproduced below. As chinstrap penguins are the predominant penguin species occurring in the fisheries zone and most likely to be impacted by krill fisheries, understanding their population status is essential to formulating strategies for ecosystem conservation.

Table A6.1. Change in Chinstrap penguin abundance by CCAMLR subarea.

	Increase		**Decrease**		**New Colony**		**Extirpated**		**No Change**		**Unknown**	
	% Cols	% Total	% Cols	% Total	% Cols	% Total	% Cols	% Total	% Cols	% Total	% Cols	% Total
Overall	10.6	14.5	26.4	8.8	6.5	1.1	5.8	0.0	16.1	33.3	34.7	42.2
Subarea 48.1	9.1	13.6	34.9	24.8	7.6	3.4	6.5	0.0	13.5	12.6	28.4	45.6
APEI	13.0	37.0	50.0	43.7	5.6	0.3	1.9	0.0	14.8	11.1	14.8	8.0
APDPE	2.5	3.1	37.5	12.4	10.0	2.4	5.0	0.0	7.5	10.5	37.5	71.6
APDPW	3.7	21.9	22.2	15.6	22.2	30.1	7.4	0.0	14.8	11.1	29.6	21.3
APBSE	6.9	5.1	62.1	22.1	3.4	3.8	0.0	0.0	6.9	12.8	20.7	56.1
APBSW	12.8	5.0	25.6	23.2	2.6	0.1	9.0	0.0	9.0	14.4	41.0	57.4
APE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100
APW	8.2	19.0	20.4	15.3	10.2	0.0	12.2	0.0	26.5	22.7	22.4	42.9
Subarea 48.2	12.9	6.4	8.6	3.1	5.4	0.2	3.2	0.0	25.8	20.2	44.1	70.1
SONE	17.9	12.3	7.1	0.6	7.1	0.4	3.6	0.0	25.0	35.9	39.3	50.8
SOSE	10.9	4.9	9.4	3.8	4.7	0.1	3.1	0.0	25.0	15.8	46.9	75.4
SOW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100	0.0	0.0

[6] 2020. Strycker N, Wethington M, Borowicz A, Forrest S, Witharana C, Hart T, Lynch HJ. **A global population assessment of the Chinstrap penguin (*Pygoscelis antarctica*).** Sci Rep. 2020 Nov 10;10(1):19474. doi: 10.1038/s41598-020-76479-3. PMID: 33173126; PMCID: PMC7655846. https://pubmed.ncbi.nlm.nih.gov/33173126/

Subarea 48.3	6.3	42.5	0.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0	81.3	57.5
Subarea 48.4	20.0	20.7	0.0	0.0	0.0	0.0	0.0	0.0	30.0	59.7	50.0	19.5
Subarea 48.6	0.0	0.0	50.0	83.3	0.0	0.0	0.0	0.0	0.0	0.0	50.0	16.7
Subarea 88.1	100	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note. % colonies = number of colonies divided by total colonies in each Small-Scale Management Unit or subarea; % total = breeding pairs in the colonies within each category divided by total number of pairs in each Small-Scale Management Unit or subarea.
Abbreviations. APEI = Antarctic Peninsula Elephant Island; APDPE = Antarctic Peninsula Drake Passage East; APDPW = Antarctic Peninsula Drake Passage West; APBSE = Antarctic Peninsula Bransfield Strait East; APBSW = Antarctic Peninsula Bransfield Strait West; APE = Antarctic Peninsula East; APW = Antarctic Peninsula West; SONE = South Orkney North East; SOSE = South Orkney South East; SOW = South Orkney West; Subarea 48.3 = South Georgia Island; Subarea 48.4 = South Sandwich Islands; Subarea 48.6 = Bouvet Island; Subarea 88.1 = Balleny Islands.

The authors made the following observations:

1) Chinstrap penguin breeding colonies were distributed as follows: 39.4% in subarea 48.4 (South Sandwich Islands), 32.1% in subarea 48.1 (Antarctic Peninsula and adjacent islands), 28.1% in subarea 48.2 (South Orkney Islands), and 0.4% in subarea 48.3 (South Georgia Island), with smaller populations in subareas 48.6 (Bouvet Island) and 88.1 (Balleny Islands).
2) Of those colonies for which a comparison could be made to counts in the 1980s, 40.4% have declined, 16.2% have increased, 24.6% have not changed significantly, 10.0% represent previously unrecognized colonies, and 8.8% have been extirpated. However, this picture changes when assessing total population rather than number of colonies. Of the same sample, 15.3% of the total population are in colonies that have declined or probably declined and 25.1% in colonies that have increased or probably increased, with 57.6% of the population not changing significantly and 2.0% representing previously unrecognized colonies. This is due to the fact that more than one-third of the global Chinstrap penguin population is concentrated in a few large colonies in the South Sandwich Islands, where the species is apparently stable.
3) For colonies that could be assessed against a historic benchmark, the majority of chinstrap colonies on the Western Antarctic Peninsula (WAP) are declining (see Table A6.1).

The authors further review and critique the various hypotheses that have been forwarded to explain penguin declines generally.

1) *Whale and seal competition*: While perhaps the most parsimonious theory, does not explain why other penguin species (e.g., gentoos) are increasing.
2) *Sea ice retraction:* Described differences observed in the 1980s between pagophillic Adélie and pagophobic chinstrap penguins but failed to account for declines in chinstrap populations subsequent to the 1980s.
1) *Krill hypothesis:* Inclusive theory that suggested krill fishing, sea ice retraction, interspecific competition and climate all exerted downward pressure on populations. However, this

theory is not useful in terms of distinguishing which of these broad impacts is most significant. It also does not explain why gentoo penguins are increasing.

2) *Climate change:* Affecting inshore productivity (through reduction in sea ice, warmer temperatures) is an obvious driver and cannot be ruled out.
3) *Krill fishing: "*Watters et al. (see 2020 report) predicted that today's "precautionary" limits on krill fishing would affect penguin breeding success with a similar magnitude to climate change, if seasonal local harvest rates exceed a threshold of 0.1. This is especially pertinent to Chinstrap penguin colonies adjacent to krill-fishing hotspots, though continued declines in areas currently experiencing less intense krill trawling (e.g. Elephant Island, see below) suggest that krill fishing does not fully explain the widespread Chinstrap penguin population changes identified by our assessment."

The authors further suggest that a renewed focus on overwintering habitat could explain declines if, as it has been suggested, climate-mediated changes to offshore stocks of krill are undergoing changes in distribution and abundance. Chinstrap penguins are some of the farthest travelling winter migrants of penguin species on the Antarctic Peninsula. If such decoupling (between timing and location of winter prey and penguin foraging) is taking place, chinstraps could be disproportionately affected (relative to other penguin species), and this would partially explain differences in observed species response. This also raises the concern that, at least for chinstrap penguins, protection from harvest reductions during the breeding season alone may be insufficient to avert population declines.

Elephant Island (Subarea 48.1)

A study referenced in our 2020 Report has been published[7] and warrants additional comment. Declines (56% overall) reported for a 50-yr period at Elephant Island may represent some of the most accurate comparisons of nesting population trends for penguins over the long term yet reported for the Antarctic Peninsula. While the data represent only two discrete points for most of the colonies surveyed, more frequent monitoring at several colonies (e.g., Point Wordie) is consistent with the decline observed island-wide, which has been most pronounced over the last 10-15 years. Interestingly, declines were not consistent for all colonies on the Island, with colonies located along the northern shore showing less decline than colonies on the southern and western shores. This suggests the possibility that differences in foraging habitat quality may occur between colonies over relatively short distances, which in turn has implications for the design of any study to assess impacts based on differences in fishing pressure.

Gentoo and chinstrap penguins (Subarea 48.1)

There is additional evidence on the importance of inshore non-breeding (winter) habitat for gentoo penguins on the WAP.[8] Gentoo penguins make use of high-quality and increasingly ice-free inshore habitat during the winter, particularly in the Bransfield Strait. Movements of birds suggest greater food

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[7] 2020. Strycker N, Borowicz A, Wethington M, Forrest S, Shah V, Liu Y, Singh H, Lynch HJ . ***Fifty-year change in penguin abundance on Elephant Island, South Shetland Islands, Antarctica: results of the 2019-20 census.*** Polar Biol. doi: 10.1007/s00300-020-02774-4

[8] Korczak-Abshire M, Hinke JT, Milinevsky G, Juáres MA, Watters GM. 2021. **Coastal regions of the northern Antarctic Peninsula are key for gentoo populations.** Biol. Lett. 17: 20200708. https://doi.org/10.1098/rsbl.2020.0708

availability along the margins of the Antarctic Peninsula relative to the south Shetland Islands during winter. The authors state: “Winter habitats used by gentoo penguins outline high priority areas for improving the management of the spatio-temporally concentrated krill (*Euphausia superba*) fishery that operates in this region during winter.”

These recommendations, when coupled with a separate modelling study[9] that found that Increases in fishing catch during the non-breeding period were likely to result in impacts on both chinstrap and gentoo populations. Catches and climate change together elevated the probability of negative population growth rates: very high fishing catches on years with warm winters and low sea ice (associated with negative Southern Annular Mode values) where potential fisheries overlapped implied a decrease in population size in the following year.

IBA proposal

Although technically based on a precautionary principle (indirectly related to negative observed trends and overlap with krill fisheries), an analysis[10] resulting in designation of Important Bird Areas (IBA’s) for penguin species that assesses both Marine Protected Areas and VRZs was concluded in early 2021. The analysis resulted in designation of 63 marine IBAs, based on a foraging model that assumed a density distribution surface based on a bearing from the colony and a density decay function for the relatively short distance foraging bouts during the chick-rearing phase. For each layer derived, only cells selected where those which had >1% of the global population (Figure A6.1).

With the exception of the Elephant Island area, all of the IBAs identified in this analysis for the Antarctic Peninsula fell within the existing VRZs. Relevant to the preceding discussion in this report, the proponents’ analysis showed that despite a generally contracted range of operation by the krill fishery in Antarctica over the past five decades, there is consistently a disproportionate amount of krill being harvested within marine IBAs identified in this analysis compared to the total area the fishery operates. In addition, the authors note that the potential for competition between krill fisheries and penguins in the winter (outside of the period of the VRZ closures and in other locations) suggests that their identified marine IBAs provide only a part of the conservation regime that would fully protect the Antarctic marine ecosystem.

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[9] Krüger, L., Huerta, M.F., Santa Cruz, F. *et al.* **Antarctic krill fishery effects over penguin populations under adverse climate conditions: Implications for the management of fishing practices.** *Ambio* **50,** 560–571 (2021). https://doi.org/10.1007/s13280-020-01386-w

[10] Handley J, M-M Rouyer, EJ Pearmain, V Warwick-Evans, K Teschke, JT Hinke, H Lynch, L Emmerson, C Southwell, G Griffith, CA Cárdenas, AMA Franco, P Trathan, MP Dias. 2021. **Marine Important Bird and Biodiversity Areas for Penguins in Antarctica, Targets for Conservation Action.** Frontiers in Marine Science 7, 1190. https://www.frontiersin.org/article/10.3389/fmars.2020.602972 DOI=10.3389/fmars.2020.602972

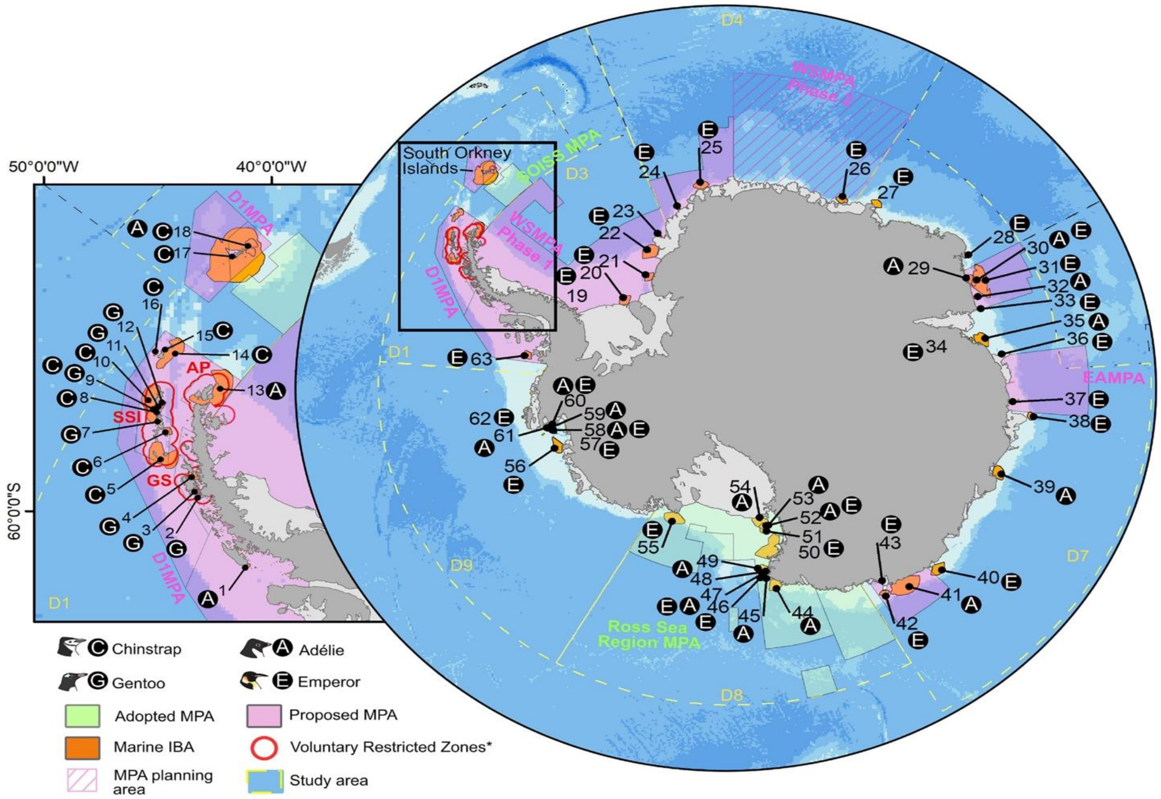

Figure 1. Important Bird Areas (Figure 2, Handley et al 2021).

Timing of fledgling mortality (Subarea 48.1)

Analysis of telemetry data on cohorts of juvenile *Pygoscelid*[11] (Adelie, chinstrap and gentoo penguins) species indicates an acute bottleneck for juvenile penguins post-fledging occurring within the first three weeks after post fledging dispersal. The authors contend that observed tag losses suggest that 33% of all juvenile mortality (based on observed adult recruitment from other studies) may occur during this period.

Summary of recent information

1) New information suggests significant overlap with fisheries outside of the breeding season post fledging in February-March;
2) New information suggests that the high sensitivity period for fledgeling survival may occur outside of the breeding areas;

[11] Hinke J.T., Watters G.M., Reiss C.S., Santora J.A., Santos M.M. 2020. Acute bottlenecks to the survival of juvenile *Pygoscelis* penguins occur immediately after fledging. Biol. Lett. 16: 20200645. https://doi.org/10.1098/rsbl.2020.0645

Appendix 7. Conservation benefits.

EP members

There seems to be an assumption by the RP that the VRZs have "Conservation Benefits" and that the task of the Expert Panel is to assess these benefits. However, the review panel has provided no information on the definition of "Conservation Benefits". Relevant information could include:

- Whether these "Conservation Benefits" are expected to (i) reverse a previous dis-benefit (e.g. an impact of fishing within the VRZs) or (ii) prevent a future dis-benefit.
- Which parts of the ecosystem are expected to respond to the benefit?
- The metrics used to assess the benefit
- Reference points which separate positive, neutral, and negative responses.

The situation is complicated by the fact that in 2020 the Review Panel invoked a lack of "significant ecological benefits to the ecosystem" to support its rejection of a recommendation from the Expert Panel. The EP wants to underline that the VRZs are apparently designated purely to protect breeding penguins and have thus no scientific design that supports a normal scientific assessment of conservation benefits. The recommendation in the 2020 report had an implicit design where a year-around protection area potentially could be statistically compared with a seasonally closed area and thus over time support a normal statistical evaluation.

Further, there is a need to define and agree on variables and data. In the Conservation benefit table (Table A7.1) we have tried to clarify the complexity in this issue by demonstrating the various components of the ecosystem involved and the current gap between available and ideal data to support a conservation benefit analysis.

The VRZs were defined in function of colony distribution and main foraging range of penguin species during the brooding phase of breeding. As such, any analysis of VRZs benefit should include a review of penguin performance. The EP considered the question of whether it is possible to ascertain if some quantifiable benefit can be shown to penguin populations three years post initiation of the VRZs. Briefly, such analysis is not possible at this time for the following reasons:

- Penguins are long-lived species. Along with variability from year to year in breeding numbers and among breeding locations, any changes will likely be masked until significant population shifts have occurred, which may take a number of years (possibly a decade or more) to observe.
- The VRZs were not designed to test assumptions regarding the removal of fishing pressure during the breeding season (eg, there are no control areas, there was no pre-treatment baseline established, there was no randomized treatment plan). A historic baseline that could be used to compare pre and post treatment (less robust) is largely unavailable over the range of the treatment area.

Other relevant measures of life history (fledgling rates, chick weights, prey composition, recruitment indices, adult return rates) that could reflect post-treatment change are only available for a limited number of sites due to the expense and time of obtaining such data and these sites are not replicated sufficiently to provide any meaningful statistical analysis.

Further, the EP has discussed the possibility of using qualitative measures to evaluate conservation benefit. In the discussion between the EP and RP, the appeared like the RP indicated that a comparison between the pros and cons of the various management alternatives might be helpful. If that is the case, some qualitative assessment of the various protection schemes, their shortcomings or advantages might be something to consider for future EP reports.

Table A7.1. Conservation benefits table - a working note from the 2021 EP report preparation. Filling in the relevant information in the various cells of this table will require further input if EP is going to follow this approach.

Component	Current Risk/Threat	Expected Benefit	Currently available data	Current issues	Ideal data	Potential conclusions that could be drawn from ideal data.
Krill - adults	Are current catch levels a risk to krill populations?	Harvest levels impose minimum impacts to ecosystem components and processes	Annual acoustic survey. Incomplete overlap with subarea 48.1/VRZs. Irregular complete surveys of Area 48	No hypothesis about the benefits of VRZs to assess the suitability of data.	Adequate coverage in time and space of acoustic data	Spatial distribution Assessment of local depletion Impact on predators
Krill - adults (spawners)	Fishery overlap with spawning stock during spawning season	Protect spawning stock during breeding season	Sporadic research cruises	No hypothesis regarding differential impact of harvest during spawning vs. non-spawning	Well designed scientific studies with adequate space - time coverage	Potential of fisheries impact of spawners and thus on recruitment

Krill – larvae	Any??? Any reason to suspect that the fishery : - Catch significant amounts of larvae Larvae concentrate at VRZs?	Higher recruitment to adult age classes (if impacted)	Occasional observations in net surveys. Incomplete overlap with subarea 48.1/VRZs.	No hypothesis about the benefits of VRZs to assess the suitability of data. No compilation of data regarding extent/impacts of fishing to larvae	Research progressing understanding of recruitment mechanisms	Fisheries impacts on krill recruitment
Fish	Is there a significant risk from the krill fishery?	Increase in fish stocks (if impacted)	Very limited data	No hypothesis about the benefits of VRZs to assess the suitability of data.	Abundance surveys Krill consumption information by fish	Quantification of consumption of krill by fish
Penguins	Local depletion of krill near colonies during the breeding season Local depletion of krill during post-fledging near in-shore foraging areas	Optimal provisioning of chicks during the breeding season Reduced competition (resulting in optimal survival) during highly sensitive life history stage	Breeding colony counts and performance (e.g. breeding success) data. Data availability and sampling frequency varies between colonies. Limited data on post fledging performance, survival	No hypothesis about the benefits of VRZs to assess the suitability of data.	Routine information on: - penguin abundance - breeding success -survival	Quantification of population response to various harvest levels, location and timing of harvest

Whales	Local depletion of krill at identified hotspots, particularly at the start of the season (when whales are returning from fasting)	Increased survival rates	Fragmented and non-systematic data collection	No hypothesis about the benefits of VRZs to assess the suitability of data.	Abundance surveys Overlap information	Quantification of population response to various harvest levels, location and timing of krill harvest
Seals	Potential impacts to population stability--species- specific	Increased survival rates	Time -space irregularity in data collection	No hypothesis about the benefits of VRZs to assess the suitability of data.	Routine abundance surveys and overlap information (fishery-feeding)	Quantification of population response to various harvest levels, location and timing of krill harvest